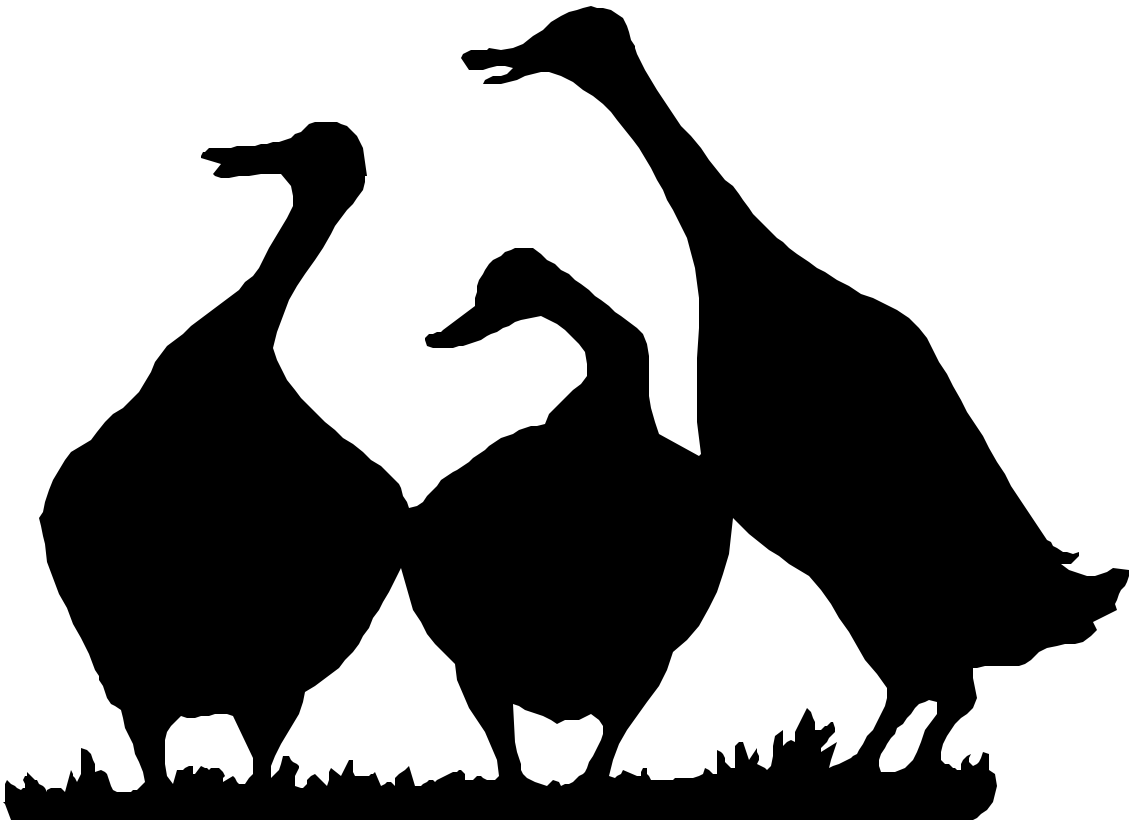
Goose Creek Vulnerability Analysis

A Baseline Assessment of the Current and Future Conditions in the Goose Creek Subwatersheds in Northern Virginia



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GOOSE CREEK VULNERABILITY ANALYSIS

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EXECUTIVE SUMMARY

For many, the rolling hills of the Goose Creek countryside form a changeless landscape. Current growth and land management practices, however, have the potential to sharply degrade both the rural character and aquatic health of this historic and scenic region. To establish a baseline from which we can develop plans to protect and enhance the watershed, we evaluated the condition of forty subwatersheds that together comprise the 385 square mile Goose Creek watershed in Loudoun and Fauquier Counties of Virginia. Specifically, subwatersheds were evaluated for vulnerability to current and future land development, and impacts of current land management practices on rural subwatersheds.

This report summarizes the first phase of work in the Goose Creek watershed, which presents a system to classify and manage subwatersheds in Goose Creek. This information will be used by the Piedmont Environmental Council, Goose Creek Association, and other stakeholders to select three individual subwatersheds for further analysis in the remaining two phases of the study. In the next phase, the Center and other watershed partners will conduct intensive stream and riparian management assessments within the selected watersheds to ground-truth the analysis and identify opportunities to protect and restore stream health within each subwatershed. This work will provide the technical foundation to develop rapid subwatershed plans in consultation with Goose Creek stakeholders in the third and last phase of the project. These subwatershed plans are anticipated for use as transferable models for other subwatersheds in Goose Creek.

An analysis of the current impervious cover of the subwatersheds showed that 38 were in the sensitive category (<10% impervious cover) and only two were in the impacted category (10%-25% impervious cover). A combination of current and future impervious cover, in-stream factors, and other subwatershed factors was then used to reclassify the 40 subwatersheds of Goose Creek into one of four possible categories-- High Quality, Rural Impacted, Urban Impacted and Non-Supporting subwatersheds.

The reclassification required the development of the "Rural Watershed Quality Point Method" which assigned favorable and unfavorable rural watershed quality points. Favorable points were awarded to subwatersheds with a high fraction of forest cover, high coverage of land with conservation easements, and extensive streamside forest cover. Unfavorable points were assigned to subwatersheds with poor in-stream and subwatershed factors including designated impaired waters, water quality violations, poor to fair IBI (Index of Biotic Integrity) scores, presence of fish barriers, unusual nonpoint source areas, septic and animal density, bacteria level, and high animal bacteria density.

After applying impervious cover and the Rural Watershed Quality Point Method, the current conditions for the Goose Creek subwatersheds yielded 25 High Quality, 13 Rural Impacted, and 2 Urban Impacted subwatersheds. None are currently Non-Supporting.

Based on future land use, four subwatersheds will become Urban Impacted and two will become Non-Supporting. Without improved land management, 11 subwatersheds will continue to be Rural Impacted and 23 are expected to remain High Quality.

Lastly, using these data and the application of another point system (the "High Quality Point Method") we identified twelve subwatersheds in Goose Creek as "Most Vulnerable." Three subwatersheds from this "Most Vulnerable" list will be selected as the first set of subwatersheds for further planning and assessment.

INTRODUCTION TO THE GOOSE CREEK AND THE VULNERABILITY ANALYSIS

Goose Creek has a 385 square mile watershed that straddles Loudoun and Fauquier Counties in Virginia and includes urban, suburban and rural communities within the northern Piedmont (see Figure 1). The Goose Creek Watershed contains many natural resources and has the notable distinction of having approximately 18% of its watershed area preserved in conservation easements (as of January 2001). Goose Creek also serves as a major drinking water source for the City of Fairfax and half of suburban Loudoun County.

An initial assessment of Goose Creek shows a mix of urban and agricultural impacts to this unique watershed. For example, Loudoun County was among the fastest growing counties in Virginia in recent years (DED, 2002). As a result, residential and commercial development has increased dramatically. In the Goose Creek watershed, this is particularly evident in the Leesburg area. The growth in Loudoun County is expected to continue with the current population of over 190,000 residents growing by over 75% in the next decade (DED, 2002). Growth in Fauquier County has been more modest, reporting 1.4% per year (Fauquier County, 2002).

Goose Creek also experiences water quality impacts that are unrelated to development in the watershed. For example, many stream segments are listed by the Virginia Department of Environmental Quality as impaired due to elevated bacteria and have very little development in their drainage areas. Stream segments within the Beaverdam Direct Drainage, Cromwells Direct Drainage, Little River Direct Drainage, North Fork Lower Direct Drainage, North Fork Upper Direct Drainage, and Sycolin 101 subwatersheds are all listed as impaired by the Virginia Department of Environmental Quality, although none of these subwatersheds, nor any subwatersheds that drain to them, have more than 10% impervious cover. Some of the potential rural impacts, along with other watershed characteristics, are provided in Table 1.

An effective watershed plan for Goose Creek requires an understanding of the dynamics of the entire watershed, including its environmental status, growth in residential and commercial sectors, and agricultural land management practices. The Goose Creek Watershed Vulnerability Analysis represents the first phase of a three-phase watershed study. In this first phase, we analyze existing watershed information and GIS data for Goose Creek to develop an environmental assessment for both the current and the projected future conditions in the watershed. Based on this assessment, 12 subwatersheds were identified that are most vulnerable to current and future land development and management problems (thus the term “vulnerability analysis”).

Within the context of this study, vulnerability can have several definitions, depending on the nature of the subwatershed. High quality subwatersheds are vulnerable because of their inherent value, and impacts even small changes can have on them. The ability of these streams to support wildlife and aquatic habitat makes protecting and enhancing them even more important because they provide a unique resource. In addition, the sensitive species that inhabit these high quality environments are more vulnerable to changes in water quality, as well as changes to their physical habitat. Some subwatersheds within Goose Creek are termed vulnerable because of the threat of current and future development. Lastly, others are deemed

vulnerable due to the impacts of rural land management practices rather than development pressure.

The information for this analysis came from a multitude of resources including the staff of Loudoun and Fauquier Counties. This Vulnerability Analysis was performed to determine key watershed management issues and provide detailed information for stakeholders to prepare plans to protect and restore vulnerable watersheds within Goose Creek. This report will be supplemented by detailed follow-up studies within several of Goose Creek's subwatersheds in the second phase. In the last phase, we will develop specific management recommendations for these subwatersheds.

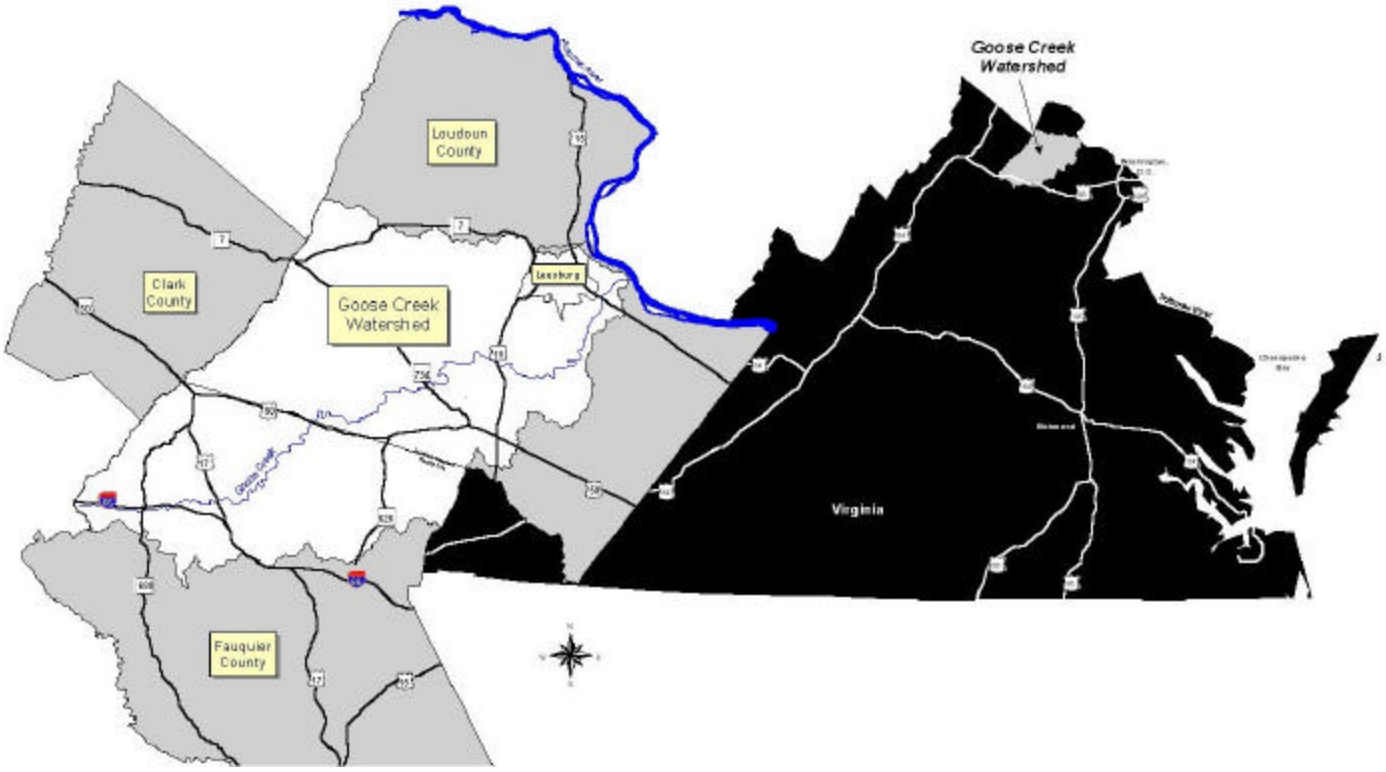

Figure 1: Location of the Goose Creek Watershed

Table 1: Current Conditions in Goose Creek Watershed	
Watershed Factor	**Current Conditions**
Total Area	386 square miles (247,182 acres)
Number of Subwatersheds	40
Mapped Perennial Stream Miles	736 miles
Current Impervious Cover (as of Jan 2001)	5%
Future (buildout) Impervious Cover	7%
Estimated Forest Area (based on 1997 MRLC landuse data)	101,153 acres (41% of watershed)
Forested Streamside (100 feet on either side of stream)	8,656 acres (49% of streamside is forested)
Conservation Easements (as of January 2001)	43,936 acres (18% of watershed)
Forested Conservation Easements	14,556 acres (9% of watershed)
Potentially Developable Area (as of January 2001)	128,664 acres (52% of watershed)
Agricultural Characteristics (as of January 2001)	Over 40,000 beef cattle Over 10,000 horses
Septic/ Sewer Characteristics (as of January 2001)	Almost 9,000 septic systems Nine wastewater treatment plants
Other Land Use Characteristics (as of January 2001)	Seven vineyards Six golf courses

The Goose Creek Watershed Vulnerability Analysis is organized as follows. The next section, "The Subwatershed Approach in Goose Creek," provides background information on how we classify urban and rural watersheds within Goose Creek. The methods used to process and analyze subwatershed data are described in detail in the third section, "Methods and Discussion." This section outlines the methods and techniques used to delineate subwatershed and calculate current and future impervious cover. In addition, it includes the detailed methodology that was developed to analyze conditions within rural subwatersheds. The fourth section, "Select the 12 Most Vulnerable Watersheds," provides methods with respect to overall subwatershed classification within Goose Creek, and describes the factors used to select the twelve most vulnerable watersheds. The last section contains the initial conclusions with respect to further subwatershed management within Goose Creek.

