Section 3
Piedmont and Blue Ridge Provinces: Streamflow-Based Water Budgets

3.1 Modeling Approach

A water budget approach was selected as the most appropriate mechanism to provide a planning level assessment of groundwater resource sustainability in basins of the Piedmont and Blue Ridge physiographic provinces of Georgia. The selected basins for the water budgets were:

- The Middle Oconee River Lower Basin, which covers 163 square miles in portions of Clarke, Oconee, Barrow, and Jackson counties of the Piedmont; and

- The Chattahoochee River-Chickamauga Creek and Soque River basins, which cover 315 square miles in portions of Habersham, Towns, Union, and White counties of the Blue Ridge.

The location of the Piedmont and Blue Ridge Watersheds are shown in **Figure S-2**.

A water budget is an accounting of water movement within the hydrologic cycle, both natural and artificial. Water budgets can be completed at a basin or subbasin level, although each approach may have unique limitations based on the quantity and quality of data available to provide an assessment of the system. Water budgets serve as useful tools for a number of reasons. In the context of assessing groundwater resource sustainability, the process of collecting, compiling and analyzing the data necessary to develop water budgets is useful for:

- Estimating groundwater withdrawal rates and recharge.

- Identifying the relationship between streamflow and baseflow.

- Identifying the areas served by domestic wells and onsite wastewater systems.

- Developing an understanding of the potential impacts that sanitary sewers have on groundwater recharge.

- Developing an understanding of the movement and use of water within a drainage basin.

- Developing a concise means of comparing drainage basins with each other in terms of water consumption, baseflow, and runoff.

- Identifying drainage basins that have a relatively high level of water consumption.

- Comparing the natural versus man-made components of the hydrologic cycle.

- Identifying subbasins where large exports or imports of water are occurring.
- Identifying where management decisions will result in the most impact and allowing the resource managers and planners to focus management efforts on the most pressing issues.
- Providing a basis to assess sustainability of the water resource.

The full water budget accounts for both the natural and artificial movement of water within the hydrologic cycle. The equation used in the assessment generally reflects water "in" to the system:

- Average precipitation;
- Wastewater and industrial discharge to groundwater systems;
- Estimated domestic recharge from onsite wastewater treatment systems (i.e., septic systems); and
- Discharge to streams.

and water "out" of the system:

- Evapotranspiration;
- Runoff component of precipitation;
- Surface water withdrawal from streams/creeks;
- Groundwater withdrawal from public water supply systems, industrial, commercial and agricultural wells;
- Estimated withdrawal from domestic wells; and
- Median baseflow of streams.

The components of the water budget equation which specifically relate to groundwater can be rearranged to develop an estimate of net groundwater consumption. Net groundwater consumption can thereby be defined as the estimated withdrawal from all groundwater wells (public water supply systems, industrial, commercial, domestic, and agricultural wells) minus the groundwater recharge from wastewater treatment plants, onsite treatment systems and other sources including industrial discharges to groundwater. By comparing net groundwater consumption to the sustainable yield criteria discussed in Section 2 of this Synopsis, estimates of net groundwater availability can be developed.

For shallow, water table aquifers in direct connection with surface water, water budgets can be constructed using existing data on rainfall, streamflow, aquifer and surface water withdrawals, and aquifer and surface water discharges. These water budgets are usually created on an annual basis due to limited information on the withdrawals, and they rely on stream baseflow estimates to approximate the recharge of the groundwater system. An underlying assumption of this method is that the surface watershed and the groundwater basin cover the same area, making them appropriate for unconfined, surficial aquifers.

Water budgets offer no ability to estimate impacts due to the locations of groundwater withdrawals, nor do they account for possible "lag time" between withdrawals and impacts to streams. Because the water budget focuses on streamflow as the primary estimator of recharge and groundwater availability, the most practical method is to apply a variant of the Tennant Method to make an initial estimate of sustainable yield.

3.2 Estimated Range of Sustainable Yield

In the Piedmont and Blue Ridge area, the modified Tennant Method was used to develop values for sustainable yield. Tennant suggests several categories of streamflow reduction, and these are modified here into minimum, mid-level, and maximum allowable streamflow reduction categories and are subtracted from the mean monthly flow during the most severe stress period of the year (September).

Because of the limited ability of the Crystalline-Rock aquifers in the Piedmont and Blue Ridge areas to provide water, an even more stringent or conservative estimate of sustainable yield is also provided as the lower end of the range of sustainable yield. In this case, the streamflow reduction targets are further reduced, allowing only 20% of the difference between the mean September flow and the Tennant reduction category thresholds to calculate groundwater availability. The Tennant Method was further modified to provide an indication of sustainable yield considering only the baseflow component of streamflow. In this way, an attempt is made to provide an upper limit to groundwater withdrawals that will leave sufficient water in the stream during the period of lowest flows to support opportunities for surface water withdrawals.

