GWLF Data Requirements - May 2010

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The Generalized Watershed Loadings Function model (GWLF) was originally developed in the US at Cornell University in Quick BASIC. It is available in now several forms which include a modified form developed by the New York City Department of Environmental Protection (DEP) in the Visual programming language VENSIM (http://www.vensim.com/). This version of the model was applied during the EU CLIME project to catchments across Europe (Schneiderman et al. 2009; Moore et al. 2009; Pierson et al. 2009). GWLF has a number of sub-models, which simulate hydrologic, sediment, and dissolved and particulate nutrient export from a watershed. The DEP version of GWLF also now incorporates a model of dissolved organic carbon (DOC) production and transport (Naden et al. 2009).

In addition to the summary information here, the model and data requirements are described in the GWLF user manual (Haith et al. 1992). The DEP version of the model is available and can be run using the freely available VENSIM model reader. Below is a summary of the *most important* data requirements needed for the model.

Climate Data

GWLF is driven by daily variations in air temperature and precipitation. These can be input to the model as simple time series, and are read in the model from external files. Air temperature data are input as daily maximum and minimum temperature data or as daily mean temperature. Daily precipitation depth is in cm. For large watersheds there can be considerable spatial variability in precipitation, and care must be taken to derive spatially representative time series.

Spatial data

Three important parameters needed to define (parameterize) the model response to the driving data are:

1. Runoff curve numbers used to predict surface runoff (SCS curve numbers)
2. The erosion factor (K) used in the Universal Soil Loss Equation (USLE).
3. A land-slope factor (LS) also used in the USLE

All of these parameters and the equations in which they are used have been developed by the US soil conservation service. Information on them is widely available in the US. To apply the GWLF in Europe it was be necessary to derive the parameters from soil texture and organic matter information, land use data, and topographic data. Thus the following spatial coverages are required

1. Land use

2. Soil data
3. Topography

In GWLF the watershed division is in terms of land use, so all spatial parameters are averaged by land use category. Optimally, spatial data will be available in digital form so that the land use based calculations can be made with the aid of a GIS program. It is also important to have information on agricultural practices. Ideally this would also be spatial and a GIS layer. In practice however, such data is usually available as statistical summaries. For the application in European catchments land use categories were based on CORINE land cover classes (Schneiderman et al., 2009)

Below is some information to illustrate how these parameters are derived. The information used here is taken from the GWLF user manual.

SCS Curve number

Runoff is computed from daily weather data by the U.S. Soil Conservation Service's Curve Number Equation (Ogrosky & Mockus, 1964):

$$Q_{kt} = \frac{(R_t + M_t - 0.2\ DS_{kt})^2}{R_t + M_t + 0.8\ DS_{kt}}$$

Rainfall R_t (cm) and snowmelt M_t (cm of water) on day t are estimated from daily precipitation and temperature data.

The detention parameter DS_{kt} (cm) is determined from a curve number CN_{kt} as

$$DS_{kt} = \frac{2540}{CN_{kt}} - 25.4$$

Curve numbers are selected as functions of antecedent moisture as described in Haith (1985)

1) To calculate SCS Curve numbers it is necessary to assign a hydrologic class to the soil as described below

Runoff Curve Numbers. Runoff curve numbers for rural and urban land uses have been assembled in the U.S. Soil Conservation Service's Technical Release No. 55, 2nd edition (Soil Conservation Service, 1986). These curve numbers are based on the soil hydrologic groups given in Table B-1.

Table B-1. Descriptions of Soil Hydrologic Groups (Soil Conservation Service, 1986)

Soil Hydrologic Group	Description
A	Low runoff potential and high infiltration rates even when thoroughly wetted. Chiefly deep, well to excessively drained sands or gravels. High rate of water transmission (> 0.75 cm/hr).
B	Moderate infiltration rates when thoroughly wetted. Chiefly moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. Moderate rate of water transmission (0.40-0.75 cm/hr).
C	Low infiltration rates when thoroughly wetted. Chiefly soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. Low rate of water transmission (0.15-0.40 cm/hr).
D	High runoff potential. Very low infiltration rates when thoroughly wetted. Chiefly clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, or shallow soils over nearly impervious material. Very low rate of water transmission (0-0.15 cm/hr).