Many data layers were analyzed including current land cover, projected future land cover, forest cover, stream bioassessment scores, agricultural practices, water quality monitoring data, and other information. The analysis was organized into five primary tasks that were focused toward delineation of subwatersheds and an initial analysis of what the data reveals. These five tasks include:

1) Delineation of subwatersheds.
2) Calculating current impervious cover.
3) Determining future impervious cover.
4) Scaling and utilizing other screening factors for further characterization.
5) Prioritizing subwatersheds.

THE SUBWATERSHED APPROACH IN GOOSE CREEK

The large size of the Goose Creek Watershed encompasses many different land uses and political jurisdictions, as well as more than 700 stream miles of varying quality. While considering the Goose Creek Watershed as a whole system is important, one cannot draw informed inferences about the watershed as a whole without first analyzing its subwatersheds. Consequently, the watershed was broken down into 40 smaller subwatershed units ranging in size from approximately five to fifteen square miles (Figure 2). Each of these subwatersheds was independently analyzed in terms of development pressures and other watershed impacts (see Appendix A for more details).

The Scale of Watershed Planning

Subwatersheds are the preferred unit for developing watershed plans, because the small scale allows for easier analysis and implementation (CWP, 1998). Many watershed management units exist to describe watersheds (refer to Figure 3 and Table 3). Large scale management units such as watersheds, subbasins and basins, are not useful as planning units since the influence of impervious cover and land management on resource quality become weak, and is difficult to recommend specific management practices to improve water quality. On the smallest catchment scale, the influence of impervious cover is very strong, but the area is so small that it can be best managed through the normal development review plans and more on detailed site recommendations.

There are several other reasons for the subwatershed approach and assessment, including the influence of impervious cover, the ability to distinguish between pollutant sources, and the ability to treat subwatersheds (CWP, 1998). For example, the influence of impervious cover on the hydrology, water quality, and biodiversity of streams is most evident at the subwatershed level. Pollutant sources (e.g., agricultural runoff, point sources, etc.) are easier to distinguish in subwatersheds and thus specific management options are easier to develop. Lastly, subwatershed units also simplify jurisdictional boundaries and allow for a rapid approach to mapping, monitoring, and other watershed assessment steps.

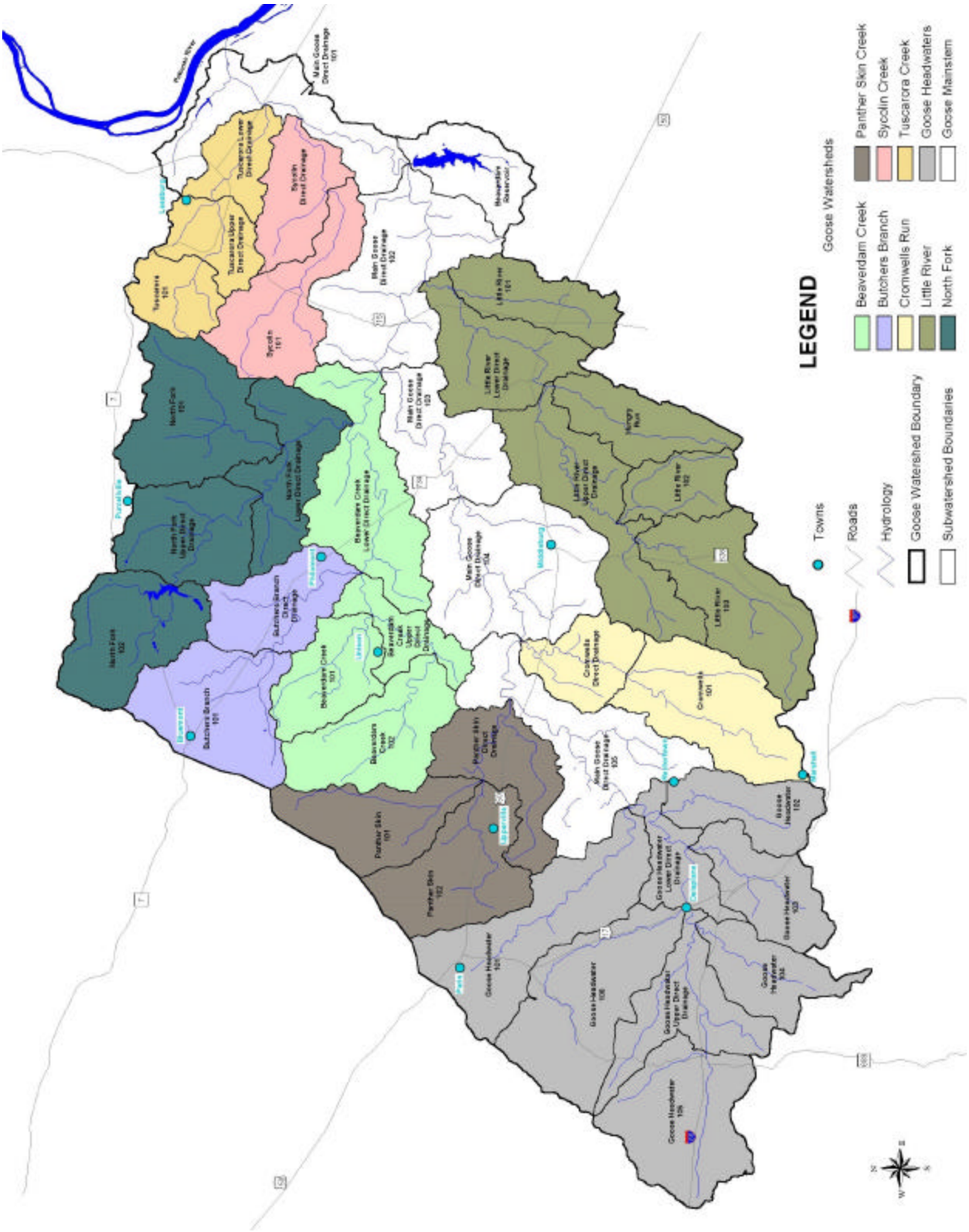

Figure 2: 40 Subwatersheds of Goose Creek

Table 2: Description of the Various Watershed Management Units		
Unit	**Typical Area (square miles)**	**Influence of Impervious Cover**
Catchment	0.05 to 0.50	very strong
Subwatershed	1 to 10	strong
Watershed	10 to 100	moderate
Subbasin	100 to 1,000	weak
Basin	1,000 to 10,000	very weak

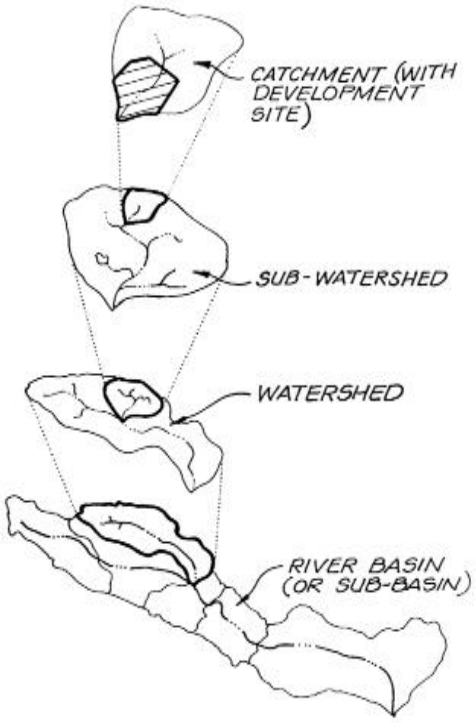

Figure 3: Watershed Management Units

The Impacts of Impervious Cover

Impervious cover is defined as the sum of all surfaces within the watershed that do not allow water to infiltrate through the ground. Examples include roadways, driveways, houses, sidewalks, and parking lots that are covered by concrete, asphalt or other impermeable surface (see Figure 4). Hundreds of studies across the country have shown that when subwatersheds exceed 10% impervious cover, the effects on the streams and other natural resources can be irreversible (Schueler, in press) (see Figures 5 and 6).

Figure 4: Examples of Impervious Cover– Parking Lots, Streets, Buildings, and Sidewalks

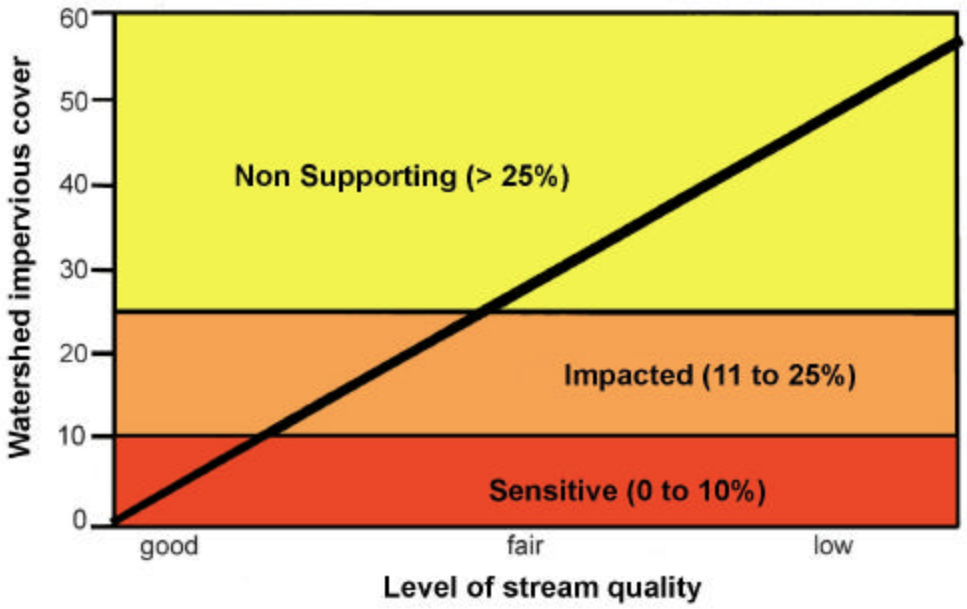

Figure 5: The Impervious Cover Model

Figure 6: Impact of Impervious Cover on Stream Quality

In the first step of the analysis, the impervious cover model was applied to each of the 40 subwatersheds in Goose Creek. Once subwatershed delineations were made, the amount of current and future impervious cover was calculated using current GIS data layers and projections from zoning ordinances and comprehensive plans. Subwatersheds were designated as sensitive (<10% impervious cover), impacted (10-25% impervious cover), or non-supporting (>25% impervious cover). Based on this initial assessment, 38 out of 40 subwatersheds were classified as sensitive and two were considered to be impacted.

