Memorandum

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To: Chris Dreps
Upper Neuse River Basin Association

From: Lisa Fraley-McNeal, Sally Hoyt, and Anne Kitchell
Center for Watershed Protection

Re: Lick Creek – Watershed Treatment Model Analysis

This memorandum summarizes the Watershed Treatment Model's (WTM) pollutant load and treatment option analysis on the Lick Creek Watershed. The model was developed by the Center for Watershed Protection (CWP) and applied here in association with the Upper Neuse River Basin Association as part of a larger assessment and planning effort to develop a comprehensive watershed restoration strategy. Pollutants modeled for Lick Creek include total nitrogen and sediment due to Neuse River and Falls Lake management objectives. This memo includes a basic description of the WTM, results and implications for watershed management, as well as details on model inputs and assumptions. Attached are result summaries for each watershed. The actual spreadsheets will be provided to UNRBA on CD. The memo is organized into the following sections:

1.0 Description of the WTM

The Watershed Treatment Model (Caraco, 2002) was developed by CWP as a simple spreadsheet model used to:

1. Estimate pollutant loading (nutrients, sediment, and bacteria) under current watershed conditions
2. Determine the effects of existing management practices on minimizing these pollutant loads
3. Evaluate effects of proposed structural and non-structural management practices identified during field assessments on current pollutant loads
4. Evaluate the effects of future development on pollutant loads

The WTM assesses uncontrolled pollutant loads from two broad categories of pollutant sources: *primary sources and secondary sources*. Primary sources are related to the urban stormwater runoff loads from major land uses (i.e. commercial, residential, agricultural). Secondary sources (i.e. sanitary sewer overflows, septic system failure, and channel erosion) are pollutant sources dispersed through the watershed whose magnitude cannot easily be estimated from available land use information.

The model is primarily based on the Simple Method (Schueler, 1987) for pollutant load calculations where impervious cover is used to estimate primary loads from various land uses. At its core, the Simple Method is based on the relationship between impervious cover and runoff volume. Specific concentration assumptions used for loading estimates in the WTM model are based on values for different land uses summarized in the National Stormwater Quality Database (NSQD), a summary of national stormwater data from over 200 communities nationwide (Pitt et. al., 2003). Estimated runoff volumes are multiplied by pollutant concentration data to compute stormwater loads.

The *existing management practices* and *future management practices* components of the WTM assess the ability of the treatment options in a watershed to reduce the uncontrolled pollutant loads from primary and secondary sources. The pollutant removal efficiencies associated with various structural and nonstructural stormwater management practices are based on existing research and studies in the National Pollutant Removal Performance Database for Stormwater Treatment Practices (Winer, 2000) and research compiled in the Watershed Treatment Model (Caraco, 2002). A number of additional BMP performance studies have been published since the National Database was created in 2000. These studies have recently been added to the National Database and the updated pollutant removal efficiencies were used in the WTM.

A unique feature of the WTM is the inclusion of "treatability" and "discount" factors. Treatability is the fraction of a source that can be treated by a practice. For structural practices, treatability is best defined as the area that can be treated, while for education programs, it may reflect the fraction of the population that can be reached. Discount factors are applied to potential load reductions to account for imperfect practice application and upkeep, inability of educational programs to reach all citizens, and inadequate funding to implement all practices, to name a few.

The Watershed Treatment Model is a planning level model. There are many simplifying assumptions made by the WTM, and the model results are not calibrated. Therefore, the results of the model simulations should be compared on a relative basis rather than used as absolute values.

2.0 Input Data and Assumptions

Most of the WTM input data for Lick Creek was taken from GIS data provided to CWP by the Triangle J Council of Governments (TJCOG). Some values for secondary sources are based on fieldwork conducted by CWP, UNRBA, and other project partners during February/March 2007. The future management practices are based on the spectrum of possible projects identified during fieldwork.

