Using Conservation Easements as a Water Quality Protection Tool in the Goose Creek Watershed, Northern Virginia

Master's Project

by
Tracy Hamm

Dr. Dean Urban, Advisor
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ABSTRACT

Goose Creek was placed on Virginia's list of impaired waters in 1998 for its failure to attain the standards for both primary contact use and aquatic life use due to fecal coliform and sedimentation, respectively. The Middle Goose Creek Subwatershed is dominated by large parcels and is covered by a mosaic of forest and agriculture. It is also immediately upstream of the rapid development pressures of Loudoun County, Va. One particularly comprehensive tool for encouraging and implementing water quality protection is to place a parcel under conservation easement. The objectives of this project are as follows: (1) develop and utilize a prioritization scheme for targeting parcels to be placed under conservation easements, (2) compare the existing easements with this prioritization, and (3) make management recommendations as to which priority parcels remain to be targeted for easement and which existing easements need to be strengthened.

The prioritization scheme is based on four metrics: runoff potential, buffer potential, forested streambank, and agricultural streambank. The top five highest ranking parcels of each metric were overlaid to produce a total of 14 priority parcels. Despite 43% of the land in this subwatershed already being under conservation easements, only six of the 14 priority parcels were already under easement.
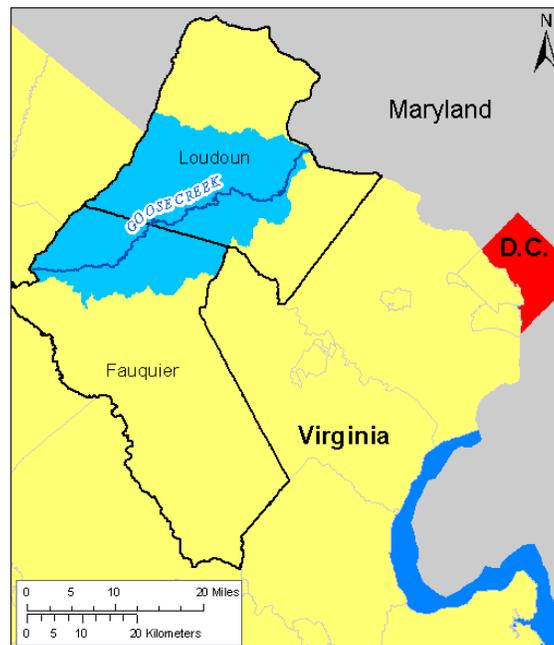
My recommendations are to target priority parcels not yet under conservation easement to be placed under easement and to amend existing easements on priority parcels to strengthen riparian buffer requirements. I suggest first focusing restoration efforts on those "source" parcels identified as having the greatest potential to contribute sediment and fecal coliform bacteria to Goose Creek, then shifting to preserving those "sink" parcels which have the greatest potential to decrease levels of sediment and fecal coliform. I have thus developed a flexible framework for prioritizing a landscape with the goal of maximizing water quality and using conservation easements as the tool to accomplish this protection. This methodology can be used by organizations with limited resources to focus efforts most efficiently.

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INTRODUCTION

Goose Creek has its headwaters in the heavily forested Blue Ridge Mountains in rural Fauquier County, Virginia. Although Interstate 66 runs through northern Fauquier and is roughly an hour's drive from Washington, D.C., approximately 90% of the land cover is either agriculture (49%) or forest (41%). Goose Creek next meanders into Loudoun County, Virginia, the western part of which is dominated by a similar agricultural and forested landscape. The eastern part of Loudoun, however, is arguably included in the Washington D.C. metropolitan area. It contains most of Dulles International Airport and has warranted the county a growth rate of almost 60% between 2000 and 2006 (US Census Bureau 2007). Goose Creek is dammed here to create a 300 million gallon drinking water reservoir (Hosaka 1999) before it flows into the Potomac River (Figure 1).

Fig. 1 Location of Goose Creek watershed (light blue) in Loudoun and Fauquier Counties, Virginia (yellow), approximately 25 miles upstream from Washington D.C. (red).

In addition to providing drinking water to the City of Fairfax, Virginia and some Loudoun suburbs, Goose Creek and its tributaries provide a variety of services. The creek itself plays host to an array of algae, invertebrates, mollusks, and fish, many of which are designated as Federal or State Species of Concern (Virginia Department of Game and Inland Fisheries 2007). Freshwater springs and streams provide drinking water for cattle farms. Riparian areas provide unique wildlife habitat and serve as a water filtration system.

In 1998, Goose Creek failed to achieve the standards for both primary contact use and aquatic life use (EPA 2007). The reason for the former was a level of fecal coliform bacteria which violated Virginia's water quality criteria. While fecal coliform itself is not pathogenic, elevated levels indicate elevated risk of the presence of pathogens from the associated fecal material. According to EPA models used in the decision rationale, pastures were the greatest source of fecal coliform bacteria in the water, followed by direct deposition from cattle standing in streams. These two sources account for 99% of the total estimated loading (61% from pastures and 38% from in-stream cattle; EPA 2007).

The creek was also unable to attain the general standard for aquatic life use. Because more sediment-tolerant species of macroinvertebrates were identified in Goose Creek than in a reference watershed, sediment was identified as the stressor of concern. Models indicate that streambank erosion contributes three times more than the next leading source of sediment (31,860 tons/yr). Pasture and cropland are the other two main contributors at 9,930 tons/yr and 1,166 tons/yr respectively (EPA 2007).

Because of these violations of water quality standards, Goose Creek was listed as impaired on Virginia's 303(d) list. The Clean Water Act requires that Total Maximum Daily Loads (TMDLs) be established for those water bodies identified as impaired by a state. Thus

Virginia's Department of Environmental Quality (DEQ) submitted and received approval for TMDLs for both sediment and fecal coliform bacteria, respectively (EPA 2007).

EPA model predictions are that no more than 10% of the samples collected will violate the fecal coliform and *E. coli* criteria after cattle are removed from the stream, failing septic systems are repaired, and there is a 50% reduction of bacteria loading from pastures. The Decision Rationale for the aquatic life use TMDL states that these same practices will also limit the annual sediment load into the impaired waters (EPA 2007).

Applied research on cattle exclusion from streams supports these statements. A study by Sheffield et al. (1997) observed a decrease in streambank erosion (by 77%) and in levels of fecal coliform bacteria simply by installing an off-stream water source. A similar study in which the stream was actually fenced off demonstrated a 66% decrease in fecal coliform levels downstream of the pasture. Prior to fencing, the fecal coliform levels downstream were measured to be 300% higher than upstream of the pasture. Significant reductions in turbidity and suspended sediment levels were also observed (Line 2003). Thus it seems that cattle exclusion from streams is indeed an efficient way to reduce both sedimentation and bacterial loading.

Vegetated riparian buffers are another method generally used to reduce such issues. It seems to be most effective at reducing sedimentation and erosion. Beeson and Doyle (1995) found that stream bends without riparian vegetation were nearly five times as likely as vegetated bends to have undergone detectable erosion during the major floods in a particular year. Further, they found that major bank erosion was 30 times more prevalent on non-vegetated bends as on vegetated bends. In terms of what type of vegetation specifically is most effective, woody riparian vegetation is best at reducing streambank erosion by fluvial entrainment (Wynn et al. 2004). Further reasoning for preferring a forested buffer/streambank is that a forested riparian

buffer is effective at removing fecal coliform (Brenner et al. 1991). It should be noted, however, that some other studies have failed to provide additional support for this, especially in the case of storm events (Parkyn et al. 2003, Sovell et al. 2004, Collins et al. 2005). Finally, it should be noted that having a forested buffer provides for a healthy in-stream ecosystem. Not only does it reduce erosion as mentioned above, it provides reduced stream temperatures by shading the stream and providing a source of large woody debris and other organic matter (Richards and Host 1994, Wenger 1999).

The challenge faced by Virginia's DEQ and Department of Conservation and Recreation and all those organizations and individuals interested in improving—or at least maintaining—the water quality of Goose Creek is: How can private landowners in the watershed be motivated to adopt practices towards this goal?