Other Impacts

One of the key assumptions of the impervious cover model is that sensitive subwatersheds have the potential to have good to excellent quality streams. This may not always realized because of other watershed factors. For example, research on streams in the Georgia Piedmont indicated that other watershed factors such as forest and agricultural cover can be useful indicators of stream quality in sensitive streams (see Figure 7). Agricultural reference streams had lower quality scores than similar forested reference streams. Indeed, these agricultural reference streams exhibited similar IBI scores to streams with population density up to four people per acre. This population density corresponds to approximately 15% impervious cover. This result suggests that agricultural land uses can result in stream impacts equivalent to those from development that brings streams to the "impacted" (10-25% impervious cover) management category. Other key watershed indicators to consider include livestock density, nutrient loads, forest cover, and riparian forest cover. Likewise, factors such as the presence of sewage treatment plants, golf courses, and septic systems impact stream quality, and can be useful indicators within sensitive subwatersheds.

Since 95% of the subwatersheds within Goose Creek were below 10% impervious cover, the "Rural Watershed Quality Point Method" was developed for further evaluation of the health of the 40 subwatersheds. The Rural Watershed Quality Point Method involved assigning a mix of favorable and unfavorable rural watershed quality points that incorporated a mixture of in-stream and subwatershed factors (see Table 3). Favorable points were assigned for the following subwatershed factors: high fraction of forest cover; high coverage of land with conservation easements; and extensive streamside forest cover. Unfavorable points were assigned for a combination of in-stream (designated impaired waters, water quality violations, poor to fair IBI scores, and fish barriers) and subwatershed factors (unusual nonpoint source areas, septic and animal density, bacteria level, low wetland coverage, high cattle density, high horse density, and high animal bacteria density) (see Appendix B & C). Details on this scoring method are provided in Step 4 of the Methods and Discussion.

To further screen the watersheds identified as High Quality, the "High Quality Point Method" involved assigning points to sensitive subwatersheds by incorporating good to excellent fish IBI scores (the only in-stream factor) and subwatershed factors such as high fraction of forest cover; high coverage of land with conservation easements; extensive streamside forest cover; and the presence of special places (see Appendix D).

Table 3. Assignment of Favorable and Unfavorable Points to In-stream and Other Subwatershed Factors					
Type	Factor	Favorable Points	Unfavorable Points	High Quality Points	Defined as
In-stream	Impaired water		1		Designation by VA DEQ
	Water quality violations		1		Violations of temperature, dissolved oxygen or turbidity
	Poor to fair fish IBI		1		VA monitoring data
	Good to excellent fish IBI			1	VA monitoring data
	Fish barriers		1		Presence of dams on stream
Subwatershed	▲ Forest Cover	1		1	> 48%
	▲ Conservation Easements	1		1	> 25%
	▲ Streamside Forest	1		1	> 60%
	Forested Con. Easements	1		1	> 50%
	▼ Wetlands		1		< 1%
	Unusual NPS		1		Two or more wastewater treatment plants, golf course, landfill, or vineyards
	Septic Density		1 or 3		> 30 septics/ mile 3 pts for adjacent to impaired
	Cattle Density		1		> 150 cattle/ mile
	Horse Density		1		> 35 horses/ mile
	Bacteria Level		1 or 3		High fecal coliform levels 3 pts for adjacent to impaired
Note: Favorable and Unfavorable Points were used to determine those subwatersheds that would be classified as either "Rural Impacted" or "High Quality." High Quality Points were used to further screen "High Quality" subwatersheds to determine the highest quality subwatersheds that could potentially make the 12 Most Vulnerable List.					

Based on this analysis, the current and future status of many of the subwatersheds were revised and resulted in the reclassification into one of the four management categories: High Quality, Rural Impacted, Urban Impacted, and Non-Supporting (see Table 4). Both the High Quality Point Method and the Rural Watershed Quality Point Method allowed for further distillation of the 40 subwatersheds into 12 subwatersheds considered the most vulnerable. The current and future classification for all 40 subwatersheds is portrayed in Table 5.

Table 4. Management Category Definitions		
Management Category	**Impervious Cover**	**Rural Watershed Quality Points**
High Quality	Sensitive	Net unfavorable score less than 3
Rural Impacted	Sensitive	Net unfavorable score of 3 or greater
Urban Impacted	Impacted	N/A
Non-Supporting	Non-supporting	N/A

Table 5. Current and Future Management Categories for the 40 Goose Creek Subwatersheds		
Subwatershed ID	**Current Management Category**	**Future Management Category**
Beaverdam Creek 101	High Quality	High Quality
Beaverdam Creek 102	High Quality	High Quality
Beaverdam Crk Up DD	High Quality	High Quality
Cromwells 101	High Quality	High Quality
Cromwells DD	High Quality	High Quality
Hungry Run	High Quality	High Quality
Little River 102	High Quality	High Quality
Little River 103	High Quality	High Quality
Little River Upper DD	High Quality	High Quality
Goose Headwater 103	High Quality	High Quality
Goose Headwater 104	High Quality	High Quality
Goose Headwater 105	High Quality	High Quality
Goose Headwater 106	High Quality	High Quality
Goose Headwater Lower DD	High Quality	High Quality
Goose Headwater Upper DD	High Quality	High Quality
Main Goose DD 102	High Quality	High Quality
Main Goose DD 103	High Quality	High Quality
Main Goose DD 105	High Quality	High Quality
North Fork 101	High Quality	High Quality
Panther Skin 101	High Quality	High Quality
Panther Skin 102	High Quality	High Quality
Panther Skin DD	High Quality	High Quality
Tuscarora 101	High Quality	High Quality
Beaverdam Reservoir	High Quality	Urban Impacted
Sycolin DD	High Quality	Urban Impacted
Main Goose DD 101	Rural Impacted	Urban Impacted
North Fork Upper DD	Rural Impacted	Urban Impacted
Beaverdam Crk Low DD	Rural Impacted	Rural Impacted
Butchers Branch 101	Rural Impacted	Rural Impacted
Butchers Branch DD	Rural Impacted	Rural Impacted
Little River 101	Rural Impacted	Rural Impacted
Little River Lower DD	Rural Impacted	Rural Impacted
Goose Headwater 101	Rural Impacted	Rural Impacted
Goose Headwater 102	Rural Impacted	Rural Impacted
Main Goose DD 104	Rural Impacted	Rural Impacted
North Fork 102	Rural Impacted	Rural Impacted
North Fork Lower DD	Rural Impacted	Rural Impacted
Sycolin 101	Rural Impacted	Rural Impacted
Tuscarora Lower DD	Urban Impacted	Non-Supporting
Tuscarora Upper DD	Urban Impacted	Non-Supporting

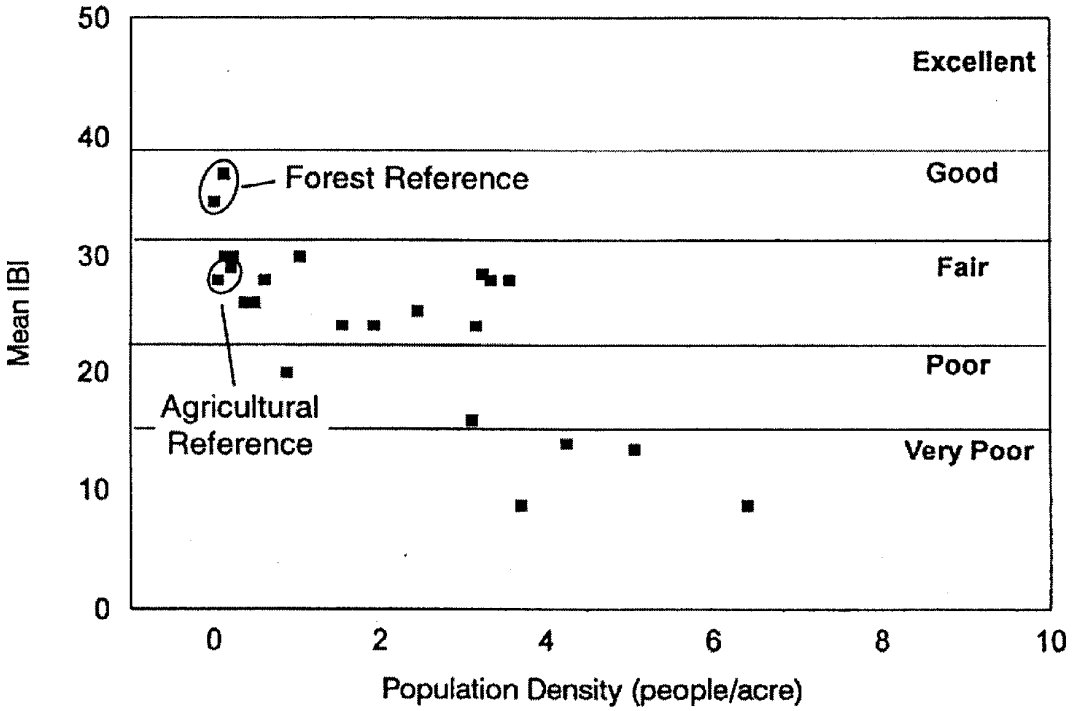

Figure 7: Impacts of Urbanization and Agriculture on IBI Scores (Divivo *et al*., 1995 and Couch, 1997)

METHODS AND DISCUSSION FOR GOOSE CREEK

The Goose Creek Vulnerability Analysis focused on categorizing the subwatersheds, primarily through the manipulation of GIS data. The methods for each of the following five steps is described in detail below:

Step 1: Delineation of subwatersheds
Step 2: Current impervious cover
Step 3: Future impervious cover
Step 4: Other subwatershed screening factors
Step 5: Final current and future conditions

Step 1: Delineation of subwatersheds

Delineation of the 385 square mile watershed resulted in 40 subwatersheds that ranged from approximately five to 15 square miles. GIS data provided by Loudoun and Fauquier Counties were used as the initial base to make the delineation of watersheds and subwatersheds. The layers obtained from Loudoun County included: watershed and subwatershed delineations, stream networks, and topography. GIS layers obtained from Fauquier County included topography and the stream network.

Step 2: Current Impervious Cover

Current impervious cover was estimated from 2001 impervious cover data from Loudoun County and land use data derived from the 2001 parcel layer from Fauquier County GIS mapping. The land use data from each County varied greatly. Due to these differences, two separate methods were utilized to calculate impervious cover for the subwatershed. In the Loudoun County portion of Goose Creek, we utilized the direct measurement technique. This technique uses GIS to sum up the area of all rooftops, streets, sidewalks, and other impermeable surfaces in a subwatershed. The streets were assigned into one of five street types and multiplied by an associated width. Table 6 describes the street types and their assigned width.

Table 6. Street Types and Assigned Width

Street Type	Width (ft)
Major Highway	63
Major Road	55
Connector Road	36
Private Road	18
Driveway	15

For Fauquier County, impervious cover was calculated using the land use method. The land use method involves calculating the total area of each current land use then multiplying it by an impervious cover coefficient (ICC). The ICC requires that the built area of each land use be multiplied by a unique ICC to yield a provisional estimate of impervious cover for each land use. Major roads were not included in the land use classifications, and instead appeared as a blank.

The unaccounted for area was therefore designated as "Roadway." The land use classifications and their associated ICC used for Fauquier County are outlined in Table 6.

Table 7. Fauquier County Current Land Use and Assigned Impervious Cover %

Land Use Classification	% Impervious
Agricultural 100+ acres	1.9
Agricultural 20 - 100 acres	1.9
Cemeteries	8.6
Charitable	8.6
Commercial and Industrial	63.46
Educational	34.4
Electric and Power Corp	8.6
Federal Government	either forest or agriculture
Forest	0
Other Government	either forest or agriculture
HOA	8.6
Interstate Pipeline	1.9
Middleburg	53.4
Multiple Family	44.4
Other	1.9
Religious	34.4
School Board	34.4
Schools	34.4
Single Family Suburban	dependent on lot size see Table 8
Single Family Urban	dependent on lot size see Table 8
State Government	either forest or agriculture
Telecom Co	8.6
Water Corp	8.6
WSA	8.6
Roadway	70

The ICC assigned to single family suburban and urban zones were dependent on the lot size (i.e., smaller lots have a higher percentage of impervious cover). Table 8 outlines the ICC

for these lots. In Loudoun County, buildings and road casing layers (including streets, driveways, and parking lots) were utilized. In Fauquier County, a GIS layer that contains land use classifications for each parcel was used. A graphical representation of the current impervious cover in Goose Creek is presented in Figure 8. For current impervious cover, subwatersheds were designated as sensitive (<10% impervious cover), impacted (10-25% impervious cover), or non-supporting (>25% impervious cover). Based on impervious cover, only two subwatersheds (Tuscarora Upper Direct Drainage and Tuscarora Lower Direct Drainage) are currently classified as "Impacted." The results of the calculations are presented in Appendix A.

