Appendix A. Development of Watershed Loading Model

Loading of water, sediment, and nutrients in the Sugar Creek watershed was simulated using the Generalized Watershed Loading Functions or GWLF model (Haith et al., 1992). The complexity of the loading functions model falls between that of detailed, process-based simulation models and simple export coefficient models which do not represent temporal variability. GWLF provides a mechanistic, but simplified simulation of precipitation-driven runoff and sediment delivery, yet is intended to be applicable without calibration. Solids load, runoff, and ground water seepage can then be used to estimate particulate and dissolved-phase pollutant delivery to a stream, based on pollutant concentrations in soil, runoff, and ground water.

GWLF simulates runoff and streamflow by a water-balance method, based on measurements of daily precipitation and average temperature. Precipitation is partitioned into direct runoff and infiltration using a form of the Natural Resources Conservation Service's (NRCS) Curve Number method (SCS, 1986). The Curve Number determines the amount of precipitation that runs off directly, adjusted for antecedent soil moisture based on total precipitation in the preceding 5 days. A separate Curve Number is specified for each land use by hydrologic soil grouping. Infiltrated water is first assigned to unsaturated zone storage where it may be lost through evapotranspiration. When storage in the unsaturated zone exceeds soil water capacity, the excess percolates to the shallow saturated zone. This zone is treated as a linear reservoir that discharges to the stream or loses moisture to deep seepage, at a rate described by the product of the zone's moisture storage and a constant rate coefficient.

Flow in streams may derive from surface runoff during precipitation events or from ground water pathways. The amount of water available to the shallow ground water zone is strongly affected by evapotranspiration, which GWLF estimates from available moisture in the unsaturated zone, potential evapotranspiration, and a cover coefficient. Potential evapotranspiration is estimated from a relationship to mean daily temperature and the number of daylight hours.

The user of the GWLF model must divide land uses into “rural” and “urban” categories, which determines how the model calculates loading of sediment and nutrients. For the purposes of modeling, “rural” land uses are those with predominantly pervious surfaces, while “urban” land uses are those with predominantly impervious surfaces. It is often appropriate to divide certain land uses into pervious (“rural”) and impervious (“urban”) fractions for simulation. Monthly sediment delivery from each “rural” land use is computed from erosion and the transport capacity of runoff, whereas total erosion is based on the universal soil loss equation (USLE) (Wischmeier and Smith 1978), with a modified rainfall erosivity coefficient that accounts for the precipitation energy available to detach soil particles (Haith and Merrill, 1987). Thus, erosion can occur when there is precipitation, but no surface runoff to the stream; delivery of sediment, however, depends on surface runoff volume. Sediment available for delivery is accumulated over a year, although excess sediment supply is not assumed to carry over from one year to the next. Nutrient loads from rural land uses may be dissolved (in runoff) or solid-phase (attached to sediment loading as calculated by the USLE).

For "urban" land uses, soil erosion is not calculated, and delivery of nutrients to the water bodies is based on an exponential accumulation and washoff formulation. All nutrients loaded from urban land uses are assumed to move in association with solids.

GWLF Model Inputs

GWLF application requires information on land use, land cover, soil, and parameters that govern runoff, erosion, and nutrient load generation. In order to determine loads (needed to calibrate a water quality model), flow measurements (or estimates) are needed at the time that water quality samples are collected. Streamflow data was determined from an existing USGS gaging station and 8 temporary bridge gages set up by Ohio EPA at various locations in the Sugar Creek basin.