This section summarizes the Lick Creek specific input data. For further detail on the WTM methodology and inputs see Caraco, 2002, which is available for free download at http://www.cwp.org/PublicationStore/TechResearch.htm

Primary Sources

Existing Land Use

TJCOG analyzed land use in the watershed (Hodges-Copple 2007). In this analysis, the existing land use codes in the parcels GIS layer were used. A detailed description of the analysis can be found in Appendix B. The land use data for the whole watershed is shown in Table 1. Active construction was estimated based on field observations in February/March 2007. Impervious cover estimates were assigned to each land use based on factors derived in *Impervious Cover and Land Use in the Chesapeake Bay Watershed* (Cappiella and Brown, 2001). Stormwater runoff was calculated based on the land use, impervious cover, and an annual rainfall of 43 inches.

Table 1. Land Use in Lick Creek Watershed, as Input in the WTM Model

	Land Use Category Description	Impervious Cover for Category (%)	Existing Area (acres)	Projected Future Change in Area (acres)
Urban	Residential – LDR (2-3 ac)	11	187	-131
	Residential – LDR (0.5 - 2 ac)	14	434	+189
	Residential – LDR (0.25 - 0.5 ac)	21	42	+72
	Residential – (0.125 – 0.25 ac)	30	5	+5269
	Residential – MDR	44	36	-3
	Urban Green – Open Urban	8	281	-122
	Urban Green – Protected Natural	8	35	+3557
	Commercial	72	169	+113
	Institutional	35	113	+19
	Roadway - Major	55	123	+20
	Roadway - Local	55	331	+1180
	Industrial	53	30	+204
	Active Construction	0	695	-695
Rural	Forest	0	2993	-3688
	Protected Natural Areas	0	1351	-1351
	Pasture/Undeveloped/Unmanaged	2	5852	-5842
	Cropland	2	362	-362
	Rural Residential	5	658	+874
	Open Water	0	363	0

Pollutant Loadings

The stormwater concentration data used in the WTM Modeling Scenario is based on the National Stormwater Quality Database (NSQD) (Pitt et al., 2003). The concentration data from the NSQD are summarized in Table 2. The NSQD data set was chosen as the source for concentration data due to the high number of observations in the data set and the resulting certainty that data has not been skewed by anomalies that may be present in much smaller local data sets. Since completing the model for Lick Creek, CWP has obtained North Carolina specific pollutant load concentrations which were found to be higher than the national averages. Speculatively, the pollutant loads calculated for Lick Creek are on the low side.

Pollutant concentrations were converted to annual pollutant loading rates based on the volume of runoff.

Table 2. Primary Loading Concentrations used in the WTM Scenarios			
Land Use	**Total Nitrogen (mg/l)**	**Total Phosphorus (mg/l)**	**Total Suspended Solids (mg/l)**
Residential	1.9	0.3	68
Open Space	1.9	0.27	78
Commercial	2.0	0.25	54
Roadway	2.3	0.25	99
Industrial	2.1	0.2	82

Secondary Sources

Secondary sources that were present in the watershed and quantifiable based on existing data were also considered. The input was based on GIS data provided to CWP by TJCOG/UNRBA, default values of the WTM, or field observations. This data was compiled for each of the 11 subwatersheds. Table 3 provides quick reference for Lick Creek specific inputs.

Table 3. Secondary Source Input Data	
Input	**Notes**
General Sewage Information	The number of dwelling units was obtained from the Durham County Health Department. Parcels with building values were assumed to have buildings with wastewater disposal needs. Parcels in the city were assumed to have municipal sewer service. Those outside the city were assumed to treat wastewater with on-site wastewater systems. Of the calculated 817 on-site septic systems, an estimated 79 are discharging sand filter systems. This is based on the GIS layer for this type of system.
Septic Systems	Nutrient and bacteria loads from septic systems are based on the number of systems, the percent failing, and the characteristics of effluent. The fraction of failing septics is based on the WTM default of 30%. Nutrient defaults were used for the characteristics of effluent from septic systems; however, these values were compared to septic system effluent samples from Durham Stormwater Services.
Sanitary Sewer Overflows (SSOs)	Overflows were estimated using the WTM default value for annual overflows per mile of sanitary sewer. Miles of sanitary sewer were calculated from GIS.