Table 8. Single Family Suburban and Urban Lots Assigned Impervious Cover %

Lot Size (Acres)	% Impervious
1	14.3
2	10.6
3	8.1
4	6.6
5	5.6
6	5.0
7	4.6
8	4.2
9	4.0
10	3.8
11	3.6
12	3.5
13	3.3
14	3.2
15	3.1
16	3.1
17	3.0
18	2.9
19	2.9
20	2.8

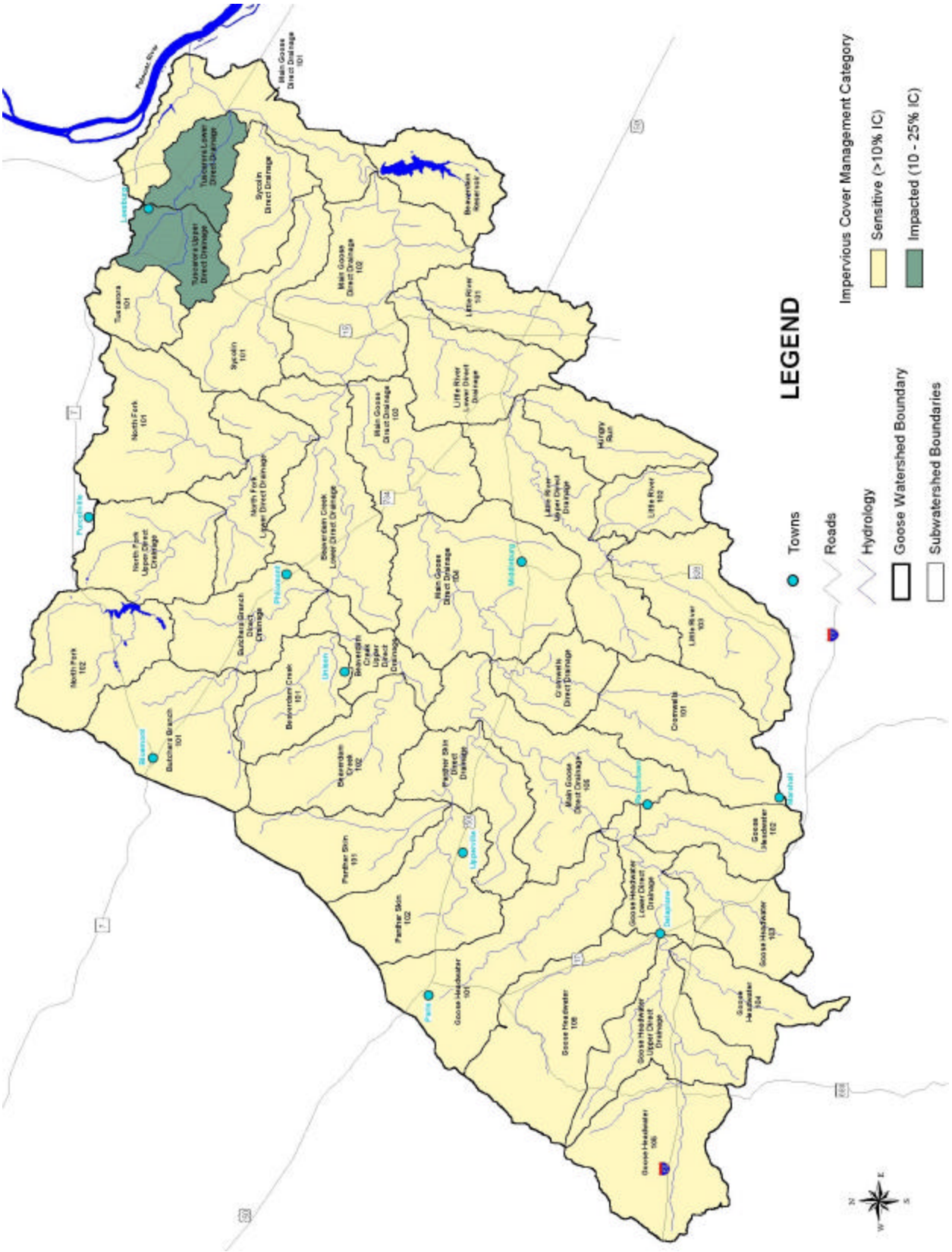

Figure 8: Current Impervious Cover in Goose Creek

Step 3: Future Impervious Cover

Future impervious cover estimates were projected based on developable parcels and zoning. Impervious cover coefficients were developed for each major zoning category outlined in Fauquier County's Zoning Ordinance and Loudoun County's newly revised Comprehensive Plan (FCZO, 2000 and DBD, 2002). For the purposes of this analysis, full build-out (of current zoning in Fauquier and proposed zoning for Loudoun) was assumed for future conditions. Consequently, the future impervious cover estimates represent the maximum level of development that can be expected in the subwatershed, since not all parcels that are zoned for a particular land use will ultimately be built (i.e., economic conditions, access, lack of infrastructure, etc.).

To project future impervious cover, similar methodologies were utilized in Loudoun and Fauquier Counties. In Loudoun County, undeveloped parcels were identified in each subwatershed. Next, conservation easements, floodplain buffer (buffered 50 feet on each side), and slopes greater than 25% were subtracted from parcel area as unbuildable land. Finally, we selected "pipeline" development, or development that is slated to occur under existing zoning. These pipeline lots included undeveloped parcels included within Loudoun County's Subdivision Layer.

For buildable lots that are not identified as "pipeline" lots, we multiplied the buildable area by impervious cover coefficients for the zoning categories identified in the Loudoun County Revised Comprehensive Plan. For "pipeline" lots, we used impervious cover coefficients for current zoning categories. The impervious cover percentages in both of these cases are provided in Table 9.

Table 9. Impervious Cover Coefficients for Loudoun County	
Zone	**% Impervious**
Comprehensive Plan	
50 ac	2.8
20 ac	3.8
Transition	8.1
Suburban	27.8
Joint Land Management Area	(Use Existing Zoning Below)
Towns	53
Existing Zoning	
A10	3.8
A3	8.1
CR1	14.3
CR2	21.2
PDIP	53.4
PDH3	24.5
PDH4	27.8
PDOP	72.2
PDRV	8.1
PDSA	8.6
R4	27.8
RC	72.2
Roads	70
Towns	53

A second scenario was also conducted to take into account changes that might result from Leesburg's proposed annexation plan. In this analysis, land proposed for annexation by Leesburg was assigned impervious cover coefficients based on planned land use within the Annexation Area (see Table 10).

Table 10. Impervious Cover Coefficients for Land Within Leesburg's Annexation Area	
Planned Land Use	**% Impervious**
Business	53.4
Commercial	72.2
Low Density Residential	14.3

In Fauquier County, undeveloped parcels were identified in each subwatershed. Next, conservation easements were subtracted from the parcel area. The remaining area for each undeveloped parcel in a distinct zoning category was then multiplied by an estimated impervious cover coefficient (see Table 11). Parcels within the floodplain were subject to more stringent development criteria (see the Fauquier County Zoning Ordinance) and thus a reduced impervious cover coefficient.

Table 11. Fauquier County Zoning Categories and Assigned Impervious Cover %

Zone	Zone Name	% Impervious
RR-2	Rural Residential	10.6
V	Village	18
Settlement	Settlements	N/A
R-1	General Purpose Residential District	14.3
R-2	Residential District	21.2
R-3	Residential District	25
R-4	Residential District	27.8
TH	Townhouse	40.9
GA	Garden Apartment	18
I-1/I-2	Industrial Park	53.4
C-1	Commercial Neighborhood	72.2
C-2	Commercial Highway	72.2
RC	Conservation District	see Table 12
RA	Agriculture	see Table 12

Parcels zoned RA and RC, are subject to the "sliding scale." The sliding scale determines the number of lots permitted based on the size of the parcel. The density permitted affects the amount of impervious cover. Table 12 describes the sliding scales density for the RA and RC zoning categories used within Fauquier County Zoning.

Table 12. Fauquier County Sliding Scale (Source: Fauquier County Zoning Ordinance, 2000)	
Size of Parcel (acres)	**Number of Permitted Lots**
0 – 9.99	1
10 - 19.0	2
20 - 34.99	3
35 - 54.99	4
55 - 79.9	5
80 - 104.99	6
105 - 129.99	7
130 - 154.99	8
155 - 179.99	9
180 - 204.99	10
205 and above	10*
*plus one additional lot for each 50 acres	

The data layers used for Loudoun County include topography (used to identify steep slopes); floodplain; existing land use (used to identify undeveloped parcels); zoning; areas slated for development prior to the implementation of the new zoning ordinance; and conservation easements. For the town of Leesburg, GIS layers included the city and proposed annexation boundaries. Finally for Fauquier County, the GIS data included a layer that contains land use classifications for each parcel, floodplains, zoning, and conservation easements.

A graphical presentation of future impervious cover for the entire Goose Creek watershed is provided in Figure 9. In addition, a graphical presentation of future impervious cover in the annexation scenario is provide in Figure 10.