The increase of impermeable cover within a basin would result in a decrease in recharge to groundwater and a subsequent decrease in stream base flow. The water budgets developed for the Water Plan did not consider decreased stream base flows resulting from future increases in impermeable cover. Because of the way stream base flow was used as a metric in the water budgets to determine sustainable yields, increases in impermeable cover and subsequent decreases in stream base flows would result in lower sustainable yields.

Daily streamflow data from the period 1989 – 2008 for the Middle Oconee River (Piedmont) and Chattahoochee River (Blue Ridge) were used to calculate the mean annual streamflow and baseflow and a range of streamflow and baseflow reduction amounts (40% to 60%) were evaluated. The 50% mid-level streamflow was chosen as the criterion to estimate the net amount of groundwater available for use in both basins. Using the 40% streamflow reduction amount (60% of flow remains in the stream) in the Piedmont basin resulted in a situation in which current consumption already exceeded the sustainable yield. This was not considered reasonable given the negative net groundwater consumption in the basin. Therefore a mid-level reduction of 50% was used in both the Piedmont and Blue Ridge basins.

30Q2 (driest monthly flow with a recurrence interval of 2 years) and 7Q10 (driest weekly flow with a recurrence interval of 10 years) values were also developed for comparative purposes only. The resulting values are shown in **Table S-3** for total streamflow. The values shown under the label "Tennant Method Thresholds" are simply the mean annual streamflow multiplied by the appropriate reduction factors. The threshold values are given in several different units (cubic feet per second, inches per year, million gallons per day, and million gallons per square mile) to provide appropriate units for a variety of applications. The values in the columns labeled "Net Amount Available for Use" show the net amount of groundwater consumption that could occur on an average annual basis so that mean monthly streamflow does not drop below the minimum flow reduction category during the month of September.

In Table S-3, the Net Amount Available for Use in the Piedmont has a lower range of 0 million gallons per day (mgd), meaning that based on the most conservative or minimum allowable streamflow reduction estimate, the watershed is currently consuming levels equal to or greater than the sustainable yield. If less conservative criteria are applied, then additional groundwater is available.

Table S-3 also presents a more restrictive use of the Tennant Method similar to an approach applied in the New Jersey Highlands to estimate sustainable yield. In this case, the Tennant Method streamflow reduction categories are further reduced, allowing only 20% of the difference between the mean September flow and the Tennant threshold to calculate groundwater availability.

Table S-4 compares the net groundwater consumption values derived from the water budgets to the groundwater sustainability measures calculated via the modified Tennant Method using the mid-level (50%) streamflow reduction category.

- Column "a" is taken from the estimates found in Table S-3. In the Piedmont, the water budget was completed for the Middle Oconee River Lower Basin, which is only a portion (roughly 41%) of the larger drainage basin for which Tennant Thresholds and the net amount available for use were calculated in Table S-3. Therefore, the values were normalized to reflect the smaller basin size. In the upper part of the table, the estimate uses the streamflow reduction percentage value from the modified Tennant Method. In the lower part of the table, the estimate uses the more restrictive estimate of sustainable yield based on only 20% of the value provided in the upper part of the table. The intent is to provide a range of sustainable yield estimates for consideration by the Regional Councils.

- Column "b" shows current groundwater use.

- Column "c" shows net groundwater consumption (accounting for water used but returned to the groundwater or stream).
- Column "d" gives the percentage of water available currently being consumed (if negative, it is shown as 0%).
- Column "e" provides an estimate of the amount of water available for future consumption.

As previously noted, net groundwater consumption in the Piedmont basin was negative, meaning that more water is estimated to be returning though onsite wastewater treatment systems than is leaving through wells. Using the mid-level (50%) streamflow reduction category presented in the upper part of Table S-4, the net amount of groundwater available is estimated to be 7.9 mgd, which is over 6 times the amount currently being used in the watershed. If the more restrictive method is used (lower part of Table S-4), the net amount of groundwater available is estimated to be 1.6 mgd, which is 33% more than the amount currently being used in the watershed. If only the baseflow component is considered and the mid-level (50%) Tennant Threshold is calculated using baseflow, the net amount of groundwater available is estimated to be 0.8 mgd, which is 0.5 mgd below the amount currently being used in the watershed.

Net groundwater consumption in the Blue Ridge basin is positive, meaning that water is being consumed within the watershed. Using the least restrictive measure described above and presented in the upper part of the table, the net amount of groundwater available is estimated to be 99.5 mgd, which is over 41 times the amount currently being used in the watershed. If the more restrictive method is used (lower part of Table S-4), the net amount of groundwater available is estimated to be 19.9 mgd, which is over 8 times the amount currently being used in the watershed. If only the baseflow component is considered and the mid-level (50%) Tennant Threshold is calculated using baseflow, the net amount of groundwater available is estimated to be 55.6 mgd, which is over 23 times the amount currently being used in the watershed.

The water budgets show that more groundwater is available from the crystalline rock aquifer than is currently being withdrawn. It might be difficult to find sufficient water-bearing fractures in the crystalline rock aquifer to develop the full range of sustainable yield, however. Therefore, it is recommended that the lower-end of the sustainable yield range be used for planning purposes.