How can we protect a natural resource that flows through two different counties as well as a variety of land covers from cattle farms to subdivisions under construction? In this part of northern Virginia, only a miniscule percentage of land is publicly owned; therefore, environmental stewardship of private lands is essential to preserving acceptable water quality standards. This is often done through tax incentive programs such as Conservation Reserve Enhancement Programs and agricultural best management practices (BMPs). Some landowners may find taking advantage of all the incentives provided by the various programs to be intimidating due to the fact that each program has its own requirements and paperwork necessary to qualify.
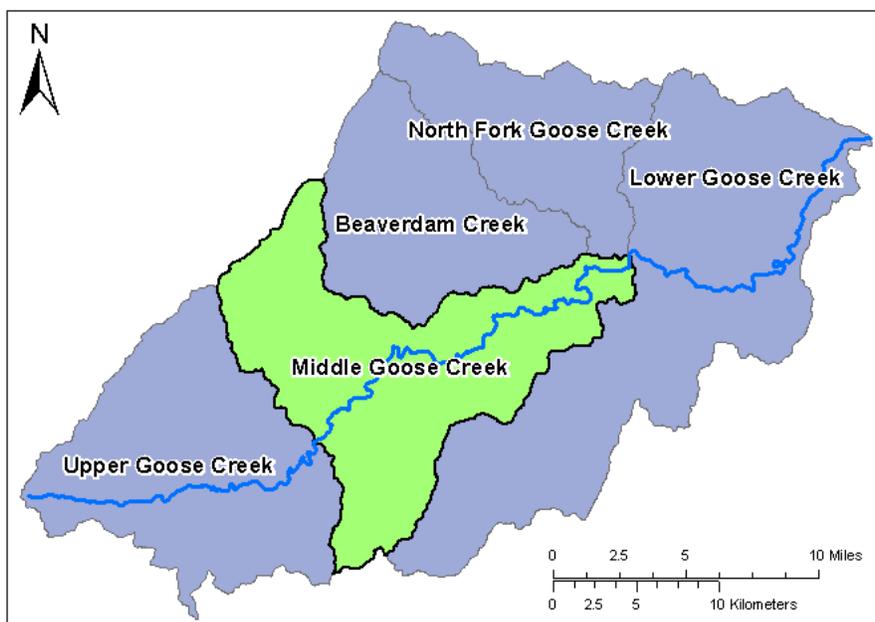
A more comprehensive approach—a "one-stop-shop" approach to conservation—is to put the entire parcel under a conservation easement. Conservation easements offer tax-based incentives to private landowners and afford varying degrees of environmental protection to the

parcels placed under easement. They often include such restrictions on land use as requiring the use of BMPs and the establishment of riparian buffers. Additionally, in a vast majority of cases, such easements are intended to restrict land use on the parcel "in perpetuity." This means that restrictions on land development and land use should apply to every subsequent landowner.

Study Area

Figure 2 outlines the subwatersheds within the Goose Creek basin. The Lower Goose Creek subwatershed contains the Loudoun County seat of Leesburg and is undergoing the most rapid development of any of the Goose Creek subwatersheds. For the purpose of this study, we will assume that the high levels of development that have already taken place make this subwatershed a poor candidate for a conservation-based approach to water quality protection.

The Middle Goose Creek subwatershed (highlighted in green in Figure 2) straddles the Loudoun-Fauquier border and is still relatively undeveloped; as such, its conservation potential is relatively high. It also contains a relatively high percentage (43%) of land already under easement, which means that a comparison between what might be most useful to be preserved and what is actually being preserved should be very interesting. Also, the Piedmont Environmental Council (PEC)—a local non-profit organization which initiates most easements in that area—and the Virginia Outdoors Foundation (VOF)—a state agency which holds most easements in that area—are interested in an evaluation of how the easements are providing watershed protection.

Fig. 2 The subwatersheds within the Goose Creek basin, highlighting the Middle Goose Creek subwatershed in green.

Objectives

Specifically, the objectives for this study are as follows: (1) Develop and demonstrate a prioritization scheme to determine which parcels should be placed under easement to maximize protection and/or improvement of water quality, based on each parcel's potential to serve as a source or sink of fecal coliform and/or sediment; (2) compare the existing easements with this prioritization; and (3) make management recommendation as to which parcels remain to be targeted for easement and which existing easements need to be strengthened (e.g. to include a riparian buffer or to specify livestock exclusion). In doing so, I will provide the PEC and VOF with concrete suggestions for how to target their limited resources towards protecting the water quality of Goose Creek. The methods outlined below will also serve as a template that can be used in other watersheds for similar purposes.

METHODS

Background

As discussed above, riparian buffers offer a variety of services including filtration of sediment and fecal coliform (Brenner et al. 1991, Beeson and Doyle 1995) . Forested buffers in particular are effective buffers because of the way in which they are able to most effectively retain sediment (Wynn et al. 2004) and provide for a healthy in-stream ecosystem (Richards and Host 1664, Wenger 1999).

To narrow the focus of this study on a particular environmental issue, I targeted the water quality impairments of the Goose Creek watershed addressed by TMDLs. These same methods are well-suited for adaptation for other non-point source pollutants associated with agricultural land use such as nutrients (specifically nitrogen and phosphate).

The utility of geographic information systems (GIS) has been well-documented and accepted as a tool for estimating land use/land cover impacts on water quality (Stuebe and Johnston 1990, Richards and Host 1994, Baker et al 2001). A recent study by Baker et al (2006) compared the traditional constrained distance method of quantifying potential nutrient interception by riparian buffers with flow-path and unconstrained methods. A constrained distance analysis takes into account only the land cover/land use within a certain Euclidean distance of a stream; in contrast, an unconstrained analysis includes all relevant land cover/land use contiguous with the stream regardless of distance. Unconstrained distance analysis may do a better job of describing the functional landscape of a watershed than a constrained distance analysis, but neither of these include topographical considerations. A "flow-path" analysis includes the use of the hydrology tools developed by Environmental Systems Research Institute, Inc. (ESRI) for GIS which calculate a flow path from a digital elevation model. Baker et al (2006)

found the latter metrics provided greater detail, interpretability and flexibility than the fixed-distance approach.

This study focused on describing the connectivity of cropland to streams through riparian buffers because croplands have been identified as a major source of stream nutrients (Baker et al. 2006). Despite the fact that the ability of vegetated buffers to reduce fecal coliform loading is in question (especially in the case of storm events; Collins et al. 2005), fecal coliform half-lives can be as short as 11 days where sedimentation is reduced (Sovell et al. 2004). The ability of vegetated buffers to reduce sedimentation is not in question (Richards and Host 1994, Wenger 1999); therefore, I expect vegetated buffers to provide some level of reduction in fecal coliform runoff from agricultural land uses while also providing definite reductions in sedimentations from the same land uses. I used an unconstrained flow-path distance analysis adapted from Baker et al (2006) to assign a buffering potential metric to each parcel. This metric quantifies a parcel's ability to reduce fecal coliform and sedimentation from agricultural land uses, which are the secondary contributors of both pollutants (EPA 2007). Since similar methods can be used to determine the amount of source cells flowing directly into a stream (i.e. without flowing through a buffer such as forest), a metric measuring the potential for unbuffered runoff was assigned to parcels as well.

The primary contributor of sediment to the streams is streambank erosion (EPA 2007); therefore, a metric measuring the length of forested streambank will be assigned to each parcel. I chose to restrict this metric to forest instead of vegetation for several reasons. First, agricultural streambanks as classified by the NLCD may be heavily eroded by livestock or consist only of grasses. While a grassy streambank is preferred to a bare streambank, forested streambanks have been shown to provide the greatest benefits to the in-stream ecosystems and are easily

distinguished from agricultural land use in the NLCD. Finally, it should be noted that since we are using remotely sensed data with a spatial resolution of 30 meters by 30 meters, some forested streambanks may not be detected. A visual in situ examination would be more accurate but is too time-consuming to be considered for a study of this scope.

The primary contributor of fecal coliform to the steams is direct deposition by cattle (EPA 2007); therefore, a metric measuring the length of agricultural streambank will be assigned to each parcel to reflect the potential for in-stream cattle. Since the NLCD groups pasture and hay land uses as one category which was used for this metric, again an in situ observation of the existence of livestock and/or fencing and/or alternative drinking sources would make this a more accurate assessment. Unfortunately, these site visits are outside the scope of this study.

Rather than simply combine all four metrics described above into a single index, they will be considered separately and then overlayed to show areas of both conservation and restoration priorities. For instance, parcels with high potential for runoff and a high length of agricultural streambank will be a high priority for restoration efforts, and conversely, parcels with the highest potential for buffering and with the longest forested streambanks will be a conservation priority.

Data

Most GIS data needed for this study are available to the public on government servers. This includes the following layers: the high resolution version of the National Hydrology Dataset (available at http://nhd.usgs.gov/) describes the surface water features on a 1:100,000 scale; National Elevation Data (available on the USGS Seamless Server: http://seamless.usgs.gov/) which is available at a 1/3 arc second resolution in this area; the National Land Cover Dataset

(NLCD) is also available on the USGS Seamless Server at a 30 meter by 30 meter resolution; and Goose Creek subwatersheds (14-digit Hydrologic Unit Code, available from http://water.usgs.gov/GIS/huc.html).