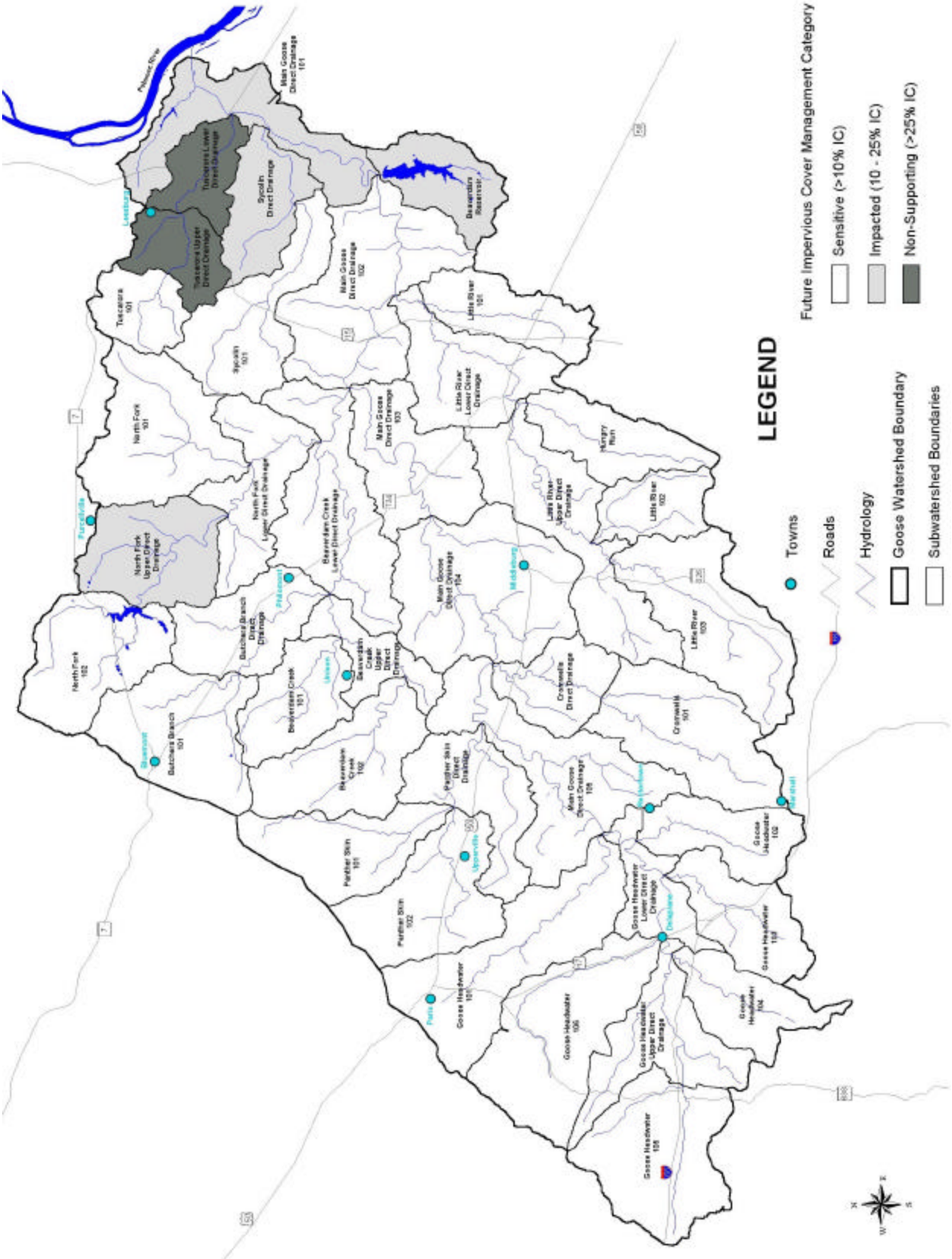

Figure 9: Future Impervious Cover

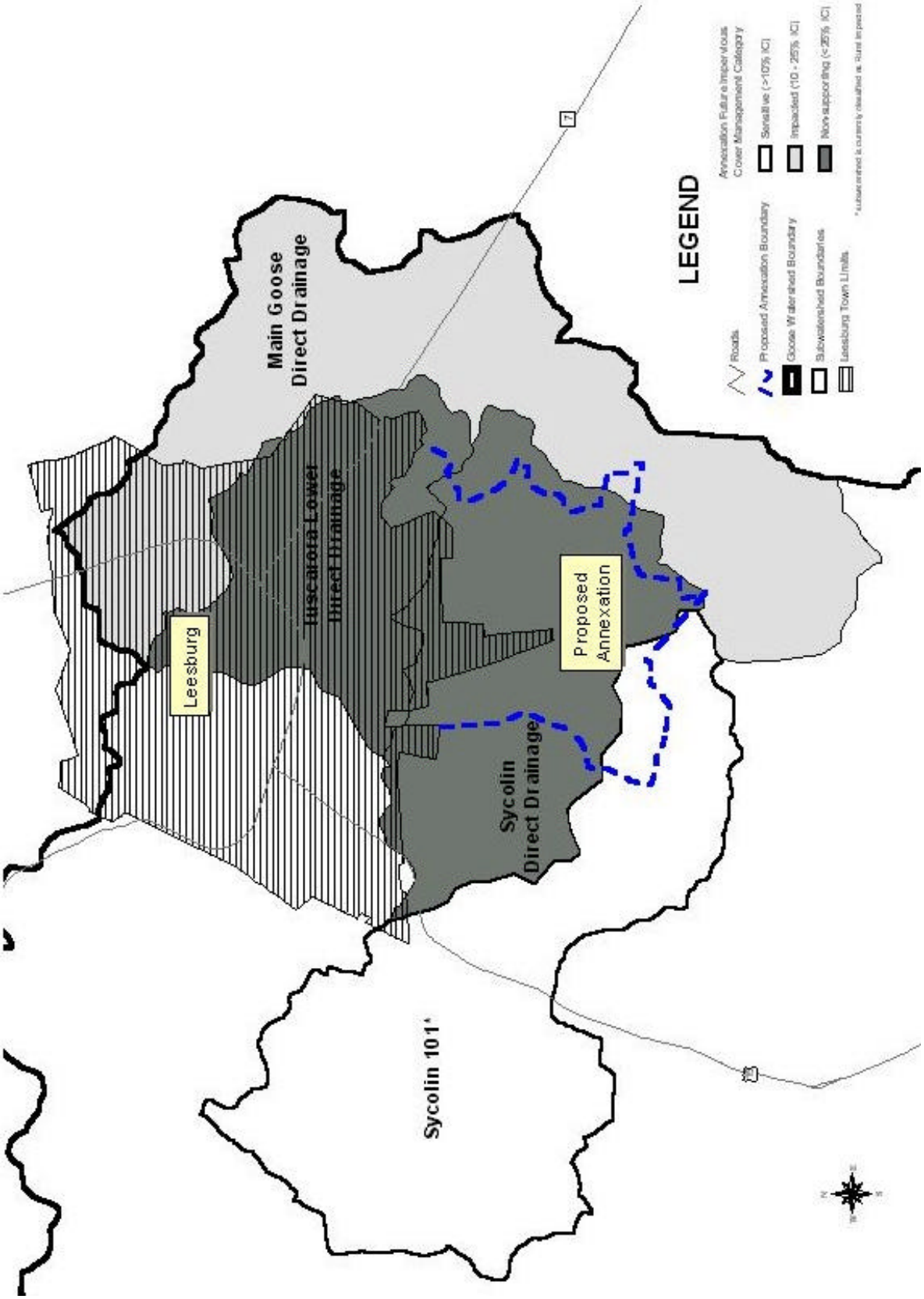

Figure 10: Future Conditions Assuming Annexation of Leesburg

Step 4: Other Subwatershed Screening Factors

Initial impervious cover analysis revealed that the great majority of the subwatersheds within the Goose Creek watershed are sensitive using impervious cover alone as an indicator. To further refine the subwatershed classification system the Rural Watershed Quality Point Method was developed for further evaluation of the health of the 40 subwatersheds. This method incorporated a mixture of in-stream and watershed factors (see Figure 11).

Rural Quality Point Method

The Rural Watershed Quality Point Method required assigning a mix of favorable and unfavorable rural watershed quality points. In this system, data such as poor fish diversity are assigned unfavorable points. Characteristics such as high forest cover are assigned favorable points. The subtotal of favorable points was subtracted from the subtotal of unfavorable points to obtain the net unfavorable score. The higher the score, the more impacted the subwatershed. The net unfavorable score was then used to designate a subwatershed as rural impacted.

Favorable points were exclusively land use factors and included high fraction of forest cover; high coverage of land with conservation easements; and extensive streamside forest cover. Unfavorable factors included a combination of in-stream (designated impaired waters, discharges to adjacent impaired water, water quality violations, fish barriers, and poor to fair IBI scores); land use factors (unusual nonpoint sources, high septic system density, and less than 1% wetlands); and rural factors (high cattle density, high horse density, and high animal bacteria density).

Favorable Points

Favorable points included high fraction of forest cover; high coverage of land with conservation easements; and extensive streamside forest cover.

Subwatersheds with greater than 48% forest cover are considered to have a favorable rural quality point because this result confirms original classification as a sensitive subwatershed. Thus one favorable point was awarded to each of the ten subwatersheds with high forest cover.

For subwatersheds with at least 25% covered by conservation easements, one favorable point was given. Analysis shows that one-quarter of all the subwatersheds have 25% or more land in conservation easements. An additional favorable point was given to those subwatersheds with 25% of land covered by conservation easements which are greater than 50% forest.

Subwatersheds with greater than 60% forested streamside (i.e. forest within 100 feet of mapped perennial streams) received one favorable point. Eleven subwatersheds were awarded points for good forest streamsides.

Unfavorable Points

Unfavorable factors included a combination of in-stream, land use, and rural factors

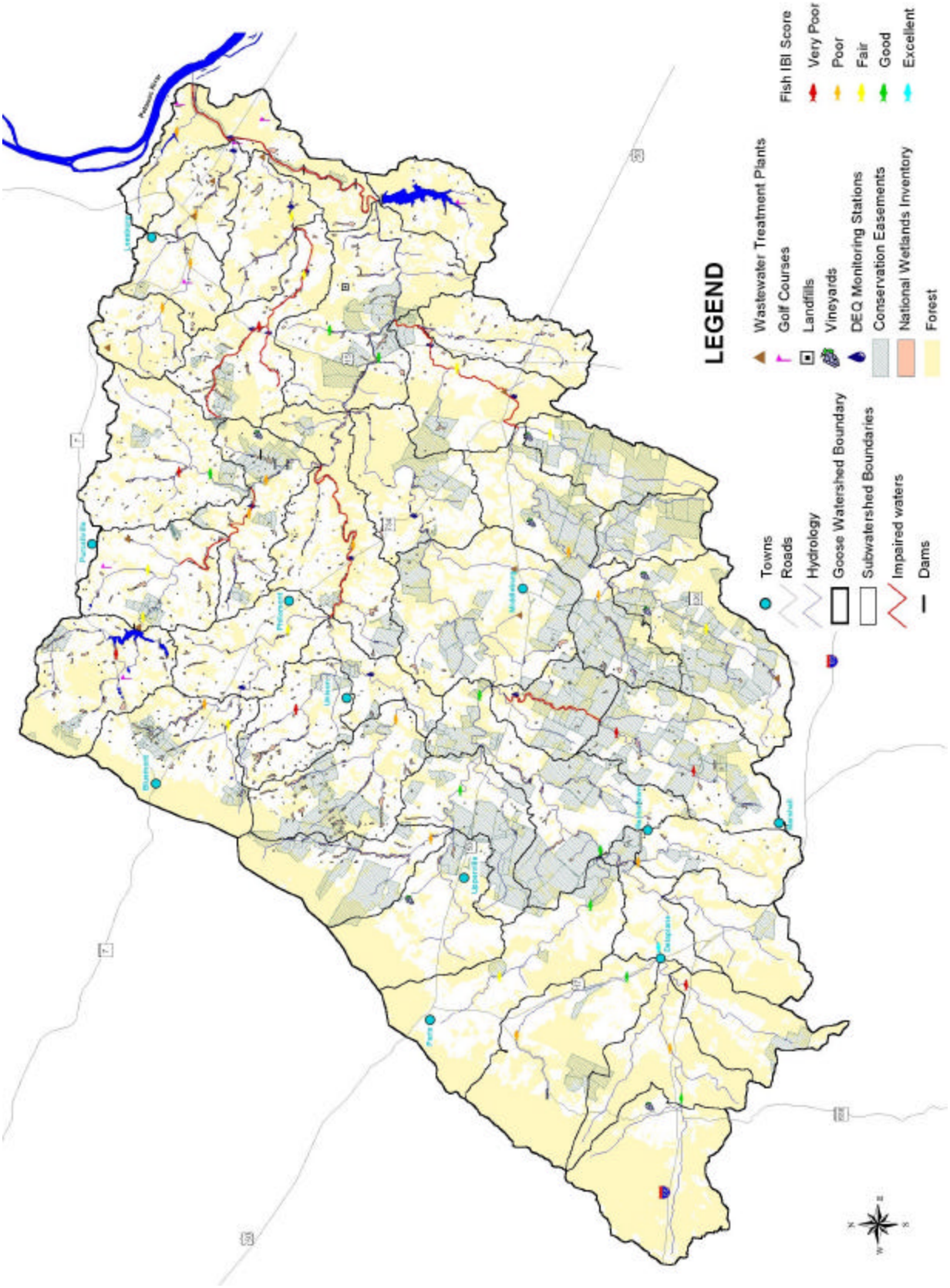

Figure 11: Other In-stream and Subwatershed Factors

In-stream factors included designated impaired waters, water quality violations, poor to fair IBI scores, and fish barriers. Subwatersheds that include stream segments designated as an impaired water by the Virginia Department of Environmental Quality received one unfavorable point. There are seven subwatersheds with impaired waters within Goose Creek: Beaverdam Creek Lower Direct Drainage (DD), Cromwells DD, Little River Lower DD, Main Goose DD 101, North Fork Lower DD, and North Fork Upper DD, and Sycolin 101.

In watersheds that had monitoring stations, water quality violations were assigned one unfavorable point. The following water quality parameters were analyzed—water temperature, dissolved oxygen, and turbidity. Standard violations were defined as temperature above 68 degrees (in the months between June and September), turbidity above 200 NTU (nephelometric turbidity units), and dissolved oxygen below five mg/l. For most stations, violations of turbidity or dissolved oxygen were rare or non-existent. Temperatures exceeding 68 degrees were fairly common, however. One unfavorable point was assigned to each subwatershed that had recorded any violations for turbidity or dissolved oxygen. One unfavorable point was assigned to subwatersheds that had more than 10 summer temperature observations and 50% exceedance of 68 degrees. Due to limited monitoring data, water quality could only be analyzed at 13 of 40 subwatersheds. Only five subwatersheds received unfavorable points for water quality violations: Beaverdam Creek Lower DD, Little River Lower DD, Main Goose DD 101, Sycolin DD, and Tuscarora Lower DD.

Many subwatersheds had biological monitoring stations that measured fish data. Subwatersheds with a fair or poor fish IBI (index of biotic integrity) score based on available fish data received one unfavorable point. Twenty-six of the 40 subwatersheds had low IBI scores. Due to a limited number of biological monitoring data, this variable could only be computed in 31 out of the 40 subwatersheds.

Subwatersheds with dams received one unfavorable point. The Virginia Department of Environmental Quality has mapped all dams in the watershed. We only utilized dams along major steam reaches. The six dams present in the Goose Creek Watershed are located in the following subwatersheds: Beaverdam Creek Lower DD, Beaverdam Reservoir, Goose Headwater 106, Main Goose DD 101, North Fork 102, and North Fork Lower DD.

In addition to the in-stream factors, unfavorable points were also assigned to a series of land use/ land cover factors. Unfavorable land use factors included unusual nonpoint source areas, septic and animal density, bacteria level, and low wetland coverage.

Unusual nonpoint source areas include those areas with the potential to degrade subwatershed quality. The presence of wastewater treatment plants, golf courses, landfills and vineyards within each subwatershed was noted. Subwatersheds with two or more of these (e.g., two golf courses or a golf course and a vineyard) were assigned one point. Golf courses and vineyards were manually placed on GIS maps based on available hard copy information and maps. Wastewater treatment plants were available from the EPA NPDES database. Landfills were located on GIS maps using parcel information provided by PEC. The only four subwatersheds that received unfavorable point for unusual nonpoint source areas include: Little River 103, Main Goose DD 104, North Fork Upper DD, and Tuscarora Lower DD.

