Return Flows Guidance

from Wastewater Disposal Systems

Georgia's State Water Plan

Georgia Environmental Protection Division

February 2012

Section 1: Introduction to Return Flows

The Return Flows Guidance creates a consistent procedure and calculation methodology for region-specific assessments for future return flows from wastewater disposal systems to support the development of regional Water Development and Conservation Plans (regional water plans). Specifically, this Return Flows Guidance:

- Introduces the concept of return flows and summarizes the background for this guidance related to the Georgia Comprehensive State-wide Water Management Plan (Section 1).
- Identifies key factors for conceptualizing the rate of return in a given basin for wastewater disposal systems (Section 2).
- Provides information regarding the differences in return flows expected in the various MLRAs of Georgia (Section 3).
- Establishes region-specific ranges of values that may be used toward identifying benchmarks for return flows and mechanisms for meeting those benchmarks (Section 3).
- Provides a glossary of terms that are used in this Guidance. Terms included in the glossary of terms are shown in bold the first time that they are used in this Guidance (Appendix A).
- Provides a method for estimating the time required for return flows to reach surface water, the volume reaching surface water, and the rates of return from such systems (Appendix B).
- Includes reference table information that supports return flow calculations (Appendix C).

Background

Return flow, as defined in the Georgia Comprehensive State-wide Water Management Plan (State Water Plan), refers to that portion of withdrawn water that is returned to surface water or groundwater systems, and is then available for other uses. This Return Flows Guidance Document outlines a process to estimate the volume and timing of return flows to surface waters in support of regional water planning activities. Return flows, for the purpose of this Return Flows Guidance, include flows from **wastewater disposal systems**, which include **land application systems (LAS)** and **on-site sewage management systems (OSSMSs, or septic systems)**.

The Return Flows Guidance is intended to support regional water planning and is called for in Section 9 of the State Water Plan, Water Return Management Practices. This document creates a consistent procedure and calculation methodology for regional water planning councils, with the support of their regional planning contractor, to calculate their return flows. As with any technical guidance, terminology is very important, therefore terms defined in Appendix A: Glossary of Terms are shown in bold the first time that they are used in this Guidance.

The State Water Plan identifies that different wastewater management practices return water to surface water bodies at varying rates. While permitted wastewater discharges to surface water are considered to be immediately available for water supply, discharges from LAS and OSSMS can be slower to return water to streams, depending on soil and geological conditions. Thus, the purpose of estimating return flows from these two types of systems is to quantify their contribution to surface flow in terms of quantity and travel time.

The approach for estimating return flow rates is intended to assist regional water planning councils and their regional planning contractors in evaluating the future changes in return flows under varying management practice scenarios. For the purpose of this Guidance, return flows are estimated at the Hydrologic Unit Code (HUC8) watershed scale and based on regional **(Major Land Resource Area, or MLRA)** characteristics. The MLRA boundaries are provided in Figure 1-1 and HUC8 boundaries in Figure 1-2. The MLRA boundaries were originally delineated by the National Resources Conservation Service (NRCS), but were modified by the Georgia Environmental Protection Division (EPD) to differentiate the Dougherty Plain from the Southern Coastal Plain.

Optimizing the use of future LASs and OSSMSs may be a component of managing consumptive use. For example, if a water planning region anticipates a water supply deficit in the future based on the baseline resource assessments and demand forecasts, a regional water plan may limit the placement of these systems to areas where return flows are quickly returned to surface waters and made available for **contemporary use**. For the purposes of this Return Flows Guidance and regional water planning, return flows with travel times greater than 10 years are not considered to return water in time for contemporary use.

This Guidance includes **region-specific benchmarks**, as called for in the State Water Plan. Regional water planning councils may consider the region-specific benchmarks during the evaluation of future scenarios and refinement of selected water management practices. Regional water planning councils may also consider the relative significance of the consumptive use of individual water sources and the factors that can determine the technical and economic feasibility of different return management practices within that region.

The **return flow estimation tool (tool),** a spreadsheet analysis tool that accompanies this Guidance, will assist regional water planning councils and regional planning contractors evaluate the return flow component of proposed management scenarios. The tool is intended to be applied to future wastewater returns, and applied only at the MLRA-scale and HUC8 level of detail. Estimations derived by the tool need to be interpreted in the context of the variability and limitations inherent to the assumptions required for its development.

This Guidance and the associated tool focus on the application of future wastewater disposal systems because return flows to surface water bodies from existing facilities are accounted for in the baseline resource assessment flow data. In some instances, newly constructed LAS and septic systems may be included in the calculations, only if their lag time is such that their return flows may not be factored into the baseline resource assessments.

Figure 1-1: Major Land Resource Areas (MLRAs) in Georgia

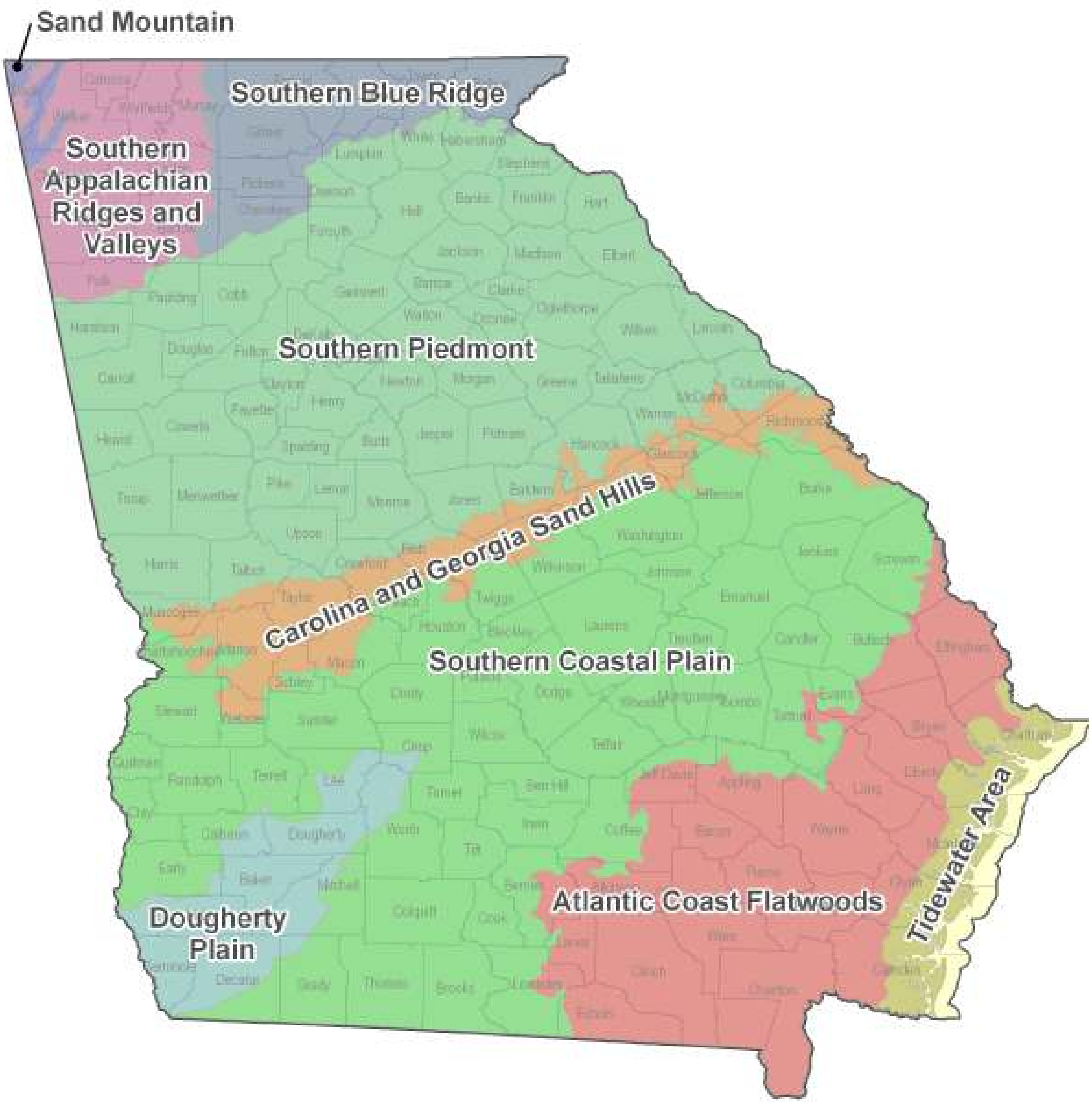
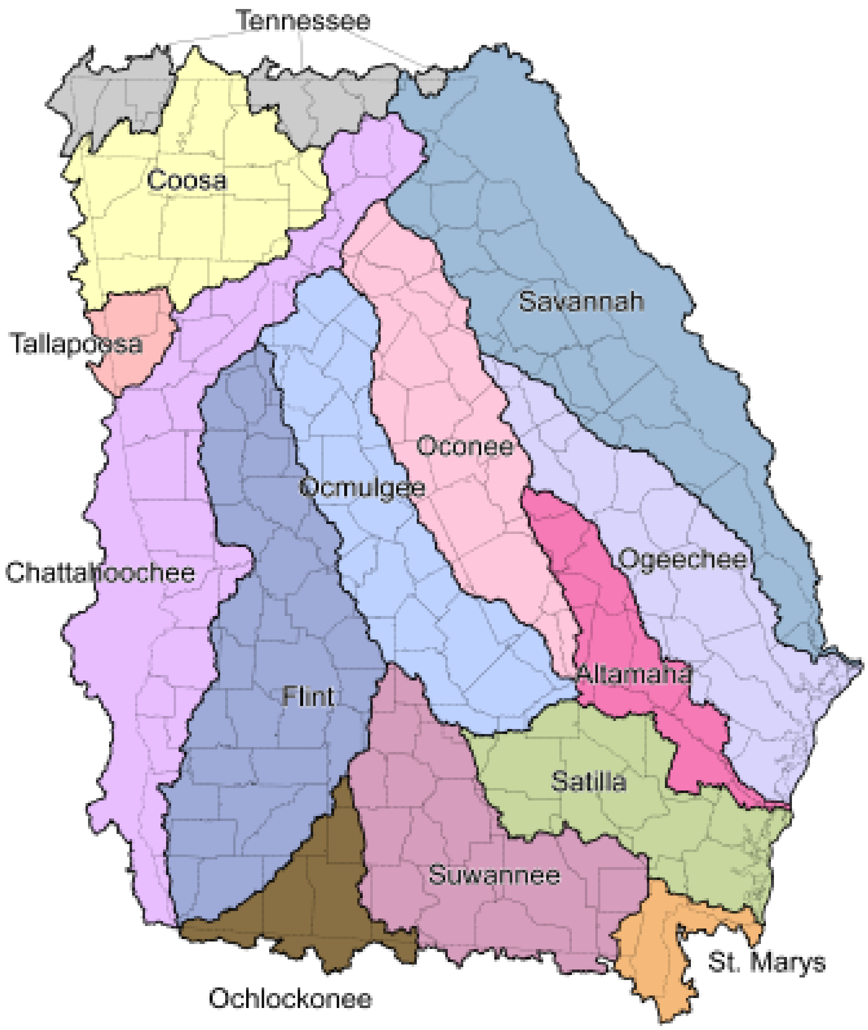


