THE ALBEMARLE COUNTY RURAL AREA AS A SOURCE OF WATERSHED ECOSYSTEM SERVICES*

"The nation behaves well if it treats the natural resources as assets which it must turn over to the next generation increased; and not impaired in value."[1]

\- Theodore Roosevelt -

PURPOSE AND OVERVIEW

Land and water are inextricably linked. The purpose of this paper is to describe the current scientific understanding of that link, specifically the relationships of forests, healthy soils, and stream buffers with water resources. These landscape elements provide "ecosystem" or "watershed services" on which the County relies. Such services include groundwater recharge, flood moderation, clean water, and places for animals and plants to live. These services have value to the County just as do agriculture, forestry, land development, and pastoral views. The connection between land and water is not new to Albemarle County. However, if watershed services truly are to be valued, the land-water link achieved in community planning must be as strong as the link observed in nature.

This paper provides a review of scientific literature on the land-water interaction and potential tools for incorporating that scientific knowledge in the policy discussion. There are three major sections:

- Ecosystem Services / Watershed Services describes the watershed service concept, four such services that watersheds can provide, the landscape condition associated with these services, and the summary concept of ecosystem resilience.
- Key Watershed Service Planning Concepts describes practical concepts (impervious surface and waterway buffers) for use in planning to protect watershed services.
- Recommendations for Comprehensive Planning for Watershed Services includes specific thoughts on building science into policy.

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ECOSYSTEM SERVICES / WATERSHED SERVICES

The Concept

Though often taken for granted, natural systems (ecosystems) provide essential services to human society. These services include providing a clean, reliable source of water, clean air, temperature and radiation moderation, pollination, a genetic library for food and medicine, and aesthetic, cultural, and recreational benefits.[2] This paper provides scientific description of the services that watersheds (one kind of ecosystem) provide in maintaining clean, reliable water. One hundred years ago, President Roosevelt highlighted the national interest in natural "assets." Today the local government role is widely recognized. The Chesapeake Bay Program emphasized local government's frontline position in protecting watersheds in its Chesapeake 2000 Agreement.[3] Albemarle County has formally recognized goals, objectives, and strategies for watershed protection in the Natural Resources and Cultural Assets Chapter of the Comprehensive Plan among other places.[4]

Watersheds should be valued for providing these services. However, ecosystem services are almost never accounted for in the traditional economy. When attempts are made to assign economic value to ecosystem services, they often involve valuing a replacement or surrogate service. A few such attempts have been made regarding water. New York City has estimated that adding filtration plants to its water system would lead to annual water rates of $800 to $864 for an average family in the year 2018.[5] If New York can successfully invest in protecting natural filtration in the watersheds that supply its water, rates would rise to only $707.[5] In the Yangtze Watershed in China, trees have been estimated to have three times more value for water protection than as forest products.[6,7] Desalination to generate the freshwater used in the world would cost $3 trillion or 12% of the gross world product each year.[8] The numbers associated with freshwater fisheries, recreation, dilution of pollution, and other services are similarly mind-boggling. Whether or not we can assign a numeric value to an ecosystem service, we can value the service in our political and administrative decision making processes. Viewing nature as a service provider may be seen as crass, but it is only one way of valuing this important system. It does not preclude inherent, psychological, or spiritual values that people may attribute to nature.

Four critical services that watershed ecosystems provide in Albemarle County are:

1. <u>Keeping aquifers full</u>- Recharge of aquifers keeps water flowing to reservoirs and wells during dry periods.
2. <u>Moderation of high streamflows</u>- Reducing flood flows protects property and reduces stream bank erosion and minimizes lost reservoir capacity due to sedimentation.
3. <u>Cleaner water</u>- Delivering cleaner water from nature reduces water treatment demands and provides for healthy aquatic life and safe recreation.
4. <u>Protection of plants and animals</u>- Healthy watersheds provide a place in and around streams, rivers, and reservoirs for aquatic and riparian organisms to live.

Of course, these water protection services function in the context of other activities in the watersheds including land development, agricultural, forestry, gardening and yard maintenance, hobby farming, pastoral views, and more, all of which have their own value. The watersheds will provide their services naturally if we let them. However, we can alter watersheds to the point that those services are reduced or eliminated. The challenge is to plan for land use in a way that the watersheds can still do their work.