Land Use/Land Cover

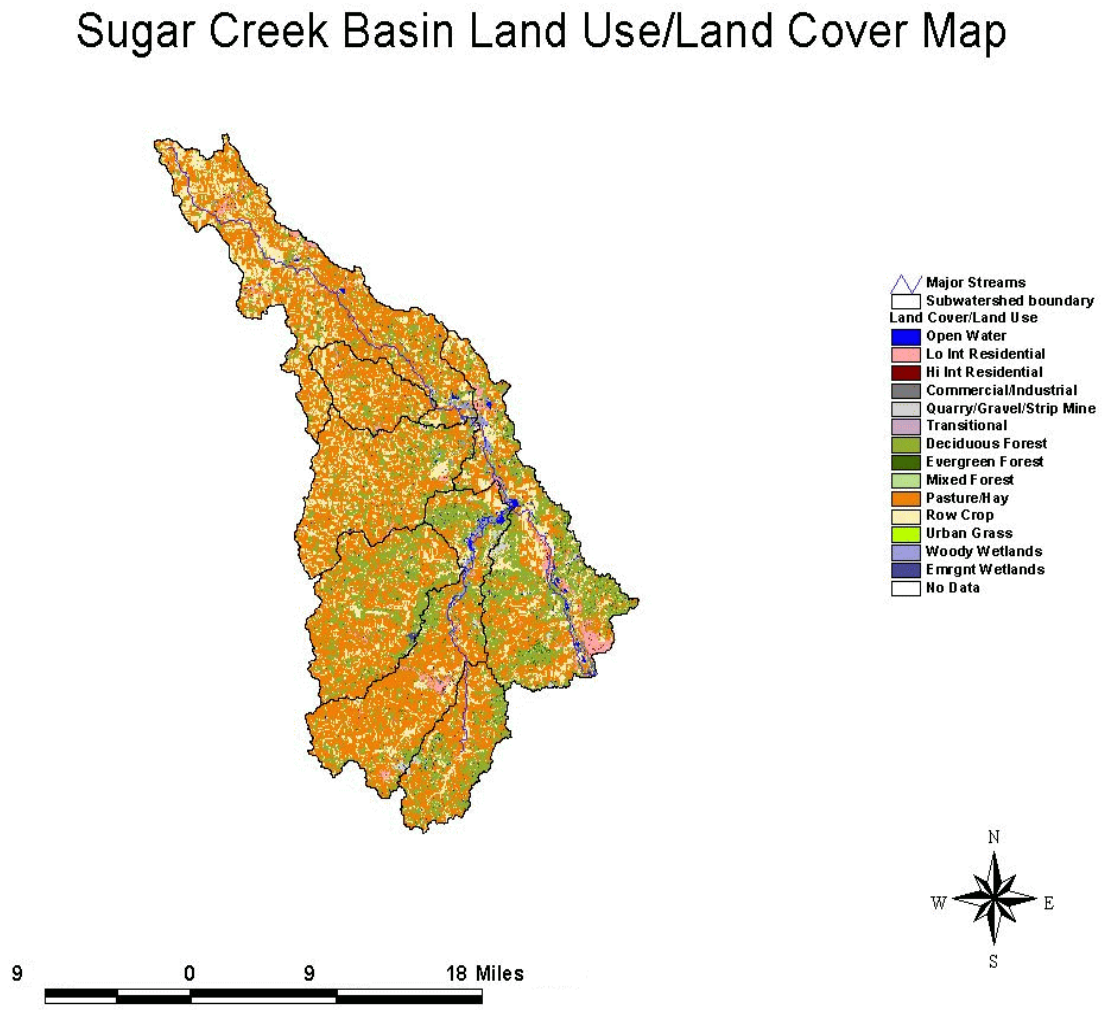
Digital land use/land cover (LULC) data for the Sugar Creek watershed were obtained from the National Land Cover Dataset (NLCD). The NLCD is a consistent representation of land cover for the conterminous United States generated from classified 30-meter resolution Landsat thematic mapper (TM) satellite imagery data. The NLCD is classified into urban, agricultural, forested, water, and transitional land cover subclasses. The imagery was acquired by the Multi-Resolution Land Characterization (MRLC) Consortium, a partnership of federal agencies that produce or use land cover data. The imagery was taken between 1990-1994. Table 1 summarizes the acreage in each land use category in the Sugar Creek watershed.

Table 1. Land uses in the Sugar Creek watershed, 1990-1994 (MRLC data)

Land Use	Acres	% of Total
Pasture/Hay	115,985	50.8%
Deciduous Forest	52,026	22.8%
Row Crops	46,109	20.2%
Low Intensity Residential	4,725	2.1%
Evergreen Forest	2,212	1.0%
Woody Wetlands	1,613	0.7%
Open Water	1,362	0.6%
Mixed Forest	1150	0.5%
Emergent Herbaceous Wetlands	905	0.4%
Transitional (Barren)	862	0.4%
Commercial/Industrial/Transportation	853	0.4%
High Intensity Residential	353	0.2%
	228,155	100%

Figure 1 shows a land use/land cover map of the Sugar Creek watershed. The seven subwatersheds for which nonpoint source modeling was performed are outlined.

Figure 1. Land Use map of the Sugar Creek Basin



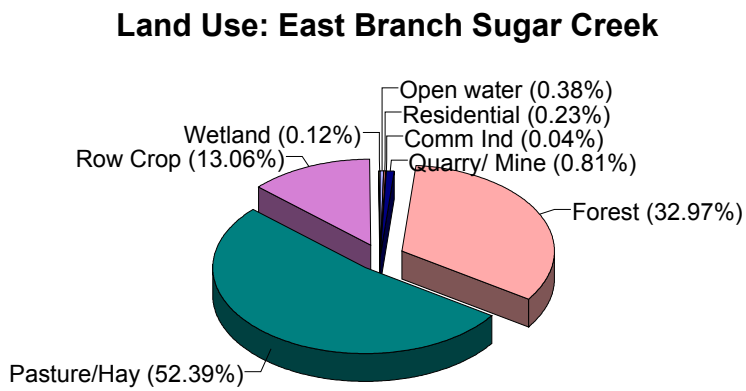
Soils data for the Sugar Creek watershed were obtained from the NRCS State Soil and Geographic (STATSGO) database (http://www.ftw.nrcs.usda.gov/stat_data.html). Attribute data associated with soil map units were used to assign soil hydrologic groups and to estimate values for some of the USLE parameters, as described in sections below.