Table 3. Secondary Source Input Data	
Input	**Notes**
Illicit Connections	Fraction of population with sewer illicitly connected to the storm drains was based on the WTM's default assumption. The number of businesses, which are counted independently of residences, was estimated based on fieldwork.
Channel Erosion	Method 1 was used, which calculates channel erosion as the difference between a default average in-stream load and the total of all other sediment source loads. The model default of 500 pounds/acre/yr was used for the in-stream load. For subwatersheds with more than 10% active construction, the sediment load from construction was considered separately from the default 500 lb/acre/year loading. This default value is based on typical urbanized watersheds, not on watersheds undergoing massive simultaneous land development.
Lawns	The runoff from lawns is calculated based on hydrologic soil group. GIS soil data was used. Model defaults were used to correlate lawn area with land use.
Hobby Farms/Livestock	Livestock counts were based on notes made during the February/March 2007 fieldwork. This was likely underestimated as fieldwork did not comprehensively cover the uplands.
Marinas	The Rollingview Marina is located in subwatershed 11 and includes 235 berths.
Road Sanding	This was assumed to be a minimal impact and was not included.
Non-Stormwater Point Sources	There are no major permitted point sources discharging in the Lick Creek Watershed. The only identified NPDES permits are for sand filter septic systems with spray irrigation discharge.
Active Construction	Acreage based on observed construction sites during February/March 2007 fieldwork. Clear-cut areas were also treated as active construction because of the exposed soil. This was likely underestimated as fieldwork did not comprehensively cover the uplands.

Existing Management Practices

The existing management practices included in the WTM are based on observations during February/March 2007 fieldwork and CWP knowledge of the City of Durham Stormwater Services and Durham County Stormwater programs. CWP used best professional judgment when applying discount factors to adjust the load reduction of existing practices. Table 4 summarizes the assumptions used for applying existing management practices.

Table 4. Existing Management Practice Input Data	
Input	**Notes**
Lawn Care and Pet Waste Education	Based on the many types of education items, awareness of 40% of the population was chosen. Education types include city newsletter, posters, presentations to community groups, publications from EPA and Audubon, and CWEP TV.
Erosion and Sediment Control	The fraction of building permits regulated is approximately 90%. A compliance factor of 50% (monthly inspection) and installation/maintenance factor of 60% (pre-construction meetings for large sites; regulations prohibit least effective practices) were used based on observations during fieldwork.
Street Sweeping	No current street sweeping was assumed. This decision was based on the limited amount of curb and gutter in the watershed.
Impervious Cover Disconnection	Assumed 95% of homes and businesses are disconnected based on observations during fieldwork.
Structural Stormwater Management Practices	The impervious area captured by existing BMPs was estimated from GIS. The following discounts were assumed: capture = 0.9; design = 1.0; maintenance = 0.6.
Riparian Buffers	Buffer length was calculated from fieldwork. A design factor of 0.25 a buffer setback without design guidance. The maintenance factor of 0.6 was based on lack of signage or property owner education.
Catch Basin Cleanouts	None assumed for this watershed, as few catch basins exist.
Marina Pump-outs	1 marina pump-out in Subwatershed 11 was located during fieldwork.

Future Management Practices

This section incorporates the restoration projects and practices identified during the fieldwork conducted in February/March 2007 and described in the field findings memorandum dated June 2007. These practices were quantified to the extent possible and full implementation was assumed. Realistically, not all of the restoration projects will be recommended for implementation, and not all recommendations will be implemented. Therefore, the load reductions seen in the application of future management practices is considered a best-case scenario.

Best professional judgment was applied to the selection of discount factors to adjust the load reduction of future practices. Table 5 summarizes the assumptions used for applying future management practices. Existing practices that were not changed are not included in this table.