A geospatial parcel layer was provided by the Piedmont Environmental Council (PEC). The PEC also has a database outlining the land use restrictions imposed on each parcel by its respective easement. For the most part, the parcels under conservation easement are identified by a "PECID" in their GIS easement layer, which can then be matched to the Excel database. Unfortunately, the database was started recently (2004) and has never been updated with all the details of the older easements. Thus, in order to complete the database with the relevant specifications, the 270 easements in the Middle Goose Creek subwatershed were researched at the Fauquier and Loudoun land records offices. The details to be recorded for this study are as follows: presence of riparian buffer, size of riparian buffer, and type of riparian buffer (i.e. requirements for vegetation and/or livestock exclusion).

Analysis

First, the landscape was classified by land use (according to the NLCD 2001) as either sediment and bacteria source, sink (i.e. buffer) or "other." This last classification actually represented open water and was included in the stream raster where it was contiguous. Development and agricultural land uses were classified as sources. Forests and wetlands were classified as sinks. The sink land uses are also referred to as buffers.

Next, the parcels were assigned the metrics described earlier: buffer potential, runoff potential, length of forested streambank, and length of agricultural streambank. The method for calculating buffer level was adapted from Baker et al.'s (2006) flow path method. All GIS

analyses were conducted using ESRI's ArcGIS 9.2, and much of the analysis involves the use of

the hydrology tools included in the Spatial Analyst extension. The digital elevation model from

the National Elevation Dataset (USGS) was filled to remove any imperfections in the data layer

(it removes those areas with an unspecified drainage direction). This filled elevation layer was

then used to establish the layer defining the direction of water flow in one of eight possible

directions. This layer was then used to define the accumulation of each cell according to the

number of upslope cells for the Middle Goose Creek subwatershed. The values in this raster were

compared with the "NHDflowline" shapefile of the high resolution National Hydrography

Dataset to select a threshold for declaration of "stream" pixels. The result was that pixels

accumulating a value of more than 700 were designated as streams (this gave us a slightly more

conservative measure of stream networks than the NHD).

The upstream Flow Length tool also used the flow direction raster to calculate the

number of cells upstream to a particular source (in this case, any other land use classification).

For instance, a cell at the edge of a stream at the bottom of a forested slope was assigned a value

equal to the total number of cells that a drop of water would have to travel through from the edge

of that forest patch.

The upstream flow length for the entire subwatershed was compared to flow lengths

weighted by either a source or sink binary layer (where the source or sink was identified as 1 and

all other land use was represented as 0) to identify the contiguous upland source/sink pixels (i.e.

those pixels that flow contiguously through the same classification of land use). Pixels with a

flow length of zero were assumed to be crests of hills and were masked out in an effort to isolate

the flow contiguous with the stream. As the final step to ensure that those patches were

contiguous with the stream, a cost distance from the stream was calculated. The resulting layer

was used to mask out those patches that were not contiguous with the stream. The remaining

flow length values were set to one and used as a source (or sink) level metric. Scripts detailing

these methods are provided separately (Appendix A).

The last two metrics were calculated simply as the number of pixels classified as streams

which overlap with either agriculture or forest cover as identified in the NLCD.

The process of placing a parcel under easement can be a tedious one and some

landowners will not be receptive to the idea despite tax incentives. Given that the Virginia

Outdoors Foundation generally accepts between 10 to 15 new easements in this subwatershed

per year (from 2000 to 2005), I decided that overlaying the top five parcels for each metric

would serve as the prioritization scheme. A maximum of 20 parcels would result from this

scheme.

Once I developed my prioritization scheme, I compared existing easements with the

prioritization and evaluate the effectiveness of current easements and any strategy that may be

behind their establishment. I also formulated management recommendations for the near future.

Which easements remain to be placed under easement? We can also identify which of these

easements need amendments to fulfill their potential for conservation (e.g. should it be amended

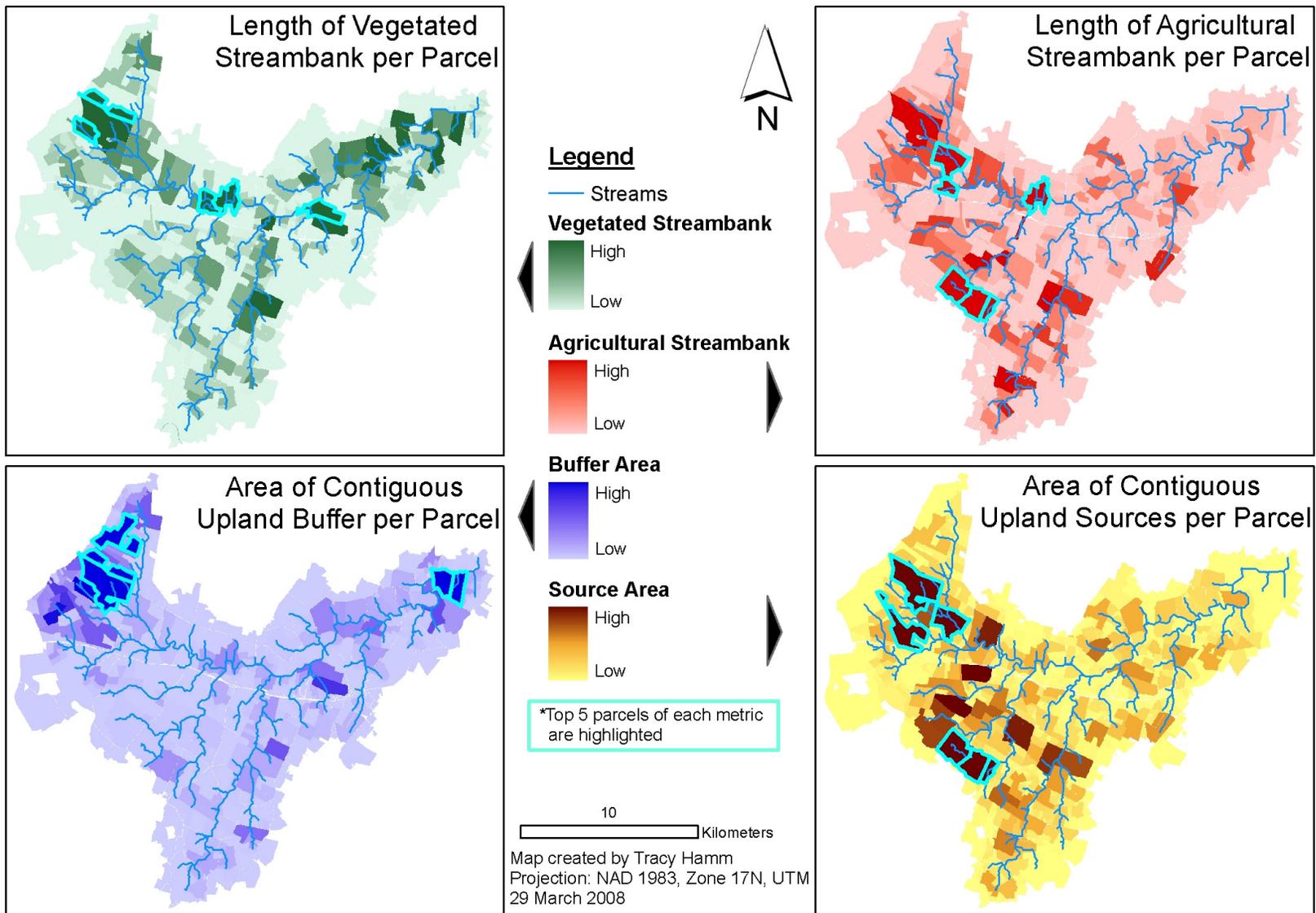to include a specification of livestock exclusion?).