Figure 1-2: Hydrologic Unit Code 8 (HUC8) Watersheds



It is important to note that this tool is intended for general planning purposes only. There is inherent spatial and temporal variability in the factors that affect return flow. Default values provided in the tool are based on MLRA-scale approximations, and thus are intended to represent the large range of hydrogeological and climatic conditions that exist within each MLRA. The output from the tool is limited to statistical summaries of the return flow and lag time, as opposed to site-specific numerical estimates. The tool and the region-specific benchmarks included therein are limited in the ability to represent finer geographic scale scenarios, since several assumptions regarding the hydrogeological conditions and groundwater flow characteristics were required in order to encompass the range of possible scenarios in each MLRA. Increasingly accurate results may be obtained by assigning site-specific information; however, the tool is not intended to provide the specific or absolute return flow or lag time for any individual or group of wastewater disposal systems. This tool is not intended to replace any requirements for design or permitting of these wastewater disposal systems.

Section 2: Calculating Return Flows

This Return Flows Guidance is accompanied by an Excel® spreadsheet-based tool (the return flow estimation tool) that may be used by regional water planning councils and their regional planning contractors to estimate future return flows as part of the regional planning process. This section outlines the **key factors** considered and applied by the tool as well as background information related to the calculations. The tool provides the flexibility for the user to accept generalized default values for return flow parameters based on the MLRA, or to input more site-specific information when that information is available. The tool's instructions and greater details on the tool are provided in Appendix B. The default MLRA values used in the tool are provided in Appendix C.

Key Factors

The key factors used in describing return flow from wastewater disposal systems are derived from a generalized **conceptual model**, shown in Figure 2-1. The components of this model are outlined in Table 2-1 and further defined in the Glossary of Terms, provided in Appendix A.

Figure 2-1: Conceptual Model of Flow from Wastewater Disposal Systems to Surface Water

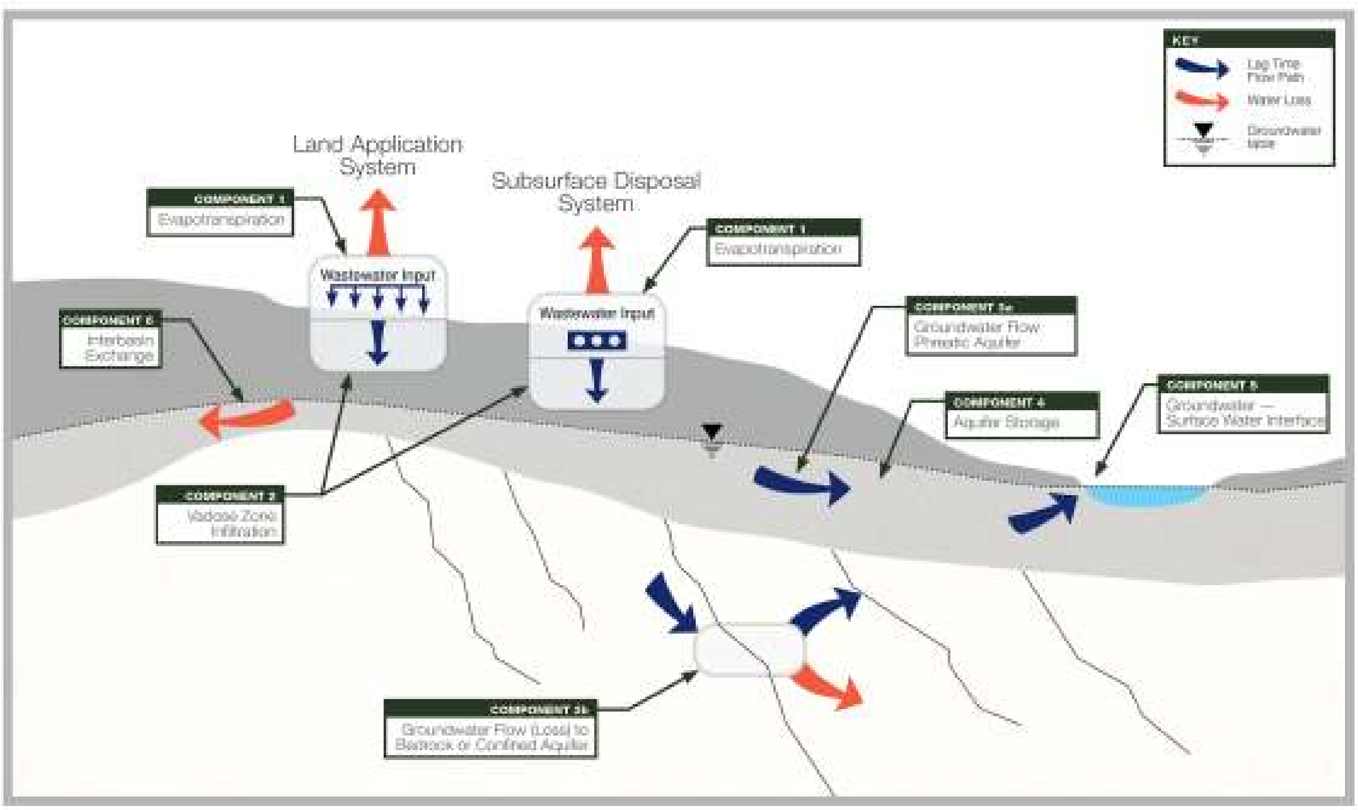


TABLE 2-1: Conceptual Model Components	
COMPONENT	DEFINITION
Component 1	Evaporation and transpiration losses from the wastewater disposal systems.
Component 2	Downward infiltration through the soil profile above the water table (vadose zone).
Component 3	Lateral flow of water through the water table. Component 3a is the groundwater flow path through the unconfined aquifer that reaches surface water. Component 3b is the groundwater flow path through the confined aquifer and is designated as a loss.
Component 4	Quantity of water to storage. Soil and geologic properties create flow rates that do not return flows to surface water bodies in a time-efficient manner; flows are not available for contemporary use, and are considered a loss.
Component 5	Process of groundwater baseflow to surface water streams or seepage into surface water.
Component 6	Losses due to the transfer and discharge of wastewater to a watershed other than the watershed from which the source water was withdrawn.

Each of these generalized components involves multiple physical and chemical processes, which ultimately influence the volume, quality, and timing of return flow. The conceptual model identifies the various processes at work in routing the flow from the point of wastewater application to its point of discharge at a perennial surface-water feature. Not all components in the conceptual model are used to estimate return flows; some processes are deemed insignificant relative to others and some are too spatially variable for regional evaluations. The components of the conceptual model used in the return flow estimations are discussed in this section.

Return Flow Calculations

Due to the regional scale at which return flows are estimated, and the limited availability of information to quantify conceptual model components, the key factors that are used in the tool include: Component 1 (evapotranspiration), Component 3 (groundwater flow), and Component 6 (**interbasin exchange**). Component 2 (infiltration), Component 4 (aquifer storage) and Component 5 (seepage) are not used in the tool.

Infiltration (Component 2) is a factor that affects **lag time**; however, it is not included in the tool calculations because the travel time associated with this component is highly variable, and likely to be very small relative to the travel time associated with the groundwater flow component (Component 3).

Aquifer storage (Component 4) is a factor that accounts for the temporal changes in unconfined groundwater systems that influence groundwater flow velocity. Changes in storage are marked by rises and falls in the groundwater table. Because the level of the groundwater table determines the hydraulic **groundwater gradient** between a wastewater application site and the **receiving surface water**, this factor affects the flow rate, and thus the lag time, of the water returning to surface water; however, because this temporal variation cannot be accurately quantified using available, regional-scale data, this component is not used in the tool.

Component 5 of the return flow conceptual model accounts for the process of groundwater baseflow to receiving surface water features, also known as seepage. As is the case with Component 4, factors influencing Component 5 are highly variable, requiring site-specific data. Accordingly, it is not used in the tool.