Disturbed Soils (Major altering of soil profile by construction, development):

A	Sand, loamy sand, sandy loam.
B	Silt loam, loam
C	Sandy clay loam
D	Clay loam, silty clay loam, sandy clay, silty clay, clay.

2) Given these Classes the SCS Curve Numbers can be predicted from LU data and an assigned hydrological condition as illustrated below (note there are also other land uses than those illustrated here)

Table B-2. Runoff Curve Numbers (Antecedent Moisture Condition II) for Cultivated Agricultural Land (Soil Conservation Service, 1986).

Land Use/Cover	Hydrologic Condition	Soil Hydrologic Group A	B	C	D
Pasture, grassland or range - continuous forage for grazing	Poor[a/]	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow - continuous grass, protected from grazing, generally mowed for hay	-	30	58	71	78
Brush - brush/weeds/grass mixture with brush the major element	Poor[b/]	48	67	77	83
	Fair	35	56	70	77
	Good	30	48	65	73
Woods/grass combination (orchard or tree farm)[c/]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods	Poor[/d]	45	66	77	83
	Fair	36	60	73	79
	Good	30	55	70	77
Farmsteads - buildings, lanes, driveways and surrounding lots	-	59	74	82	86

[a/] Poor: < 50% ground cover or heavily grazed with no mulch; Fair: 50 to 75% ground cover and not heavily grazed; Good: > 75% ground cover and lightly or only occasionally grazed.

[b/] Poor: < 50% ground cover; Fair: 50 to 75% ground cover; Good: > 75% ground cover.

[c/] Estimated as 50% woods, 50% pasture.

[d/] Poor: forest litter, small trees and brush are destroyed by heavy grazing or regular burning; Fair: woods are grazed but not burned and some forest litter covers the soil; Good: Woods are protected from grazing and litter and brush adequately cover the soil.

The Universal Soil Loss equation (USLE)

To estimate soil erosion associated with overland flow (sheet and rill erosion) GWLF makes use of the USLE. The USLE is based on four major parameters, which are derived from land use, agricultural practice, topography, and soil characteristics. Below is information from the GWLF Manual

In the model monthly sediment yields are determined from the model developed by Haith (1985). The model is based on three principal assumptions: (i) sediment originates from sheet and rill erosion (gully and stream bank erosion are neglected); (ii) sediment transport capacity is proportional to runoff to the 5/3 power (Meyer & Wischmeier, 1969); and (iii) sediment yields are produced from soil which erodes in the current year (no carryover of sediment supply from one year to the next).

Erosion from source area k on day t (Mg) is given by

$$X_{kt} = 0.132\ RE_t\ K_k\ (LS)_k\ C_k\ P_k\ AR_k$$

in which K_k, $(LS)_k$, C_k and P_k are the standard values for soil erodibility, topographic, cover and management and supporting practice factors as specified for the Universal Soil Loss Equation (Wischmeier & Smith, 1978). RE_t is the rainfall erosivity on day t (MJ-mm/ha-h). The constant 0.132 is a dimensional conversion factor associated with the SI units of rainfall erosivity.

Of the USLE parameters described above those that must be derived from spatial data sets are K and LS Cover (C) and practice (P) data can be derived from spatial information, but more often are derived from a knowledge of the land use and agricultural practices in the area of study. For example, if there is a land use category of cultivated fields, it may be possible to assign crop data to the fields based on a knowledge of what is normally planted in the area. Likewise the cropping and cultivation practices may also be assigned in a similar manner.