RESULTS

Priority Parcels

By joining the sum of each metric (agricultural streambank, forested streambank, runoff

potential, and buffer potential) to the parcel layer, I was able to easily extract and overlay the top

five parcels of each metric. The parcels are identified here by the feature identification (FID) as
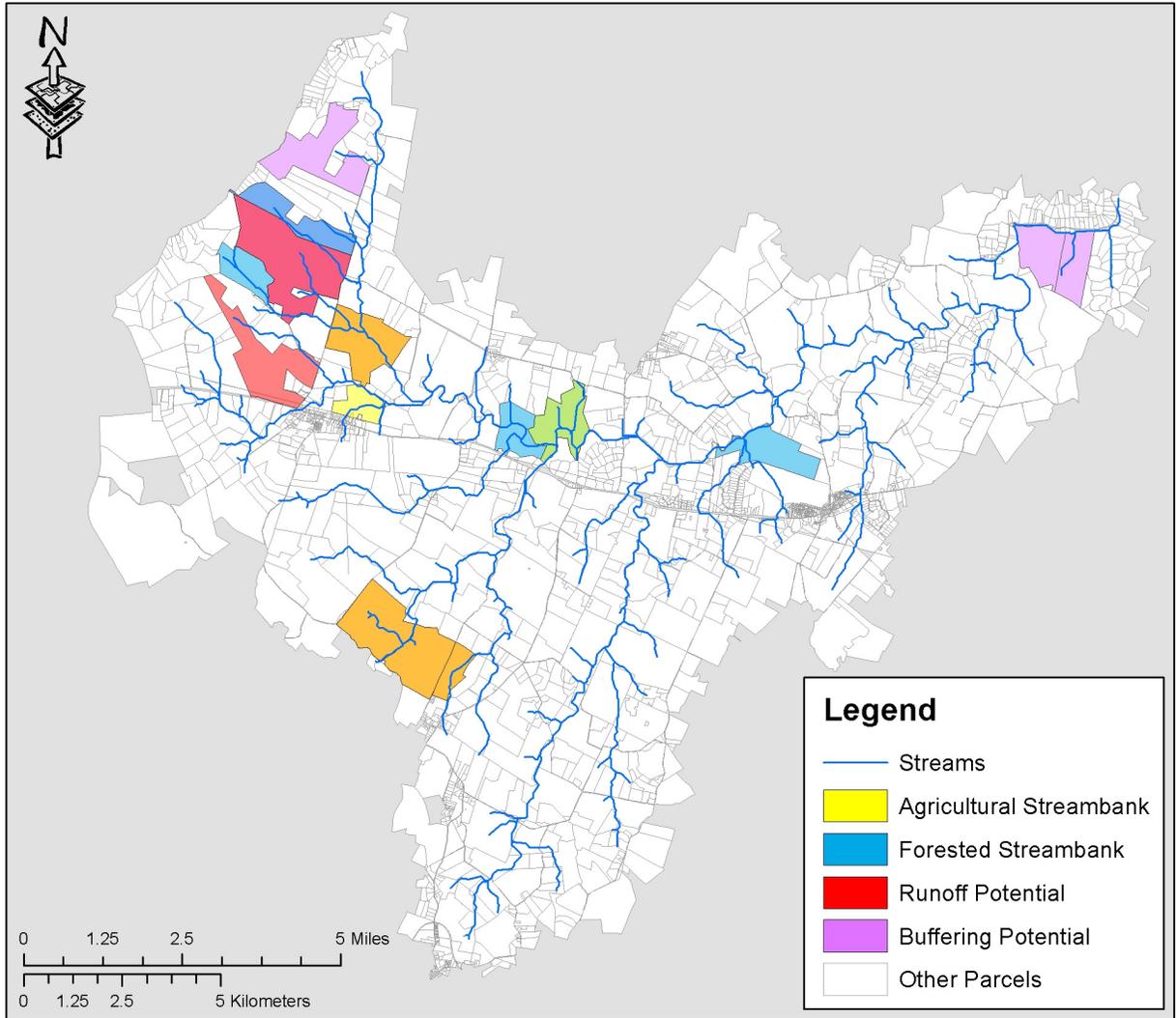
assigned in ArcGIS. I chose to use this because of both the inconsistent availability of a more

accurate identifier such as a geographic personal identification number (GPIN) and in order to

maintain anonymity of land ownership. These top five parcels per metric are listed below in

Table 1 and are displayed spatially in Figure 3. Note that there is some overlap between metrics

which leads to 14 priority parcels, visualized in Figure 4. The overlap is shown on the map by

the combination of colors. For instance, the three parcels which are in the top five of agricultural

streambank and runoff potential (1915, 1920, and 323) are displayed in orange.

Table 1 The top five parcels (identified by FID) of each metric used for conservation scheme formation.

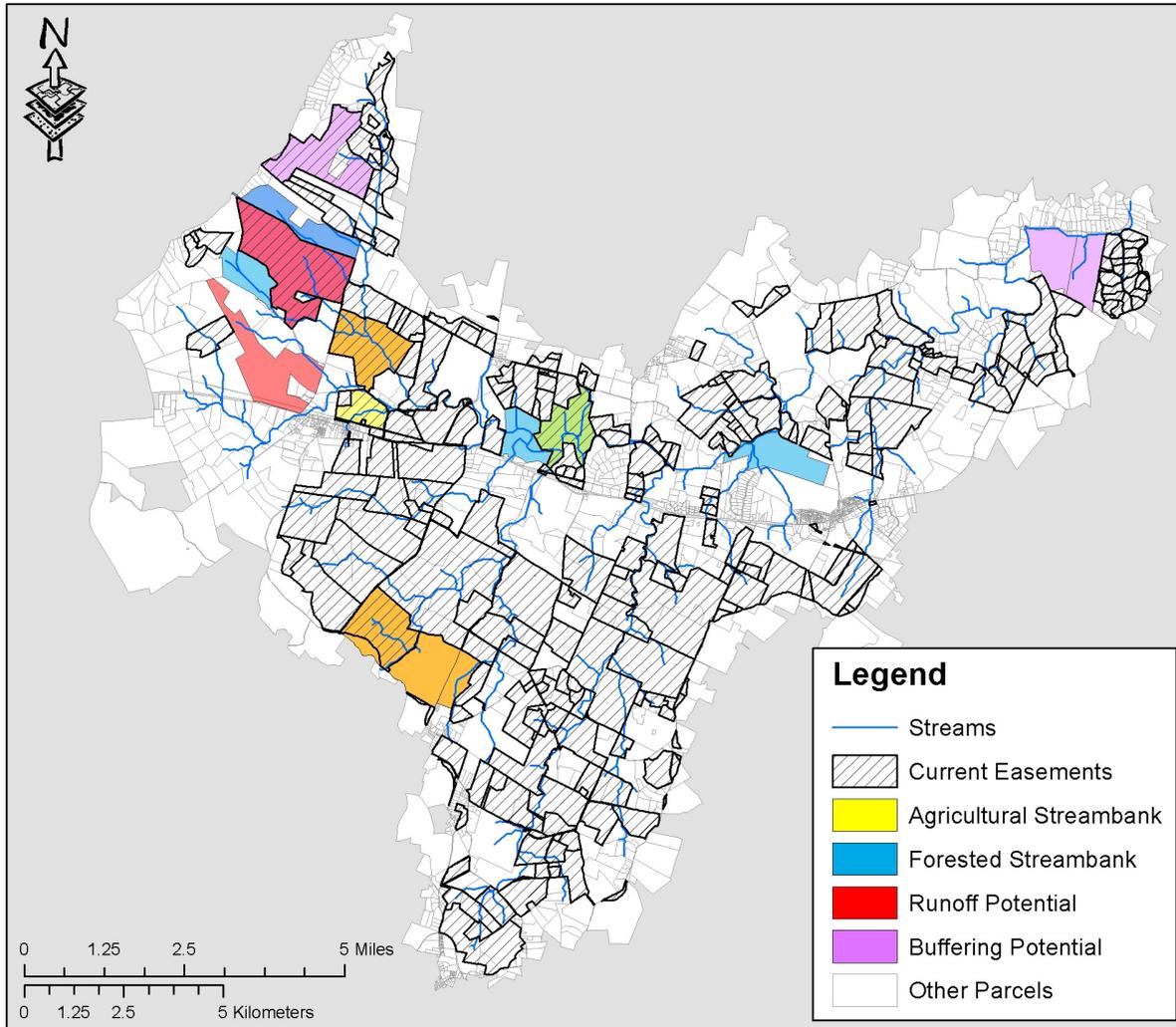| Rank	Metric			
	Agricultural Streambank (source)	**Forested Streambank** (sink)	**Runoff Potential** (source)	**Buffer Potential** (sink)
1	580	633	79	44
2	323	698	1920	79
3	1915	580	240	178
4	575	168	1915	211
5	1920	74	323	74

Fig. 3 Components of the prioritization scheme, highlighting the top five ranking parcels for each component.

Fig. 4 Priority parcels as identified by high values of one or more metrics (agricultural streambank, forested streambank, runoff potential, and/or buffering potential). Colors are displayed as 50% transparent so that overlap of metrics can be visualized (e.g. orange parcels were in the top five of both agricultural streambank and runoff potential).

Comparison to Existing Conservation Easements

As is apparent in Figure 5, approximately 43% of this landscape is already under conservation easement (represented by cross-hatch). Even with such a high proportion of land already protected in some degree by easement, only six of our 14 priority parcels are already under easement. This leaves eight more priority parcels to be targeted for easement to maximize protection of the water quality in this particular subwatershed.

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Fig. 5 Priority parcels colored as in Fig 4 overlayed with existing conservation easements. Inconsistencies in boundaries are due to the fact that the conservation easement parcels are from 2005; the general parcel layer is dated 2007.

