Appendix B

Modeling of Future Development Impacts

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Section 1
General Approach

During Phase 3 of the Peachtree-Martins Creek Local Watershed Plan, Equinox estimated the extent of new development in the planning area over a 10 year period and modeled the impact of expected development on annual total suspended solids and nutrient loads (total nitrogen and total phosphorus). This task was carried out using the IPSI (Integrated Pollutant Source Inventory) NPS (nonpoint source) model developed by the Tennessee Valley Authority (TVA) and was conducted in collaboration with the Hiwassee River Watershed Coalition (HWRC) and the Local Advisory Committee (LAC).

The analysis consisted of several components.

1. Estimation of future land use for two time points: a 5 year period extending from the month the IPSI aerial photography was flown (March 2005), and a 10 year period extending from the same month. The land use distribution at these points defines two scenarios, representing anticipated land use conditions in March 2010 and March 2015. These are termed the 2010 and 2015 base scenarios.
2. Estimation of additional model inputs and running of the IPSI NPS model for the base scenarios. The 2010 and 2015 land use data were entered into the IPSI model along with other inputs. Estimates of the annual load of the three pollutants were derived for each time period.
3. Options for several local management policies were explored with the HRWC and the LAC. Several of these measures were operationalized in the model and their impact on pollutant loads estimated.

Additionally, the impact of new development on the extent of impervious area was estimated.

This Appendix outlines the methods used for this analysis and presents additional results to supplement those presented in the main text of this report.

Section 2

Methods

Methods are summarized below for each component of the analysis.

2.1 Derivation of Base Scenarios

2010 and 2015 land use estimates were derived for each sub-watershed. Since the IPSI model for the planning area operates based on drainages defined by TVA, which are more detailed than the sub-watersheds used in this Local Watershed Plan, land use was updated for TVA sub-drainages, as appropriate (see Section 2.2.1 of this Appendix).

The increase in commercial development was based on estimates derived from the LAC. The increase in residential areas was based on LAC interpretation of building permit data and LAC judgments about the likely location of development, as discussed below.

2.1.1 Extent of New Commercial Development

LAC members identified parcels in the study area where they felt commercial development should be anticipated within the 10 year period. Parcels totaling 373 acres were identified as likely candidates for commercial development between 2010 and 2015. No parcels were identified for commercial development between 2005 and 2010. It was assumed that the pace of commercial development would be constant between 2010 and 2015. In the 2015 scenario, 20% of the new commercial development was classified as under construction and 80% as completed commercial development.

2.1.2 Total Number of New Homes

The total amount of residential development likely in the planning area was estimated by the LAC based upon building permit data and knowledge of the local area. About 500 permits for single family homes are being issued per year in Cherokee County. LAC members expect this rate of growth to continue, and estimate that approximately one quarter of the permits issued in the county are for the Peachtree-Martins Creek planning area. Accordingly, the number of new homes expected in the planning area over the period to be modeled was estimated as 125 per year (625 new homes over five years and 1250 over 10 years).

2.1.3 New Dwellings per Sub-watershed

The level of overall residential development anticipated by the LAC was distributed across sub-watersheds using the approach described below.

1. LAC members reviewed maps of the planning area and identified parcels they felt had a reasonable potential for residential development over the next 10 years. These totaled about 4,500 acres. While this far exceeds the amount of land likely to be developed, this information was used to indicate where residential development was most likely to occur.

2. The new homes expected in the planning area (125 per year) were distributed across sub-watersheds based upon the sub-watershed distribution of the acreage flagged by the LAC for residential development. For example, if a sub-watershed had 10% of the acreage flagged by the LAC as having development potential, that sub-watershed was allocated 10% of the 125 new homes expected annually.
3. A 351 acre parcel in SUT (see Section 2 of the main text for a list of sub-watershed abbreviations) was flagged for mixed use development. Per the HRWC, the developer currently plans strip commercial development along Harshaw Road with residential areas behind it. Given an approximate road frontage of 4200 feet (GIS measurement of road frontage) and assuming that commercial development is 200 feet deep, the commercial area will encompass about 28 acres. The remaining 323 acres are assumed to be residential.
4. Four sub-watersheds had no acres flagged for residential development and were allocated no additional homes.
5. Two additional sub-watersheds (PBR and PBT) had very few acres flagged for residential development, such that less than one dwelling per year would be allocated. It was assumed that no additional residential development would occur in these sub-watersheds and the few homes involved were allocated to an adjacent sub-watershed (MPT).
6. Based on the location of flagged parcels within each sub-watershed, new homes were either classified as falling within the area currently served by the Murphy sanitary sewer system, or outside the service area. MPT and SUT were the only two sub-watersheds with land falling within the service area that was flagged for likely residential development.
7. The final number of homes allocated to each sub-watershed is shown in Table 1. The number of dwellings in each sub-watershed was rounded to the nearest whole number.

2.1.4 Increase in Developed Land Acreage

The 2005 IPSI land cover distribution for individual sub-watersheds was modified to accommodate the number of new homes anticipated, as well as the commercial development expected by the LAC.

1. For residential development, lot sizes of 1 acre (IPSI low density residential classification) were assumed for areas not served by the Murphy sanitary sewer system. Lot sizes of one half acre (IPSI medium density residential classification) were assumed for the area with sewer service.
2. The number of new low and medium density residential acres in each sub-watershed was calculated by multiplying the lot sizes noted above by the corresponding number of new homes expected.
3. Parcels flagged by the LAC for commercial development were reclassified to commercial use in their entirety.
4. The pace of new development was intended to roughly approximate the current rate. For the 2010 and 2015 scenarios, the total number of new residential acres under construction in the planning area as a whole was set at the same level as in the 2005 model. This was distributed across planning areas based upon the extent of residential development.

Table 1 Final Allocation of New Homes, by Sub-Watershed

Sub-WS	% of Potential New Residential Acres Flagged by LAC	# of New Homes, 2005-2010			# of New Homes, 2005-2015		
		Sewered Area	No Sewer	Total # New Homes	Sewered Area	No Sewer	Total # New Homes
PHW	0%	0	0	0	0	0	0
UPT	4%		24	24		49	49
MOB	6%		37	37		73	73
PBR	0%		0	0		0	0
MPT	10%	18	54	72	36	108	144
SHW	2%		14	14		27	27
SMD	2%		15	15		30	30
MBR	0%		0	0		0	0
LSL	1%		7	7		15	15
PBT	1%		0	0		0	0
CMB	6%		35	35		70	70
MQT	0%		0	0		0	0
MCB	0%		0	0		0	0
FBR	11%		71	71		142	142
SUT-05L*	3%		21	21		42	42
SUT-04L**	14%	86	0	86	173	0	173
HCK	4%		28	28		56	56
UMC	6%		40	40		80	80
MMC	17%		107	107		214	214
LMC	11%		68	68		135	135
Total	100%	104	521	625	209	1041	1250

See Section 2 of the main text for a list of sub-watershed abbreviations
Sewered area denotes areas currently served by Murphy sanitary sewer system
*TVA drainage 05L within SUT
**TVA drainage 04L within SUT

2.1.5 Reduction in Undeveloped Acreage

The amount of undeveloped land in each sub-watershed was reduced by an amount that offset the increase in developed acres, keeping the total area of each sub-watershed constant.

1. The current IPSI land use of those areas flagged by the LAC for development was examined by sub-watershed. Areas flagged for residential and commercial development were examined separately.
2. Simplifying assumptions were made regarding existing land use for ease of calculations. GIS analysis indicated that 80% of all land flagged for residential development is currently in forest cover, while 18% is in pasture, predominately pasture in fair condition. Very little land is currently in any other use. With the exception of a small area of medium residue crop land, only these two land cover classes were reduced to offset new residential development. Pasture in fair condition and medium residue crop land were reduced in rough proportion to current flagged area, on a sub-watershed basis. The remaining newly developed land was assumed to currently be in forest.
3. The existing land cover of flagged commercial areas consists of forest, pasture (mostly in fair condition) and crop land (mostly medium residue). Only these classifications were reduced to offset new commercial development. As described above for residential

areas, rural uses were reduced in rough proportion to current flagged area, on a sub-watershed basis.