Keeping Aquifers Full

A critical service that the watershed provides is transporting the rain from the landscape into the aquifers (Figure 1). Aquifers are underground cracks, fissures, and pore spaces filled with water that originated as rain. Aquifers are the source of well water and of stream flow between rainstorms.

The key ingredient in groundwater infiltration and recharge is healthy soil. Healthy soil has as structure of small soil blocks with space between them and pore spaces within them that can transmit water.[9] Soil with a high organic content (coming from plants growing on it) takes on a healthy structure more easily and infiltrates water better than soil with little organic matter mixed into the mineral soil.[9,10] Living and decaying plant roots can conduct water into the ground and are part of a healthy soil.[9] Activity of animals, particularly worms but also insects and mammals, does a great deal to maintain soil infiltration capacity.[11]

Activities that disturb or compact the soil reduce infiltration. Plowing for farming and grading for site development break up the soil structure. Plowing may increase

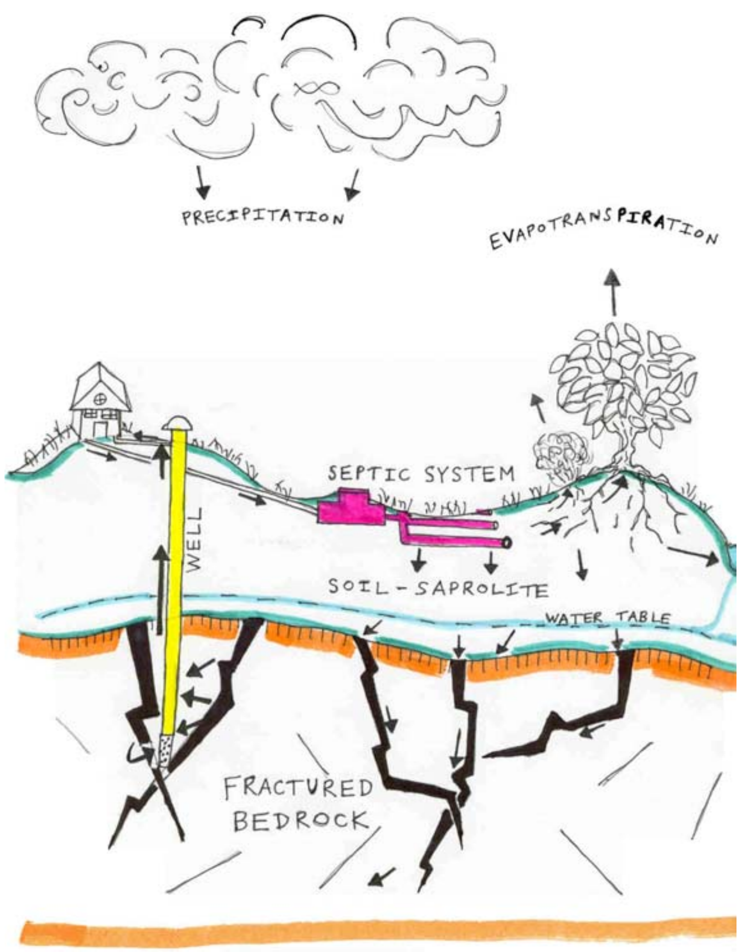

Figure 1. Schematic showing how aquifers are recharged and used for well water supply.

infiltration temporarily, but over the long run infiltration is reduced.[10] Agriculture generally reduces soil organic content and alters soil structure. Compaction can be caused by vehicles or animals.[12] Compaction closes the openings and reduces infiltration. Similarly, direct exposure to rain drops where there is little vegetative cover can fill soil openings. As the rain impacts the soil, it can throw soil particles into the voids with the result of clogging them.[9] Pastures will not have as healthy a soil structure as forests, but how healthy the pasture soil is will depend on how the grazing and grassland are managed. If the grazing is intense with little rotation and little attention to the health of the grass, the soil will become compacted and the thatch will thin resulting in low infiltration.[12] Similar problems can occur in suburban and urban areas as a result of foot or vehicle traffic. It can take a very long time for the soil structure to reestablish once lost. One study showed that infiltration in a grassland setting had not been substantially restored even ten years after ending tillage and restoring grasses.[10]