Table 5. Future Management Practice Input Data	
Input	**Notes**
Erosion and Sediment Control	Assumed improved future enforcement of erosion and sediment control regulations. Therefore, the compliance and installation/maintenance factors were both raised to 90% to represent weekly inspection and increased inspector and contractor training. The fraction of building permits regulated was raised to 95%.
Structural Stormwater Management Practices	Potential stormwater retrofits were identified during fieldwork and included as part of the future management practices. The capture and design discount remained the same as existing practices. However, the maintenance factor increased to 90%
Riparian Buffers	Future buffer length was calculated by adding the lengths of buffer planting projects to the existing buffer length. The design factor was increased to 0.8 to account for design guidance and the maintenance factor was increased to 0.9 to account for signage and maintenance information to property owners.
Channel Protection	The percentage of stream miles assumed unstable was 15% based on fieldwork observations. The miles of stream channel stabilized was based on the sum of stream repair and restoration project lengths.
Septic System Education	System education would reach 10% of the population. The fraction of the population willing to change their behavior was assumed to be the WTM default value of 40%.
Septic System Repair	A mandatory inspection of all septic systems was assumed and that 60% of owners with failing septics would be willing to make repairs with no incentives.

Future Land Use and New Development
The future land use was also calculated by TJCOG. Refer to Table 1 for values and Appendix B for the detailed description of the analysis. Future pollutant loads associated with new development were calculated by subtracting existing land use from future land use acres and applying the simple method in a similar fashion as for existing loads. Other factors considered in future pollutant loads are explained in Table 6 below.

Table 6. New Development Input Data	
Input	**Notes**
New Septic and Wastewater Customers	None. Assumed all new development would be hooked up to sewer system.
Street Sweeping	Approximately 50% of the new roads are assumed to be swept.
Controls on New Development	Program option 4 was selected, requiring on-site load calculation with an offset fee. The fraction of new development regulated and the fraction of development with flow control were assumed to be 90%.

3.0 Results and Conclusions

Below are the WTM results for the entire Lick Creek watershed, as well as general findings based on an analysis for individual subwatersheds. Existing and future TN and TSS loads categorized by source are presented for the entire Lick Creek watershed. Results specific to each of the eleven subwatersheds are located in Appendix A. TP and Bacteria loads were also modeled, but generally follow the patterns seen in the TN and TSS loads. Additionally, the effect of the proposed restoration projects is presented.

Differences in Existing and Future Loads

The general trend in land use in the Lick Creek watershed is a shift from rural existing conditions to urban future conditions (Figures 1 and 2). The new development scenario considered full build-out in the watershed, with future management practices. Under future conditions, protected natural areas and roadways increase, forest and cropland do not exist, and the dominant land use becomes low-medium density residential.

The shift from rural to urban land uses is accompanied by TN and TSS load increases under future conditions. The main source of TN shifts from rural land to urban land (Figure 3). This shift can be attributed to the increase in urban land, specifically residential land uses. Nitrogen fertilizers are often applied to lawns at a higher rate than to cropland (Barth, 1996). Load increases from urbanization of the watershed exceed the decrease from rural land.

Septic systems are also major contributors to the TN load in subwatersheds 3, 8, and 10 for both existing and future conditions. This load does not substantially change between existing and future conditions. In subwatershed 7, livestock is a significant TN source.

Channel erosion is the greatest existing TSS source for most subwatersheds and becomes an even greater source in the future (Figure 3). A sediment load attributed to channel erosion is part of a natural stream system; however, this increase in channel erosion is a predictable outcome of urbanization (Caraco, ND). Active construction and rural land are large TSS sources under existing conditions, but are replaced as a source by urban land in the build-out condition. In subwatersheds with a high percentage of existing active construction, such as subwatersheds 1 and 3, the TSS load decreases under future conditions.

Effects of Recommended Future Management Practices on Existing Loads

The modeled recommended future management practices, as recommended based on field assessment, were improved erosion and sediment control, structural stormwater management retrofits riparian buffer plantings, and septic system educations.