DISCUSSION

Prioritization Method

When considering this prioritization scheme, one should keep in mind that these results

are based on assumptions about broad land use classifications derived from remotely sensed data

at a 30 meter by 30 meter resolution. Also there was an issue in ensuring that the land was indeed

contiguous on a flow path, which is discussed below. I would like to emphasize that this

prioritization is based on the *potential* of a parcel to serve as a sink or source of sediment and/or fecal coliform. Since the National Land Cover dataset identifies "Pasture/Hay" as a single classification, there those parcels that have been identified as having a high potential source value for fecal coliform, may in fact contribute none at all if it is not an actual pasture. The same issue applies to the agricultural streambank metric. If the "agriculture" is not livestock grazing, there is likely to be little to no contribution of fecal coliform from that parcel. Thus, the accuracy of this prioritization should be confirmed through speaking with the landowner or some other method which could more reliably report the actual land use occurring on each parcel.

While overall, this method does an admirable job of isolating those patches of land cover that are contiguous with the stream on an upland flow path, I was never able to prevent ArcMap from excluding the flow around the sides of hills. I had originally wanted to use the flow length as a weight to reflect that forest patches which are "buffering" for a longer flow length are more valuable; however, because I could not successfully isolate flows on the "back" sides of hills which flowed into agricultural land use, I used binary patches instead and assigned sums of pixels which were contiguous and, for the most part, upland of the streams I defined earlier. It is possible that if I had used a lesser flow accumulation to form my streams that the sections which I was trying to cut out of my analysis would likely flow into a perennial stream.

Given that a previous study found both unconstrained distance and flow-path analyses to provide greater detail, interpretability and flexibility than a fixed-distance approach (Baker 2006), my flow path methods should provide a much better picture of the way in which the landscape is functioning that using either a fixed-distance of unconstrained distance approach, despite my issue with the flow direction. These methods should also be relatively simple to reproduce in other watersheds since they only require parcel data (which can sometimes be acquired from a

local county government) and widely available elevation, hydrography, and land use/land cover data. It is quite possible that these same methods can be used for other non-point source pollutants such as nitrogen and phosphorus.
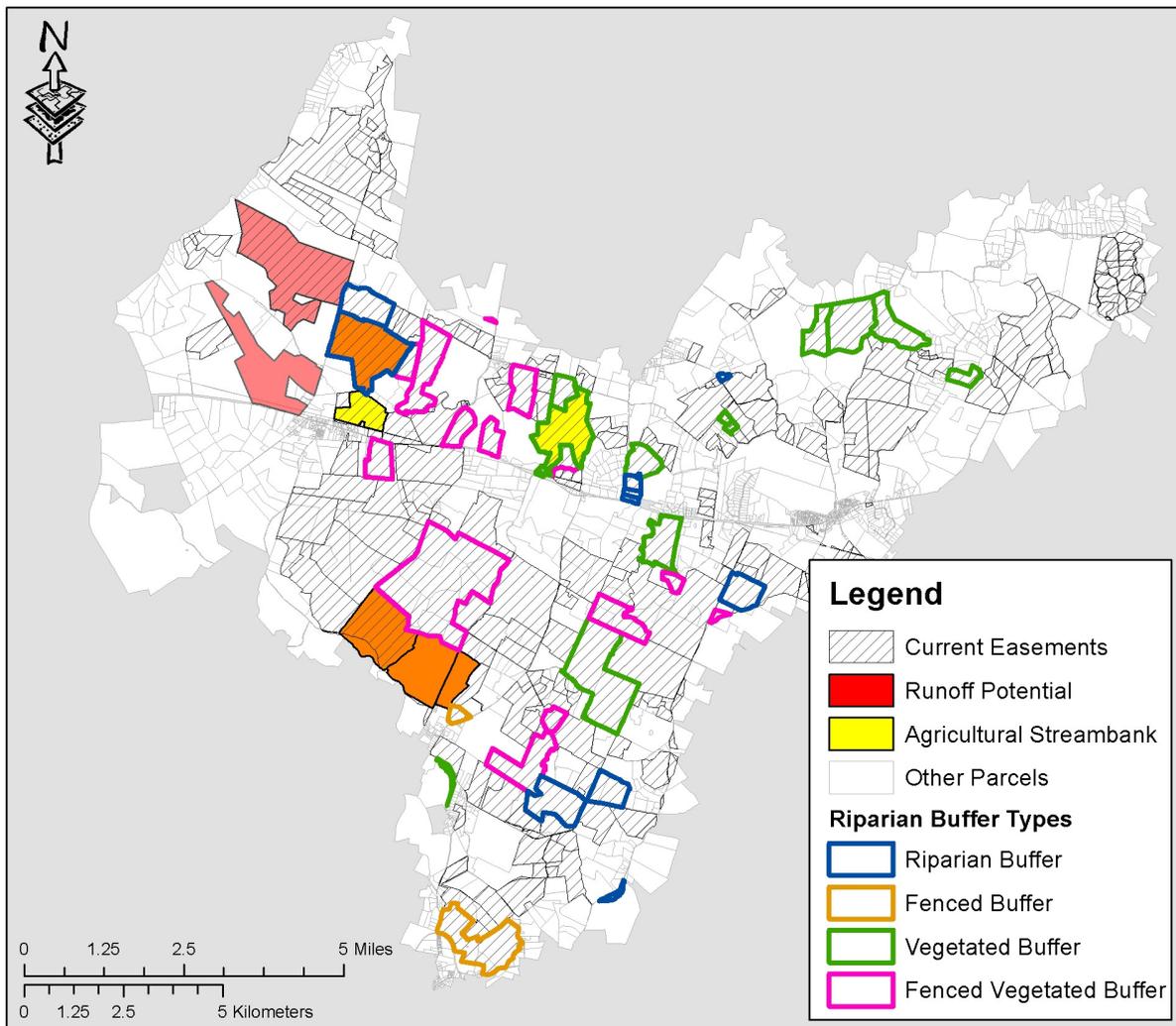
Recommendations

Despite the unusually heavy concentration of conservation easements already blanketing this landscape, the creek was originally listed as impaired for general contact use and aquatic life use in 1998 (EPA 2007) and, while there was some improvement in sedimentation levels as of 2002, the improvements were insufficient to warrant the de-listing of the creek (VA DEQ 2002). Because of this existing impairment, I suggest that the PEC focus its efforts on those parcels with the greatest potential to contribute fecal coliform and sediment to streams firsts in the hopes of improving water quality. Once this has been achieved, efforts can be redirected at ensuring maintenance of those parcels with the greatest potential to prevent sedimentation and fecal coliform runoff.

According to EPA models, removing cattle from streams and a 50% reduction in bacteria loading from pastures are two of the three components (the third being the repair of failing septic systems, which is outside the scope of this project) of reducing fecal coliform and e-coli bacteria to more acceptable levels. The Decision Rationale for the aquatic life use TMDL states that these same practices will also limit the annual sediment load into the impaired waters (EPA 2007). Thus I recommend that those parcels with the highest agricultural streambank and highest area of potential direct runoff be targeted for "restoration" efforts first.

Figure 6 shows these restoration targets in the same colors as in the combined prioritization results. It also shows where conservation easements already exist (as of 2005). The

colored outlines indicate the presence of some sort of riparian buffer specifications in the

easement. Those with the dark blue outline generally only specify no building within a certain

distance of streams on the property (the specified distance varies from easement to easement).

An orange outline specifies cattle exclusion, a green outline specifies a vegetated buffer, and a

pink outline indicates that both fencing and vegetation are required within a certain distance of

one or more streams on the property.