The issue of whether logging increases or decreases infiltration is complex. The healthiest soils are associated with forests.[9,12] However, watershed manipulation studies generally show that infiltration and resulting stream baseflow increases for at least a few years after logging.[13,14,15,16,17] The reason for this finding is that as plants photosynthesize, they transpire water from the ground to the sky at a high rate. Trees use more water from a greater depth in the soil than other vegetation. When they are cut, less water is transpired and more can infiltrate. However, in order for infiltration to be maintained, the soil must be only lightly disturbed during cutting to maintain the healthy soil. Does this mean forests should be cut as a means of generating water? No, it simply means that forestry employing good practices is not incompatible with maintaining soil infiltration. It is worth noting that some evidence shows that pine forests yield somewhat less water than hardwoods.[7,14] It is important to remember that forests play an essential role in other watershed services described below.

The extreme case of soil alteration is pavement, which eliminates all infiltration. A surface with no infiltration is labeled “impervious.” Roofs and cement patios are other examples of impervious surfaces. Any area where the health of the soil structure to allow infiltration has been reduced can be considered partially impervious.

Moderation of High Streamflows

Another service provided by watersheds, particularly forests, is flood moderation. The size and frequency of storm flows is a major concern because flood flows can present a threat to property and life (Figure 2). On a more routine basis, high flows contribute to erosion of stream banks. The eroded stream banks probably are the dominant source of reservoir sedimentation that reduces water storage capacity that costs millions of dollars to replace.[18,19,20] The Rivanna Water and Sewer Authority is planning to spend $13.2 million on reservoir expansion and other water supply plan elements.[21] Perhaps half of that cost is incurred due to reservoir sedimentation, much of it from stream bank erosion during high flow events.[22] Stream erosion and sediment deposition also result in destruction of habitat for aquatic life.[23]

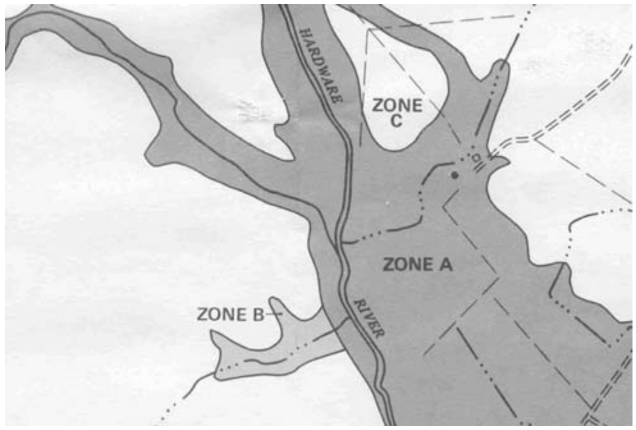

Figure 2. Example of a map of an estimated 100-year floodplain (Zone A) from a Federal Emergency Management Agency Flood Insurance Rate Map.[24]

The condition of the watershed determines the magnitude of flow that will result from a storm of a particular size. Forests and healthy soils help watersheds moderate storm flows.[14] The leaves and needles of the forest intercept rainwater.[9,7] Some of that water evaporates and some reaches the ground after a delay. The fallen leaves and branches and the root systems of the trees slow and trap water that might otherwise run along the surface of the ground. As mentioned above, healthy soils, usually associated with forests, tend to encourage more water to soak into the ground- as much as 10 to 15 times more than grass turf and 40 times more than plowed land (Table 1).[25] Forests and soils are particularly helpful in moderating stream flows from storms that occur fairly commonly (every few years or more often).