2.2 Modeling of Land Use Change

2.2.1 Use of the IPSI Nonpoint Source Model

Model overview

The nonpoint source (NPS) loading model was developed by TVA as part of the IPSI conducted for the planning area under contract with NCEEP. The model uses Microsoft Excel to estimate annual pollutant loads based upon the data in the IPSI nonpoint source inventory. The nonpoint source loading model estimates total phosphorus (TP), total nitrogen (TN), five-day biochemical oxygen demand (BOD_5) and total suspended solids (TSS) loads for each sub-watershed.

The IPSI NPS model is a spreadsheet-based screening level model. Like all models of this type, and indeed all models, simplifying assumptions are made to approximate complex real world processes. The model is intended to predict average annual pollutant loads. Loads are predicted for each land use/land cover classification, as well as for other features in the nonpoint source inventory, such as eroding streambanks, unpaved roads and livestock.

Loads are calculated on a sub-watershed basis. However, location of features within a sub-watershed is not tracked by the model. For example, whether agricultural activity or developed land is located on a ridge, adjacent to a stream, or in between is not specified in the model.

The model is described in the documentation produced by TVA (TVA, 2006) and is discussed in the Phase 2 report (Equinox, 2007).

Sub-watersheds in the model

The IPSI model for the planning area operates based on drainages defined by TVA. The sub-watersheds used for the Peachtree-Martins Creek Local Watershed Plan (n=19) sometimes consist of two or more TVA drainages (n=32). Many of the TVA drainages are small and often contained no parcels identified as likely candidates for development (see below). To facilitate the derivation of revised land use data, all changes in land use were made to the major drainage within each of the 19 sub-watersheds. The only exception to this approach was for SUT, where the two TVA drainages (TVA codes 04L and 05L) were of similar size and both were likely to see significant development. In this case, land cover changes were calculated for each drainage separately.

Assumptions in use of the model

The model estimates pollutant loading based on land use and a variety of watershed features, including: the extent of livestock operations, the disturbed area of Mission Quarry, road and road bank erosion, streambank erosion and other factors. In consultation with NCEEP and HRWC it was decided to leave these features unchanged in the model except for land use (discussed above) and road erosion (see Section 2.2.2). The model was modified to allow pollutant factors for development occurring in the 2005-2015 window to be input separately from factors for pre 2005 development. Pollution loads from areas developed prior to 2005 are not affected by any of the considerations applied to 2005-2015 development. No other modifications were made to IPSI model inputs were made other than those discussed in this Appendix.

It is important to emphasize that the IPSI model estimates pollution loads based upon a snapshot of watershed features at a single point in time for each scenario—in this case March 2010 and March 2015. Estimated pollutant loading were modeled for each of these scenarios under the assumption that development occurs under current regulatory requirements.

2.2.2 Derivation of Road Erosion

Increasing the extent of developed areas in the IPSI model does not account for increases in pollutant loads due to erosion features associated with the expanded road network. Eroding road features are tracked separately in the model, and increasing developed acres does not automatically alter the extent of these features. Additional eroding road banks and ditches were therefore added to the model as follows. To determine the extent of roads likely to be associated with new development, the IPSI GIS data base and aerial photography were examined for selected areas identified by the IPSI as residential areas under construction in March 2005. IPSI data were also examined for selected areas where residential construction was known to be completed just prior to that time. According to the IPSI data, the extent of roads in these areas ranged from 148 to 311 linear feet per developed acre, averaging 221 linear feet. Analysis of the IPSI GIS data base indicated that 19% of the roads in the planning area had eroding banks/ditches.

It was assumed that new residential development added between 2005 and 2015 would have characteristics similar to those noted above. Specifically it was assumed that each new acre of residential development would add 221 linear feet of additional road and that 42 feet of these (19%) would have eroding banks/ditches. For each sub-watershed, the number of new residential acres to be added to a scenario was multiplied by 42 to obtain the estimated additional linear feet of eroding road banks/ditches. The number of additional feet thus calculated was added to the existing eroding banks/ditches for each sub-watershed.

2.3 Modeling of Management Measures

In consultation with the LAC and the HRWC a number of management measures to limit the impacts of development were selected. These are by no means exhaustive, but are intended to illustrate potential management effects by including a range of options. One additional management option not intended to mitigate development impacts was also included. This is an extension of the service area of the Murphy sanitary sewer system through the McComb Branch sub-watershed into the Mission Branch-Calhoun Branch area.

2.3.1 Measures to Mitigate Development Impacts

LAC members suggested a number of management measures for which they felt modeling of potential impacts would be useful. Based on discussions with NCEEP and the HRWC, the following were selected.

Limits on vegetative clearing
Currently there is no limit on the extent of clearing of forest vegetation that may occur during development. Based on input from the LAC, the clearing of 75% of forested vegetation during residential development is assumed to be a typical practice at present. The potential impacts of two vegetative clearing limits were analyzed: limiting vegetative clearing to 50% of woody

vegetation on forested tracts, and limiting clearing to 30%. Both construction and post-construction impacts were considered.

Enhanced standards for development in high elevation areas
Development at higher elevations has the potential for increased environmental impact because of the difficulties inherent in building on steep slopes. The effectiveness of stricter development standards for these areas in reducing post construction pollution was modeled. This measure is not intended to reduce the overall amount of residential development, but to reduce impacts though better planning and the use of more appropriate design criteria.

Based on suggestions from the LAC, an elevation of 2000 feet was used for the implementation of these standards. Approximately twenty three percent of the land flagged by the LAC for residential development is at an elevation of 2000 feet or greater. Accordingly, the design standard scenario was applied to 23% of the new homes built over the 10 year period. This was done proportionally by sub-watershed. That is, sub-watersheds with a higher proportion of flagged land that is over 2000 feet have a higher proportion of new homes built under the new standards (Table 2).

Table 2 Percent of New Residential Areas to Which Elevation-Based Standards Apply

Sub-WS	%	Sub-WS	%
PHW*	0.0%	CMB	4.5%
UPT	40.0%	MQT*	0.0%
MOB	79.9%	MCB*	0.0%
PBR*	0.0%	FBR	12.8%
MPT	48.3%	SUT-05L	34.2%
SHW	13.6%	SUT-04L	0.0%
SMD	0.0%	HCK	22.6%
MBR*	0.0%	UMC	28.4%
LSL	21.4%	MMC	12.5%
PBT*	0.0%	LMC	29.0%

*Sub-watershed in which no new residential development is projected

Post construction stormwater management
The impact of requiring stormwater management measures for new development was modeled. The specific requirements are unspecified, but it is assumed that treatment of runoff exceeding predevelopment levels will be part of the measure.

Erosion and sediment control improvements
LAC members believe that a lack of enforcement of sediment and erosion control requirements is a major problem. The fact that existing regulations are overseen by state personnel who are several hours away is one reason for the limited enforcement. The impact of stricter enforcement, most likely through the establishment of a local erosion and sediment control program was modeled.

Road design standards
Eroding road banks and ditches are currently an important source of sediment in the planning area. It is likely that poor planning and design contributes to this problem (e.g. cut/fill slopes too high to allow stabilization, ditch not constructed with features to reduce velocity in channel). This measure involves the implementation of road design standards (regarding road grades, cut

and fill slope design) so that roads are more likely to have stable banks/ditches and post construction pollution is reduced.