Fig. 6 Map illustrating those priority parcels which have the greatest potential to contribute fecal coliform and sediment to streams along with existing easements and their level of riparian buffer specifications.
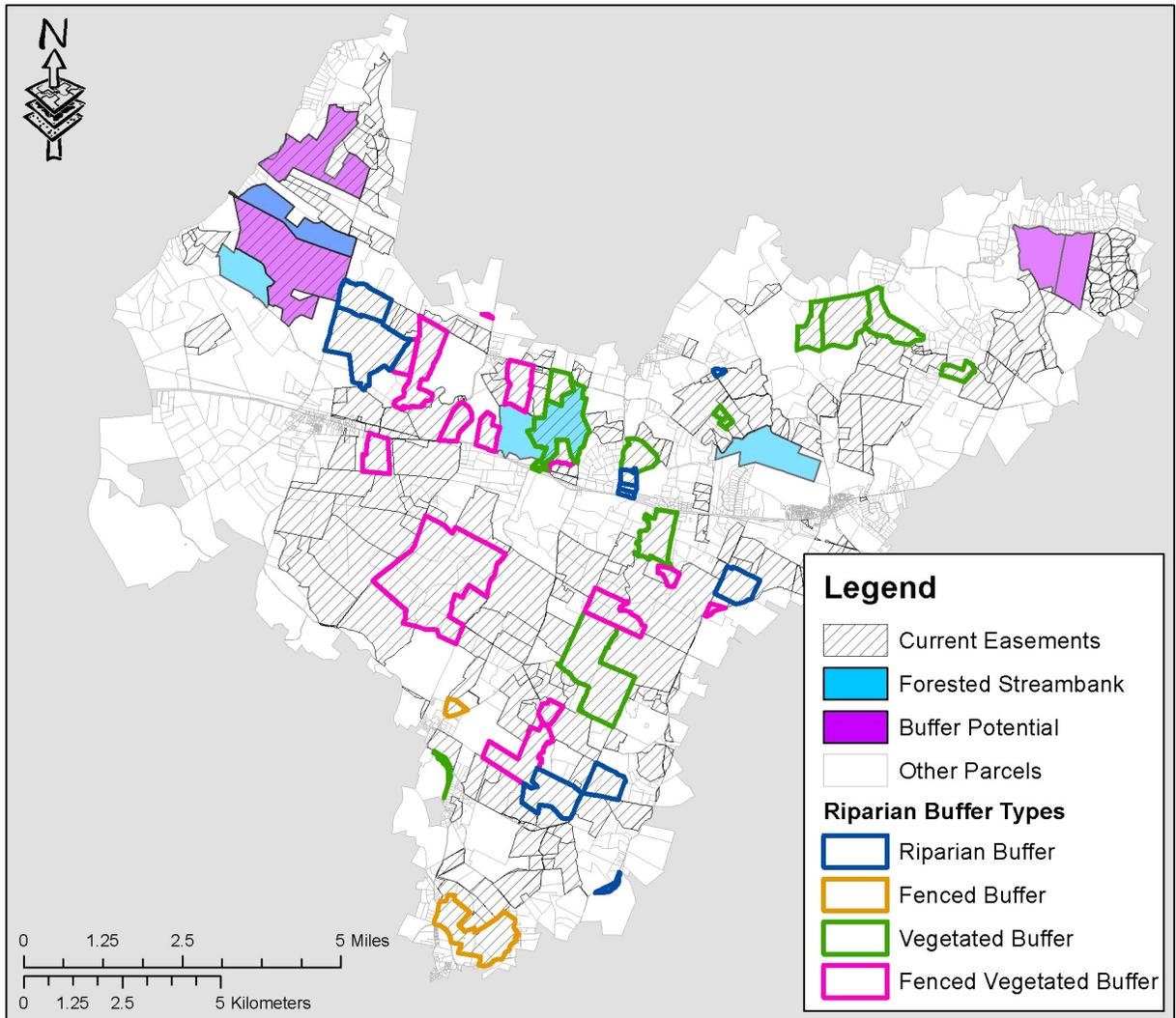
Only two of the seven parcels listed as potential sources are not yet under easement (FID 240 and 1920). Some effort should be made to see how this land is actually being used, i.e. is it all cattle pasture? If the parcels do indeed seem to be heavy contributors to fecal coliform and/or sediment, the landowners should be approached about placing an easement on their land.

It is fortunate that most of the identified priority parcels are already under easement because it is possible that the land is still under the same ownership that originally placed the easement on the property, and it is possible (though certainly not guaranteed) that the owner may be receptive to amendments to the easement. Parcels identified as 79, 575, and 1915 are currently under easement, but those easements do not require any sort of riparian buffer. Ideally, these easements would be amended to include both vegetation (preferably forests) and fencing requirements. Even if the land is not currently used to graze cattle, it would not be meaningless to include cattle exclusion requirements since they would apply to future landowners.

Finally, parcels 323 and 580 both are under conservation easements which require riparian buffers. In the case of parcel 323, a no-build riparian buffer is specified within 100 feet of streams. This sort of specification will prevent excessive sedimentation associated with development near streams and will reduce the amount of impervious surface associated with development and the resulting high-energy runoff. The quality of buffer could be increased, however, with the addition of specifications about the type of vegetation cover in the buffer and the exclusion of cattle. Parcel 580 requires a vegetated buffer within 200 feet of streams. Once again, if this land is indeed being used for cattle grazing, the inclusion of a fencing requirement could reduce the amount of fecal coliform and sediment being contributed to streams by this parcel.

Once the parcels assumed to be contributing the most pollution to Goose Creek have been addressed, I recommend moving on to preserving those parcels assumed to be providing the most protection to Goose Creek. I refer to this advice as conservation recommendations; they are illustrated by Figure 7. The basic strategy is the same as for the restoration recommendations: target parcels not yet under easement and amend easements with non-specific riparian buffer requirements.

First of all, parcels 79 and 580 should have been addressed by the restoration recommendations above. Of the remaining seven sink parcels, only one is already under easement—parcel 44. This easement has no riparian buffer specifications, thus I recommend the addition of a vegetated riparian buffer which specifies exclusion of livestock from streams. Finally, in order to provide the best insurance that those parcels which are currently doing the most to prevent fecal coliform and sediment from entering Goose Creek, parcels 74, 168, 178, 211, 633, and 698 should be placed under conservation easement, and these easements should include appropriate riparian buffer specifications.

Fig. 7 Map illustrating those priority parcels which have the greatest potential to reduce the amount of fecal coliform and sediment in streams along with existing easements and their level of riparian buffer specifications.

One final consideration in addressing these priority parcels which are already under easement is that of enforcement. Most easements are held by the Virginia Outdoors Foundation. This state agency is staffed with 30 people in eight offices around the state (VOF 2007). These 30 staff members are responsible for enforcing thousands of easements across the state. As such, it is unrealistic to expect that they will achieve the required annual inspection of each property to ensure that the easement specifications have not been violated. In addition to the possibility of amending relatively "weak" easements, those parcels with riparian buffers that were listed as priority parcels for restoration might be visited to ensure compliance with the easement.

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CONCLUSIONS

The overall method of prioritizing parcels to maximize water quality protection in a particular watershed can serve as a way of targeting limited resources for most efficient results. The simplest and thus most often used methods of measuring riparian buffers in GIS involve an analysis of land cover within a certain distance of streams. However, studies have shown that flow-path and unconstrained methods provide greater detail, interpretability and flexibility than the fixed-distance approach (Baker 2006). Thus, while my flow length methods still have room for improvement, they are likely a more accurate indicator of "on the ground" conditions than using a fixed-distance method which ignores topography. It should also be noted that while I developed these methods with the aim of reducing fecal coliform bacteria and sediment in streams, other non-point source (NPS) pollutants such as nitrogen and phosphorus are affected by similar processes and originate from the same sources; therefore, it is likely that this prioritization could also be used for additional NPS applications.

Overall, it should be a simple task to apply this prioritization method to other watersheds. As long as an organization (be it a land trust or state agency) has a GIS parcel layer, the following layers can be easily acquired from the USGS online: hydrologic unit codes, a digital elevation model, and the National Land Cover Dataset. Some states may also have higher-resolution elevation models (such as LIDAR) or more detailed land use data layers available which would increase the accuracy of the prioritization. Depending on an organization's mission and resources, they can focus their efforts on either conservation or restoration and can alter the number of parcels highlighted.

It is interesting that a creek running through a watershed where 43% of land is currently under conservation easement would still qualify to be placed on the state's list of impaired

waters. Of course, watershed protection is only one of an easement's possible primary goals. Other possible goals are limiting subdivision and development of the parcel or protecting local historic or cultural resources (VOF 2007). My results emphasize that when easements are considered as a water quality protection tool, they are only as effective as their restrictions. Additionally, as parcels are transferred from the landowner who placed the land under easement to new owners, enforcement of easement restrictions will become increasingly important. Thus, in the field of resource conservation and protection where funds and staff are often a limiting factor, a prioritization scheme such as the one developed here can serve to focus efforts for the most effective results.