The improved erosion and sediment control as a future management practice can provide the greatest reduction in TSS (11%) and TP (5%) (Table 7). This effect is more pronounced in subwatershed 1, where active construction comprises 20% of the existing land use. Here, TSS reductions are estimated at 18%, TP reductions at 12%, and TN reductions at 3%. These reductions correlate with the significant TSS loads the model shows under existing conditions (Figure 3). Additionally, two major findings from February/March 2007 field assessment were "inadequate erosion and sediment control at construction sites" and "uncontrolled sediment discharges from 'agricultural' sites" (see Findings 1 and 2 in Hoyt, 2007). As stated in the input data assumptions, the improvements include a shift from monthly to weekly inspection and increased training for inspectors and contractors. The increase inspection frequency is a major recommendation based on the field assessment. Also, a slight increase in the percentage of sites regulated (90% to 95%) was included to account for erosion and sediment controls at agriculture-exempt parcels. The results from the WTM support recommendations in the field assessment memorandum (Hoyt, 2007) to increase inspection of sites with building permits and exercise regulatory authority over agricultural sites.

Riparian buffer plantings provide the greatest TN reduction (Table 7). This assumes that existing 50 foot stream buffers will be left intact and the recommended buffer plantings from field assessment will be planted. Details on the proposed retrofit and buffer practices can be found in field assessment findings 8 and 9 (Hoyt, 2007).

Structural stormwater management retrofits modeled were those found during field assessment. These retrofits would treat approximately 17 acres of impervious cover. This has a small impact on a watershed scale. The two largest retrofits are located in subwatershed 1, and the model shows a 0.8% reduction in TN and 0.6% reduction in TSS for that subwatershed.

Septic system inspection, repair, and education were modeled as having an impact, particularly in subwatersheds 3, 8, and 10 where the greater number of septic systems contributed significantly to the pollutant loads. In these subwatersheds, the septic system programs could reduce TN loads by 3%. For more on the current septic system problems and solutions, see field finding 10 (Hoyt, 2007).

Table 7: Pollutant Load Reductions for Recommended Future Management Practices

	TN	TP	TSS	Bacteria
Erosion and Sediment Control	1.0%	5.4%	11.2%	-
Structural Stormwater Management Retrofits	0.1%	0.1%	0.1%	0.9%
Riparian Buffers	3.1%	0.9%	3.4%	-
Septic System Education	0.1%	0.1%	-	-
Septic System Inspection/Repair	1.5%	0.8%	0.1%	0.1%
Total Reduction	**5.8%**	**7.3%**	**14.7%**	**1.0%**

Overall Conclusions

The modest pollutant load reductions the model shows from future management practices will only be realized if the restoration practices are fully implemented. This will require increased funding in the erosion and sediment control programs as well as the political will to hold land developers to a high standard for construction site controls. Additionally, a combination of grant funding for materials and staff time, a local government commitment to serve as project managers, and a sizable public education effort will be needed to realize the pollutant load reductions from retrofits, buffer plantings, and septic repairs.

Even with restoration practices, which are included in the future conditions scenario, the model show that pollutant loads will be higher in the future. This is based on build-out conditions given the current urban growth boundary and zoning. The model also considered the existing post-construction stormwater management requirements applied to the future development. Clearly, more rigorous efforts to prevent the increase of future nutrient, sediment, and bacteria loads are needed in order to achieve goals for Lick Creek and Falls Lake.