2.3.2 Other Management Options

The LAC was interested in exploring the potential impacts of extending sewer service along US 64 east of the Tri-County Community College, continuing along Mission Branch Road through the CMB sub-watershed. The potential impact of this extension is included as an additional scenario to be modeled. Under this scenario, parcels with access to the new line are assumed to be built at a density of two dwellings per acre instead of one dwelling per acre. This impacts residential areas in CMB only, as there are no parcels flagged for residential development along other portions of the new line. Under this scenario, the new homes allocated to CMB are classified as medium density in the model instead of low density. This is assumed to represent an increase in the number of homes built. That is, it is not offset by a decrease in homes built elsewhere in order to remain within the residential development target (125 homes per year) set by the LAC. No other land cover changes are made under this scenario.

2.3.3 Estimating Impacts of Management Options

General approach
There are four general mechanisms which could be used to simulate the impacts of management actions using the IPSI model:

A. Altering the land cover distribution entered into the model.
B. Modifying the extent of other watershed features in the model (e.g. eroding road banks).
C. Altering model parameters used to calculate pollution inputs. The most likely parameters to alter in the present case include 1) the Universal Soil Loss Equation (USLE) C (cover) factor or USLE P (practice) factor for land under construction; and 2) the pollutant concentration or runoff coefficient for developed areas (both with separate values for low density residential, medium density residential and commercial).
D. Adjusting model loading estimates after the fact to account for expected changes in loads from management actions.

The mechanisms used to estimate the impact of each management option are listed in Table 3. Approach A was used to define the base scenarios but was not used to estimate the impacts of management options. Management measures will be simulated primarily by modifying pollution input parameters (approach C).

After the fact adjustments (approach D) are used in one case to overcome specific limitations of the IPSI model. Parameters used to calculate pollution from developed areas cannot be varied by sub-watershed, and are thus not useful for management measures impacting only specific sub-watersheds, notably enhanced standards for high elevation areas.

Values to be used were derived by Equinox using existing research, available data and professional judgment. All management scenarios were run under the assumption that measures were implemented in 2005. The selection of parameter values for each measure is discussed below.

Table 3 Management Measures and Proposed Mechanisms

Management Option	Proposed Mechanism
Vegetative Clearing Limited to 50%	Modify USLE C factor (construction) and runoff coefficient (post construction)
Vegetative Clearing Limited to 30%	Modify USLE C factor (construction) and runoff coefficient (post construction)
Standards for High Elevation Development	Adjust model outputs
Post-Construction Stormwater Management	Adjust pollutant concentration
Erosion and Sediment Control	Adjust USLE P Factor
Road Design Standards	Modify extent of eroding road banks

Modeling of the pollutant loads associated with land use changes and potential management actions is intended to represent anticipated loads as closely as possible given the tools and data available. Load estimation is subject to a number of constraints however. As a spreadsheet-based screening level tool, the IPSI nonpoint source model makes many simplifying assumptions about the complex processes by which pollutant loads are generated. There is considerable uncertainty regarding how well model assumptions reflect real world processes in any particular watershed. Given limited ability to anticipate future land use patterns and limited scientific knowledge about the effects of management policies, there are additional uncertainties associated with the land use change projections and with estimates of the likely impacts of potential management actions. Readers should exercise caution in using the estimates reported here, which should be considered rough approximations of anticipated trends in pollution loads under each scenario rather than precise estimates of impact. Despite these limitations, the load estimates are adequate to assist the LAC and members of the Peachtree-Martins Creek community in visualizing the expected impacts of development activity as well as possible management options.

Limits on vegetative clearing

Mechanism for Inclusion in the Model. For construction phase impacts, the C Factor of the USLE was adjusted for land classified as under development. Post construction impacts were dealt with by reducing the runoff coefficient. The pollutant concentration could be adjusted instead, or the concentration and the runoff coefficient in combination, but since load is calculated as the product of various factors (including pollutant concentration and the runoff coefficient) adjusting any of those factors by the same proportion will produce the same result. Since the pollutant concentration will be adjusted for the stormwater scenarios (see below), for practical reasons the runoff coefficient was used to capture the impact of vegetative clearing.

Parameter Values. No studies of the impact of vegetative clearing limits per se were found and parameter values were determined based on professional judgment. For areas under construction, it was assumed that clearing limits would decrease pollution but not proportionally to the decrease in cleared area. For example, cutting clearing in half will not cut construction-related pollution loads in half. Even with reduced clearing, significant disturbance will still occur, including construction of the drainage (pollutant delivery) network, and major land disturbances associated with roads and buildings and septic systems.

Once development is completed, having cleared less land may limit the potential for erosion from unstabilized areas and may reduce the total amount of intensively managed land. However many pollution-generating activities associated with development will not be limited proportionally to the reduction in clearance (for example the area of rooftop, number of cars washed, number of pets, etc. seems unlikely to change much). Imperviousness is not likely to be much affected, though soil compaction may be lessened and some hydrologic functioning preserved.

Going from 75% clearing to 50% is a 1/3 reduction in cleared area. Going from 75% to 30% is a 60% drop in cleared area. These percentages set theoretical upper limits on pollution reductions. It seems likely that actual reductions will be far below these levels.

For land under construction, the C factor was reduced from .25 to .23 (8% decrease) and from .25 to .21 (16% drop) for the 50% and 30% vegetative clearing limits respectively. The percent decrease in pollutant load will be the same as the percent decrease in the C factor.

For post construction: pollutant reductions of 8% and 16% were assumed for the 50% and 30% vegetative clearing limits respectively. The runoff coefficients must be adjusted downward by this percentage. Adjusted runoff coefficients are shown by land cover in Table 4. The same runoff coefficients are used for all pollutants.

Table 4 Runoff coefficient for Vegetative Clearing Scenarios

Medium Density Residential	
% reduction assumed, 50% clearing	0.08
% reduction assumed, 30% clearing	0.16
Current Runoff Coefficient	0.19
Runoff Coefficient with Clearing Limited to 50%	0.175
Runoff Coefficient with Clearing Limited to 30%	0.160
Low Density Residential	
% reduction assumed, 50% clearing	0.08
% reduction assumed, 30% clearing	0.16
Current Runoff Coefficient	0.14
Runoff Coefficient with Clearing Limited to 50%	0.129
Runoff Coefficient Clearing Limited to 30%	0.118
Commercial	
% reduction assumed, 50% clearing	0.08
% reduction assumed, 30% clearing	0.16
Current Runoff Coefficient	0.5
Runoff Coefficient with Clearing Limited to 50%	0.46
Runoff Coefficient with Clearing Limited to 30%	0.42

Enhanced standards for development in high elevation areas

Mechanism for Inclusion in the Model. This measure was modeled by adjusting model outputs. Slope requirements apply only to specific areas, which vary in extent by sub-watershed. However existing model parameters used to calculate pollution from developed areas cannot be varied by sub-watershed. It was therefore most practical to make adjustments outside of the model.

Parameter Values. Standards for steep slope development are being considered (or have been adopted) by a number of local governments in western North Carolina and Northern Georgia, and state legislation has been proposed in North Carolina. The measure used in the model does not assume any specific set of requirements but is intended to represent a generic approach to the issue.

The effects of steep slope measures on water quality have not been studied. The degree of impact can be expected to depend on a variety of site-specific factors, including: slope, type of soils and rock present, extent and nature of disturbance (cut vs. fill) and density of development. Stricter standards may have a minimal impact on many sites (those which would have been largely stable without the additional requirements), yet major impacts on those sites where slope failure or major erosion is prevented.