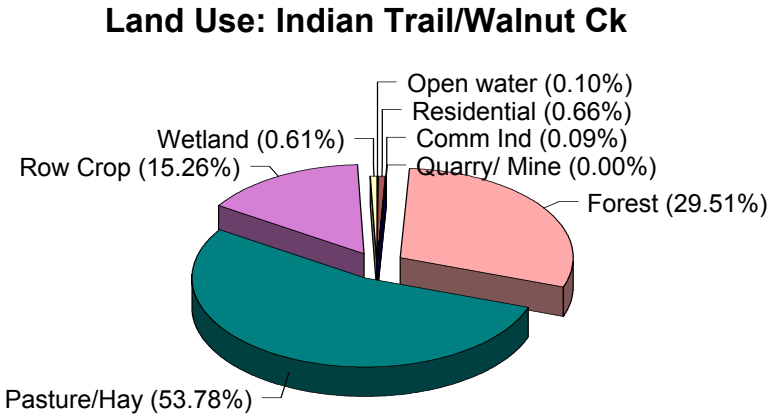
Table 2 shows land use data for each of the 7 subwatersheds that were selected for non point source modeling in the Sugar Creek basin. The data from this table was plotted as pie charts for a few subwatersheds to illustrate the relative magnitude of agricultural land uses, and are shown in Figure 2. The location of the 7 subwatersheds is shown in Figure 3.

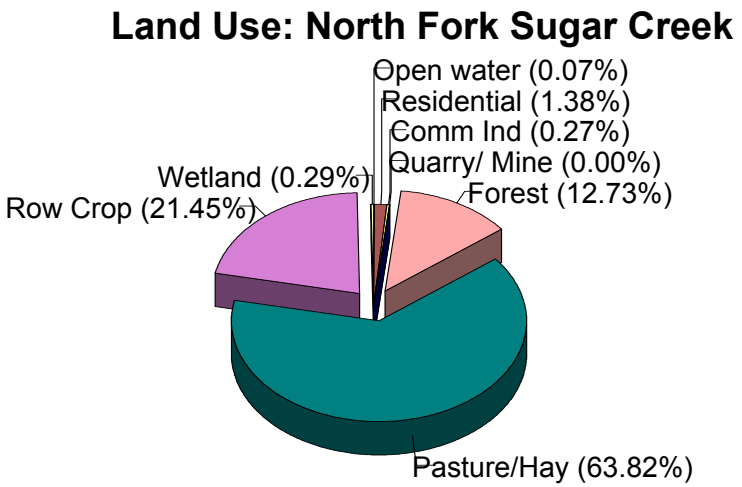
Table 2. Land use area (mi^2) for Sugar Creek sub-basins

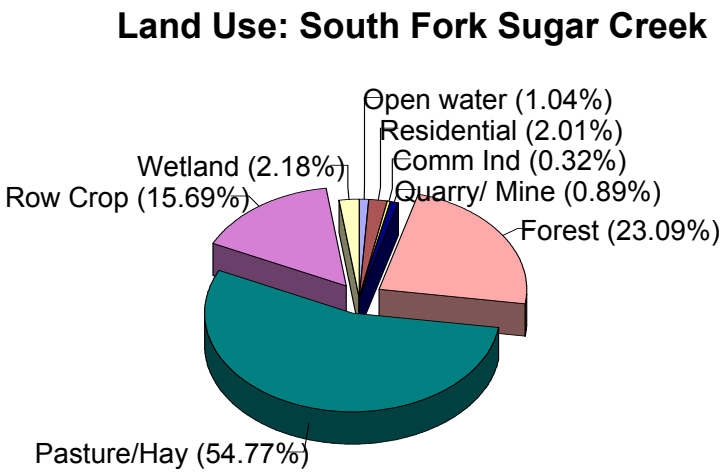
Sub Basin	Open Water	Residential Lo	Residential Hi	Comm Industr	Quarry/ Mine	Deciduous Forest	Evergreen Forest	Mixed Forest	Pasture/ Hay	Row Crop	Wood Wetland	Herb. Wetland
Upper Sugar Ck	0.343	1.677	0.125	0.337	0.017	9.439	0.334	0.147	43.970	22.171	0.532	0.215
Lower Sugar Ck	0.882	3.636	0.278	0.651	0.480	25.453	1.331	0.803	24.695	14.746	0.705	0.468
N Fork	0.012	0.222	0.026	0.048	0.000	2.144	0.112	0.039	11.501	3.865	0.036	0.016
M Fork	0.097	0.325	0.028	0.041	0.076	8.514	0.355	0.187	26.742	10.591	0.237	0.058
S Fork	0.639	1.156	0.080	0.199	0.546	13.398	0.573	0.238	33.699	9.655	0.974	0.369
Ind-Walnut Ck	0.049	0.303	0.013	0.043	0.000	13.738	0.301	0.147	25.851	7.335	0.030	0.263
E Branch	0.106	0.066	0.000	0.013	0.227	8.608	0.450	0.237	14.772	3.683	0.007	0.026

Figure 2. Land use in major Sugar Creek basin tributaries









For modeling purposes, the Sugar Creek watershed was divided into 7 subwatersheds to provide more resolution for major tributaries and parts of the mainstem. The subwatersheds are shown in figure 3.

In order to determine loads (needed to calibrate a water quality model), flow measurements should be made at the time that water quality samples are collected. Since there was only one active USGS gaging station in the Sugar Creek basin (Sugar Creek below Beach City dam), Ohio EPA set up temporary bridge gages at several sites throughout the basin. The Sugar Creek basin was subdivided into 7 sub-watersheds based on the following factors:
1. Ecoregion: 2 sub-basins are located in the EOLP, and 5 in the WAP ecoregion.
2. Resolution vs. simplicity: Need to provide more detail than could be obtained from calculating a global load at the basin outlet, while minimizing the complexity of the simulations.
3. Data availability: Desire to simulate loads for subwatersheds where historical water quality data was available (North Fork) or represented special cases (East Branch, a subwatershed with no point source impacts).
4. Stakeholder groups: Existence of watershed/stakeholder groups (North Fork, East Branch) desiring more detailed information to assist them with development of implementation plans .
5. Hydrologic Units: The selected subwatersheds fall within the three units identified by their "11 digit hydrologic unit code".