Techniques to mitigate this future increase in pollutant loads are available and could be instituted. The following recommendations based on the field assessment could be expected to mitigate future increases and could be modeled using the WTM:

Post-Construction Stormwater Management

- Require post-construction water quality treatment for all new development.
  From Field Assessment Finding 3 (Hoyt, 2007):
  "In order to meet overall water quality goals of Falls Lake and the larger Neuse River Basin, we recommend post-construction water quality treatment be required for all new developments."
- Encourage less than the maximum allowed impervious cover at development site by lowering the threshold at which post-construction stormwater management is required.
- Institute more rigorous design standards for post-construction stormwater practices.
- Institute more rigorous maintenance and inspection standards for post-construction stormwater management.
- Use a volume based, rather than peak flow based, water quantity requirement.
  - *From Field Assessment Finding 3 (Hoyt, 2007):*
    "In addition to the 1-year detention requirement, which provides some channel protection storage, discharge volume criteria should be considered. A performance criteria which limits the increase in volume, rather than peak discharge, could spur the use of environmentally sensitive design (LID/BSD)."
- Increase offset fees to promote on-site treatment.
  - *From Field Assessment Finding 3 (Hoyt, 2007):*
    "Increase nutrient offset fee to push the economic incentive towards providing stormwater management rather than paying a nitrogen offset fee."
  - *From Field Assessment Finding 6:*
    "Encourage natural drainage channels should be used for drainage in new developments. The value of these zero-order, ephemeral, intermittent streams has been document and supports a focus on environmental sensitive design/LID/BSD."

Reduced Impervious Cover

- Change zoning to cluster dense residential areas near transportation corridors while protecting other lands. This could result in less roadway construction and widening and therefore less imperviousness.
- Improve subdivision roadway design standards to allow reduce impervious cover in new residential areas through better site design.

Buffers

- Minimize allowed future impacts to the 50 foot buffer.
    - *From Field Assessment Finding 4:* *"Review proposed infrastructure mapping to determine number and location of stream crossings; propose alternative layouts or designs (i.e. reduce number of crossings through site design, use bottomless culverts where possible)."*
    - *From Field Assessment Finding 6:* *"Stop approving buffer impacts. The 50 foot buffer required by the Neuse rules is minimal. DWQ should hold the line here and not approve impacts or exceptions."*
    - *From Field Assessment Finding 6:* *"Utilize the wider buffer requirement made possible by the East Durham Open Space plan (300 ft from top of bank on each side)."*
    - *From Field Assessment Finding 6:* *"Increase the 25' required wetland buffer to match the Neuse stream buffer rules. Increases in the stream and wetland buffer would have a significant benefit in the Triassic basin."*

Land Protection

- Protect existing forested and rural land to reduce the amount of land developed. (See Hoyt, 2007 - Finding 6)

The WTM shows that with restoration practices alone, the pollutant loads exported from the Lick Creek watershed will increase. The implementation of both restoration techniques and controls on future development will be needed to hold the line on future nutrient and sediment load increases to Lick Creek and Falls Lake.