APPENDIX A

Script 1 Identifies Streams & Classifies Source/Sink Land Cover

```
# ---------------------------------------------------------------------------
# python1.py
# Created on: Thu Apr 17 2008 04:50:21 PM
#   (generated by ArcGIS/ModelBuilder)
# ---------------------------------------------------------------------------

# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Conversion Tools.tbx")

# Set the Geoprocessing environment...
gp.XYResolution = ""
gp.scratchWorkspace = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM"
gp.MTolerance = ""
gp.randomGenerator = "0 ACM599"
gp.outputCoordinateSystem =
"PROJCS['NAD_1983_UTM_Zone_17N',GEOGCS['GCS_North_American_1983',DATUM['D_North_American_
1983',SPHEROID['GRS_1980',6378137.0,298.257222101]],PRIMEM['Greenwich',0.0],UNIT['Degree',0.01745329
25199433]],PROJECTION['Transverse_Mercator'],PARAMETER['False_Easting',500000.0],PARAMETER['False
_Northing',0.0],PARAMETER['Central_Meridian',-
81.0],PARAMETER['Scale_Factor',0.9996],PARAMETER['Latitude_Of_Origin',0.0],UNIT['Meter',1.0]]"
gp.outputZFlag = "Same As Input"
gp.qualifiedFieldNames = "true"
gp.extent = "763984.108074266 4306433.73310117 791074.108074266 4331033.73310117"
gp.XYTolerance = ""
gp.cellSize = "30"
gp.outputZValue = ""
gp.outputMFlag = "Same As Input"
gp.geographicTransformations = ""
gp.ZResolution = ""
gp.mask = ""
gp.workspace = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM"
gp.MResolution = ""
gp.ZTolerance = ""


# Local variables...
ned_utm_maybe = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\ned_utm_maybe"
ned_utm_fill = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\ned_utm_fill"
flow_dir = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\flow_dir"
Output_drop_raster = ""
flow_accum = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\flow_accum"
```

```
nlcd_clipped = "nlcd_clipped"
nlcd_reclass = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\nlcd_reclass"
buffer = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\buffer"
source = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\source"
streams_bin = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\streams_bin"
streams_feature_shp = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\streams_feature.shp"
flow_recl = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\flow_recl"
other = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\other"
other_dist = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\other_dist"
Output_backlink_raster = ""
streams_1 = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\streams_1"
Input_false_raster_or_constant_value__2_ = "1"
water = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\water"
water_0 = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\water_0"
water_bin = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\water_bin"

# Process: Fill...
gp.Fill_sa(ned_utm_maybe, ned_utm_fill, "")

# Process: Flow Direction...
gp.FlowDirection_sa(ned_utm_fill, flow_dir, "NORMAL", Output_drop_raster)

# Process: Reclassify (2)...
gp.Reclassify_sa(nlcd_clipped, "VALUE", "11 0;21 2;22 2;23 2;24 2;41 1;42 1;43 1;81 2;82 2;90 1;95 1",
nlcd_reclass, "DATA")

# Process: Reclassify (3)...
gp.Reclassify_sa(nlcd_reclass, "VALUE", "0 NODATA;0 1 1;1 2 NODATA", buffer, "DATA")

# Process: Reclassify (4)...
gp.Reclassify_sa(nlcd_reclass, "VALUE", "0 NODATA;0 1 NODATA;1 2 1", source, "DATA")

# Process: Flow Accumulation...
gp.FlowAccumulation_sa(flow_dir, flow_accum, "", "FLOAT")

# Process: Reclassify...
gp.Reclassify_sa(flow_accum, "Value", "0 700 0;700 505039 1", flow_recl, "DATA")

# Process: Single Output Map Algebra...
gp.SingleOutputMapAlgebra_sa("flow_recl * midgoose_1", streams_bin, "'Z:\\MP\\Goose Creek
Watershed\\scratch_UTM\\flow_recl'")

# Process: Set Null...
gp.SetNull_sa(streams_bin, Input_false_raster_or_constant_value__2_, streams_1, "\"VALUE\" = 0")

# Process: Raster to Polyline...
gp.RasterToPolyline_conversion(streams_1, streams_feature_shp, "ZERO", "0", "SIMPLIFY", "VALUE")

# Process: Reclassify (5)...
gp.Reclassify_sa(nlcd_reclass, "VALUE", "0 1;0 1 NODATA;1 2 NODATA", other, "DATA")

# Process: Cost Distance...
gp.CostDistance_sa(streams_1, other, other_dist, "", Output_backlink_raster)

# Process: Single Output Map Algebra (2)...
```

```
gp.SingleOutputMapAlgebra_sa("con(other_dist >= 0, 1)", water, "'Z:\\MP\\Goose Creek
Watershed\\scratch_UTM\\other_dist'")

# Process: Is Null...
gp.IsNull_sa(water, water_0)

# Process: Single Output Map Algebra (3)...
gp.SingleOutputMapAlgebra_sa("con(water_0 == 0, 1, 0)", water_bin, "'Z:\\MP\\Goose Creek
Watershed\\scratch_UTM\\water_0'")
```

Script 2 Identifies Contiguous Source/Sink Land Use Upland of Streams

```
# ---------------------------------------------------------------------------
# python2.py
# Created on: Thu Apr 17 2008 04:50:37 PM
#   (generated by ArcGIS/ModelBuilder)
# ---------------------------------------------------------------------------

# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst Tools.tbx")

# Set the Geoprocessing environment...
gp.XYResolution = ""
gp.scratchWorkspace = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM"
gp.MTolerance = ""
gp.randomGenerator = "0 ACM599"
gp.outputCoordinateSystem =
"PROJCS['NAD_1983_UTM_Zone_17N',GEOGCS['GCS_North_American_1983',DATUM['D_North_American_
1983',SPHEROID['GRS_1980',6378137.0,298.257222101]],PRIMEM['Greenwich',0.0],UNIT['Degree',0.01745329
25199433]],PROJECTION['Transverse_Mercator'],PARAMETER['False_Easting',500000.0],PARAMETER['False
_Northing',0.0],PARAMETER['Central_Meridian',-
81.0],PARAMETER['Scale_Factor',0.9996],PARAMETER['Latitude_Of_Origin',0.0],UNIT['Meter',1.0]]"
gp.outputZFlag = "Same As Input"
gp.qualifiedFieldNames = "true"
gp.extent = "763984.108074266 4306433.73310117 791074.108074266 4331033.73310117"
gp.XYTolerance = ""
gp.cellSize = "30"
gp.outputZValue = ""
gp.outputMFlag = "Same As Input"
gp.geographicTransformations = ""
gp.ZResolution = ""
gp.mask = "midgoose_1"
gp.workspace = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM"
gp.MResolution = ""
gp.ZTolerance = ""
```

```
# Local variables...
flow_dir = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\flow_dir"
flow_len = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\flow_len"
buf_flowlen = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\buf_flowlen"
ag_flowlen = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\ag_flowlen"
buffer = "buffer"
source = "source"
buf_eqflow_bi = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\buf_eqflow_bi"
ag_eqflow_bi = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\ag_eqflow_bi"
buf_eqflow = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\buf_eqflow"
ag_eqflow = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\ag_eqflow"
flowlen_recl = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\flowlen_recl"
flowlen_non0 = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\flowlen_non0"
buf_flow_dist = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\buf_flow_dist"
Output_backlink_raster = ""
buf_flow_wa = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\buf_flow_wa"
water_bin = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\water_bin"
ag_flow_wa = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\ag_flow_wa"
buf_flow_nul = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\buf_flow_nul"
ag_flow_nul = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\ag_flow_nul"
Input_false_raster_or_constant_value = "1"
ag_flow_dist = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\ag_flow_dist"
Output_backlink_raster__2_ = ""
water = "water"
buf_contig_1 = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\buf_contig_1"
ag_contig_1 = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\ag_contig_1"

# Process: Flow Length (2)...
gp.FlowLength_sa(flow_dir, buf_flowlen, "UPSTREAM", buffer)

# Process: Flow Length...
gp.FlowLength_sa(flow_dir, flow_len, "UPSTREAM", "")

# Process: Reclassify...
gp.Reclassify_sa(flow_len, "Value", "0 1;0 141888.75 2", flowlen_recl, "DATA")

# Process: Single Output Map Algebra (5)...
gp.SingleOutputMapAlgebra_sa("con(flowlen_recl == 2, flow_len)", flowlen_non0, "'Z:\\MP\\Goose Creek
Watershed\\scratch_UTM\\flowlen_recl'")

# Process: Equal To...
gp.EqualTo_sa(flowlen_non0, buf_flowlen, buf_eqflow_bi)

# Process: Single Output Map Algebra (3)...
gp.SingleOutputMapAlgebra_sa("buf_eqflow_bi + water_bin", buf_flow_wa, "'Z:\\MP\\Goose Creek
Watershed\\scratch_UTM\\buf_eqflow_bi';'Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\water_bin'")

# Process: Set Null...
gp.SetNull_sa(buf_flow_wa, Input_false_raster_or_constant_value, buf_flow_nul, "\"VALUE\" = 0")

# Process: Cost Distance...
gp.CostDistance_sa(water, buf_flow_nul, buf_flow_dist, "", Output_backlink_raster)

# Process: Single Output Map Algebra...
```

```
gp.SingleOutputMapAlgebra_sa("con(buf_flow_dist > 0, buf_flowlen)", buf_eqflow, "'Z:\\MP\\Goose Creek
Watershed\\scratch_UTM\\buf_flowlen';'Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\buf_flow_dist'")

# Process: Flow Length (3)...
gp.FlowLength_sa(flow_dir, ag_flowlen, "UPSTREAM", source)

# Process: Equal To (2)...
gp.EqualTo_sa(flowlen_non0, ag_flowlen, ag_eqflow_bi)

# Process: Single Output Map Algebra (4)...
gp.SingleOutputMapAlgebra_sa("ag_eqflow_bi + water_bin", ag_flow_wa, "'Z:\\MP\\Goose Creek
Watershed\\scratch_UTM\\water_bin';'Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\ag_eqflow_bi'")

# Process: Set Null (2)...
gp.SetNull_sa(ag_flow_wa, Input_false_raster_or_constant_value, ag_flow_nul, "VALUE = 0")

# Process: Cost Distance (2)...
gp.CostDistance_sa(water, ag_flow_nul, ag_flow_dist, "", Output_backlink_raster__2_)

# Process: Single Output Map Algebra (2)...
gp.SingleOutputMapAlgebra_sa("con(ag_flow_dist > 0, ag_flowlen)", ag_eqflow, "'Z:\\MP\\Goose Creek
Watershed\\scratch_UTM\\ag_flowlen';'Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\ag_flow_dist'")

# Process: Single Output Map Algebra (6)...
gp.SingleOutputMapAlgebra_sa("con(buf_flow_dist > 0,1)", buf_contig_1, "'Z:\\MP\\Goose Creek
Watershed\\scratch_UTM\\buf_flow_dist'")

# Process: Single Output Map Algebra (7)...
gp.SingleOutputMapAlgebra_sa("con(ag_flow_dist > 0, 1)", ag_contig_1, "'Z:\\MP\\Goose Creek
Watershed\\scratch_UTM\\ag_flow_dist'")
```