A 15% reduction in pollutant loads is assumed for areas where the ordinance applies. An adjustment factor for model outputs was calculated for each sub-watershed based upon the proportion of residential development in the sub-watershed to which the restrictions apply and the level of effectiveness assumed (15%). The load estimated by the IPSI model was multiplied by the adjustment factor (Table 5). Identical effectiveness is assumed for all pollutants. All commercial development is below 2000 feet in elevation and is therefore not affected by this measure.

Table 5 Adjustment Factor for Slope Measure

	A	B	C
Sub-WS	% of Sub-WS in Which Ordinance Is Applied	Overall Reduction Expected in Sub-WS Load*	Adjustment Factor for Model Output**
PHW	0	0.00	1.00
UPT	0.4	0.06	0.94
MOB	0.799	0.12	0.88
PBR	0	0.00	1.00
MPT	0.483	0.07	0.93
SHW	0.136	0.02	0.98
SMD	0	0.00	1.00
MBR	0	0.00	1.00
LSL	0.214	0.03	0.97
PBT	0	0.00	1.00
CMB	0.045	0.01	0.99
MQT	0	0.00	1.00
MCB	0	0.00	1.00
FBR	0.128	0.02	0.98
SUT-05L***	0.342	0.05	0.95
SUT-04L***	0	0.00	1.00
HCK	0.226	0.03	0.97
UMC	0.284	0.04	0.96
MMC	0.125	0.02	0.98
LMC	0.29	0.04	0.96

* This is equal to (column A) x (assumed % effectiveness)
** C=1-B
***For SUT an adjustment factor of 0.975 was used (average of 04L and 05L)

Post construction stormwater management

Mechanism for Inclusion in the Model. Post-construction stormwater requirements were modeled by adjusting the pollutant concentration for the appropriate land cover classes. The runoff coefficient could be adjusted instead, but both have the same effect on loads.

Parameter Values. Load reductions obviously depend on the nature of the measure implemented. The expected removal efficiencies for common stormwater structures in the southeast are shown in Table 6, though how well these efficiencies apply to western North Carolina is not clear.

Use of these removal percentages may be appropriate if the primary result of the stormwater requirements is the installation of these BMPs. However, if stormwater requirements are met in part in some other way, such as by reducing impervious area, or by promoting infiltration (thus reducing the runoff entering treatment devices or eliminating the need for these devices) then the results of BMP studies may not be applicable.

Table 6 Median Pollutant Removal Efficiencies from BMP Studies in the Southeast and Mid-Atlantic*

BMP Type	Removal Efficiency (%)		
	TSS	TP	TN
Wet Ponds	65	46	28
Stormwater Wetlands	61	33	22
Sand Filters	79	59	41
Bioretention	NA	71	45

*Source: Wossink and Hunt (2003)
Notes: TSS= total suspended solids, TP= total phosphorus, TN= total nitrogen, NA= not available

A conservative approach was taken for this analysis. It was assumed that the removal efficiencies given above represent an upper limit for removal that will not be attained in practice. It was further assumed that ponds will be the dominant practice and that removal efficiencies will be three quarters of those listed above. Removal efficiencies would be higher if bioretention is used and lower if stormwater wetlands are used.

The resulting removal rates are: TSS = 0.49; TP = 0.35; TN = 0.21 (21-49% reduction, depending upon the pollutant). Adjusted pollutant concentrations reflecting these reductions are shown in Table 7.

Erosion and sediment control improvements

Mechanism for Inclusion in the Model. This measure was modeled by adjusting the USLE P Factor, currently set at 1.0.

Parameter Values. A study of NC erosion and sediment control practices conducted in the 1990s (Patterson, 1994) concluded that poor installation and maintenance of practices was widespread. While it is possible that the situation has improved since then, anecdotal observations in the study area indicate that significant improvements in erosion and sediment control effectiveness are probably possible with better enforcement. ***The P factor was reduced from 1.0 to 0.7, corresponding to a sediment load reduction of 30%.***

Table 7 Adjusted Pollutant Concentrations for Stormwater Management Scenario

	TSS	TP	TN
Medium Density Residential			
% reduction assumed	0.49	0.35	0.21
Current Concentration (mg/L)	100	0.2	1.7
Adjusted Concentration with SW controls	51	0.13	1.343
Low Density Residential			
% reduction assumed	0.49	0.35	0.21
Current Concentration (mg/L)	100	0.2	1.2
Adjusted Concentration with SW controls	51	0.13	0.948
Commercial			
% reduction assumed	0.49	0.35	0.21
Current Concentration (mg/L)	150	0.4	3.1
Adjusted Concentration with SW controls	76.5	0.26	2.449

Road design standards
Mechanism for Inclusion in the Model. In the absence of this measure, eroding road banks are added to the model as new development occurs. The road resign measure was simulated by reducing the rate at which eroding road banks/ditches are added.

Parameter Values. ***The road resign measure was simulated by reducing the extent of new eroding banks/ditches to 25 feet per new acre of development, or about 60% of the level that would occur in the absence of the measure.***

Cumulative impacts of multiple policies
If the management measures described above were implemented together their effects would interact in ways that are not clear. For example, there would likely be some interaction between the ways in which better enforcement of erosion and sediment control measures, steep slope design standards and limits on vegetative clearing work in practice to reduce sediment inputs from construction activities. Similarly, measures implemented to meet stormwater requirements may interact with other measures affecting post-construction pollutant loads. The IPSI model cannot simulate these interactions. The multiple measures run included the joint impacts of:

- 30% vegetative clearing limit;
- post construction stormwater; and
- Improved erosion and sediment control

Standards for high elevation development and road design standards had little impact on the overall loads (see discussion below) and were not included in this simulation.

2.3.4 Summary of Model Scenarios

In total 10 model runs (scenarios) were conducted.

1. 2010 base run;
2. 2015 base run;
3. 2015 run with sewer line extension;
4. 30% vegetative clearing using 2015 base condition;
5. 50% vegetative clearing using 2015 base condition;

6. Standards for high elevation development using 2015 base condition;
7. Post construction stormwater management using 2015 base condition;
8. Erosion and sediment control using 2015 base condition;
9. Road design standards using 2015 base condition;
10. 2015 run with multiple management measures (including options 4, 7 and 8).

Management measure scenarios were run using 2015 land use only. For each model run, the annual loads of the three pollutants (TSS, TP and TN) were estimated by sub-watershed.

Section 3

Results

Key results of the model simulations are discussed in the main text of this report. Supplemental data are presented below.

Expected changes in land use and other features
The detailed land cover distribution input into the IPSI model is shown in Tables 8 and 9 for 2010 and 2015 respectively.

Impacts of land use change on pollutant loads
Total sub-watershed loads for each base scenario and each pollutant are shown in Table 10. Effects at the sub-watershed level are extremely variable, since the extent of new development differed substantially from one sub-watershed to another.

Substantial drops in pollutant loads are seen for several sub-watersheds. In several other sub-watersheds the load does not increase despite new development. These results are due primarily to changes in the amount of land under construction. Land under construction generates a much higher load per acre than any other land use (other than mining), and changes in the extent of this land can therefore have significant impacts on loads at the sub-watershed scale.

In the 2005 model, the land classified as under construction was based on the IPSI land use data. For 2010 and 2015, this land was reclassified as existing development, which has lower loads per acre. New land under construction in 2010 and 2015 was allocated to each sub-watershed based upon the extent of new development anticipated. While the extent of new residential construction in the study area as a whole is approximately equal in 2005, 2010 and 2015, its location varies. Sub-watersheds which had land under construction in 2005 but which were expected to see no new development (or reduced development) for the subsequent period experienced a decline in pollutant loads (e.g. SMD and MBR sub-watersheds). Sub-watersheds may experience little change in estimated loads despite new development, as in MMC where there was significant new development after 2005, but not enough to generate as much ongoing construction as there was in 2005.

Effects of selected local policies
Pollution load estimates for management strategy scenarios are shown in Table 11.