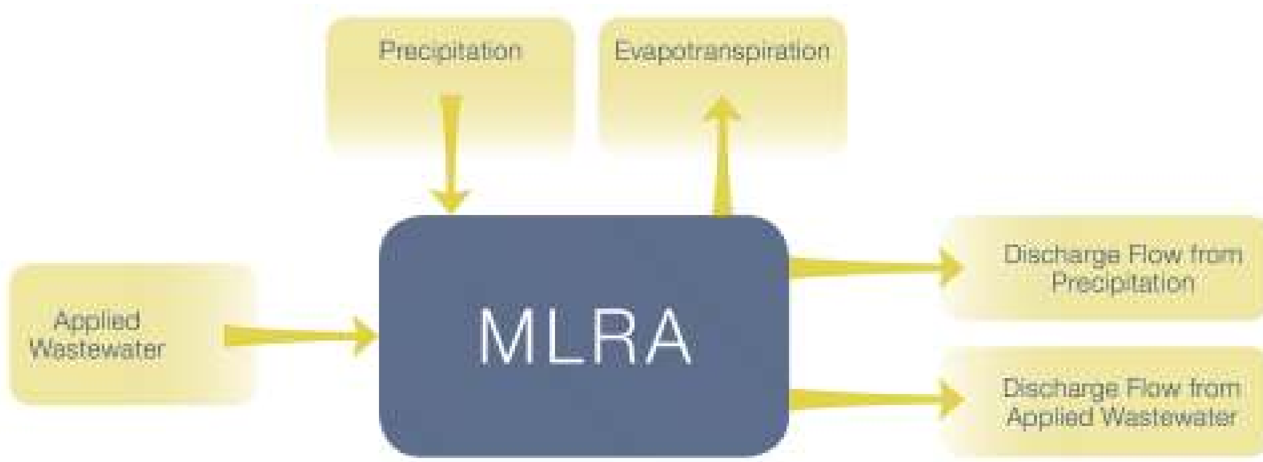
The following discussion elaborates on the components of the conceptual model that are considered and used in the tool (Components 1, 3, and 6) and provides background on how those components are quantified as default values within the tool.

Component 1 - Evaporation and Transpiration

Component 1 of the return flow conceptual model accounts for water losses from wastewater disposal systems through evaporation and transpiration, collectively referred to as evapotranspiration (ET). The ET is calculated for LASs and OSSMSs based on the methodologies outlined below.

ET for Land Application Systems (LASs). Figure 2-2 illustrates the system inputs and outputs for LAS sites. The calculations outlined below account for the volume of wastewater discharged from LAS sites.

Figure 2-2: LAS Water Balance Schematic



The Guidelines for Slow-Rate Land Treatment of Wastewater, published by EPD, recommends the use of the Penman or the Blaney-Criddle Method for assessing site-scale ET rates for row and forage crops, and the Thornthwaite equation for forested systems or when insufficient data are available for other methods. The Thornthwaite method, which estimates potential ET, was identified as the most appropriate for use in estimating return flows due to the Major Land Resource Area (MLRA)-scale on which estimates are made. Potential ET (or PET) is the maximum amount of ET that may occur, in terms of depth of water per unit time, if the amount of water applied (through land application and/or precipitation) is not limiting. Based on the assumptions used to derive ET on the MLRA-scale, LAS application rates that are greater than 0.64 inches per week will yield ET estimates that are equivalent to the PET estimates. Parameters applied by the Thornthwaite method include daylight hours, air temperatures (mean monthly) and annual heat index. The Thornthwaite equation and associated required data are summarized below:

$$PET = 1.6 * L_d * [(10*T)/I]^a * (1 \text{ in}/2.54 \text{ cm}), \text{ where}$$

PET = Potential evapotranspiration in inches per 30 days

L_d = Daylight hours in units of 12 hours

T = mean (normal) monthly air temperature in degrees Celsius

I = Annual Heat Index based on monthly normal temperature ($I = \sum (T/5)^{1.514}$)

a = empirical term derived from annual heat index

$(a = 0.000000675(I)^3 - 0.0000771(I)^2 + 0.01792(I) + 0.49239)$

ET losses for land application systems are calculated and expressed as a percentage of total input (precipitation and land application):

% lost through ET = Annual ET / (Annual Precipitation + Annual Land Application)

The percent lost through evapotranspiration is then multiplied by the applied wastewater to determine what volume is lost to ET, and what volume is routed via groundwater flow. For example, if ET was calculated to be 30 inches/year (in/yr), and precipitation and land application was 100 in/yr, the percent lost to ET of the total water input would be 30%. Of the total water input of 100 in/yr, if the land-applied fraction was 45 in/yr, the ET loss from land-applied water would be 30% X 45 in/yr, or 13.5 in/yr, resulting in a volume of land-applied water being routed through groundwater flow of 31.5 in/yr (45 in/yr – 13.5 in/yr = 31.5 in/yr).

Climate data including temperature and precipitation data for each MLRA are used in LAS ET calculations. Climate data varies to some degree across any given MLRA, so for the purposes of this Guidance the National Oceanic and Atmospheric Administration (NOAA) weather station located nearest to the MLRA's centroid forms the basis for calculations. These data are provided in Appendix C as Table C-1. Latitude at the centroid is also used to interpolate the daylight hours for the Thornthwaite equation. The NOAA average monthly temperature was compared to data ranges for each MLRA as stated by the Natural Resources Conservation Service (NRCS) to confirm the centroid data to be valid. The NRCS ranges are summarized in Appendix C as Table C-2.

The monthly average daylight hours (L_d) required for ET calculations are provided in Appendix C as Table C-3. The base values stated at 30º and 35º latitude were estimated for each monitoring station, based on linear interpolation.

ET and Septic Systems (OSSMS). Evapotranspirative losses from OSSMS were quantified based on a literature review for studies done in Georgia. Table 2-2 below provides the estimated return flow from septic systems from three different studies in Georgia. Based on the literature data reviewed, a range of 80% to 91% returned is defined for septic systems in Georgia. From this range, a conservative return flow percentage of 85% (i.e., 15% lost water) is suggested for use in return flow calculations described in this Guidance.

TABLE 2-2: Return Flows from Septic Systems based on Literature

REFERENCE	RETURN FLOW SUGGESTED
Radcliffe et al. (2006)[1]	91%
Georgia Water Coalition[2]	80% - 90%
USGS (2008)[3]	83%

[1]Radcliffe, D.E., et al., "*Onsite Wastewater and Land Application Systems: Consumptive Use and Water Quality*." May 11, 2006.
[2]Georgia Water Coalition, "*Response to Onsite Wastewater and Land Application Systems*." 2007. http://www.garivers.org/gawater/pdf%20files/GWC%20Septic-Water%20Quantity2.pdf
[3]USGS, "*Preliminary Results - An Approach to Evaluate the Effects of Septic Wastewater Treatment Systems on Stream Baseflow and Consumptive Use*." August 7, 2008.

Component 3 - Groundwater Flow

Component 3 of the return flow conceptual model accounts for the groundwater flow path portion of return flow. Calculations within Component 3 compute a flow velocity from the point water reaches the groundwater table to the point water reaches the receiving surface water. This velocity is a factor in computing the amount of time required for discharged wastewater to reach the receiving surface water, and whether this water is available for contemporary use. Component 3a is the groundwater flow path through the unconfined aquifer. Component 3b is the groundwater flow path through the confined aquifer and related aquitard (where applicable) and is conceptualized as loss of return flow. Groundwater flow through fractured bedrock, karstic limestone, and large confined aquifers may be highly complex with respect to flow direction and bulk **hydraulic conductivity** and localized conditions may significantly affect lag time in specific areas. Thus, generalizations of these factors for the large-scale to which the tool is designed may produce highly inaccurate results. For this reason, MLRA-scale assumptions should not be applied to Component 3b. Return flow losses may be input into the spreadsheet tool, as a percent of total water discharged (total applied minus ET losses), if the user has a valid site-specific information.

Groundwater flow velocity in aquifers is controlled by the hydraulic conductivity and **effective porosity** of the saturated aquifer material and the groundwater gradient across a given segment of the aquifer system. For site-specific studies on the travel time/groundwater velocity between wastewater disposal systems and receiving surface water features, considerable testing is required to accurately characterize hydraulic conductivity and effective porosity values, flow direction, and the groundwater gradient.. For the purposes of estimating return flows on a large-scale for regional water planning, the calculation and data requirements have been simplified.

The lag time T_L, or the time required to travel from the point of discharge to the recieving surface water, is defined as:

$$T_L = L/v = L / ((K_{sat}/n_e)*(I)), \text{ where:}$$

L = distance between wastewater disposal system and receiving surface water, in feet;

v = groundwater velocity, in feet per day;

K_{sat} = saturated hydraulic conductivity of surficial aquifer, in feet per day;

n_e = effective porosity of surficial aquifer, as a fraction; and

I = groundwater gradient in feet per foot.

In order to derive approximations of groundwater-flow velocity at an appropriate scale, several assumptions were made to simplify the analysis. The parameters included in the tool are presented below with their associated data sources. These sources of data were selected based on their state-wide availability and their applicability with respect to the scale for which the return flow estimation tool is intended.

- *Saturated Hydraulic Conductivity (Ksat)*: Ranges of saturated hydraulic conductivity were determined using the Southern Association of Agricultural Experiment Station Directors (SAAESD) database for the majority of soil types within each MLRA. Available data by MLRA was used for the “C” horizon and “BC” horizon based on the soil layer depths where possible, looking at soils below the water table. If information on water table depth was not available, information for the deepest soil layer in that MLRA was used. The SAAESD database did not provide information for two of the MLRA’s, Southern Blue Ridge and Tidewater Area. The Southern Blue Ridge used the same data as the Southern Piedmont and the Tidewater Area used the same data as the Atlantic Coast Flatwoods.