Figure 1: Existing Land Use for Entire Lick Creek Watershed

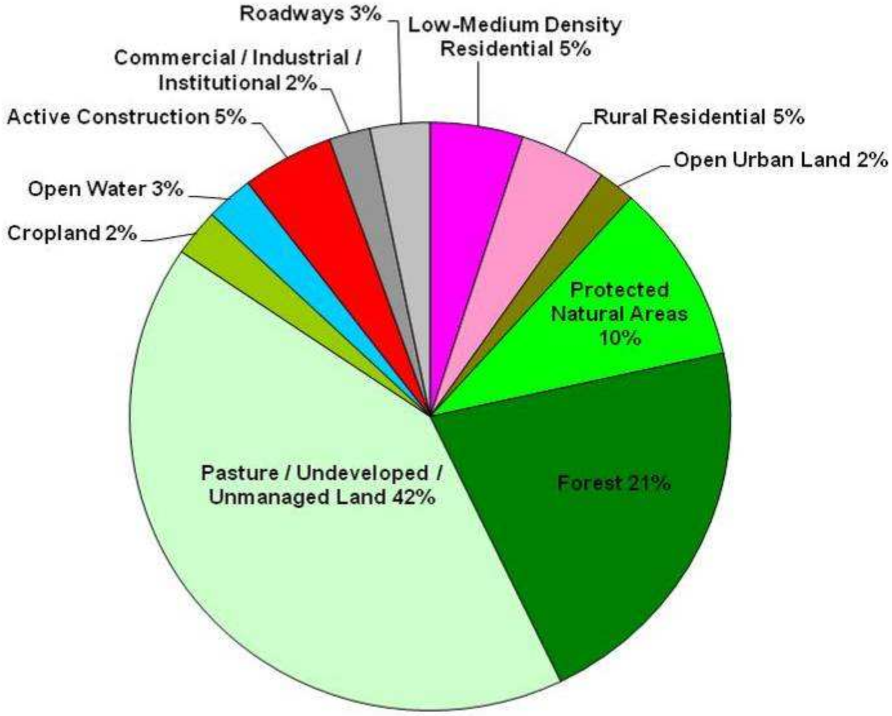
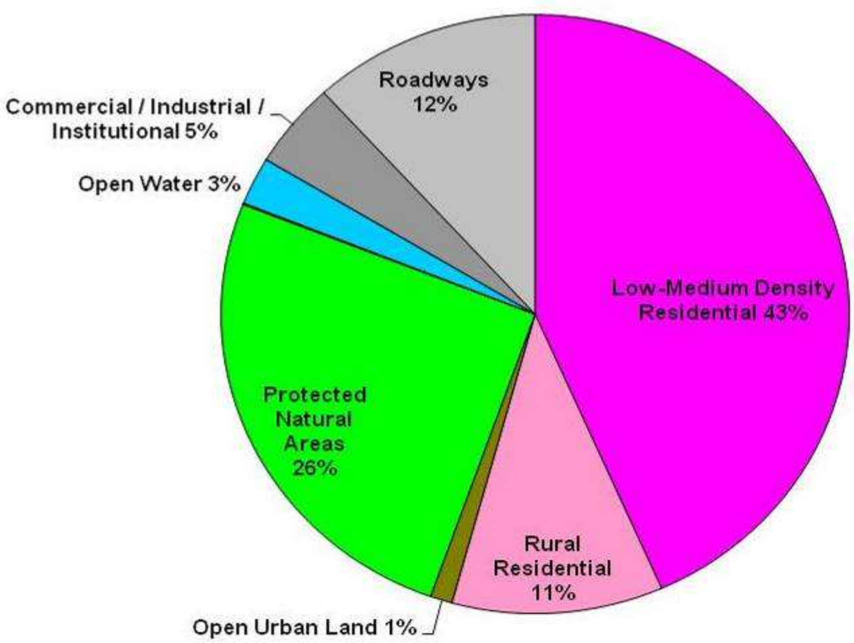
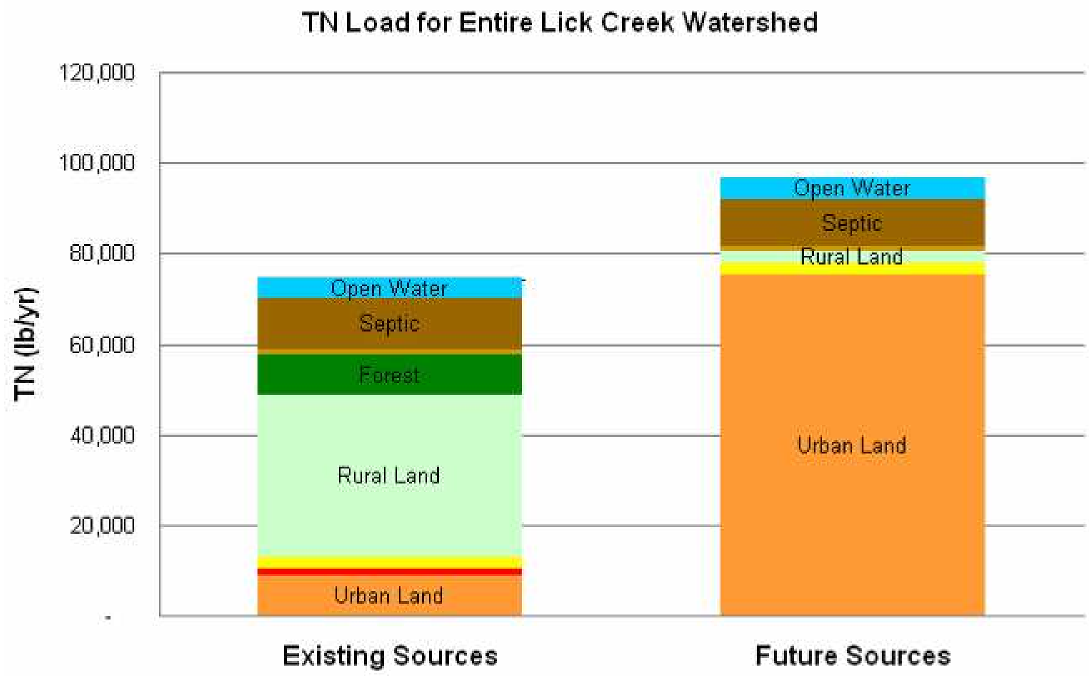