The GWLF model was first run for the whole watershed, and the simulated hydrograph was calibrated against the USGS gage located in Sugar Creek at Strasburg. Once the hydrology was calibrated, the model was set up and run for each of the 7 subwatersheds. The detailed information about the subwatersheds will be useful for stakeholder groups as they prepare implementation plans. Table 3 shows the subwatershed descriptions and their drainage area. The subwatersheds, land uses, and the soils coverages were overlaid in a Geographic Information System (GIS) environment. For the purposes of the GWLF modeling of runoff and erosion, the land use categories were grouped as summarized in Table 4. Runoff and erosion potential are expected to be affected both by land use and by the soil hydrologic group, so each land use group was divided into sub-categories based on the hydrologic group (A, B, C or D) of the underlying soil type.

Figure 3. Sugar Creek subwatersheds for nonpoint source modeling

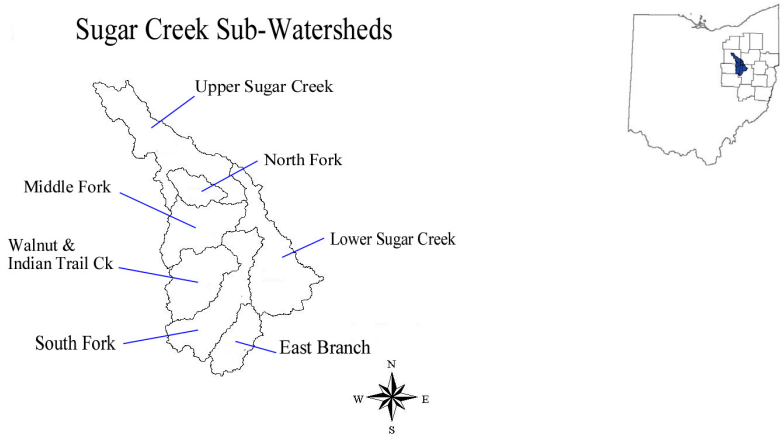


Table 3: Drainage Area in 7 major Sugar Creek Subbasins

Sub Basin	Area (mi^2)	Comments
Upper Sugar Ck	79.4	From headwaters to upstream of Middle Fork, excluding N. Fork
Lower Sugar Ck	74.2	From downstream Middle Fork to mouth, excluding South Fork
North Fork	18.0	
Middle Fork	47.3	
South Fork	61.6	Excluding Walnut Ck and East Branch
Indian Trail/Walnut Ck	48.1	
East Branch	28.2	
Total area:	356.8	

Table 4. Land Use Groupings for GWLF Modeling

NLCD Land Use	Pollutant Simulation
Deciduous Forest	Rural
Evergreen Forest	Rural
Mixed Forest	Rural
Transitional (Barren)	Rural
Pasture/Hay	Rural
Row Crops	Rural
Low Intensity Residential	Urban
High Intensity Residential	Urban
Commercial/Industrial/ Transportation	Urban
Woody Wetlands	Rural
Emergent Herbaceous Wetlands	Rural
Open Water	--

Rainfall and Runoff Input Data and Parameters

Meteorology

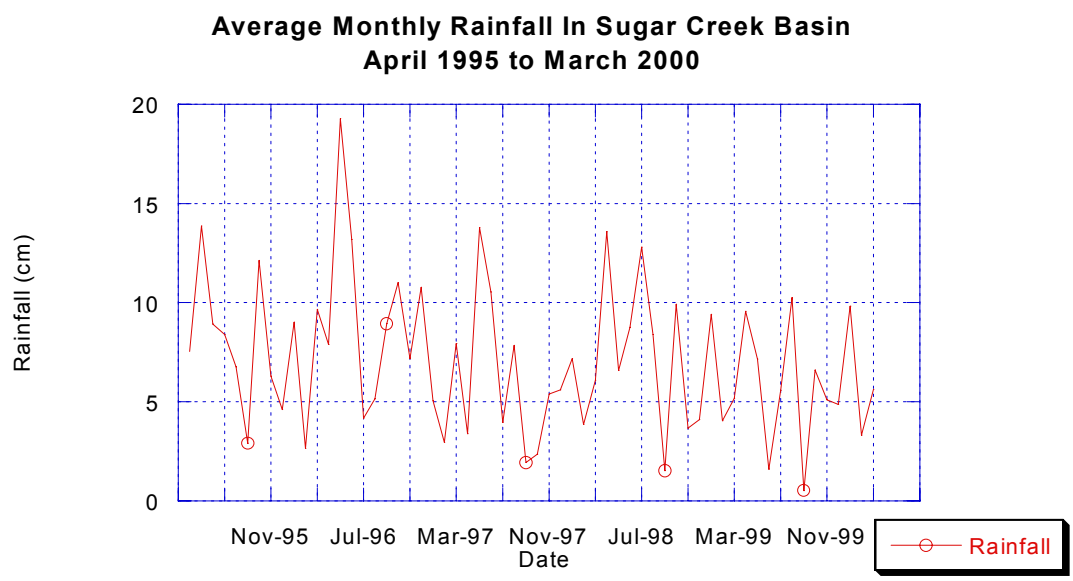
Hydrology in GWLF is simulated by a water-balance calculation, based on daily observations of precipitation and temperature. A search was made of available Midwestern Regional Climate Center reporting stations. Based on this review, four weather stations were selected according to their proximity to the Sugar Creek watershed and availability of the necessary data. The stations provide daily data on precipitation and minimum and maximum temperature. Daily mean temperature was estimated as the mean of the minimum and maximum values. The best model calibration results were obtained by using the average of the 4 selected stations. Table 5 shows the name and location of the selected weather stations.