[4] McWhorter and Sunada, 1977

- *Effective Porosity (n_e)*: To derive the average linear flow velocity of the groundwater, the specific discharge calculated by Darcy's Law is divided by the effective porosity of the aquifer material. Effective porosity values referenced in the tool are based on values published for specific soil textures[4]. The effective porosities were calculated from saturated hydraulic conductivity values as described in the report "Evaluation of Spatial Distribution of Hydraulic Conductivity Using Effective Porosity" (Cronican & Gribb, 2007) using the equation below:

$$K_{sat} = 1058.4 * n_e^{3.3545}$$

- *Groundwater Gradient* (*I*): In certain MLRAs, it was assumed that the groundwater gradient is a reflection of the land-surface-topographic slope. In other MLRAs (i.e., Southern Appalachian Ridges and Valleys, Southern Blue Ridge, and Carolina and Georgia Sand Hills), correlations between the topographic slope and the groundwater gradient were derived based on available information. Mean topographic slopes for each MLRA were derived from 30x30 meter Digital Elevation Model (DEM) grid data.

- *Distance between Wastewater Disposal Site and Receiving Stream*: Due to the complexity of the analyses involved with the estimation of return flows and the inherent limitations of scale, calculations for the distance between the disposal site and the receiving stream are based on the assumption that groundwater flow is perpendicular to the nearest surface water feature. The accuracy of return flow calculations could be improved in future models that incorporate detailed groundwater flow directions.

In certain MLRAs it can be assumed that aquifer boundaries and otherwise represented subsurface drainage boundaries are coincident with topographic divides unless specific data are available that counter this assumption. These MLRAs are the Piedmont and Southern Blue Ridge, the Southern Coastal Plain (except the Dougherty Plain), the Atlantic Coast Flatwoods, and the Tidewater Area.

Component 6 - Interbasin Exchange

Component 6 of the return flow conceptual model accounts for water gains from, and losses to, watersheds other than the watershed from which the source water is withdrawn. The locations of the disposal system and the source water withdrawal relative to watershed divides must be evaluated to identify these losses and gains. The location at which input from return flow is assessed will also be a factor in determining the inter-basin exchange. For example, if the LAS watershed is different from the water supply watershed, there would be a 100% loss with respect to return flow in the water supply watershed. On the other hand, a return flow would constitute an import of water to the receiving basin if the receiving basin was different from the basin from which the water supply was originally withdrawn.

Limitations of Return Flow Estimates

Because of spatial and temporal variability of the factors which affect return flow, there are limitations on the use of the results from the tool. Default values for return flow parameters are provided on an MLRA-scale and represent the range of values representative for that area. The output is limited to statistical summaries of the return flow and lag time, as opposed to site-specific numerical estimates. The tool is limited in the ability to represent finer geographic scale scenarios, since several assumptions regarding the hydrogeological conditions and groundwater flow characteristics were required in order to encompass the range of possible scenarios in each MLRA. Increasingly accurate results may be obtained by **users** assigning site-specific information; however, the tool is not intended to provide the return flow or lag time for any individual or group of wastewater disposal systems.

Beyond limited accuracy from spatial and temporal variation, there are also other factors which limit the accuracy of the results produced by the tool. These include:

- The lag time associated with the percolation of discharged water through unsaturated soils is not considered in the proposed approach. Factors controlling this characteristic, such as the depth to the groundwater table and soil percolation rates, are highly variable and may be assumed to be short relative to the lag times of groundwater flow.
- Return flow is assumed to only occur from groundwater flow through unconfined aquifers. Groundwater flow through bedrock and confined aquifers is too complex and spatially variable to be accounted for by this tool. If discharges are known to recharge bedrock and confined aquifers they are considered lost with respect to return flow calculations.
- Horizontal and vertical hydraulic characteristics are not differentiated. Hydraulic conductivity and effective porosity values are assumed to be representative of the characteristics of the aquifer between the discharge point and the receiving water. Further expansion of the tool to incorporate the finer scale components of horizontal and vertical differences are beyond the scope of this investigation and the intention of the tool.
- Increased groundwater gradients that are established by groundwater mounding beneath wastewater disposal systems are not considered in the groundwater flow equations used by the tool. Groundwater mounding of this type is generally a highly localized feature, dependent upon site-specific loading rates and soil characteristics.
- Aquifer storage is a factor in groundwater flow that is dynamic and spatially variable at a finer scale than the MLRA scale. The tool is designed for MLRA-scale evaluations.
- Groundwater withdrawals and their potential influence upon return flows are not accounted for by the tool. Consideration of downgradient withdrawals, which may intercept return flow, may be appropriate in some cases.
- The accuracy of the water losses due to evapotranspiration from LASs is reflective of regionalized values and annual averages, as applied in the Thornthwaite equation.
- Evapotranspiration losses from OSSMSs are approximated as 15% based upon literature values. Additional or different site-specific losses are not included in the approach.

With these limitations in mind, this tool may be used to estimate return flow and lag time on a regional (HUC8 and/or MLRA) scale for the purposes of regional water planning. The release of this tool reflects EPD's first attempt at quantifying return flow. The sophistication of the tool is anticipated to evolve as more data becomes available and state water planning progresses.

Water Quality Considerations

Although not a stated component for the return flow calculations, the regional water planning process should consider the cumulative water quality impacts associated with planned OSSMS and LAS facilities.

Properly sited, constructed, and maintained OSSMSs are a cost-effective, long-term option for meeting public health and water quality goals, particularly in less densely populated areas. In addition to proper siting, installation, and maintenance of septic systems the pumped septage from these systems must also be managed in an environmentally sound manner. Laws and rules are currently in place and implemented by the Department of Human Resources, Division of Public Health to address OSSMS siting, design, and installation.

As with OSSMSs, LASs have been effectively used to treat wastewater and should continue to be used as a water management practice under appropriate circumstances. Proper design, installation, and maintenance of LASs is important to the long-term viability of these treatment systems. LASs are permitted and managed following the provisions of DNR Rules 391-3-6-.11, 391-3-6-.19 and 391-3-6-.24 and changes are not anticipated as a result of this Return Flows Guidance.

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Section 3: Benchmarks

For the purposes of this Return Flows Guidance, region-specific benchmarks provide general return flow information for each MLRA that regional water planning councils may compare to water planning needs for return flows within their water planning region. The benchmarks allow early and quick decision making during the planning process that can be followed by more detailed analysis. This section includes a series of figures that provide summary return flow estimates based on the MLRA. Regional water planning councils may use these benchmarks to refine the level of detail entered into the spreadsheet tool. For example, in the Southern Blue Ridge MLRA, a wastewater disposal system greater than 700 feet from the receiving water on average would likely return water too slowly to the receiving water for the return flow to be considered for additional water supply. Therefore, the regional water planning councils may limit consideration of only those facilities that would enhance return flows for the contemporary user based on this Guidance.

Figures 3-1 through 3-3 provide estimated planning average, maximum and minimum lag times for return flow within the various MLRAs as a function of distance to receiving stream. These charts may be used as initial guidance to assist the regional water planning councils in developing a preliminary basic planning estimate of the extent to which wastewater disposal systems may be used in the water planning region and still provide water for contemporary use. It is important when reviewing the estimated planning average lag time graphic in Figure 3-1 to also consider the range of potential timing of return flow as indicated in Figures 3-2 and 3-3. Planning decisions should not be made solely on review and interpretation of estimated planning average lag times, since there is a wide range of time for which return flow may actually occur, for all MLRAs.

Figure 3-1: Estimated Planning Average Lag Time as a Function of Distance to Receiving Stream