The septic density represents the number of septic systems per square mile. These data were assembled based on data from the Interstate Commission on the Potomac River Basin (ICPRB) assembled as a part of the ongoing total maximum daily load (TMDL) process within the Goose Creek watershed. In some cases, the ICPRB watersheds were larger than those in this study. In these cases, the number of septic systems was distributed between the subwatersheds based on the total number of parcels greater than one acre. A "high septic density" was assigned to subwatersheds with greater than 30 septic systems per square mile. Thirty septic systems per square mile corresponds to the upper quartile among the subwatersheds of Goose Creek.

One unfavorable point was assigned to ten subwatersheds with high septic density. Subwatersheds with high septic density that were also classified as impaired waters were assigned three unfavorable points to reflect the possibility that these systems may contribute to the impaired status.

Lastly in the land use category, in subwatersheds with less than 1% wetland cover, one unfavorable point was assigned. Beaverdam Creek Upper DD, Butchers Branch DD, Main Goose DD 103, and Tuscarora 101 were the only subwatersheds to have less than 1% wetland cover. Due to data limitations, wetland cover could only be computed in 23 of the 40 subwatersheds.

The rural factors considered unfavorable included high cattle density, high horse density, and high animal bacteria density. Again, the animal density data were derived from ICPRB and were apportioned within subwatersheds based on the total acres of agricultural land.

Cattle and horses were the most numerous animals in the subwatershed. Using this data, two analyses were conducted. First, subwatersheds with high concentrations of cattle or horses were assigned one unfavorable point. These included subwatersheds with more than 150 cattle per square mile or more than 35 horses per square mile. Thirty-five horses per square miles corresponds to the upper quartile among the subwatersheds of Goose Creek. Secondly, total bacteria count was developed for each subwatershed, based on the total fecal coliform produced per animal per day for both cattle and horses. Subwatersheds with high fecal coliform counts were assigned a score of three if the subwatershed is impaired or drains to an impaired subwatershed. Otherwise, one unfavorable point was assigned. High animal density and/or high animal bacteria levels impact eighteen subwatersheds.

A summary of the classification changes as a result of both favorable and unfavorable rural watershed quality points is provided in Table 13.

Table 13. Classification Changes as a Result Of Favorable and Unfavorable Rural Watershed Quality Points					
Subwatershed ID	**Current Mgt Category**	**Unfavorable Tipping Points**	**Favorable Tipping Points**	**Net Unfavorable Score** (Unfavorable-Favorable)	**Classification Change?**
Beaverdam Creek 101	High Quality	2	0	2	stays same
Beaverdam Creek 102	High Quality	1	1	0	stays same
Beaverdam Crk Low DD	High Quality	12	1	11	Rural Impacted
Beaverdam Crk Up DD	High Quality	2	1	1	stays same
Beaverdam Reservoir	High Quality	1	1	0	stays same
Butchers Branch 101	High Quality	3	0	3	Rural Impacted
Butchers Branch DD	High Quality	6	0	6	Rural Impacted
Cromwells 101	High Quality	2	1	1	stays same
Cromwells DD	High Quality	2	2	0	stays same
Hungry Run	High Quality	1	3	-2	stays same
Little River 101	High Quality	3	0	3	Rural Impacted
Little River 102	High Quality	0	4	-4	stays same
Little River 103	High Quality	2	2	0	stays same
Little River Lower DD	High Quality	6	1	5	Rural Impacted
Little River Upper DD	High Quality	1	2	-1	stays same
Goose Headwater 101	High Quality	3	0	3	Rural Impacted
Goose Headwater 102	High Quality	3	0	3	Rural Impacted
Goose Headwater 103	High Quality	2	0	2	stays same
Goose Headwater 104	High Quality	1	1	0	stays same
Goose Headwater 105	High Quality	0	2	-2	stays same
Goose Headwater 106	High Quality	2	1	1	stays same
Goose Headwater Lower DD	High Quality	2	0	2	stays same
Goose Headwater Upper DD	High Quality	1	2	-1	stays same
Main Goose DD 101	High Quality	4	1	3	Rural Impacted
Main Goose DD 102	High Quality	0	0	0	stays same
Main Goose DD 103	High Quality	1	1	0	stays same
Main Goose DD 104	High Quality	4	1	3	Rural Impacted
Main Goose DD 105	High Quality	2	1	1	stays same
North Fork 101	High Quality	2	0	2	stays same
North Fork 102	High Quality	6	0	6	Rural Impacted
North Fork Lower DD	High Quality	6	1	5	Rural Impacted
North Fork Upper DD	High Quality	7	0	7	Rural Impacted
Panther Skin 101	High Quality	3	2	1	stays same
Panther Skin 102	High Quality	2	0	2	stays same
Panther Skin DD	High Quality	2	1	1	stays same
Sycolin 101	High Quality	5	0	5	Rural Impacted
Sycolin DD	High Quality	2	0	2	stays same
Tuscarora 101	High Quality	2	0	2	stays same

Step 5: Final Current and Future Conditions

Based on these analyses, the current and future conditions of many of the subwatersheds were revised and resulted in the reclassification of many of the subwatersheds. For example, while impervious cover alone originally indicated 38 High Quality subwatersheds, application of the Rural Watershed Quality Point Method resulted in 25 High Quality subwatersheds and the recategorization of 13 subwatersheds as Rural Impacted. The Rural Impacted subwatersheds include:

* Beaverdam Creek Lower DD
* Butchers Branch DD
* Little River Lower DD
* Goose Headwater 102
* Main Goose DD 104
* North Fork Lower DD
* Sycolin 101
* Butchers Branch 101
* Little River 101
* Goose Headwater 101
* Main Goose DD 101
* North Fork 102
* North Fork Upper DD

Figures 12 and 13 show the revised current and future management categories, respectively. Spreadsheets presented in Appendices B, C, and D include additional information on the basic calculations for the classification system. Please note that since the Rural Impacted category only applies to High Quality subwatersheds.

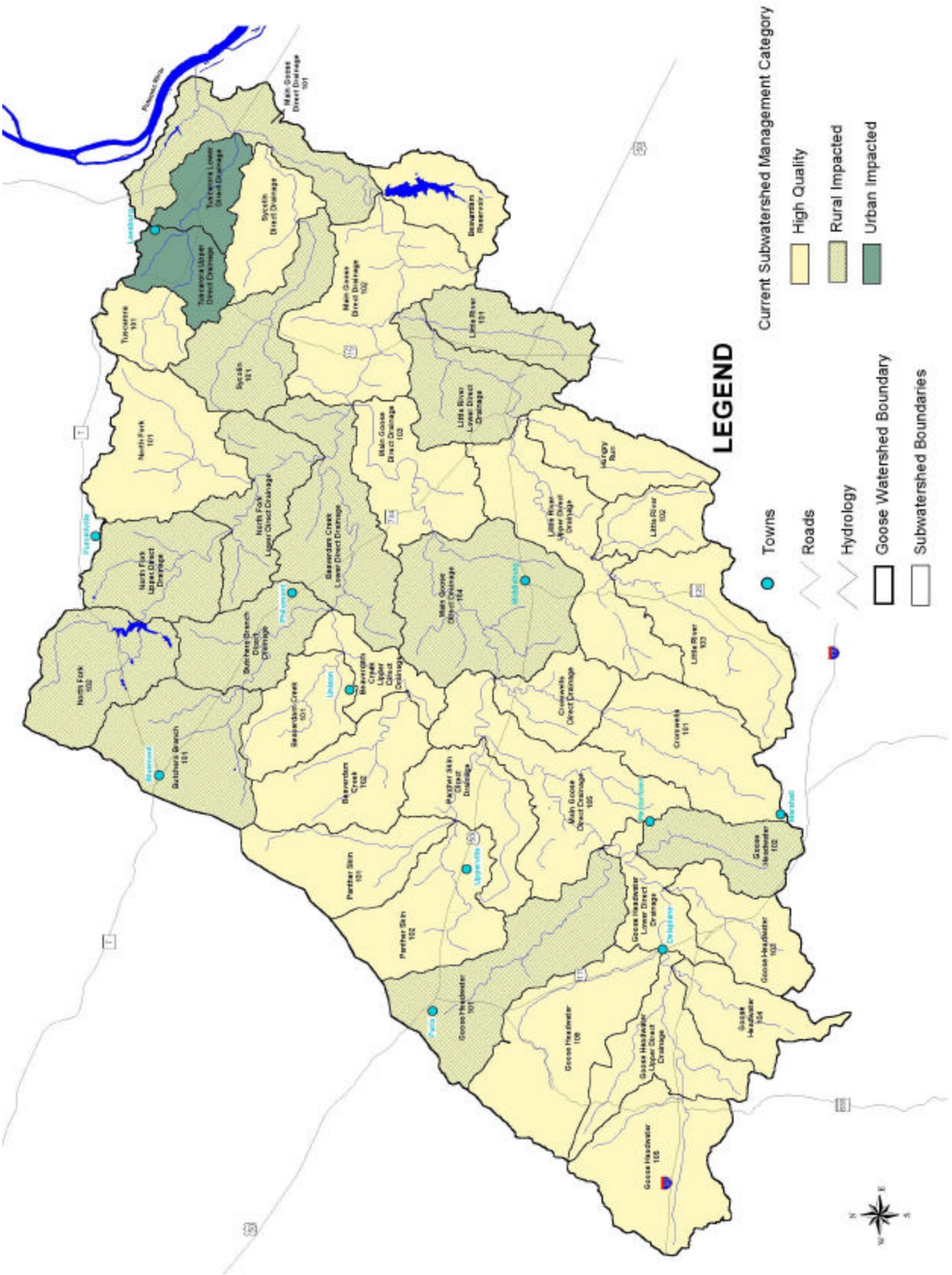

Figure 12: Revised Current Conditions

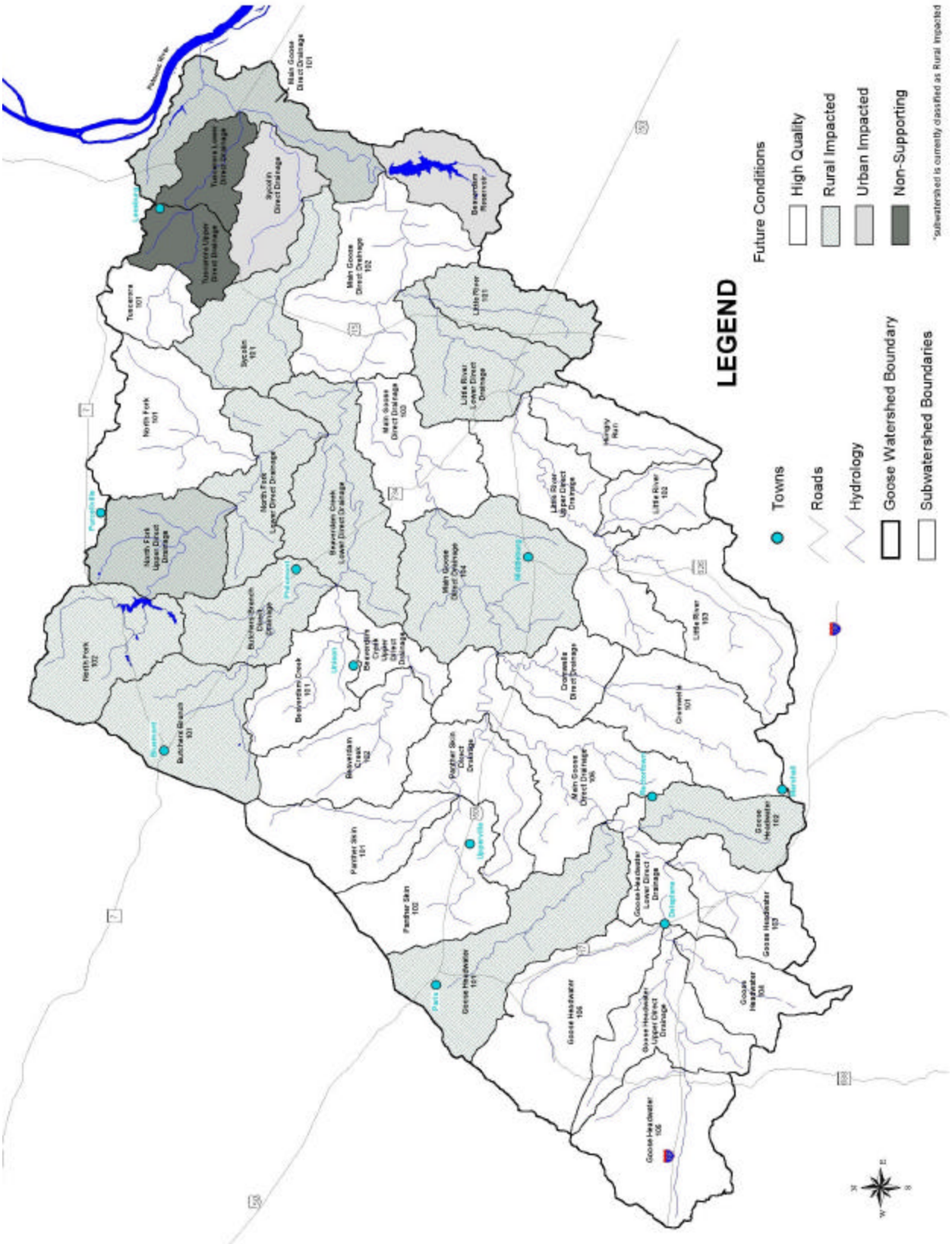

Figure 13: Future Conditions for Goose Creek

Factors that Could Not Be Included in the Current Analysis

Two potentially important factors that could not be incorporated into the analysis because of data availability at this time were Rare, Threatened and Endangered (RTE) species and Contiguous Forest blocks. The Piedmont Environmental Council (PEC) is in the process of securing RTE data. Contiguous forest cover could not easily be evaluated with the available forest data, which is at a very coarse scale. These variables can be added to the spreadsheet model if and when they become available.