Table 5. Meteorological Stations Selected for Sugar Creek GWLF Modeling

Station Name	County	Station No.	Latitude	Longitude
Wooster Exp Sta	Wayne	339312	40° 47'	81° 55' W
New Philadelphia	Tuscarawas	335894	40° 30'	81° 28' W
Millersburg	Holmes	335297	40° 33'	81° 55' W
Akron-Canton	Summit	330058	40° 55'	81° 26' W

Figure 4 shows the average monthly precipitation during the GWLF simulation period (April 1995 to March 2000) based on the average of the 4 selected stations. The average annual precipitation for the calibration period (April 1995 to Mar 2000) was 33.6 inches. This is below the typical 38-40 inch annual average.

Figure 4. Average Monthly Rainfall in Sugar Creek Basin, 1995-2000



Runoff Curve Numbers

The direct runoff fraction of precipitation in GWLF is calculated using the curve number method from the SCS TR55 method literature based on land-use and soil hydrologic group (SCS 1986). Curve numbers vary from 25 for undisturbed woodland with good soils, to, in theory, 100, for impervious surfaces. The hydrologic soil group was determined from available soils data and curve numbers were calculated for each land use category/soil hydrologic group. Curve numbers assigned for the Sugar Creek watershed are summarized in Table 6. The curve numbers are weighted averages based on soil type and land use area. For each land use, the table also indicates whether GWLF simulates nutrient loading via the USLE equation ("rural" areas) or a buildup-washoff formulation ("urban" areas).

Table 6. Runoff Curve Numbers for the Sugar Creek Watershed.

Land Use /Land Cover	GWLF Loading Methodology	Area Weighted Ave. Curve Number
Forest	USLE	72
Pasture/Hay	USLE	72
Row Crops	USLE	84
Hi and Low Intensity Residential	Buildup-Washoff	82
Commercial/Industrial/ Transportation	Buildup-Washoff	98
Transitional/Quarry/Mines	USLE	87
Wetlands	USLE	100
Open Water	USLE	100

Evapotranspiration Cover Coefficients

The portion of rainfall returned to the atmosphere is determined by GWLF based on temperature and the amount of vegetative cover. For urban land uses, the cover coefficient was calculated as (1 - impervious fraction). For all other land uses it was assumed that land had vegetative cover during the growing season (cover coefficient = 1) and limited vegetative cover during the dormant season (cover coefficient = 0.3). The cover coefficients were area-averaged to result in one coefficient value for the growing season (March-October) and one for the dormant season (November-February).

Soil Water Capacity

Water stored in soil may evaporate, be transpired by plants, or percolate to ground water below the rooting zone. The amount of water that can be stored in soil (the soil water capacity) varies by soil type and rooting depth. Based on soil water capacities reported in the STATSGO database, soil types present in the watershed, and GWLF user's manual recommendations, the GWLF default soil water capacity of 10 cm was used.

Recession and Seepage Coefficients

The GWLF model has three subsurface zones: a shallow unsaturated zone, a shallow saturated zone, and a deep aquifer zone. Behavior of the second two stores is controlled by a ground water recession and a deep seepage coefficient. The recession coefficient was set to 0.29 per day and the deep seepage coefficient to 0.02 cm/day, based on several calibration runs of the model.

Erosion Parameters

GWLF simulates rural soil erosion using the Universal Soil Loss Equation (USLE). [Note: For land uses indicated as "Buildup-Washoff" in Table 6, solids loads are generated separately, as described below in the section entitled Parameters Governing Nutrient Load Generation.] This method has been applied extensively, so parameter values are well established. This computes soil loss per unit area (sheet and rill erosion) at the field scale by the following equation:

$$A = RE * K * LS * C * P$$

where

A = rate of soil loss per unit area,
RE = rainfall erosivity index,
K = soil erodibility factor,
LS = length-slope factor,
C = cover and management factor, and
P = support practice factor.

Soil loss or erosion at the field scale is not equivalent to sediment yield, as substantial trapping may occur, particularly during overland flow or in first-order tributaries or impoundments. GWLF accounts for sediment yield by (1) computing transport capacity of overland flow, and (2) employing a sediment delivery ratio (DR) which accounts for losses to sediment redeposition.