Table 8 Land Use-Land Cover Inputs, 2010 Base Scenario (Acres)*

			Urban/developed					Row Crop			Pasture			Forest/Scrub/Shrub			Mining/Disturbed				New Development		
TVA Sub-WS ID	**NCEEP Sub-WS ID**	**Total Area, acres**	**Resid.-medium density**	**Resid. - low density**	**Commer-cial**	**Indust.**	**Right of Way**	**Low Residue**	**Medium Residue**	**High Residue**	**Good**	**Fair**	**Over-grazed**	**Scrub/ shrub**	**Forest**	**Harvest Forest land**	**Mining**	**Dis-turbed Areas**	**Areas Under Const.**	**Open Water+ Wetland**	**Resid.- medium density**	**Resid. - low density**	**Commer-cial**
			111	**112**	**12**	**13**	**14**	**2101**	**2102**	**2104**	**212**	**213**	**215**	**32**	**4**	**45**	**75**	**76**	**1121/1171**	**5**	**111**	**112**	**12**
01L-1	LMC	117.5	0.4	2.1	0.0	0.0	5.8	0.0	8.7	0.0	0.0	0.0	0.0	0.0	95.9	0.0	0.0	0.0	0.0	4.7	0.0	0.0	0.0
0201	LMC	1353.5	0.0	201.7	0.8	0.0	8.1	0.0	1.6	0.0	23.4	75.6	0.0	10.6	941.9	19.1	0.0	0.0	20.4	2.7	0.0	47.6	0.0
0202	MMC	3376.7	0.0	343.8	13.3	0.0	14.8	0.5	0.0	0.0	127.0	699.1	69.1	15.5	1933.8	48.4	0.0	3.1	32.1	1.3	0.0	74.9	0.0
0203	UMC	1026.2	0.0	62.2	0.0	0.0	12.0	0.0	0.0	0.0	0.0	69.0	0.0	0.0	842.5	0.0	0.0	0.0	8.0	0.5	0.0	32.0	0.0
02L	LMC	71.7	0.0	0.7	0.0	0.0	3.8	0.0	10.0	23.5	0.0	0.0	0.0	0.0	14.9	0.0	0.0	0.4	0.0	18.4	0.0	0.0	0.0
0301	HCK	1261.3	8.7	303.7	130.7	0.0	0.4	0.0	0.0	1.7	3.5	84.0	0.0	2.3	673.2	21.4	0.0	0.0	8.4	3.7	0.0	19.6	0.0
03L	HCK	225.5	0.0	14.3	0.9	0.0	5.9	0.0	0.0	0.0	0.0	50.9	0.0	10.9	106.3	21.6	0.0	3.1	0.0	11.6	0.0	0.0	0.0
04L	SUT	752.0	0.4	13.5	0.2	0.0	10.0	0.0	16.3	44.1	51.4	105.6	0.0	0.0	374.1	77.0	0.0	0.0	12.9	16.4	30.1	0.0	0.0
04R	FBR	1268.6	0.0	66.6	4.5	0.0	0.0	24.5	0.0	0.0	7.8	68.8	0.0	6.4	999.0	0.0	0.0	1.4	14.2	18.6	0.0	56.8	0.0
0501	PBT	965.9	10.0	74.1	44.6	0.0	0.0	4.6	22.8	52.1	144.6	171.9	75.6	18.4	306.6	36.9	0.0	1.4	0.0	2.4	0.0	0.0	0.0
0502	MPT	1783.0	30.6	222.1	35.9	0.0	4.4	11.5	3.7	0.0	134.5	205.7	52.4	6.5	996.5	3.7	0.0	2.8	18.9	9.7	7.2	36.9	0.0
050201	LSL	1510.5	8.9	339.5	26.0	0.0	0.0	4.7	0.0	0.0	66.4	220.3	0.0	2.0	806.1	26.4	0.0	0.8	2.1	2.4	0.0	4.9	0.0
050202	SMD	513.2	0.2	82.5	12.8	0.0	0.0	0.0	0.0	0.0	51.0	76.7	0.0	6.3	258.4	0.0	0.0	0.9	4.5	9.5	0.0	10.5	0.0
05020201	MBR	783.4	7.4	162.7	0.0	0.0	0.0	0.0	0.0	0.0	12.0	216.3	12.3	5.4	360.6	1.5	0.0	1.5	0.0	3.7	0.0	0.0	0.0
050203	SHW	1584.8	0.0	272.3	12.9	0.0	0.0	2.8	0.0	0.0	0.0	172.1	0.0	19.4	1070.7	8.4	0.0	5.0	4.2	7.3	0.0	9.8	0.0
0503	MPT	285.2	0.0	58.0	0.0	0.0	0.9	0.0	0.0	0.0	1.9	29.0	0.0	0.1	192.4	0.0	0.0	0.5	0.0	2.4	0.0	0.0	0.0
050301	PBR	695.5	0.0	15.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	4.3	0.0	674.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0504	UPT	1713.9	0.0	17.4	0.0	0.0	0.0	0.0	0.0	0.0	0.1	20.2	0.0	0.0	1646.6	0.0	0.0	5.5	4.8	0.2	0.0	19.2	0.0
050401	MOB	1055.5	0.0	59.9	1.0	0.0	3.3	0.0	0.0	0.0	12.0	101.9	0.0	9.0	830.0	0.0	0.0	0.9	7.4	0.4	0.0	29.6	0.0
0505	PHW	779.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	779.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
05L	SUT	721.8	0.0	133.7	0.0	0.0	3.6	0.0	0.2	27.3	0.0	31.7	0.0	0.1	381.0	96.3	0.0	0.0	6.3	26.9	0.0	14.7	0.0
05R	MCB	874.6	0.0	122.9	93.8	0.0	7.2	0.0	10.3	47.2	26.9	76.3	42.9	17.0	384.1	20.1	0.0	0.2	0.0	25.7	0.0	0.0	0.0
06R	CMB	143.1	0.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.3	0.0	0.0	124.9	2.3	0.0	1.2	0.0	2.5	0.0	0.0	0.0
07R	CMB	95.6	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	37.7	0.0	45.3	0.0	6.1	0.0	0.0	0.0	0.0	5.7	0.0	0.0	0.0
0801	CMB	534.9	0.0	33.8	0.0	5.0	5.3	20.3	58.9	2.6	12.5	82.0	0.0	6.3	306.6	0.3	0.0	0.4	0.0	0.9	0.0	0.0	0.0
08R	CMB	6.9	0.0	0.0	0.0	0.0	0.0	0.0	5.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0
09R	CMB	57.2	0.0	0.0	0.0	0.0	0.0	0.0	53.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	0.0	0.0	0.0
10R	CMB	76.2	0.0	7.8	0.0	0.0	0.6	24.8	1.0	13.3	0.0	19.4	0.0	0.0	3.0	0.0	0.0	0.0	0.0	6.2	0.0	0.0	0.0
1101	CMB	348.4	0.0	26.3	0.0	0.0	0.0	0.0	7.8	0.0	29.1	42.9	3.9	0.0	238.1	0.0	0.0	0.2	0.0	0.1	0.0	0.0	0.0
11R	CMB	1019.4	0.0	106.7	0.0	0.0	11.2	0.4	8.3	0.0	64.5	111.6	0.0	0.7	657.5	10.0	0.0	0.0	7.0	13.5	0.0	28.0	0.0
1201	MQT	174.9	0.0	3.2	0.0	0.0	3.1	0.0	0.0	0.0	0.0	6.3	0.0	0.0	97.6	4.8	58.3	0.0	0.0	1.6	0.0	0.0	0.0
12R	MQT	6.0	0.0	0.6	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0