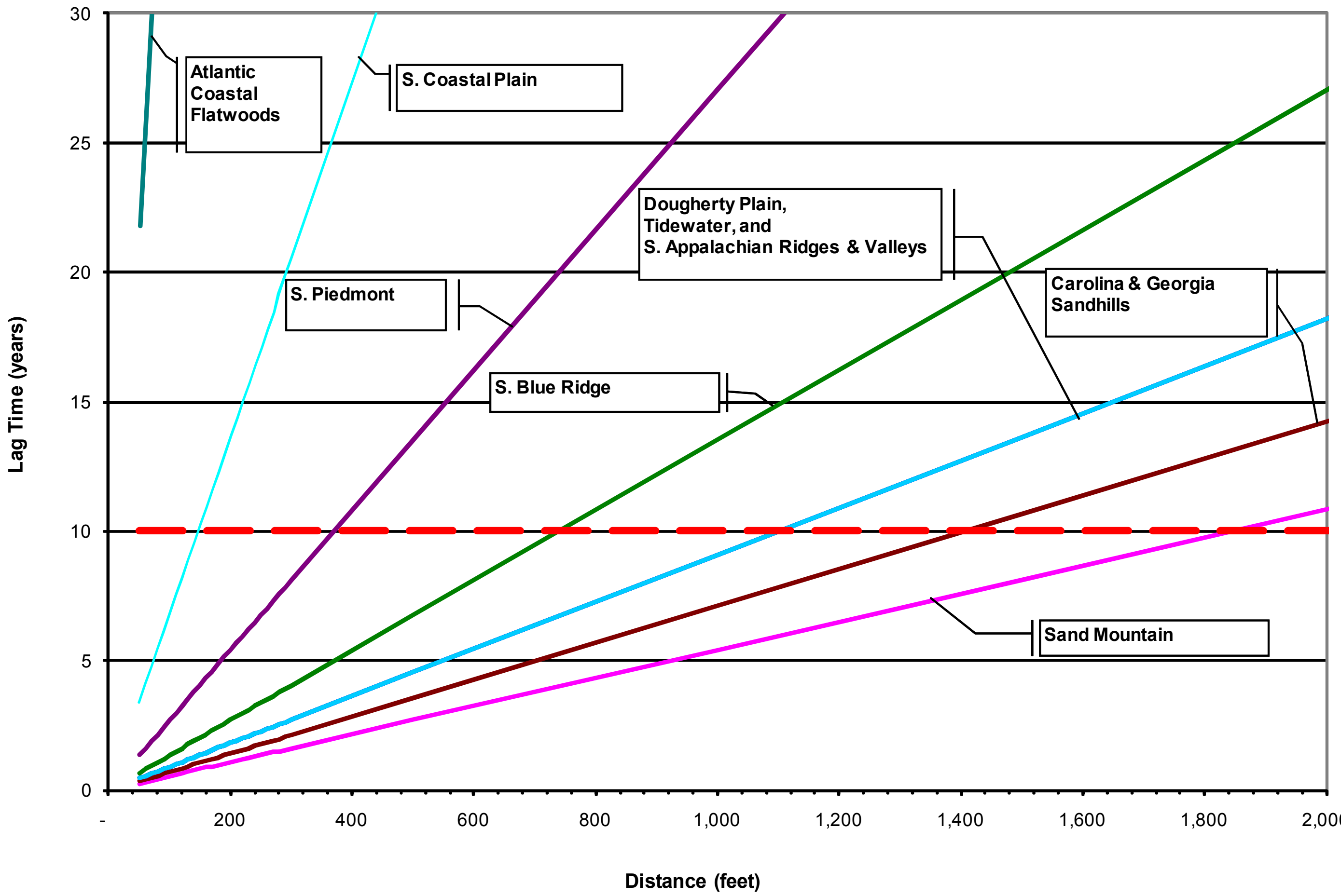


Figure 3-2: Maximum Estimated Lag Time as a Function of Distance to Receiving Stream

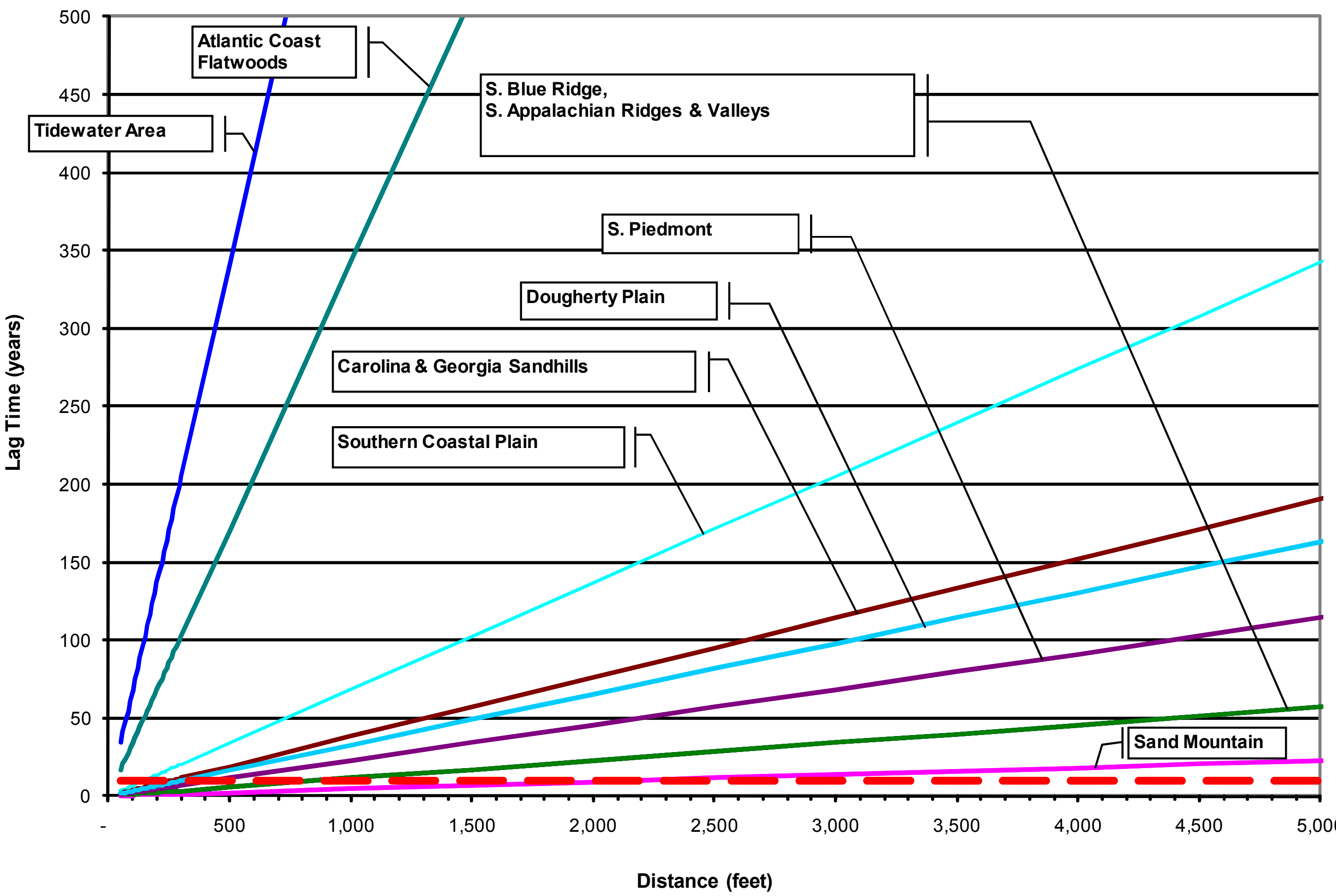


Figure 3-3: Minimum Estimated Lag Time as a Function of Distance to Receiving Stream

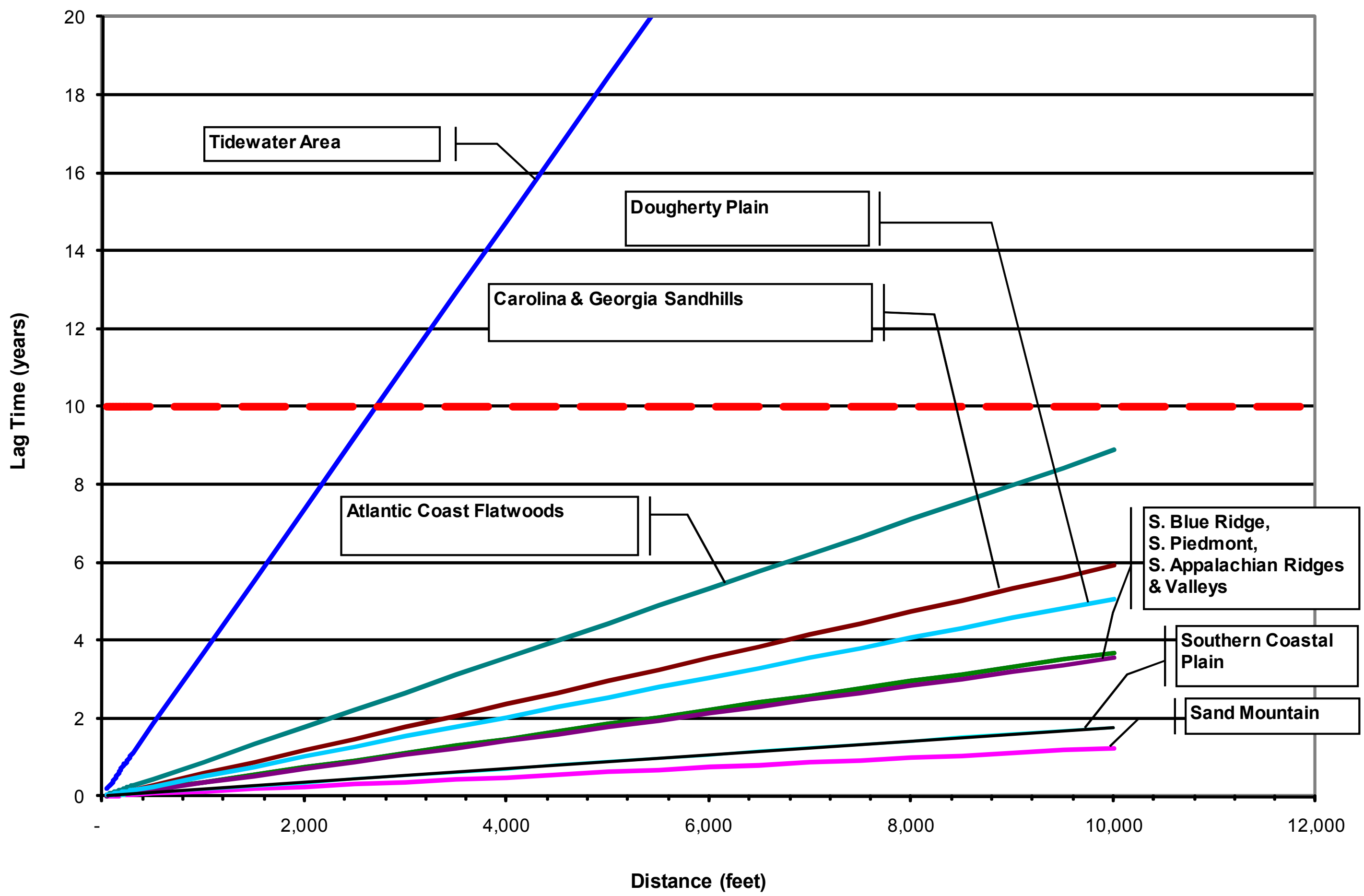
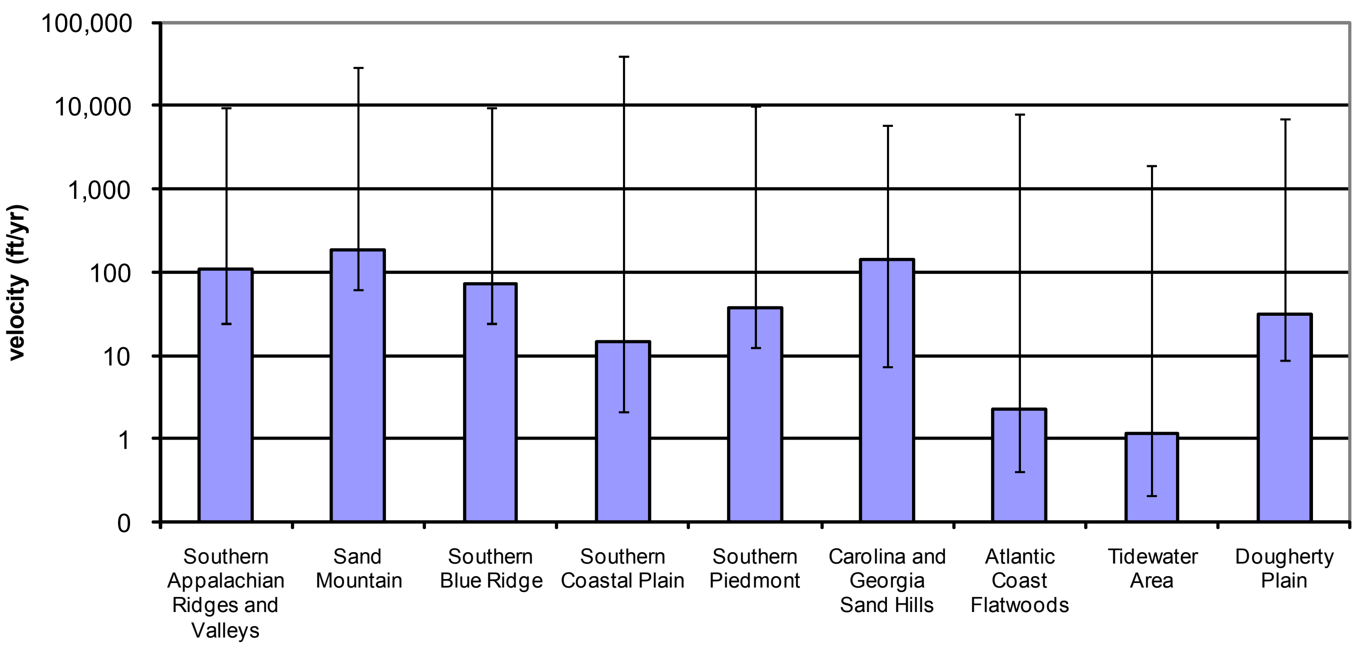