Rainfall Erosivity (RE)

Rainfall erosivity accounts for the impact of rainfall on the ground surface, which can make soil more susceptible to erosion and subsequent transport. Precipitation-induced erosion varies with rainfall intensity, which shows different average characteristics according to geographic region. The factor is used in the Universal Soil Loss Equation and is determined in the model as follows:

$$RE_t = 64.6 * a_t * R_t 1.81$$

where

RE_t = Rainfall erosivity (in megajoules mm/ha-h),
a_t = Location- and season-specific factor, and
R_t = Rainfall on day t (in cm).

The erosivity coefficient (a_t) was assigned a value of 0.26 for the growing season and 0.08 for the dormant season, based on erosivity coefficients provided in the GWLF User's Manual.

Soil Erodibility (K) Factor

The soil erodibility factor indicates the propensity of a given soil type to erode, and is a function of soil physical properties and slope. Soil erodibility factors were extracted from the STATSGO soil coverage. For each land use category, the K factors of the soil types underlying all land of this category were area-averaged to result in an overall K factor for the land use category.

Length-Slope (LS) Factor

Erosion potential varies by slope as well as soil type. The LS factor is calculated following Wischmeier and Smith (1978):

$$LS = (0.138 * x_k)b * (65.41 * \sin^2\phi_k + 4.56 * \sin\phi_k + 0.065)$$

where

ϕ_k = tan - 1(ps_k/100), where ps_k is percent slope
x_k = slope length (ft)
b = a factor of percent slope, as follows:

Percent Slope	b
0-1	0.2
1 - 3.5	0.3
3.5 - 5	0.4
5 +	0.5

Slopes were calculated from digital elevation maps produced by the USGS and downloaded from the Internet*. A second-order finite difference method (Skidmore, 1989) was used, as it should yield more representative results. This method calculates the elevation rise to the elevation run of a particular point of interest based on the 4 neighboring elevation points. The median of these slopes for each soil type and land use was used in the length slope equations mentioned above. The slope length varied by subwatershed, and was assumed to range from 100 to 150 meters based on a visual analysis of the land use/soils coverage.

* The Internet link to the digital elevation data source is:
http://gcmd.gsfc.nasa.gov/cgi-bin/md/getdif.pl?format=sgml&morph_dic=dif_to_dif-display-html.dic&entry_ids=7_MIN_DEM

Cover and Management (C) and Practice (P) Factors

The mechanism by which soil is eroded from a land area and the amount of soil eroded depends on soil treatment resulting from a combination of land uses (e.g., forestry versus row-cropped agriculture) and the specific manner in which land uses are carried out (e.g., no-till agriculture versus non-contoured row cropping). Land use and management variations are represented by cover and management factors in the universal soil loss equation and in the erosion model of GWLF. Cover and management factors were drawn from several sources (Wischmeier and Smith, 1978; Haith et al., 1992; Novotny and Olem, 1994), and from consultation with NRCS and SWCD staff from Wayne, Holmes and Tuscarawas counties. These factors are summarized in Table 7. Practice (P) factors were generally set to 1.

Table 7. Cover and Management Factors for Sugar Creek Watershed Land Uses*

Land Use	C	P
Forest	0.001- 0.003	1
Pasture	0.003 - 0.013	1
Row Crops	0.16 - 0.53	1
Barren/Transitional/Mines	0.09	1
Wetland	0.010	1
Water	0	0

* C and P factors are not required for the "urban" land uses which are modeled in GWLF via a buildup-washoff formulation rather than USLE.

Sediment Delivery Ratio

The sediment delivery ratio (DR) converts erosion to sediment yield, and indicates the portion of eroded soil that is carried to the watershed mouth from land draining to the watershed. The BasinSim program (a Windows version of GWLF) includes a built-in utility which calculates the sediment delivery ratio based an empirical relationship of DR to watershed area (SCS, 1973). The sediment delivery ratio for the entire Sugar Creek watershed was calculated at 0.065. Different values were determined for each subwatershed when simulating them individually.

Parameters Governing Nutrient Load Generation

Groundwater Nutrient Concentrations

The GWLF model requires input of groundwater nutrient concentrations excluding loads due to septic systems, which are accounted for separately. Even in the absence of septic system loads, groundwater concentrations are expected to increase with a shift from forest to either agriculture or development, due to the input of fertilizer on crops, lawns, and gardens. The effect is greatest for nitrate, which is highly soluble, but some elevation of groundwater concentrations of phosphorus is also expected with increased development.

Groundwater nutrient concentrations were estimated as an area-weighted average of concentrations expected for managed land (agriculture, and residential, commercial, and industrial development) and unmanaged land (e.g., forest). Groundwater concentrations for unmanaged land were assigned a value of 0.009 mg/l for phosphorus and 0.060 for nitrogen, based on recommended values in the GWLF User's manual. Managed lands were assigned a groundwater phosphorus concentration of 0.05 mg/l and a groundwater nitrogen concentration of 1.25 for the whole-basin simulations. These values were estimated from surface water quality samples collected at low flow conditions at 10 sites throughout the basin. Since the phosphorus was measured as total P, it was assumed that 20% of the reported value was dissolved P. These estimates, particularly for phosphorus, are considered to be somewhat high. Since GWLF doesn't take into account the effect of drainage tiles as a source of nutrients to the stream, choosing these higher concentrations provides a way to compensate for the model's limitation, and is one of the safety margins built into the TMDL process.