Although macroinvertebrate and habitat data are valuable indicators, the lack of availability of this data (only 10 sites within the 40 subwatersheds) and non-randomized locations determined the decision to exclude these data as tipping points.

SELECTION OF THE 12 MOST VULNERABLE SUBWATERSHEDS

Once subwatersheds were categorized into the current and future management categories, selection of the most vulnerable subwatersheds within the Goose Creek Watershed began. Within the context of this study, the most vulnerable subwatersheds were selected using the following five operating rules:

1. Choose at least two subwatersheds from each management category.
2. Select High Quality subwatersheds that received the most High Quality Points (see below)
3. Choose subwatersheds that change in classification from High Quality to Urban Impacted or Urban Impacted to Non-Supporting due to future growth.
4. Select headwaters whenever possible.
5. Select Rural Impacted subwatersheds that had three or more net unfavorable points.

The High Quality Point Method involved assigning points to the 25 subwatersheds classified as High Quality. High Quality Points were assigned for:

- High (good to excellent) fish IBI scores
- High fraction of forest cover in the watershed
- High coverage of conservation easements
- Significant forest cover within conservation easements (applies only to those subwatersheds with a high coverage of conservation easements)
- Extensive streamside forest cover
- Presence of special places (Banshee Reeks, Oak Hill, and Oatlands)

One point was assigned to each in-stream and subwatershed factor, and subwatersheds with three or more points were selected as candidates for the 12 most vulnerable subwatersheds list. Using this method, four subwatersheds qualified for the High Quality category of the 12 most vulnerable subwatersheds: Hungry Run, Little River 102, Goose Headwater 105 and Goose Headwater Upper Direct Drainage (DD). Of the four, Hungry Run, Little River 102, Goose Headwater 105 were selected for the list because they are all headwaters. Appendix D provides details of this analysis.

For the Rural Impacted category, Sycolin 101, North Fork 102, and Goose Headwater 102 were chosen as the three most vulnerable because they were all headwaters, had the highest unfavorable scores for headwaters, and some of the poorest IBI scores.

Both the Urban Impacted and Non-Supporting categories remained the same. The Urban Impacted category included Beaverdam Reservoir, North Fork Upper DD, Sycolin DD, and Main Goose DD 101. The Non-Supporting category included Tuscarora Upper DD and Tuscarora Lower DD began. A graphical presentation of the final dozen is presented in Figure 14.

Why Headwater Subwatersheds?

Once the classification system was developed, subwatersheds containing headwater streams were identified (see Table 14). Headwater streams are the smallest streams but they are crucial in watershed management because they dominate the landscape through their shear

number and cumulative length. Headwater streams are exceptionally vulnerable to development. What happens in the local landscape is directly translated to headwater streams and major receiving waters are affected in turn. Focusing on headwater stream level is important in watershed management for several reasons:

- Headwater streams are exceptionally vulnerable to watershed changes.
- Unlike larger watershed management units, headwater streams are at a scale where individual developments can have a measurable impact.
- Headwater streams are the "narrowest door" for water resource protection.
- Headwater streams are good indicators of watershed quality.

Protection of headwater subwatersheds is crucial to maintaining downstream water quality and habitat. Therefore, starting with the headwater subwatersheds as the first set for further study is a logical place to begin. Eight of the twelve most vulnerable have headwater streams (see Table 15).

Table 14. Identification of Headwaters in the 40 Subwatersheds of Goose Creek	
Subwatershed ID	**Headwaters?**
Beaverdam Creek 101	x
Beaverdam Creek 102	x
Beaverdam Crk Low DD	
Beaverdam Crk Up DD	
Beaverdam Reservoir	x
Butchers Branch 101	x
Butchers Branch DD	
Cromwells 101	x
Cromwells DD	
Hungry Run	x
Little River 101	x
Little River 102	x
Little River 103	x
Little River Lower DD	
Little River Upper DD	
Goose Headwater 101	x
Goose Headwater 102	x
Goose Headwater 103	x
Goose Headwater 104	x
Goose Headwater 105	x
Goose Headwater 106	x
Goose Headwater Lower DD	
Goose Headwater Upper DD	
Main Goose DD 101	
Main Goose DD 102	
Main Goose DD 103	
Main Goose DD 104	
Main Goose DD 105	
North Fork 101	x
North Fork 102	x
North Fork Lower DD	
North Fork Upper DD	
Panther Skin 101	x
Panther Skin 102	x
Panther Skin DD	
Sycolin 101	x
Sycolin DD	
Tuscarora 101	x
Tuscarora Lower DD	
Tuscarora Upper DD	

Table 15. Goose Creek Watershed's Twelve Most Vulnerable Subwatersheds			
Category	**Subwatershed ID**	**Headwaters?**	**Main Considerations**
High Quality	Hungry Run	Yes	3 High Quality points with only 1 unfavorable Rural Watershed Quality point
	Little River 102	Yes	4 High Quality points with no unfavorable Rural Watershed Quality points
	Goose Headwater 105	Yes	3 High Quality points with no unfavorable Rural Watershed Quality points
Rural Impacted	Sycolin 101	Yes	High total unfavorable Rural Watershed Quality points (5 points, including Designated Impaired Waters, Septic Density and very poor IBI Score (18 IBI points); 0 favorable points
	North Fork 102	Yes	6 total unfavorable Rural Watershed Quality points (Septic Density, Horse Density, Fish Barrier, and very poor IBI Score (24 IBI points); 0 favorable points
	Goose Headwater 102	Yes	3 unfavorable Rural Watershed Quality points (Cattle Density, Animal Bacteria, poor IBI score (28 IBI points); 0 favorable points
Urban Impacted	Beaverdam Reservoir	Yes	Increase of 11.4 % IC with planned development (note: Loudoun County is currently undertaking a study of this subwatershed)
	Main Goose DD 101*	No	Potential to have the greatest net increase in Future IC; increase of 15.4% IC
	North Fork Upper DD*	No	Development shifts management category from sensitive to impacted; increase of 4.8% IC
	Sycolin DD*	No	10.3% IC increase with development
Non-Supporting	Tuscarora Upper DD*	No	One of two subwatersheds predicted to go from Impacted to Non-Supporting
	Tuscarora Lower DD*	No	One of two subwatersheds predicted to go from Impacted to Non-Supporting
* This is a non-headwater subwatershed; to effectively conduct a plan, ideally the upstream subwatershed would be selected as well.			

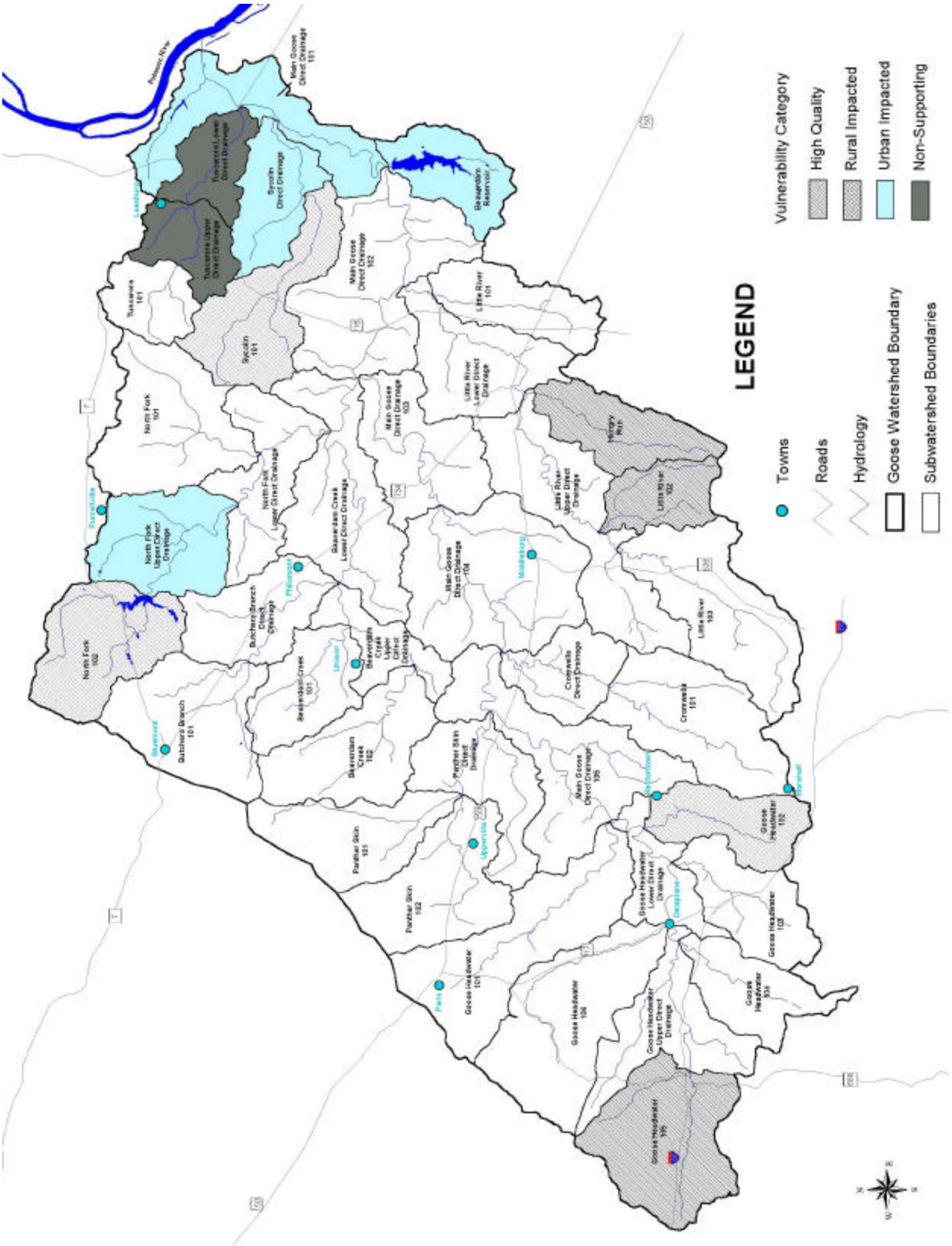

Figure 14: The Dozen Most Vulnerable Subwatersheds of Goose Creek

CONCLUSION – IMPLICATIONS FOR WATERSHED MANAGEMENT

The initial analysis of Goose Creek shows that while impervious cover is one indicator of watershed health, in-stream and subwatershed factors are needed to accurately define aquatic health. Ground-truthing through field assessments in the next phase of the study will be important to verify our classifications.

In addition to determining the baseline information on the many parameters that influence the Goose, another purpose of this initial analysis was to provide focus for the future efforts within the Goose Creek Watershed. Ideally, these efforts could be focused on subwatersheds identified in Table 15. One exception to this guideline, however, is the presence of non-headwater streams on the final most vulnerable list, which could only be effectively studied by adding an adjacent headwater stream. For example, an effective plan for Tuscarora Upper Direct Drainage could only be developed in conjunction with a plan for Tuscarora 101, despite the fact that Tuscarora 101 does not appear on Table 15.

Some other recommendations for the subwatershed studies include a Sycolin combination or a North Fork Combination. With the Sycolin combination, Sycolin 101 and Sycolin Direct Drainage could provide information about two different vulnerability categories and still meet the headwater rule. Likewise, the North Fork combination could include North Fork 102 and North Fork Upper Direct Drainage. Choosing either the Sycolin combination or the North Fork Combination option would also allow an assessment of one of the three most pristine categories that also made the top 12 Most Vulnerable list.