Figure 3-4 below provides a summary of unit-based flow velocities on a logarithmic scale, for each of the MLRAs, developed from the use of tool default values for input parameters. This chart provides the estimated planning average, minimum and maximum flow velocities for each of the MLRAs that are used in the tool as described in Appendix B and provided in Appendix C. Average flow velocities range from 29 feet per year to nearly 880 feet per year. Note that there is variability both between and within the MLRAs. The smallest range of velocity is found in the Tidewater Area MLRA, with a range of 280 ft/year. With maximum and minimum velocities of 8,960 and 66 feet per year, respectively, the highest range of velocity is found in the Southern Piedmont. Thus, it is apparent that specific user-entered values for return flow parameters will increase the precision of return flow estimates, assuming that valid data are available to better constrain the calculations. However, because this information is not widely available, the values presented here and the accompanying tool may be deemed appropriate for generalized estimates of return flow and lag times. If additional return flows are desired in a water planning region, this benchmark assists the regional water planning councils in determining whether the development and use of site-specific data is valuable.

Figure 3-4: Estimated Travel Velocity by MLRA Using Default Input Values



Mechanisms for Meeting Benchmarks

Regional water planning councils have a number of options for meeting benchmarks for return flows for their water planning region. As indicated by the ranges shown in Figure 3-4, regional water planning councils may elect to enter more site-specific data to refine the estimates provided by the tool. Some areas within an MLRA may have parameter attributes that are different than the tool default values. Similarly, regional water planning councils may also elect to locate LASs and OSSMSs closer to receiving waterbodies so that return flows are within the 10-year period considered to provide available water supply for the contemporary user. Some regional water planning councils may decide that direct returns to the stream are preferred for providing return flows. Water quality and treatment technology considerations should be factored into the decision-making process when selecting the planned wastewater disposal systems for the water planning region.

Appendix A: Glossary of Terms

The following definitions are based on the Georgia Comprehensive State-wide Water Management Plan (State Water Plan) where available. Definitions were enhanced or added as indicated within the definition.

Conceptual Model: The Return Flow conceptual model is a diagrammatic visualization that identifies Key Factors and their interrelationships (Figure 2-1).

Conceptual Model Components: The components that comprise the Key Factors described in this Return Flows Guidance and shown in Figure 2-1.

- Component 1: Accounts for water losses from Wastewater Disposal System evaporation and transpiration.
- Component 2: Accounts for the infiltration process through the unsaturated soil profile (vadose zone).
- Component 3: Accounts for the groundwater flow path portion of return flow. Component 3a is the groundwater flow path through the unconfined aquifer. Component 3b is the groundwater flow path through the confined aquifer and related aquitard (where applicable).
- Component 4: Accounts for wastewater contribution to Aquifer Storage. Component 4 is the difference between the volume of wastewater that enters the groundwater system but due to Lag Times and defined Lag-Time criteria inherent to the definition of Return Flow, does not qualify as Return Flow.
- Component 5: Accounts for the process of groundwater baseflow to Receiving Surface Water features.
- Component 6: Accounts for losses and gains due to the transfer/discharge of wastewater in a watershed other than the watershed from which the source water is withdrawn.

Consumptive Use: "Consumptive use" is the difference between the total amount of water withdrawn from a defined hydrologic system of surface water or groundwater and the total amount of the withdrawn water that is returned to that same hydrologic system over a specified period of time. Additional guidance within the State Water Plan outlines that water use is consumptive when water is removed from a specified hydrologic system of surface water or groundwater rand is not returned to that same system within a time frame that allows contemporary users and uses to avail themselves of the benefits fo the quantity of water.

Contemporary Use(r): While the State Water Plan does not define the contemporary user, the following quotes indicate the intent. "Depending upon soil and geological conditions, on-site sewage systems can be slower to return water to streams than centralized wastewater treatment systems that return water to streams via direct discharges." and "While the exact quantity and timing of returns will vary with location and other site conditions, some portion of the water treated in septic systems is not returned to the water source in a time frame that allows contemporary users of that water source, and users of hydrologically-connected adjoining water sources, to make corresponding reasonable use of that returned water." For practical purposes of this Guidance document, this temporarily absent water contributes to the cumulative consumptive use in a sub-basin or watershed.

Distance/Gradient Factor: A factor derived by dividing the distance between the Wastewater Disposal System and the Receiving Surface Water feature by the Groundwater Gradient between these locations.

Effective Porosity (ne): The ratio of the volume of liquid that a given mass of saturated rock or soil will yield by gravity to the volume of that mass (American Geological Institute). Used in the return flow estimation tool in Darcy's equation to calculate groundwater velocity.

Groundwater/Flow Factor: A factor derived by dividing Hydraulic Conductivity by Effective Porosity. This factor consists of the two terms in Darcy's equation for the calculation of groundwater velocity that corresponds to physical characteristics of the aquifer material.

Groundwater Gradient (I): The difference in hydraulic-head elevation, over a measured distance, between two points within an aquifer.

Hydraulic Conductivity (K): The constant of proportionality between groundwater flow rate over a unit area and the groundwater gradient that is derived by Darcy's Law. The value of this constant is a function of the aquifer materials and properties of the fluid flowing through it. Saturated Hydraulic Conductivity (Ksat) pertains specifically to groundwater flow under saturated conditions.

Interbasin Exchange (Gain/Loss): A key component (Component 6) of the Return Flow Conceptual Model that accounts for water losses and gains between watersheds caused by the disposal of wastewater in a watershed that is different than the source water withdrawal.

Key Factors: Interrelated physical processes that describe the continuum of wastewater migration, from its point of disposal to its point of discharge in a surface water feature. Key Factors are represented by the conceptual model components.

Lag Time: The time required for water discharged from a Wastewater Disposal System to reach the Receiving Surface Water. The tool estimates Lag Time by dividing the distance between the Wastewater Disposal System and the Receiving Surface Water by the groundwater velocity as calculated using the Darcy flow equation.

Land Application Systems: Any method of disposing wastewater directly to the land surface, including drip irrigation, rapid infiltration and slow-rate land treatment methods.

Major Land Resource Area (MLRA): Major Land Resource Areas are defined by the Natural Resources Conservation Service (NRCS) as "geographically associated land resource units, usually encompassing several thousand acres that are characterized by particular patterns of soils, geology, climate, water resources, and land use." The NRCS map of MLRA's in Georgia is available at: http://www.mo15.nrcs.usda.gov/technical/mlra_ga.html

On-Site Sewage Management Systems (OSSMS): Any method of disposing wastewater directly below the land surface, including leach fields, chamber systems and other approved sub-surface wastewater disposal systems that is permitted by the local County Board of Health under rules promulgated by the Department of Human Resources.

Receiving Surface Water: Perennial stream or lake that discharges via a perennial stream, into which water discharged from Land Application Systems or On-Site Sewage Management Systems ultimately flows (via base-flow seepage). For the purpose of the return flow estimation tool, the Receiving Surface Water is the nearest topographically down-slope perennial stream or lake that has a perennial stream discharge.

