Both point and nonpoint sources may contribute fecal coliform to a water body. Potential sources of fecal coliform are numerous, and often occur in combination. Poorly treated municipal sewage comprises a major source of fecal coliform. Urban storm water runoff and combined sewer overflows (CSOs) can be a source of fecal coliform. Rural storm water runoff can transport significant loads of fecal coliform from livestock pastures and animal feedlots. Wildlife can also contribute fecal coliform. Most sources of fecal coliform loads can be assigned to two broad classes: point source loads, and nonpoint source loads.

Point Source Loads: *Loads from Municipal and Industrial Water Pollution Control Plants*
The greatest potential source of human fecal coliform is raw sewage. Raw sewage typically has a total coliform count of 10^7 to 10^9 MPN/100 ml (Novotny et al., 1989), along with significant concentrations of fecal coliform bacteria, viruses, protozoans, and other parasites. Typical treatment in a municipal plant reduces the total coliform count in effluent by about 3 orders of magnitude, to the range of 10^4 to 10^6 MPN/100 ml. Georgia requires disinfection of the treated wastewater discharge which results in significantly reducing the fecal coliform levels and a regulatory NPDES permit limit of 200 colonies/100 ml.. Raw sewage, while usually not discharged intentionally, may reach water bodies through leaks in sanitary sewer systems and for a few communities in Georgia through combined sewer overflows (CSOs).

Nonpoint Sources Loads:
Nonpoint sources of fecal coliform are typically separated into urban and rural components. Runoff and load generation processes differ systematically between these environments. In urban or suburban settings with high amounts of paved impervious area, important sources of loading are surface storm flow, failing septic tanks, and leakage of sanitary sewer systems. In rural settings, impervious area is usually much lower, and sources of fecal coliform may include diffuse runoff of animal wastes associated with the erosion of sediments, runoff from concentrated animal operations, and failing septic tanks.

Most nonpoint loads result from storm water and rainfall washoff, and estimation of load requires both flow volume and pollutant concentration in runoff. Modeling techniques can provide good estimates of surface storm flow volume, in both urban and rural settings. Modeling is typically conducted for single targets such as fecal coliform. All loading data are complicated by a lack of data and high variability in available monitoring data.

Fecal coliform bacteria have been detected in storm runoff from urban areas at densities high enough to suggest a potential health risk. Fecal coliform concentrations in urban storm water may be higher than concentrations in treatment plant effluent. The origins of urban bacterial loads are diverse, and may include leakage from sanitary sewers, failing septic tanks and direct loading of human fecal matter, as well as bacteria derived from dog and cat feces (which generally contain few fecal coliform of concern to humans).

Buildup and washoff of pollutants on urban impervious surfaces may be simulated directly. This physically based approach is incorporated into many popular storm water models, such as the Storm Water Management Model (SWMM) and Hydrological Simulation Program-Fortran (HSPF). Buildup refers to all of the complex spectrum of dry-weather processes that deposit or remove pollutants between storms, including deposition, street cleaning, etc. These processes lead to an accumulation of material associated with solids which are then Washed off during storm events.

The rural nonpoint sources of fecal coliform of greatest concern are typically associated with animal operations, in which large quantities of fecal matter are generated. Fecal coliform from these areas may reach water bodies either through direct runoff, or following the spreading of waste on fields. Land application of municipal waste sludge may also be a significant source of fecal coliform load. Outside of these areas, a lower background loading rate can be expected, resulting from the net inputs of domestic and wild animals, and so on.

Step 4. Linkage Between Numeric Targets and Sources - Model Development

Objective: *Define a linkage between the selected targets and the identified sources. The linkage or model is defined as* *the cause and effect relationship between the selected endpoint and the identified sources. This linkage can be derived from data analysis, best professional judgment, and previously documented relationships. The linkage or model is used in determining what loading is acceptable to achieve the target value. Margin of safety is also considered in the linkage or modeling effort.*

The model is essential to defining a relationship between the source and the impact on the receiving water. Where appropriate monitoring data are available, the linkage between fecal coliform loading and exposure concentrations can be accomplished by comparing historical records of load and exposure concentrations empirically. In other cases, the linkage will need to be assessed using water quality models that attempt to address transport of fecal coliform and natural die-off in the environment.

The U.S.EPA BASINS system and the Nonpoint Source Model (NPSM) were used to derive the linkages between the measured fecal coliform levels in the stream and the sources of fecal coliform. Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) is a multipurpose environmental analysis system for use in performing watershed and water quality-based studies. A geographic information system (GIS) provides the integrating framework for BASINS. GIS organizes spatial information so it can be displayed and provides techniques for analyzing land scape information. The NPSM simulates nonpoint source runoff and pollutant loadings in runoff from selected watersheds and transport of the flow and pollutant runoff through stream reaches. The NPSM uses selected features from the HSPF comprehensive watershed model.

MODEL PARAMETER DEVELOPMENT:

Model default values, based on literature review and Georgia specific values, were developed for the fecal coliform loading and transport model used in this watershed analysis. Flow runoff from the land and flow in the stream are the driving forces for pollutant (fecal coliform) transport. The pollutant transport and water transport modules of NPSM computes the surface runoff, interflow and groundwater flow on pervious and impervious land segments. The stream reach hydrodynamic and quality modules calculates the channel flow and the pollutant decay through the stream channels. The parameters necessary to run this model are derived or estimated from existing land use data, rainfall data, available stream geometry information, land slope data, soil characteristics, literature values, best professional judgement, etc. A number of articles discussing fecal coliform nonpoint source loads were used to develop the default parameters. Georgia specific agriculture data was used to adjust the parameter values.

Fecal Coliform Parameters:

Initial default value, determined from literature and adjusted to take into account Georgia climate and soils, were used initially for fecal coliform bacteria buildup and washoff parameters. Note: In this case, parameters for pasture were assigned the same values as agricultural and those for barren were assigned the same values as urban (pervious). The following values are the Georgia default values to use initially for fecal coliform bacteria buildup and washoff parameters.

ACQOP (rate of accumulation of fecal coliform) - buildup rates were derived from literature.

Urban Pervious	1.59 E +10 (count/ac-day)
Agriculture Pervious	7.6 0E +10
Pasture Pervious	7.60 E +10
Forest Pervious	1.33 E +09
Barren Pervious	1.59 E +10
Urban Impervious	5.01 E +08

SQOLIM (maximum storage of fecal coliform) - this was taken as 9 x ACQOP. The average number of days between storms for Georgia was determined, and this value was then multiplied by 1.5.

Urban Pervious	1.43 E +11 (count/ac-day)
Agriculture Pervious	6.84 E +11