Regardless of which three subwatersheds are chosen, headwaters should be the first locations for study as they will be key to determining other issues downstream. Once Piedmont Environmental Council and Goose Creek Watershed Association are trained in the field methods, these same methods can be applied in other subwatersheds.

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Appendix A: Characteristics of the 40 Goose Creek Subwatersheds												
Subwatershed	Area (ac)	Mapped Perennial Stream Miles	Current Impervious %	Future Impervious %	Current Management Category	Future Management Category	Estimated Forest Area (ac)	Forested Streamside (ac)	Conservation Easements (ac)	Forested Conservation Easements (ac)	NWI Weltand Area (ac)	Developable Area (ac)
Beaverdam Creek 101	4622	13.6	3	6	High Quality	High Quality	834	119	426	62.44	115	2722.18
Beaverdam Creek 102	6793	17.9	4	5	High Quality	High Quality	2413	244	2091	670.15	193	3474.08
Beaverdam Creek Lower DD	8729	26.1	3	6	Rural Impacted	Rural Impacted	4146	493	646	151.00	262	4304.08
Beaverdam Creek Upper DD	3025	8.8	5	7	High Quality	High Quality	994	146	227	65.13	18	1956.04
Beaverdam Reservoir	4049	10.8	4	15	High Quality	Urban Impacted	1995	93	0	0.00	341	2478.85
Butchers Branch 101	7669	22.4	4	7	Rural Impacted	Rural Impacted	3373	234	722	233.79	155	3078.11
Butchers Branch DD	5188	15.6	4	8	Rural Impacted	Rural Impacted	1373	204	0	0.00	49	2281.47
Cromwells 101	8025	21.8	3	4	High Quality	High Quality	2084	241	3551	850.57	85	3894.80
Cromwells DD	3802	10.1	3	3	High Quality	High Quality	1232	177	2439	757.70	60	1013.44
Hungry Run	4513	10.5	3	3	High Quality	High Quality	2552	137	2206	1243.57	NA	1430.72
Little River 101	4322	10.7	5	8	Rural Impacted	Rural Impacted	1578	99	1	1.24	93	2735.68
Little River 102	3145	8.8	3	3	High Quality	High Quality	1810	141	1834	1014.13	NA	1238.61
Little River 103	8449	19.3	3	4	High Quality	High Quality	3494	283	3389	1308.46	NA	4245.10
Little River Lower DD	6138	16.6	4	6	Rural Impacted	Rural Impacted	2981	206	913	504.99	NA	3317.12
Little River Upper DD	8713	24.3	3	4	High Quality	High Quality	3049	365	4648	1416.41	NA	3147.81
Goose Headwater 101	9935	36.9	3	4	Rural Impacted	Rural Impacted	4422	338	806	293.12	NA	6883.65
Goose Headwater 102	4335	22.6	5	7	Rural Impacted	Rural Impacted	1162	248	248	9.11	NA	3142.81
Goose Headwater 103	4799	19.2	4	5	High Quality	High Quality	1940	192	235	47.31	NA	3516.80
Goose Headwater 104	4355	11.5	3	4	High Quality	High Quality	2703	161	370	158.79	NA	3283.48
Goose Headwater 105	8479	21.9	6	7	High Quality	High Quality	6389	357	0	0.00	NA	5156.68
Goose Headwater 106	9603	21.5	3	4	High Quality	High Quality	5795	256	522	354.18	NA	6266.12
Goose Headwater Lower DD	3265	16.8	3	4	High Quality	High Quality	773	193	466	53.99	NA	2457.27
Goose Headwater Upper DD	5938	18.7	5	6	High Quality	High Quality	4022	294	175	166.94	NA	4770

Appendix A: Characteristics of the 40 Goose Creek Subwatersheds												
Subwatershed	**Area (ac)**	**Mapped Perennial Stream Miles**	**Current Impervious %**	**Future Impervious %**	**Current Management Category**	**Future Management Category**	**Estimated Forest Area (ac)**	**Forested Streamside (ac)**	**Conservation Easements (ac)**	**Forested Conservation Easements (ac)**	**NWI Weltand Area (ac)**	**Developable Area (ac)**
Main Goose DD 101	6592	19.3	6	21	Rural Impacted	Rural Impacted	3753	217	239	169.31	1753	3498
Main Goose DD 102	10416	30.4	4	7	High Quality	High Quality	4815	338	1828	906.11	325	5039
Main Goose DD 103	6397	18.6	3	4	High Quality	High Quality	3433	364	953	528.14	62	3610
Main Goose DD 104	11062	33.1	6	7	Rural Impacted	Rural Impacted	3720	475	2716	716.10	NA	5662
Main Goose DD 105	9580	35.9	4	4	High Quality	High Quality	2025	109	4220	748.71	102	4431
North Fork 101	8130	21.5	6	10	High Quality	High Quality	2134	189	494	150.59	89	4132
North Fork 102	6824	18.4	5	9	Rural Impacted	Rural Impacted	2888	178	461	172.19	263	3060
North Fork Lower DD	5623	15.5	4	6	Rural Impacted	Rural Impacted	2096	227	1149	430.51	157	1737
North Fork Upper DD	6049	16.3	7	11	Rural Impacted	Urban Impacted	1208	136	357	55.76	98	2977
Panther Skin 101	5880	19.1	3	5	High Quality	High Quality	2799	204	1937	668.47	NA	2496
Panther Skin 102	7159	28.0	4	5	High Quality	High Quality	3175	311	633	111.24	NA	4959
Panther Skin DD	5396	19.7	3	4	High Quality	High Quality	1017	192	2451	310.70	NA	2349
Sycolin 101	6637	17.9	5	8	Rural Impacted	Rural Impacted	2131	126	505	174.38	179	3026
Sycolin DD	4322	10.9	6	16	High Quality	Urban Impacted	1810	125	0	0.00	118	2466
Tuscarora 101	3013	7.6	5	8	High Quality	High Quality	1400	75	0	0.00	30	1209
Tuscarora Lower DD	3024	8.5	15	36	Urban Impacted	Non-Supporting	994	83	10	3.00	129	582
Tuscarora Upper DD	3187	9.5	22	34	Urban Impacted	Non-Supporting	942	86	69	47.51	35	639

Appendix B: Favorable Rural Watershed Quality Points

Subwatershed ID	>48% Forest 1 pt	>25% Conservation Easements 1 pt	>25% Conservation Easements and >50% of that is Forest 1 pt	>60% Forested Streamside	Total
Beaverdam Creek 101					0
Beaverdam Creek 102		1			1
Beaverdam Crk Low DD				1	1
Beaverdam Crk Up DD				1	1
Beaverdam Reservoir	1				1
Butchers Branch 101					0
Butchers Branch DD					0
Cromwells 101		1			1
Cromwells DD		1		1	2
Hungry Run	1	1	1		3
Little River 101					0
Little River 102	1	1	1	1	4
Little River 103		1		1	2
Little River Lower DD	1				1
Little River Upper DD		1		1	2
Goose Headwater 101					0
Goose Headwater 102					0
Goose Headwater 103					0
Goose Headwater 104	1				1
Goose Headwater 105	1			1	2
Goose Headwater 106	1				1
Goose Headwater Lower DD					0
Goose Headwater Upper DD	1			1	2
Main Goose DD 101	1				1
Main Goose DD 102					0
Main Goose DD 103				1	1
Main Goose DD 104				1	1
Main Goose DD 105		1			1
North Fork 101					0
North Fork 102					0
North Fork Lower DD				1	1
North Fork Upper DD					0
Panther Skin 101	1	1			2
Panther Skin 102					0
Panther Skin DD		1			1
Sycolin 101					0
Sycolin DD					0
Tuscarora 101					0
Tuscarora Lower DD*					0
Tuscarora Upper DD					0

*The management category of this subwatershed was not increased because the monitoring data confirmed its "Urban Impacted" status.

Appendix C: Unfavorable Rural Watershed Quality Points												
Subwatershed ID	**Designated Impaired Waters** 1 pt	**Discharges into Adjacent Impaired? Y/N**	**High Septic System Density** 1 pt, but if Adj to and/or Impaired, then 3 pt	**High Cattle Density** 1pt	**High Horse Density** 1pt	**High Animal Bacteria** 1pt, but if Adj to and/or Impaired then 3pt	**2 or more NPS Areas** 1 pt	**<1% Wetlands** 1pt	**WQ Violations: Temp, DO, Turbidity** 1 pt	**Fish Barriers (Dams)** 1pt	**Fair to Poor I BI** 1 pt	**Total**
Beaverdam Creek 101					1				NA		1	2
Beaverdam Creek 102									NA		1	1
Beaverdam Crk Low DD	1		3	1	1	3			1	1	1	12
Beaverdam Crk Up DD		Y			1			1			NA	2
Beaverdam Reservoir		Y							NA	1	NA	1
Butchers Branch 101			1		1				NA		1	3
Butchers Branch DD		Y	3		1			1			1	6
Cromwells 101		Y			1				NA		1	2
Cromwells DD	1				1						NA	2
Hungry Run								NA	NA		1	1
Little River 101		Y	3						NA			3
Little River 102								NA	NA		NA	0
Little River 103							1	NA	NA		1	2
Little River Lower DD	1		3					NA	1		1	6
Little River Upper DD		Y						NA			1	1
Goose Headwater 101				1		1		NA	NA		1	3
Goose Headwater 102				1		1		NA	NA		1	3
Goose Headwater 103				1		1		NA	NA		NA	2
Goose Headwater 104								NA	NA		1	1
Goose Headwater 105								NA	NA		NA	0
Goose Headwater 106								NA	NA	1	1	2
Goose Headwater Lower DD				1		1		NA	NA			2
Goose Headwater Upper DD								NA	NA		1	1
Main Goose DD 101	1								1	1	1	4
Main Goose DD 102		Y							NA			0
Main Goose DD 103								1			NA	1
Main Goose DD 104				1	1	1	1	NA	NA		NA	4
Main Goose DD 105				1		1			NA			2
North Fork 101			1								1	2
North Fork 102		Y	3		1				NA	1	1	6
North Fork Lower DD	1		3							1	1	6
North Fork Upper DD	1	Y	3		1		1				1	7
Panther Skin 101				1		1		NA	NA		1	3
Panther Skin 102				1		1		NA	NA		NA	2
Panther Skin DD				1		1		NA	NA			2
Sycolin 101	1		3								1	5
Sycolin DD		Y							1		1	2
Tuscarora 101		Y						1	NA		1	2
Tuscarora Lower DD*							1		1		1	3
Tuscarora Upper DD									NA		1	1

Appendix D: High Quality Subwatersheds Analysis

Note: Includes only watersheds classified as future high quality (not rural impacted) and that do not contain impaired waters

Subwatershed ID	Current Mgt Category	Excellent to Good IBI 1 pt	>48% Forest 1 pt	>25% Conservation Easements 1 pt	>25% Conservation Easements and >50% of that is Forest 1 pt	>60% Forested Streamside	Presence of Significant Places	High Quality Points	Notes from Unfavorable Factors (See Appendix C)
Beaverdam Creek 101	High Quality							0	
Beaverdam Creek 102	High Quality			1				1	
Beaverdam Crk Up DD	High Quality					1		1	
Beaverdam Reservoir	High Quality		1					1	1 unfavorable pt from fish barrier
Cromwells 101	High Quality			1				1	
Hungry Run	High Quality		1	1	1			3	1 unfavorable pt from bad IBI
Little River 102	High Quality		1	1	1	1		4	no unfavorable pts
Little River 103	High Quality			1		1		2	2 unfavorable - IBI and unusual NPS
Little River Upper DD	High Quality			1		1		2	2 unfavorable - IBI and unusual NPS
Goose Headwater 103	High Quality							0	
Goose Headwater 104	High Quality		1					1	
Goose Headwater 105	High Quality	1	1			1		3	no unfavorable pts
Goose Headwater 106	High Quality	1	1					2	2 unfavorable - fish barriers & IBI
Goose Headwater Lower DD	High Quality	1						1	
Goose Headwater Upper DD	High Quality	1	1			1		3	one unfavorable IBI
Main Goose DD 102	High Quality	1					1	2	no unfavorable pts
Main Goose DD 103	High Quality					1		1	
Main Goose DD 105	High Quality			1				1	
Panther Skin 101	High Quality		1	1				2	3 unfavorable: cattle, bacteria, IBI
Panther Skin 102	High Quality							0	
Sycolin DD	High Quality							0	
Tuscarora 101	High Quality							0	