Dissolved and Solid Phase Nutrient Concentrations for Rural Land Uses

GWLF requires a dissolved phase concentration for surface runoff from rural land uses. Particulate concentrations are taken as a general characteristic of area soils, determined by bulk soil concentration and an enrichment ratio indicating preferential association of nutrients with the more erodible soil fraction, and not varied by land use. The estimates of dissolved phase and solid phase nutrient concentrations were selected from the GWLF User's Manual and are shown in Table 8.

Table 8. Dissolved and Solids Phase Nutrient Concentrations for Rural Land Uses

GWLF Land Use Group	Nitrogen		Phosphorus	
	Dissolved Phase (mg/L)	Solids Phase (mg/kg)	Dissolved Phase (mg/L)	Solids Phase (mg/kg)
Forest	0.25	3000	0.01	1276
Pasture	3.00	3000	0.25	1276
Row Crop	2.90	3000	0.26	1276
Barren/Transitional/Mines	0.65	3000	0.06	1276
Wetland	0.25	3000	0.01	1276

Buildup/Washoff Parameters for Urban Land Uses

Nutrients and solids generated from urban land uses are described by a buildup/washoff formulation. Pollutant accumulation is summarized by an exponential buildup rate, and GWLF assumes that 95% of the limiting pollutant storage is reached in a 20-day period without washoff. Based on land use data, most residential land use is low density. Assumed that low density residential lands are 45% pervious and 55% impervious surfaces, and that commercial/industrial lands are 20% pervious and 80% impervious, based on National Land Cover Dataset definitions (USGS, 2000). The buildup rates are based on data from the GWLF user's manual, and are summarized in Table 9.

Table 9. Pollutant Buildup Rates for Urban Land Uses.

Land use	Nitrogen build up (kg/ha-d)	Phosphorus build up (kg/ha-d)
Commercial/Industrial/Transportation	0.083	0.009
Low density residential	0.030	0.003

Septic Systems

GWLF contains routines for the simulation of nutrient loading from both normal and failing septic systems. The number of septic systems in each subwatershed was estimated from a combination of 1990 census data, 1996 population estimates for county townships, estimates of septic systems from a NEFCO report (NEFCO, 2000), and consultation with local health departments. Several assumptions had to be made to categorize the systems according to their performance. These assumptions were based on the data provided by the public health departments, where available, and best professional judgement otherwise. Table 10 summarizes the results of these assumptions.

Table 10. Estimated Population Served by Septic Systems in the Sugar Creek Watershed

Subwatershed	Estimated Population Served by Each Category			
	Normal	Ponded	Short-circuited	Direct Discharge
Upper Sugar Creek	2,425	4,850	391	156
Lower Sugar Creek	2,031	4,062	328	131
North Fork	876	1,753	141	57
Middle Fork	1,693	3,385	273	109
South Fork	1,477	2,954	238	95
Indian Tr/Walnut ck	1,504	3,009	243	97
East Branch	372	743	60	24
Whole Watershed	10,378	20,756	1,674	669

Normal: Septic systems conform to EPA standards and operating effectively.
Ponded: System failure results in surfacing of effluent.
Short-circuited: Systems are close enough to surface water (< 15 meters) that negligible absorption of phosphorus takes place.
Direct Discharge: Illegal systems discharge effluent directly into surface waters.

Parameters affecting nutrient loading from septic systems were specified at GWLF default values. Effluent phosphorus from failing septic systems was set to 1.5 g/day (default for areas with non-phosphate detergents), while effluent nitrogen was set to 12.0 g/day. Plant uptake rates were assumed to be 1.6 g/day nitrogen and 0.4 g/day phosphorus.

Point Sources

Average monthly nutrient loads from point sources were calculated either from information received from the facilities in their permits' Monthly Operating Report (1994-99), or from water quality samples collected during the 1998 Sugar Creek basin surveys. The design flow for each discharger was used to determine the load. If seasonal data was available, loads were separated into average summer and winter loadings. If winter data was not available, the winter values were assumed to be the same as the summer values. For some small dischargers, no data was available, and nutrient loads were estimated based on typical values for other small dischargers. The effluent data for phosphorus is typically reported as total phosphorus (total P). It was assumed that 80% of the effluent total P value consisted of dissolved P, because most of the suspended P is removed with the suspended solids during treatment..

Dissolved nitrogen was determined by adding NO3 +NO2 and NH3-N effluent concentrations. The ammonia loads were based on permit limits, rather than existing effluent concentrations. The East Branch is the only subwatershed without point sources. Table 11 shows the existing/estimated monthly point source load of nutrients for each Sugar Creek subwatershed. This information was used in the GWLF non point source model.

Table 11. Monthly Nutrient Point Source Load (kg/month) for Sugar Creek Subwatersheds

Subwatershed	Dissolved Nitrogen[A]		Dissolved Phosphorus[B]	
	Summer	Winter	Summer	Winter
Upper Sugar Creek	820	1126	134	134
Lower Sugar Creek	3080	4134	791	791
North Fork	1091	1364	130	130
Middle Fork	408	536	268	268
Walnut/Indian Trail	909	911	311	311
South Fork	1202	1608	593	593
East Branch	none	none	none	none

[A] Dissolved Nitrogen determined as sum of effluent NO3+NO2 and permitted NH3-N loads.
[B] Numbers represent 80% of the estimated total phosphorus loads.
Design flows were used for these load calculations.