USLE slope factor LS

The $(LS)_k$ factor is calculated for each source area k as in Wischmeier & Smith (1978):

$$LS = (0.045x_k)^b\ (65.41 \sin^2 \theta_k + 4.56 \sin \theta_k + 0.065)$$

$$\theta_k = \tan^{-1}(ps_k/100)$$

in which x_k = slope length (m) and ps_k = per cent slope. The exponent in Equation B-6 is given by b = 0.5 for $ps_k >= 5$, b = 0.4 for $5 < ps_k < 3$, b = 0.3 for $3 \leq ps_k \leq 1$, and b = 0.2 for $ps_k < 1$ (Wischmeier & Smith, 1978).

USLE erosion factor K

The information on soil texture and organic matter are used to derive an erosion factor K as illustrated by the table below.

Table B-10. Values of Soil Erodibility Factor (K) (Stewart et al., 1975).

	Organic Matter Content (%)		
Texture	<0.5	2	4
Sand	0.05	0.03	0.02
Fine sand	0.16	0.14	0.10
Very fine sand	0.42	0.36	0.28
Loamy sand	0.12	0.10	0.08
Loamy fine sand	0.24	0.20	0.16
Loamy very fine sand	0.44	0.38	0.30
Sandy loam	0.27	0.24	0.19
Fine sandy loam	0.35	0.30	0.24
Very fine sandy loam	0.47	0.41	0.33
Loam	0.38	0.34	0.29
Silt loam	0.48	0.42	0.33
Silt	0.60	0.52	0.42
Sandy clay loam	0.27	0.25	0.21
Clay loam	0.28	0.25	0.21
Silty clay loam	0.37	0.32	0.26
Sandy clay	0.14	0.13	0.12
Silty clay	0.25	0.23	0.19
Clay		0.13-0.29	-

Point Source Nutrient loads.

GWLF accounts for the inputs of point source nutrient sources from, for example, sewage treatment plants. The original version of GWLF accomplished this through lookup table. Monthly variations in point source loading were based on measured data, but the same pattern was repeated from year to year. The DEP version of the model has been modified to allow daily point source inputs if these data are available.

Septic tank loads

The septic tank module requires data on the unsewered watershed population. This can be adjusted for changes during the tourist season. It also requires data on the proportion of septic tanks in each of four performance categories. Loading calculations are based on a per capita nutrient loss.

Dissolved and particulate nutrient loads from surface runoff and groundwater flow

Nutrient export rates are achieved by assigning fixed concentrations to surface runoff and particulate matter fluxes for each land use. For example, a separate phosphorus concentration is assigned to surface runoff and to the sediment lost from a given land use category, allowing the soluble and particulate phosphorus export to be calculated. A watershed-wide nutrient concentration is assigned to groundwater.

Calibration / Validation data.

While these data are not needed to run the model, they are needed to calibrate model coefficients, and to validate model performance.

Hydrological Data.

The hydrologic portion of GWLF can be calibrated against daily measurements of stream discharge in cm (cm runoff = daily runoff volume /watershed area). Discharge data is usually available at a daily frequency and over long time periods allowing for extensive calibration and validation of the hydrologic sub-model.

Water Quality Data

The DEP version of the model has been modified to allow calibration of the nutrient concentration factors in order to obtain an optimal correspondence between the simulated and measured nutrient export rates. Obtaining the water quality data of sufficient quality to perform the water quality calibrations is however, difficult. In response to storm events GWLF simulates increased erosion and an increased particulate nutrient flux. Measured data based on infrequent sampling of particulate nutrients will inevitably suggest that the model is overestimating particulate fluxes, while in fact the model may provide a more representative picture of the true discharge driven variations in particulate matter. As a result, calibration of the models water quality components requires measurements of nutrient export based on representative flow weighted sampling methods: sampling which includes storm events. As with all models of nutrient export at least one year’s and optimally several years data are needed for calibration.

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