*IPSI Land Use Classification Code listed below class description

Table 9 Land Use-Land Cover Inputs, 2015 Base Scenario (Acres)*

			Urban/developed					Row Crop			Pasture			Forest/Scrub/Shrub			Mining/Disturbed				New Development		
TVA Sub-WS ID	NCEEP Sub-WS ID	Total Area, acres	Resid.-medium density	Resid. - low density	Commer-cial	Indust.	Right of Way	Low Residue	Medium Residue	High Residue	Good	Fair	Over-grazed	Scrub/shrub	Forest	Harvest Forest land	Mining	Dis-turbed Areas	Areas Under Const.	Open Water+ Wetland	Resid.-medium density	Resid. - low density	Commer-cial
			111	112	12	13	14	2101	2102	2104	212	213	215	32	4	45	75	76	1121/1171	5	111	112	12
01L-1	LMC	117.5	0.4	2.1	0.0	0.0	5.8	0.0	8.7	0.0	0.0	0.0	0.0	0.0	95.9	0.0	0.0	0.0	0.0	4.7	0.0	0.0	0.0
0201	LMC	1353.6	0.0	201.7	0.8	0.0	8.1	0.0	1.6	0.0	23.4	75.6	0.0	10.6	874.9	19.1	0.0	0.0	20.4	2.7	0.0	114.6	0.0
0202	MMC	3376.7	0.0	343.8	13.3	0.0	14.8	0.5	0.0	0.0	127.0	647.8	69.1	15.5	1878.1	48.4	0.0	3.1	32.1	1.3	0.0	181.9	0.0
0203	UMC	1026.2	0.0	62.2	0.0	0.0	12.0	0.0	0.0	0.0	0.0	69.0	0.0	0.0	802.5	0.0	0.0	0.0	8.0	0.5	0.0	72.0	0.0
02L	LMC	71.7	0.0	0.7	0.0	0.0	3.8	0.0	10.0	23.5	0.0	0.0	0.0	0.0	14.9	0.0	0.0	0.4	0.0	18.4	0.0	0.0	0.0
0301	HCK	1261.3	8.7	303.7	130.7	0.0	0.4	0.0	0.0	1.7	3.5	84.0	0.0	2.3	645.2	21.4	0.0	0.0	8.4	3.7	0.0	47.6	0.0
03L	HCK	225.5	0.0	14.3	0.9	0.0	5.9	0.0	0.0	0.0	0.0	50.9	0.0	10.9	106.3	21.6	0.0	3.1	0.0	11.6	0.0	0.0	0.0
04L	SUT	752.0	0.4	13.5	0.2	0.0	10.0	0.0	4.1	44.1	51.4	97.4	0.0	0.0	253.4	77.0	0.0	0.0	32.4	16.4	73.6	0.0	78.1
04R	FBR	1268.6	0.0	66.6	4.5	0.0	0.0	24.5	0.0	0.0	7.8	68.8	0.0	6.4	928.0	0.0	0.0	1.4	14.2	18.6	0.0	127.8	0.0
0501	PBT	965.9	10.0	74.1	44.6	0.0	0.0	4.6	5.5	52.1	144.6	77.2	75.6	18.4	285.3	36.9	0.0	1.4	26.7	2.4	0.0	0.0	106.7
0502	MPT	1783.0	30.6	222.1	35.9	0.0	4.4	11.5	3.7	0.0	134.5	182.3	52.4	6.5	908.8	3.7	0.0	2.8	28.5	9.7	16.2	90.9	38.5
050201	LSL	1510.4	8.9	339.5	26.0	0.0	0.0	4.7	0.0	0.0	66.4	218.8	0.0	2.0	799.7	26.4	0.0	0.8	2.1	2.4	0.0	12.9	0.0
050202	SMD	513.2	0.2	82.5	12.8	0.0	0.0	0.0	0.0	0.0	51.0	75.0	0.0	6.3	245.0	0.0	0.0	0.9	4.5	9.5	0.0	25.5	0.0
05020201	MBR	783.4	7.4	162.7	0.0	0.0	0.0	0.0	0.0	0.0	12.0	216.3	12.3	5.4	360.6	1.5	0.0	1.5	0.0	3.7	0.0	0.0	0.0
050203	SHW	1584.9	0.0	272.3	12.9	0.0	0.0	2.8	0.0	0.0	0.0	170.2	0.0	19.4	1059.7	8.4	0.0	5.0	4.2	7.3	0.0	22.8	0.0
0503	MPT	285.2	0.0	58.0	0.0	0.0	0.9	0.0	0.0	0.0	1.9	29.0	0.0	0.1	192.4	0.0	0.0	0.5	0.0	2.4	0.0	0.0	0.0
050301	PBR	695.5	0.0	15.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	4.3	0.0	674.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0504	UPT	1713.8	0.0	17.4	0.0	0.0	0.0	0.0	0.0	0.0	0.1	20.2	0.0	0.0	1621.6	0.0	0.0	5.5	4.8	0.2	0.0	44.1	0.0
050401	MOB	1055.6	0.0	59.9	1.0	0.0	3.3	0.0	0.0	0.0	12.0	101.9	0.0	9.0	794.0	0.0	0.0	0.9	7.4	0.4	0.0	65.7	0.0
0505	PHW	779.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	779.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
05L	SUT	721.8	0.0	133.7	0.0	0.0	3.6	0.0	0.2	27.3	0.0	25.8	0.0	0.1	365.9	96.3	0.0	0.0	6.3	26.9	0.0	35.7	0.0
05R	MCB	874.6	0.0	122.9	93.8	0.0	7.2	0.0	1.3	37.0	26.9	76.3	42.9	17.0	312.0	20.1	0.0	0.2	18.3	25.7	0.0	0.0	73.0
06R	CMB	143.1	0.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.3	0.0	0.0	124.9	2.3	0.0	1.2	0.0	2.5	0.0	0.0	0.0
07R	CMB	95.6	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	37.7	0.0	45.3	0.0	6.1	0.0	0.0	0.0	0.0	5.7	0.0	0.0	0.0
0801	CMB	534.9	0.0	33.8	0.0	5.0	5.3	20.3	58.9	2.6	12.5	82.0	0.0	6.3	306.6	0.3	0.0	0.4	0.0	0.9	0.0	0.0	0.0
08R	CMB	6.9	0.0	0.0	0.0	0.0	0.0	0.0	5.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0
09R	CMB	57.2	0.0	0.0	0.0	0.0	0.0	0.0	53.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	0.0	0.0	0.0
10R	CMB	76.2	0.0	7.8	0.0	0.0	0.6	24.8	1.0	13.3	0.0	19.4	0.0	0.0	3.0	0.0	0.0	0.0	0.0	6.2	0.0	0.0	0.0
1101	CMB	348.4	0.0	26.3	0.0	0.0	0.0	0.0	7.8	0.0	29.1	42.9	3.9	0.0	238.1	0.0	0.0	0.2	0.0	0.1	0.0	0.0	0.0
11R	CMB	1019.4	0.0	106.7	0.0	0.0	11.2	0.4	8.3	0.0	64.5	93.4	0.0	0.7	638.0	10.0	0.0	0.0	7.0	13.5	0.0	63.0	2.7
1201	MQT	174.9	0.0	3.2	0.0	0.0	3.1	0.0	0.0	0.0	0.0	6.3	0.0	0.0	97.6	4.8	58.3	0.0	0.0	1.6	0.0	0.0	0.0
12R	MQT	6.0	0.0	0.6	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0