Table 12 shows the existing loads determined using the GWLF model for each modelled subwatershed for dissolved nitrogen, total phosphorus and sediments. Under "existing conditions" the Nonpoint Source (NPS) column includes groundwater, urban, agricultural and natural background loads.

The Point Source (PS) column includes the sum of known point source loads in the watershed. The TMDL was determined by multiplying the existing total load by the recommended percent reduction. The TMDL was divided among background conditions, wasteload allocation for point sources (WLA) and load allocations (LA) for nonpoint sources. To determine the background load, the GWLF model was run assuming the watershed was completely covered by forests, instead of cropland, pastureland, and other urban land uses. All the point sources and septic tanks were also excluded, to determine the pollutant loads under "pristine" or pre-settlement conditions.

The WLA loads are based on permitted loads at design flow for the point sources in the basin. For total phosphorus, the effluent limits for all point sources were set to 1 mg/l. For dissolved nitrogen, only the WLA loads for the North Fork Sugar Creek were adjusted by lowering the nitrogen load because the point source nitrogen loads are probably the main source of nitrogen during low streamflow periods. The remaining load was allocated to nonpoint sources. The percent reductions for nitrogen and phosphorus were set to an appropriate percentage, based on the average reduction needed to meet the nutrient targets shown in Tables 11 and 12. The 30% reduction proposed for sediments is an estimate based on a reduction that may have a significant effect compared to existing conditions, and on the effectiveness of management practices in the Auglaize River basin, which have reduced sediment loads by 50% over the past 20 years. It should be noted that GWLF simulates sheet and rill erosion, and a multiplier (sediment delivery

ratio) determines what percent of that sediment reaches the stream. Bank and gully erosion are not simulated by GWLF, but are taken into account by the QHEI index. The QHEI will be used to guide implementation actions to address bank and gully erosion.

Table 12. TMDLs and Allocations For the Sugar Creek Basin

Subwatershed	Existing Conditions			Percent Reduction	TMDL	TMDL Allocations		
	NPS	PS	Total			Natural	WLA	LA
Dissolved Nitrogen (kg/day)								
E Branch	103	0	103	40%	62	13	0	49
Upper Sugar	426	27.3	453	70%	136	37	27.3	72
Lower Sugar	253	102.6	356	0%	356	35	102.6	218
North Fork	77	36.4	113	70%	34	8	21.2	5
Middle Fork	186	13.6	200	25%	150	22	13.6	114
South Fork	338	40.1	378	30%	265	29	28.5	207
Walnut/Indian Tr	222	30.3	252	30%	176	22	26.0	128
Total Phosphorus (kg/day)								
E Branch	24	0	24	60%	10	4	0	6
Upper Sugar	39	5.6	45	60%	18	3	2.6	12
Lower Sugar	47	33	80	50%	40	6	6.2	28
North Fork	14	5.4	19	50%	10	2	3.6	4
Middle Fork	39	11.2	50	40%	30	5	1.0	24
South Fork	59	24.7	84	60%	34	5	2.7	26
Walnut/Indian Tr	30	12.9	43	60%	17	8	2.3	7
Sediments (metric tons/year)								
E Branch	4798	0	4798	30%	3359	896	0	2463
Upper Sugar	3657	13.3	3670	30%	2569	408	13.3	2148
Lower Sugar	9774	115.2	9889	30%	6922	1270	115.2	5537
North Fork	2040	15.4	2055	30%	1439	356	15.4	1067
Middle Fork	6981	4.9	6985	30%	4890	1305	4.9	3580
South Fork	8690	17.0	8707	30%	6095	1158	17.0	4920
Walnut/Indian Tr	5025	15.2	5040	30%	3528	2047	15.2	1466

REFERENCES

Haith, D.A., R. Mandel, and R.S. Wu. 1992. GWLF, Generalized Watershed Loading Functions, Version 2.0, User's Manual. Dept. of Agricultural & Biological Engineering, Cornell University, Ithaca, NY.

Haith, D.A. and D.E. Merrill. 1987. Evaluation of a daily rainfall erosivity model. Transactions of the American Society of Agricultural Engineers, 30(1): 90-93.

NEFCO, 2000. Sugar Creek Watershed Comprehensive Watershed Management Plan Phase I, Northeast Ohio Four County Regional Planning and Development Organization, June 2000.

Novotny, V. and H. Olem. 1994. Water Quality: Prevention, Identification, and Management of Diffuse Pollution. Van Nostrand Reinhold, New York.

SCS, 1973. *National Engineering Handbook*. Section 3, Chapter 6. Soil Conservation Service, U.S. Department of Agriculture, Washington, DC.

SCS. 1986. *Urban Hydrology for Small Watersheds*. Technical Release No. 55 (second edition). Soil Conservation Service, U.S. Department of Agriculture, Washington, DC.

USGS, 2000. NLCC regional Land Cover Classification System Key, U.S. Dept. of Interior, U.S. Geological Survey, http://edcwww.cr.usgs.gov/programs/lccp/classes.html.

Wischmeier, W.H. and D.D. Smith. 1978. *Predicting Rainfall Erosion Losses, A Guide to Conservation Planning*. Agricultural Handbook 537, U.S. Department of Agriculture, Washington, DC.