Region-Specific Benchmarks: From Page 23 of the State Water Plan, "The Division's guidance for regional planning written pursuant to section 14 of this plan may address region-specific benchmarks for return flows to individual water sources and mechanisms for meeting those benchmarks. This guidance will be based on the best available information on quantities and timing of surface water returns from on-site systems in different parts of the state. This guidance will recognize the factors that determine the relative significance of this component of consumptive use of individual water sources and the factors that can determine the technical and economic feasibility of different return management practices in different regions." From Page 24, "Region-specific benchmarks may be established as guidance for return flows to individual water sources, but shall not be used as permitting criteria for land application systems, unless and until there is better consensus on the scientific validity of these criteria and the Board of Natural Resources in its discretion has adopted the criteria as part of the permitting requirements for such facilities." For the purposes of this Return Flows Guidance, region-specific benchmarks provide general return flow information for each MLRA that regional water planning councils may compare to water planning needs for return flows within their water planning region.

Return Flow: "Return Flow" refers to that portion of withdrawn water that is returned to surface water or groundwater systems, and is then available for other uses. For the purposes of this Guidance, Return Flow refers to the quantity of wastewater diverted to on-site sewage management systems and land application systems that discharges to surface water features within a time frame that allows contemporary users the benefits of that water.

Return Flow Estimation Tool (tool): A spreadsheet tool with data entry procedures that estimates Return Flow from Key Factors identified in the context of the conceptual model components.

User: In the context of the tool, is a member of a regional water planning counsel or a regional planning contractor that will use the tool by entering known LAS and OSSMS information, or projected System information to estimate ranges of Return Flow rates within HUC8 and MLRA areas.

Wastewater Disposal Systems: On-Site Sewage Management Systems and/or Land Application Systems, as defined in this Glossary of Terms.

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Appendix B: Calculating Return Flows

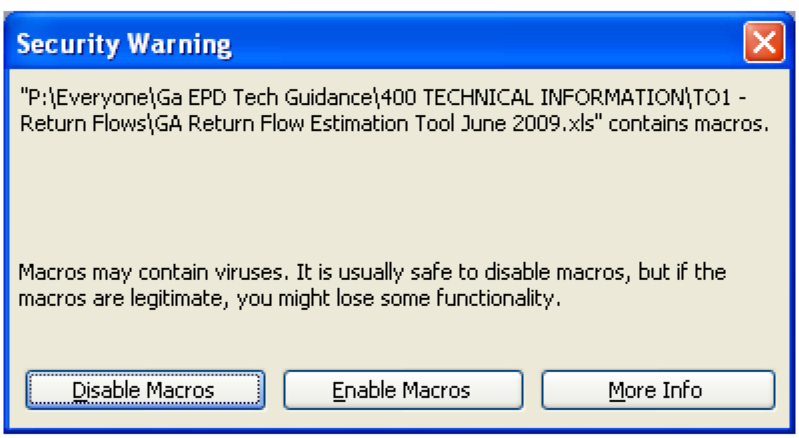
A spreadsheet-based return flow estimation tool accompanies this Return Flows Guidance. The tool was developed in Microsoft® Excel 2003 and calculates estimates of return flow rates using a three-step calculation process: (1) subtracting water losses, (2) calculating lag times, and (3) estimating return flow. The tool consists of the following worksheets:

- User Entry (facility-specific data)
- Reference Maps for MLRAs and HUC8 watersheds
- Two Output Worksheets (return flow and lag time values summarized by HUC8 watersheds and MLRA)
- Chart of return flow and lag time chart based on user-entered data
- Reference table for estimating lag time based solely on MLRA default values
- Three lag time reference charts, based on MLRA default values

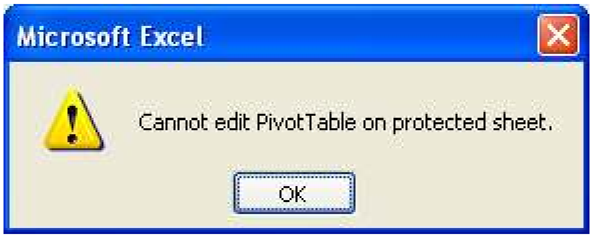
In addition, there are five hidden worksheets in the spreadsheet which serve to house the look-up tables for each MLRA and perform direct loss, return flow and lag time calculations.

The key factors and calculation process applied by the tool to estimate return flows are described in Section 2. Return flow estimates are calculated on the HUC8 watershed level for the HUC8 in which the discharge occurs. Wastewater discharged from sources beyond the HUC8 watershed in which the discharge occurs are summed and reported as interbasin losses in the source watershed or gains in the receiving watershed.

The spreadsheet tool requires Excel 2000 or any later version. When the spreadsheet is opened, the user will be prompted with the following message:



Select the 'Enable Macros' message. The following warning will appear twice, for which the user will select 'OK':



Once the spreadsheet has been opened, the user should begin with the 'User Entry' tab. The majority of the input information will be entered in this tab of the spreadsheet. The user entry is limited to 2000 rows without modification of the calculation worksheets.

Input to the Return Flow Estimation Tool

Users of the tool will enter data on the tab entitled 'User Entry.' Entries can be made for individual systems, or for groups of systems, provided they are uniform in discharge and key factors. For the input, Users may select data generalized for the MLRA or enter site-specific data, where available. Site-specific data will improve the accuracy of the results. **Note that only planned facilities should be entered into the spreadsheet; do not include existing facilities.** In special circumstances, a regional water planning council may be allowed to enter newly constructed facilities where return flows in the MLRA would not yet be accounted for in the baseline resource assessment data, as discussed in this Guidance.

The following information on Table B-1 is requested from the user on the 'User Entry' tab:

Table B-1 : User Entry Tab Components of Return Flow Estimation Tool

Column	Title	Comment	Required ?
A	# of Systems	Enter '1' for individual systems or use the summation for the planned number of similar systems (i.e., 2000 septic systems in a community)	Yes
B	MLRA#	This cell will be automatically populated when column C (MLRA) is filled	Yes
C	MLRA	Select MLRA from a drop-down menu. Use 'Maps' tab for reference.	Yes
D	Geologic Setting	This column is currently hidden and is saved for future tool functionality.	No
E	Discharge (MGD) per Facility	Input the estimated flow rate in million gallons per day (MGD) on a per unit basis.	Yes
F	Facility Type	Identify the facility as either an LAS or OSSMS	Yes
G	Application Rate	This entry, in the units of inches per week, is applicable only to LAS. If	No

Table B-1 : User Entry Tab Components of Return Flow Estimation Tool

Column	Title	Comment	Required ?
	(inches/week)	no entry is made, and the system is an LAS, a default value of 1.5 will be assigned in the calculations.	
H	HUC8 of Discharge	Select HUC8 from a drop-down menu. Use 'Maps' tab for reference.	Yes
I	Source Water HUC8	Used if the water at the application site comes from outside the HUC8 watershed in which it is discharged. If a portion of the water comes from outside the HUC8 watershed, then enter the facility in multiple listings to partition the return flows between the discharge watershed and the source watershed.	No
J	Hydraulic Conductivity (feet/day)	Enter hydraulic conductivity, as defined in Section 2. If no value is entered (if the cell is left blank), a range of default values for each MLRA/Geologic Setting will be used in calculations.	No
K	Effective Porosity (fraction)	Enter effective porosity, as defined in Section 2. If no value is entered (if the cell is left blank), a range of default values for each MLRA will be used in calculations.	No
L	Gradient (ft/ft)	Enter groundwater gradient, as defined in Section 2. If no value is entered (if the cell is left blank), the default value for each MLRA will be used in calculations.	No
M	Distance to Surface Water (feet)	Enter the distance from the application site to the closest perennial water body.	Yes
N	Percent Loss to Bedrock & Confined Aquifers	Users may enter percent loss through loss to bedrock and confined aquifers. The tool defaults to zero percent loss if no value is entered. Site-specific information or regional publications should be referenced for this factor. See Davis et.al., 1989 and Faye et.al., 1990.	No

If no entry is made for the optional parameters (columns G, J, K and L), the default values from the lookup tables provided in Appendix C will be used in calculations. All user-defined values are requested within the User Entry tab, with one exception. **In the Return Flow Estimates-HUC8 tab, the user is prompted to enter a user-defined lag time.** This entry allows the user to specify one time period of interest for which return flow estimates will be calculated.

Output from the Return Flow Estimation Tool

Based on the values input on the 'User Entry' tab, the output tabs in the spreadsheet tool are populated with various forms of lag time and return flow values. **Note that 'control-r' must be keyed in for the output in the 'Return Flow Estimates-HUC8' and 'Return Flow Estimates-MLRA' sheets to be populated or refreshed upon new data entry.** Below is a summary of the output tabs:

Return flow estimates-HUC8

This tab summarizes return flows by subwatershed. The returns are categorized according to their lag time, or the time required to travel from the point of application to the surface water body. Flows are classified into returns that reach surface water within 1 year, 5 years, 10 years, and 20 years. The spreadsheet also allows the user to define a return period of interest, for which return flows to be calculated. For each time period, the return flow is expressed in estimated planning minimum, maximum and average return flows, and as a percent of total applied in terms of estimated planning minimum, maximum and average return flows. A range of flows is generated for each time period, as the MLRA-default values for hydraulic conductivity and effective porosity are provided in a range.

Return Flow Estimates-MLRA

This tab is identical to the 'Return Flow Estimates-HUC8', with the exception that return flows are summarized by MLRA, as opposed to HUC8 subwatershed.