Script 3 Classifies Streambanks as Either Agricultural or Forested

```
# ---------------------------------------------------------------------------
# python3.py
# Created on: Thu Apr 17 2008 04:50:59 PM
#   (generated by ArcGIS/ModelBuilder)
# ---------------------------------------------------------------------------

# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst Tools.tbx")

# Set the Geoprocessing environment...
gp.mask = "midgoose_1"


# Local variables...
water = "water"
```

```
water_lc = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\water_lc"
water_veg = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\water_veg"
water_ag = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\water_ag"
nlcd_reclass = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\nlcd_reclass"

# Process: Single Output Map Algebra...
gp.SingleOutputMapAlgebra_sa("nlcd_reclass * water", water_lc, "water;'Z:\\MP\\Goose Creek
Watershed\\scratch_UTM\\nlcd_reclass'")

# Process: Single Output Map Algebra (2)...
gp.SingleOutputMapAlgebra_sa("con(water_lc == 1, 1, 0)", water_veg, "'Z:\\MP\\Goose Creek
Watershed\\scratch_UTM\\water_lc'")

# Process: Single Output Map Algebra (3)...
gp.SingleOutputMapAlgebra_sa("con(water_lc == 2, 1, 0)", water_ag, "'Z:\\MP\\Goose Creek
Watershed\\scratch_UTM\\water_lc'")
```

Script 4 Creates Rasters and Database Files for Each of the Four Metrics Used in the Prioritization Scheme

```
# ---------------------------------------------------------------------------
# python4.py
# Created on: Thu Apr 17 2008 04:51:15 PM
#   (generated by ArcGIS/ModelBuilder)
# ---------------------------------------------------------------------------

# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst Tools.tbx")

# Set the Geoprocessing environment...
gp.mask = "midgoose_1"


# Local variables...
par_buffing = "z:\\MP\\Goose Creek Watershed\\scratch_UTM\\par_buffing"
ptab_buffing_dbf = "z:\\MP\\Goose Creek Watershed\\scratch_UTM\\tables\\ptab_buffing.dbf"
parcels_midgmerg = "parcels_midgmerg"
par_agstrm = "z:\\MP\\Goose Creek Watershed\\scratch_UTM\\par_agstrm"
ptab_agstrm_dbf = "z:\\MP\\Goose Creek Watershed\\scratch_UTM\\tables\\ptab_agstrm.dbf"
par_runoff = "z:\\MP\\Goose Creek Watershed\\scratch_UTM\\par_runoff"
ptab_runoff_dbf = "z:\\MP\\Goose Creek Watershed\\scratch_UTM\\tables\\ptab_runoff.dbf"
par_vegstrm = "z:\\MP\\Goose Creek Watershed\\scratch_UTM\\par_vegstrm"
ptab_vegstrm_dbf = "z:\\MP\\Goose Creek Watershed\\scratch_UTM\\tables\\ptab_vegstrm.dbf"
watag_isnull = "z:\\MP\\Goose Creek Watershed\\scratch_UTM\\watag_isnull"
watveg_isnull = "z:\\MP\\Goose Creek Watershed\\scratch_UTM\\watveg_isnull"
waterag_bin = "z:\\MP\\Goose Creek Watershed\\scratch_UTM\\waterag_bin"
waterveg_bin = "z:\\MP\\Goose Creek Watershed\\scratch_UTM\\waterveg_bin"
buf_contig_1 = "buf_contig_1"
ag_contig_1 = "ag_contig_1"
```

```
bufcon_isnull = "z:\\MP\\Goose Creek Watershed\\scratch_UTM\\bufcon_isnull"
bufcon_unnull = "z:\\MP\\Goose Creek Watershed\\scratch_UTM\\bufcon_unnull"
agcon_isnull = "z:\\MP\\Goose Creek Watershed\\scratch_UTM\\agcon_isnull"
agcon_unnull = "z:\\MP\\Goose Creek Watershed\\scratch_UTM\\agcon_unnull"
water_ag = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\water_ag"
water_veg = "Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\water_veg"

# Process: Is Null...
gp.IsNull_sa(buf_contig_1, bufcon_isnull)

# Process: Single Output Map Algebra...
gp.SingleOutputMapAlgebra_sa("con(bufcon_isnull == 1, 0, 1)", bufcon_unnull, "'z:\\MP\\Goose Creek
Watershed\\scratch_UTM\\bufcon_isnull'")

# Process: Zonal Statistics...
gp.ZonalStatistics_sa(parcels_midgmerg, "MAPNAME", bufcon_unnull, par_buffing, "SUM", "DATA")

# Process: Zonal Statistics as Table...
gp.ZonalStatisticsAsTable_sa(parcels_midgmerg, "MAPNAME", bufcon_unnull, ptab_buffing_dbf, "DATA")

# Process: Is Null (2)...
gp.IsNull_sa(water_ag, watag_isnull)

# Process: Single Output Map Algebra (2)...
gp.SingleOutputMapAlgebra_sa("con(watag_isnull == 1, 0, water_ag)", waterag_bin, "'z:\\MP\\Goose Creek
Watershed\\scratch_UTM\\watag_isnull';'Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\water_ag'")

# Process: Zonal Statistics (2)...
gp.ZonalStatistics_sa(parcels_midgmerg, "MAPNAME", waterag_bin, par_agstrm, "SUM", "DATA")

# Process: Zonal Statistics as Table (2)...
gp.ZonalStatisticsAsTable_sa(parcels_midgmerg, "MAPNAME", waterag_bin, ptab_agstrm_dbf, "DATA")

# Process: Is Null (4)...
gp.IsNull_sa(ag_contig_1, agcon_isnull)

# Process: Single Output Map Algebra (4)...
gp.SingleOutputMapAlgebra_sa("con(agcon_isnull == 1, 0, 1)", agcon_unnull, "'z:\\MP\\Goose Creek
Watershed\\scratch_UTM\\agcon_isnull'")

# Process: Zonal Statistics (3)...
gp.ZonalStatistics_sa(parcels_midgmerg, "MAPNAME", agcon_unnull, par_runoff, "SUM", "DATA")

# Process: Zonal Statistics as Table (3)...
gp.ZonalStatisticsAsTable_sa(parcels_midgmerg, "MAPNAME", agcon_unnull, ptab_runoff_dbf, "DATA")

# Process: Is Null (3)...
gp.IsNull_sa(water_veg, watveg_isnull)

# Process: Single Output Map Algebra (3)...
gp.SingleOutputMapAlgebra_sa("con(watveg_isnull == 1, 0, water_veg)", waterveg_bin, "'z:\\MP\\Goose Creek
Watershed\\scratch_UTM\\watveg_isnull';'Z:\\MP\\Goose Creek Watershed\\scratch_UTM\\water_veg'")

# Process: Zonal Statistics (4)...
gp.ZonalStatistics_sa(parcels_midgmerg, "pin", waterveg_bin, par_vegstrm, "SUM", "DATA")
```

```
# Process: Zonal Statistics as Table (4)...
gp.ZonalStatisticsAsTable_sa(parcels_midgmerg, "MAPNAME", waterveg_bin, ptab_vegstrm_dbf, "DATA")
```

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