*IPSI Land Use Classification Code listed below class description

Table 10 Sub-Watershed Annual Pollutant Loads for Base Scenarios

Sub-WS	Total Suspended Solids					Total Phosphorus					Total Nitrogen					Sub-WS
	Annual Load (Tons/Yr)			% Change from 2005		Annual Load (Tons/Yr)			% Change from 2005		Annual Load (Tons/Yr)			% Change from 2005		
	2005	2010	2015	2010	2015	2005	2010	2015	2010	2015	2005	2010	2015	2010	2015	
PHW	58.2	58.2	58.2	0%	0%	0.01	0.01	0.01	0%	0%	0.1	0.1	0.1	0%	0%	PHW
UPT	122.2	139.0	141.4	14%	16%	0.02	0.02	0.03	32%	59%	0.2	0.3	0.3	22%	35%	UPT
MOB	92.3	119.5	122.9	30%	33%	0.03	0.04	0.05	28%	49%	0.2	0.3	0.4	30%	46%	MOB
PBR	53.6	53.6	53.6	0%	0%	0.01	0.01	0.01	0%	0%	0.1	0.1	0.1	0%	0%	PBR
MPT	417.4	394.9	453.2	-5%	9%	0.20	0.21	0.27	5%	40%	1.6	1.6	2.1	3%	37%	MPT
SHW	282.7	264.3	265.4	-7%	-6%	0.11	0.11	0.11	1%	3%	0.9	0.9	0.9	-1%	0%	SHW
SMD	228.1	143.5	144.7	-37%	-37%	0.07	0.06	0.07	-6%	-1%	0.6	0.5	0.5	-17%	-14%	SMD
MBR	206.4	132.6	132.6	-36%	-36%	0.08	0.08	0.08	-6%	-6%	0.6	0.5	0.5	-16%	-16%	MBR
LSL	236.6	232.9	233.6	-2%	-1%	0.15	0.15	0.15	1%	2%	1.1	1.1	1.1	0%	1%	LSL
PBT	402.4	402.4	529.3	0%	32%	0.18	0.18	0.33	0%	82%	1.5	1.5	2.7	0%	80%	PBT
MQT	1392.6	1392.6	1392.6	0%	0%	0.16	0.16	0.16	0%	0%	2.2	2.2	2.2	0%	0%	MQT
CMB	775.5	805.1	808.3	4%	4%	0.24	0.25	0.25	3%	8%	2.2	2.3	2.4	3%	6%	CMB
MCB	254.3	252.9	345.6	-1%	36%	0.19	0.19	0.30	0%	53%	1.6	1.6	2.4	0%	53%	MCB
FBR	216.6	276.7	283.4	28%	31%	0.07	0.09	0.10	24%	43%	0.6	0.7	0.8	26%	40%	FBR
SUT	603.7	671.1	779.1	11%	29%	0.29	0.16	0.28	-46%	-2%	1.3	1.5	2.5	12%	89%	SUT
HCK	413.5	405.6	408.2	-2%	-1%	0.14	0.29	0.30	107%	110%	2.3	2.3	2.3	1%	2%	HCK
LMC	263.3	287.6	293.9	9%	12%	0.08	0.09	0.11	17%	33%	0.7	0.8	0.9	14%	25%	LMC
MMC	626.7	611.5	619.3	-2%	-1%	0.28	0.30	0.32	6%	13%	1.9	2.0	2.1	4%	10%	MMC
UMC	75.4	110.6	114.3	47%	52%	0.03	0.04	0.05	33%	58%	0.2	0.3	0.4	40%	60%	UMC
Total	6721.4	6754.6	7179.8	0%	7%	2.34	2.44	2.97	4%	27%	19.9	20.5	24.6	3%	24%	Total

Table 11 Summary of Management Strategy Load Reductions for Developed Areas

Management Scenario	Total Suspended Solids				Total Phosphorus				Total Nitrogen			
	Total Load	Resid-ential Areas	Commercial Areas	Areas Under Const	Total Load	Resid-ential Areas	Commercial Areas	Areas Under Const	Total Load	Resid-ential Areas	Commercial Areas	Areas Under Const
Vegetative Clearing Limited to 50%												
Base Scenario (Tons/Yr)	7179.8	367.0	351.0	877.0	2.97	0.73	0.94	0.10	24.6	4.5	7.3	1.4
With Implementation (Tons/Yr)	7090.0	359.6	338.8	806.9	2.91	0.72	0.91	0.09	24.1	4.4	7.1	1.3
% Decrease	1.3%	2.0%	3.5%	8.0%	1.9%	2.0%	3.4%	8.0%	1.9%	2.1%	3.5%	8.0%
Vegetative Clearing Limited to 30%												
Base Scenario (Tons/Yr)	7179.8	367.0	351.0	877.0	2.97	0.73	0.94	0.10	24.6	4.5	7.3	1.4
With Implementation (Tons/Yr)	6999.9	351.9	326.6	736.7	2.86	0.70	0.88	0.08	23.7	4.3	6.8	1.2
% Decrease	2.5%	4.1%	7.0%	16.0%	3.8%	4.1%	6.9%	16.0%	3.7%	4.2%	6.9%	16.0%
Standards for High Elevation Development												
Base Scenario (Tons/Yr)	7179.8	367.0	351.0	877.0	2.97	0.73	0.94	0.10	24.6	4.5	7.3	1.4
With Implementation (Tons/Yr)	7150.7	363.3	351.0	851.6	2.96	0.73	0.94	0.10	24.5	4.5	7.3	1.3
% Decrease	0.4%	1.0%	0.0%	2.9%	0.3%	1.0%	0.0%	2.9%	0.3%	1.0%	0.0%	2.9%
Post-Construction Stormwater Management												
Base Scenario (Tons/Yr)	7179.8	367.0	351.0	877.0	2.97	0.73	0.94	0.10	24.6	4.5	7.3	1.4
With Implementation (Tons/Yr)	7057.1	319.2	276.2	877.0	2.76	0.67	0.80	0.10	23.6	4.2	6.6	1.4
% Decrease	1.7%	13.0%	21.3%	0.0%	7.1%	9.3%	15.1%	0.0%	3.7%	5.7%	9.1%	0.0%
Erosion and Sediment Control												
Base Scenario (Tons/Yr)	7179.8	367.0	351.0	877.0	2.97	0.73	0.94	0.10	24.6	4.5	7.3	1.4
With Implementation (Tons/Yr)	6916.6	367.0	351.0	613.9	2.94	0.73	0.94	0.07	24.2	4.5	7.3	1.0
% Decrease	3.7%	0.0%	0.0%	30.0%	1.0%	0.0%	0.0%	30.0%	1.7%	0.0%	0.0%	30.0%
Road Design Standards												
Base Scenario (Tons/Yr)	7179.8	367.0	351.0	877.0	2.97	0.73	0.94	0.10	24.6	4.5	7.3	1.4
With Implementation (Tons/Yr)	7168.8	367.0	351.0	877.0	2.97	0.73	0.94	0.10	22.5	4.1	6.2	0.8
% Decrease	0.2%	0.0%	0.0%	0.0%	0.04%	0.0%	0.0%	0.0%	8.3%	9.1%	14.5%	41.2%
Implementation of Multiple Measures												
Base Scenario (Tons/Yr)	7179.8	367.0	351.0	877.0	2.97	0.73	0.94	0.10	24.6	4.5	7.3	1.4
With Implementation (Tons/Yr)	6675.6	311.5	263.7	515.7	2.66	0.65	0.76	0.06	24.6	4.5	7.3	1.4
% Decrease	7.0%	15.1%	24.9%	41.2%	10.6%	12.0%	19.6%	41.2%	0.1%	0.0%	0.0%	0.0%

Section 4

Changes in Impervious Area

4.1 Estimation of Sub-Watershed Impervious Cover

In order to further quantify the potential impacts of the land use changes anticipated between 2005 and 2015, Equinox estimated the additional impervious cover likely to be constructed during that period. Impervious cover for 2005 was estimated by the Tennessee Valley Authority (TVA) for each sub-watershed as part of the IPSI (Integrated Pollutant Source Identification) conducted for the project area (see Section 2.2.3 of the main text). Equinox used a methodology consistent with the one utilized by TVA (see TVA, 2006).