RF-LT (Chart)

The return flow versus lag time chart plots the estimated planning average cumulative percent of applied water that is returned to surface water for any given year, for each MLRA.

Lag Time Table

This table is provided for reference in planning for wastewater disposal systems. For any given MLRA and distance to surface water, the table provides a range of expected lag times for return flows, based on MLRA default values of hydraulic conductivity, effective porosity, and groundwater gradient.

Dist-LT chart-Minimum Time (Chart)

This chart plots the estimated planning minimum lag time as a function of distance to surface water, as expressed in the lag time table (previous sheet). This reference chart is based upon default values for each of the MLRAs.

Dist-LT chart-Maximum Time (Chart)

This chart plots the estimated planning maximum lag time as a function of distance to surface water, as expressed in the lag time table. This reference chart is based upon default values for each of the MLRAs.

Dist-LT chart-AvePlanningTime (Chart)

This chart plots the estimated planning average lag time as a function of distance to surface water, as expressed in the lag time table. This reference chart is based upon default values for each of the MLRAs.

Calculation Mechanisms

There are five hidden tabs within the spreadsheet tool that serve to provide the necessary lookup tables for calculations and to provide internal calculations for output to the displayed tabs.

Direct Loss

The first hidden tab calculates direct loss from wastewater disposal systems, defined as the volume of land-applied water (through an LAS or OSSMS) estimated to be unavailable due to evapotranspiration into the atmosphere, or through entrapment in a confined aquifer or fractured bedrock. For OSSMSs, or septic systems, the ET loss is defined as 15% of the amount of water applied, leaving 85% available for routing through groundwater. For LASs, total ET, as a percentage of total water applied, is estimated by dividing the ET by total water input. This percentage is then applied to the amount of land applied water, leaving the remainder available for routing through groundwater. If the system is defined as an LAS, and no value is provided for Application Rate (column G in the User Entry tab), a default value based on typical values for each MLRA is used to estimate the losses and resulting return flow.

If the user inputs a value in the Percent Loss to Bedrock & Confined Aquifer column (column N in the User Entry tab), this loss is also applied in the Direct Loss tab. The percentage defined is applied to the post-ET discharge, leaving the remainder available for routing to surface water.

Once losses have been defined for each facility, the total available water for return to surface water is quantified. If this water originates from outside the watershed, none of the return flow is available to surface waters. Instead, the return flow is classified as an Exchange Gain.

Lag Time Loss

The second hidden tab calculates a range of lag times for each facility. Estimated planning maximum, minimum and average lag times are calculated according to the equation described in Section 2. If the user inputs values in the User Entry tab for hydraulic conductivity (column J), effective porosity (column K) and gradient (column L), then the lag time will be calculated using these user-defined values. The estimated planning maximum, minimum and average lag times will be identical, since only one value is provided for each input parameter. If no values are entered for hydraulic conductivity and/or effective porosity, a range of lag times will be calculated, based on the range of values for each input parameter. Default values for gradient are also used in the lag time equation if no user-defined values are entered for gradient; however, only one value is provided as default for each MLRA (no ranges). The user must define a distance from the point of application to the nearest surface water (column M in User Entry tab) for lag times to be calculated. The range of lag times are functions of the following parameters:

- Maximum Lag Time = a function of {default minimum hydraulic conductivity or user-defined hydraulic conductivity, default minimum effective porosity or user-defined effective porosity, default gradient or user-defined gradient, and user-defined distance to surface water}
- Minimum Lag Time = a function of {default maximum hydraulic conductivity or user-defined hydraulic conductivity, default maximum effective porosity or user-defined effective porosity, default gradient or user-defined gradient, and user-defined distance to surface water}
- Average Lag Time = a function of {default estimated planning average hydraulic conductivity or user-defined hydraulic conductivity, default estimated planning average effective porosity or user-

defined effective porosity, default gradient or user-defined gradient, and user-defined distance to surface water}

Return Flow

The third hidden tab calculates the estimated range of cumulative volumes of flow returned within a defined period for each listing. The defined years for calculation of return flow volumes are 1 year, 5 years, 10 years, 20 years and a user-defined period of time (defined by user in cell C3 of the Return Flow Estimates-HUC8 tab).

The method of estimating the planning return flows within a given period of time is summarized as follows:

- Minimum return flow volume within x years = flows associated with maximum lag time if lag time is less than or equal to x years
- Maximum return flow volume within x years = flows associated with minimum lag time if lag time is less than or equal to x years
- Average return flow within x years = flows associated with average lag time if lag time is less than or equal to x years.

Data Lookup

The fourth hidden tab provides lookup reference tables for various input parameters. The other hidden calculation tabs pull from this sheet to provide MLRA-specific information. The default values are provided in Table C-4 of the Appendix. The following values are provided:

- Minimum, maximum and average hydraulic conductivity (feet/day) for each MLRA and setting.
- Minimum, maximum and average effective porosity (as a fraction) for each MLRA.
- Hydraulic gradient for each MLRA (vertical feet per horizontal foot).
- LAS ET losses for each MLRA, as a percentage, based on the default land application rate.
- OSSMS ET losses for each MLRA, as a percentage. (All MLRAs have 15% loss assumed.)
- Total annual ET losses by MLRA in inches per year.
- Precipitation by MLRA in inches per year.

MLRA sorted

The fifth and final hidden tab summarizes lag times, distance from receiving streams, gradients, and total return flow by MLRA. This sheet provides statistics that are given in the MLRA SummaryStats tab. For all statistics, the values are weighted according to the numbers of facilities (column A in User Entry tab) in each listing. The following estimated planning minimum, maximum and average statistics are calculated:

- Lag times for facilities within an MLRA.
- Distance from facility to surface water body within an MLRA.
- Hydraulic gradient within an MLRA.
- Return flow within an MLRA.

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Appendix C: Reference Tables

Appendix C provides a collection of reference tables that serve as lookup tables imbedded in the spreadsheet tool. Tables C-1 through C-3 list data used in calculation of evapotranspiration. Table C-4 lists data used in calculation of lag time.

TABLE C-1: NOAA Station Listing for Each MLRA

MLRA NAME	NOAA STATION NAME	NOAA STATION ID	APPROXIMATE STATION LATITUDE
Southern Appalachian Ridges and Valleys	Chatsworth	91863	34.75 °
Sand Mountain	La Fayette	94941	34.79 °
Southern Blue Ridge	Blairsville	90969	34.87 °
Southern Coastal Plain	Eastman	92966	32.18 °
Southern Piedmont	Atlanta AP	90451	33.65 °
Carolina and Georgia Sand Hills	Macon	95443	32.85 °
Atlantic Coast Flatwoods	Brunswick	91340	31.15 °
Tidewater Area	Savannah AP	97847	32.09 °
Dougherty Plain	Camilla	91500	31.23 °

TABLE C-2: NRCS Average Climate Data for Each MLRA

MLRA NAME	AVERAGE ANNUAL RAINFALL (IN/YR)	ANNUAL TEMPERATURE (^oF)	
		LOW	HIGH
Southern Appalachian Ridges and Valleys	54	52	63
Sand Mountain	58	55	63
Southern Blue Ridge	58	46	60
Southern Coastal Plain	47	55	68
Southern Piedmont	50	53	64
Carolina and Georgia Sand Hills	45	59	65
Atlantic Coast Flatwoods	50	58	69
Tidewater Area	50	56	77
Dougherty Plain	53	40	78

TABLE C-3: Monthly Average Daylight Hours as a Function of Latitude		
MONTH	DAYLIGHT (x 12 HOURS)	
	AT 30^{o} LATITUDE	AT 35^{o} LATITUDE
January	0.90	.87
February	0.87	.85
March	1.03	1.03
April	1.08	1.09
May	1.18	1.21
June	1.17	1.21
July	1.20	1.23
August	1.14	1.16
September	1.03	1.03
October	0.98	0.97
November	0.89	0.86
December	0.88	0.85

TABLE C-4: Default Values for Flow Parameters Used in the Tool by MLRA

MLRA	MLRA#	SATURATED HYDRAULIC CONDUCTIVITY (K_{SAT}, FT/DAY)			EFFECTIVE POROSITY			GRADIENT	ET LOSS FROM LAS [1]	ET LOSS FROM OSSMS (FRACTION)	TOTAL ET [1] (IN/YR)	PRECIPITATION (IN/YR)
		min	max	plan	min	max	plan					
Southern Appalachian Ridges and Valleys	128	1.2	130	2.71	0.1	0.35	0.18	0.02	0.26	0.15	34.36	54.29
Sand Mountain	129	1	130	1.18	0.1	0.35	0.14	0.06	0.24	0.15	32.27	58.08
Southern Blue Ridge	130B	1.2	130	1.52	0.1	0.35	0.15	0.02	0.21	0.15	29.08	57.94
Southern Coastal Plain	133A	0.1	270	0.14	0.05	0.35	0.07	0.02	0.31	0.15	39.06	47.26
Southern Piedmont	136	1.2	270	1.52	0.1	0.35	0.15	0.01	0.28	0.15	35.94	50.19
Carolina and Georgia Sand Hills	137	1.2	270	21.83	0.1	0.35	0.34	0.006	0.32	0.15	39.06	45.33
Atlantic Coast Flatwoods	153A	0.1	270	0.11	0.05	0.35	0.07	0.004	0.34	0.15	43.37	47.29
Tidewater Area	153B	0.1	130	0.11	0.05	0.35	0.07	0.002	0.32	0.15	41.29	49.61
Dougherty Plain	--	1.2	270	1.96	0.1	0.35	0.16	0.007	0.31	0.15	40.40	52.88

1. Based on an assumed LAS application rate of 1.5 inches/week