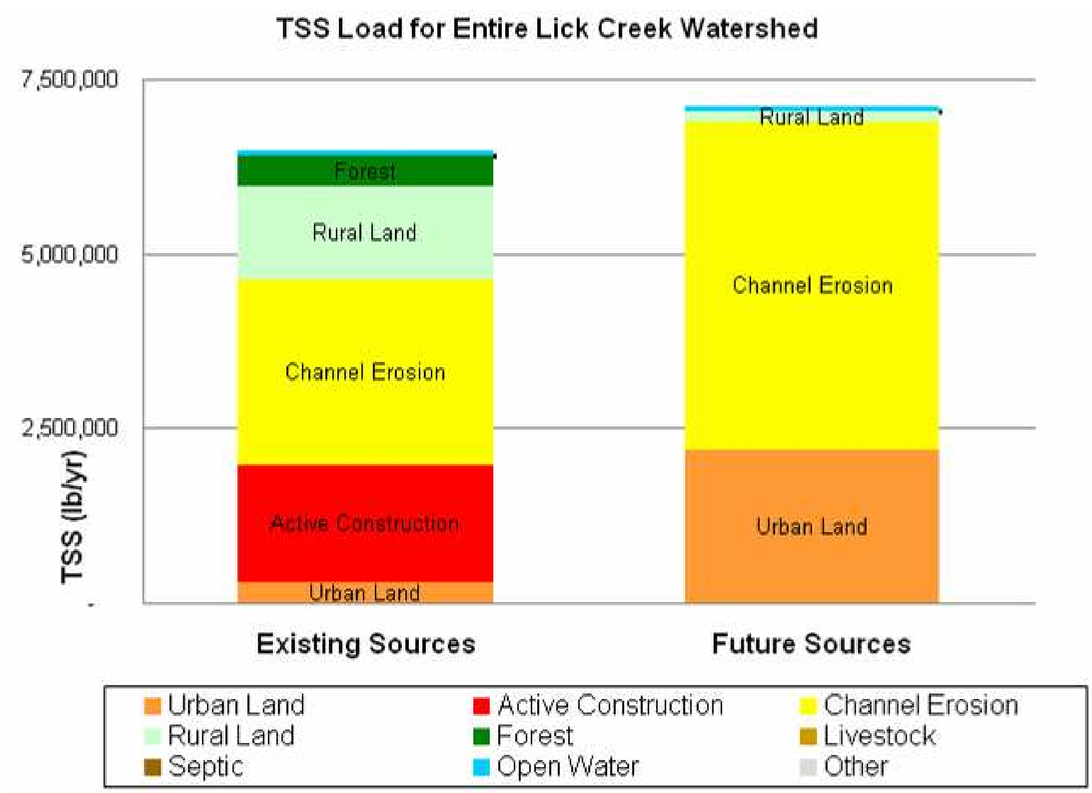


Figure 2: Future Land Use for Entire Lick Creek Watershed



Figures 3: TSS and TN Loads for Entire Lick Creek Watershed





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