The extent (acres) of new impervious cover (2005-2015) was calculated separately for roads and land use (developed areas) and these results summed to obtain the total new impervious acres in each sub-watershed. This was added to the existing (2005) impervious cover to obtain the total estimated impervious acres in each sub-watershed for 2015. The percent impervious cover in each sub-watershed was then calculated by dividing the total number of impervious acres by the sub-watershed area (Table 12). Methods are summarized below.

Road-related imperviousness

Road-related impervious cover was calculated as follows:

- The extent of new roads constructed between 2005 and 2015 was estimated as 221 linear feet per acre of development, as discussed above in Section 2.2.2. All new roads were assumed to be paved.
- A typical road width of 20 feet was used, consistent with the approach used by TVA for 2005, and impervious area calculated by multiplying road length by road width.
- Imperviousness associated with the US 64 Bypass was calculated separately, using a road length estimated using GIS and an assumed width of 40 feet. While the typical roadway width of the bypass is 32 feet, a width of 40 feet accounts for additional impervious area added by turn lanes and other paved areas (Ms. Callie Moore, Hiwassee River Watershed Coalition, personal communication).
- Impervious cover associated with the bypass and the other new roads was summed to obtain the new road-related impervious cover shown in Table 12.

Land use imperviousness

TVA calculated impervious cover for developed areas (excluding roads) by multiplying the area of each developed polygon (utilizing the IPSI land cover data base) by the percent impervious cover value assigned to each polygon (TVA, 2006). TVA used a value of 10% imperviousness for all low and medium density residential polygons in the planning area (apartment complexes were assigned a higher value). Commercial polygons were assigned individual values based upon aerial photo interpretation.

Equinox could not use an identical polygon-based approach in calculating 2015 impervious cover, since a 2015 land cover data base with impervious values for individual polygons does not exist. However, an aggregate method that is equivalent on the sub-watershed level was used.

- New land use imperviousness was estimated by taking the acreage of new low density residential, medium density residential and commercial land in each sub-watershed and multiplying each by an estimated percent imperviousness to obtain the number of new impervious acres (by sub-watershed) for each of these land cover classes.
- The new acreage of these land cover classes in each sub-watershed was estimated as described above in Section 2 and shown in Table 9.
- An impervious cover value of 10% was used for new low density residential areas, consistent with the value used by TVA for 2005.
- For new medium density residential areas an impervious cover value of 15% was used instead of the 10% value used by TVA for the 2005 imperviousness calculations. The 15% figure is consistent with the value used by TVA for this land class in the IPSI nonpoint source model (TVA, 2006) and better reflects the difference between low and medium residential areas.
- Equinox assumed that the typical percent imperviousness of commercial areas developed between 2005 and 2015 would be similar to existing commercial properties. The median 2005 impervious percent of 16 commercial polygons in the US 64-NC 141 area (65%) was used.
- For each sub-watershed, the new impervious cover acreage associated with the three developed land cover classes was summed to obtain the new land use impervious cover shown in Table 12. Since the IPSI land cover data base assumes all rural areas have zero impervious cover, no adjustment is necessary when rural land is converted to urban uses.

The acreage of new imperviousness was calculated for each sub-watershed as the sum of land use and road impervious area (Table 12). New impervious area was added to existing impervious area in 2005 to obtain total imperviousness for 2015.

4.2 Estimation of Impervious Cover for Harshaw Branch

Impervious cover was also calculated for the small (253 acre) drainage of Harshaw Branch (see map in Section 3.6 of the main text). Methods used were the same as described above, except that Equinox calculated impervious cover for both 2005 and 2015, as impervious cover for this area had not been estimated by TVA.

This drainage was a mix of forest and agricultural land in 2005. Virtually all of the drainage is contained in a large parcel identified by the LAC as likely to see mixed use development within the next 10 years. For purposes of calculating impervious area, it was assumed that the portion of this parcel within the Harshaw Creek drainage was developed in its entirety. Consistent with the approach described above in Section 2.1.3, it was assumed that that a 200 foot wide strip along Harshaw Road was developed as a commercial area while the remainder of the parcel was developed at a residential density of 2 dwellings per acre. New road-related impervious cover (for the US 64 Bypass and for other roads) was estimated as described above.

Results are shown in Table 13.

Table 12 Projected Sub-Watershed Impervious Area, 2015

Sub-Watershed		New Impervious Area, 2005-2015 (Acres)			Total Imperv. Area, 2015* (Acres)	Sub-Watershed % Impervious Cover		
		Land Use Imperv.	Road-Related Imperv.	Total New Imperv		2005	2015	Change, 2005-2015
Peachtree Creek Drainage								
PHW	Peachtree Ck. Headwaters	0.00	0.00	0.00	4.79	0.6%	0.6%	0.0%
UPT	Upper Peachtree Ck.	4.41	4.47	8.88	27.84	1.1%	1.6%	0.5%
MOB	Moore Branch	6.57	6.67	13.24	42.35	2.8%	4.0%	1.3%
PBR	Pipes Branch	0.00	0.00	0.00	8.61	1.2%	1.2%	0.0%
MPT	Middle Peachtree Ck.	36.56	10.87	47.43	133.94	4.2%	6.5%	2.3%
SHW	Slow Creek Headwaters	2.28	2.31	4.59	82.97	4.9%	5.2%	0.3%
SMD	Mid Slow Creek	2.55	2.59	5.14	29.59	4.8%	5.8%	1.0%
MBR	Messer Branch	0.00	0.00	0.00	37.25	4.8%	4.8%	0.0%
LSL	Lower Slow Creek	1.29	1.31	2.60	89.48	5.8%	5.9%	0.2%
PBT	Lower Peachtree Bottomlands	69.34	0.00	69.34	127.29	6.0%	13.2%	7.2%
Martins Creek Drainage								
UMC	Upper Martins Creek	7.20	7.31	14.51	43.98	2.9%	4.3%	1.4%
MMC	Middle Martins Creek	18.19	18.46	36.65	145.98	3.2%	4.3%	1.1%
LMC	Lower Martins Creek	11.46	16.84	28.30	81.45	3.4%	5.3%	1.8%
Other Hiwassee River Tributaries								
MQT	Mission Quarry tributary	0.00	0.00	0.00	3.74	2.1%	2.1%	0.0%
CMB	Calhoun -Mission Branch	8.03	6.39	14.43	79.47	2.9%	3.6%	0.6%
MCB	McComb Branch	47.46	4.32	51.79	145.53	10.7%	16.6%	5.9%
FBR	Fall Branch	12.78	12.97	25.75	76.48	4.0%	6.0%	2.0%
SUT	Southern un-named Hiwassee trib.	65.39	17.13	82.52	129.28	3.2%	8.8%	5.6%
HCK	Hampton Creek	4.76	9.34	14.10	98.56	5.7%	6.6%	0.9%
	Planning Area Total	*298*	*121*	*419*	*1389*	*3.9%*	*5.5%*	*1.6%*

*Sum of current (2005) imperviousness (not shown in table) and new impervious area.

Table 13 Summary of Impervious Area Calculations for Harshaw Branch

Source of Impervious Cover	Impervious Cover, 2005 (Acres)	Additional Impervious Cover, 2005-2015 (Acres)	Total Impervious Cover, 2015 (Acres)
Land Use (Residential and Commercial areas)	0.6	38.1	38.6
Streets	5.6	20.0	25.5
US 64 Bypass	-	4.3	4.3
Total, All Sources	6.1	62.3	68.5
% Impervious Cover	*(2.4%)*	*(24.6%)*	*(27.0%)*

Section 5

References Cited

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