Removal of forests increases storm flows. In a famous watershed manipulation experiment, the deforestation of a watershed in New Hampshire (by logging and herbicide application) resulted in a 40% increase in mean annual stream flow and six to ten times the pre-disturbance sediment load.[13,15] Most of the sediment load increase was attributed to stream bank erosion. Storm flows also carry other potential pollutants, such as nutrients, off the landscape. Watershed impacts that reduce infiltration (grading, plowing, compaction, and paving) increase storm flows even more. Generally, the ability of the watershed to moderate storm flow is best in forested areas, worst in heavily paved areas, with pastures, lawns, and crops falling in between.[12]

American Forests, a national urban forestry advocacy group, estimated the forest cover and stormwater benefit for an 8,281 square mile (several county) area around Charlottesville. They estimated that a reduction in forest canopy from 1976 to 2000 translated to a reduction of stormwater abatement from 5.9 billion gallons per year to 5.0 billion gallons per year.[26] The lost watershed service of flood moderation would cost $1.8 billion to restore through engineered stormwater structures. If these numbers are even remotely accurate, the value is tremendous.

Table 1. Infiltration potential of various land covers.[12]

Infiltration Potential	Land Cover
Highest	Woods, good
	Meadows
	Woods, fair
	Pasture, good
	Woods, poor
	Pasture, fair
	Small grains, good rotation
	Small grains, poor rotation
	Legumes, after row crops
	Pasture, poor
	Row crops, good rotation
	Row crops, poor rotation
Lowest	Fallow

Cleaner Water

Clean water is another service item provided by healthy watersheds. Water quality is similar in importance to water quantity. Water that carries more pollutants requires more water treatment. As mentioned above, water that carries a great deal of sediment into reservoirs removes storage capacity that must be replaced at a high cost. Poor water quality harms aquatic communities, reduces angling opportunities, and makes recreation undesirable.

Forests are particularly effective at providing relatively clean water.[27] Plants growing in the forest take up nutrients from the water that otherwise could enter a waterway as pollution. The organic material of the forest floor binds and traps nutrients and other chemicals. The forest ecosystem may remove these materials or sequester them long enough to reduce the impacts to streams, reservoirs, and groundwater. Vegetation holds soil in place. Roots, stems, and ground litter can recapture sediment that has been picked up previously by water. A forest allows only a small amount of erosion of landscape sediment, estimated to be 24 tons/square mile/year as a national average according to the USEPA.[28] The estimated average erosion rate increases by orders of magnitude as the vegetation on the land is reduced and disturbance is increased rising to 240 tons/square mile/year in grassland, 4,800 tons/square mile/year in cropland, and 48,000 tons/square mile/ year on open construction sites.

Healthy soils with high infiltration potential help provide clean water. Water that reaches streams by first soaking into the ground, and then seeping into the stream usually is cleaner than water that reaches the stream with little or no time under ground. (This principle is the basis of septic field technology.)

Protecting Animals, Plants, And Recreation

Almost all watershed services support both human needs and the needs of animals and plants living in and near streams. Fish, aquatic insects, mollusks, crustaceans, and amphibious frogs, salamanders, and reptiles all depend on reliably flowing clean water (Figure 3). (These organisms can in turn be observed as indicators of the health of a watershed, like the proverbial canary in the coal mine.) Many plants, birds, and mammals rely on a healthy stream at the core of the riparian zone. Waterway buffers tend to have a higher biological diversity than surrounding landscapes.[29]

These organisms have value in their own right and can be part of additional ecosystem services. Recreational fishing is estimated to generate $16 billion in direct expenditures with a full economic impact of $46 billion in the United States and clearly is a popular activity in Albemarle.[8] Boating, wading, walking, and wildlife observation also provide enjoyment and economic benefit.

Figure 3. An adult dragonfly. Dragonfly young develop in ponds, wetlands, and streams. Adults make use of streamside zones.

Watershed Resilience versus Brittleness

So far, this paper has attempted to describe what we know about ecosystem services related to water. There is a substantial amount we don't know. In particular, we cannot see what the future will bring. For example, are we headed for significant climate change due to global warming? Would more drought or flood or both accompany such a change? We only know we can expect change of one kind or another.

Some scientists argue that healthy ecosystems are the most resilient to extreme events and changes.[30] The diversity and continuity of function of a healthy system may help it recover and adapt. This argument is similar to the idea that healthy people are more resistant to and more likely to recover from disease or injury. An ecosystem that has been impacted to the point that it is "brittle" may not respond well to change. A shock to a brittle system may push it across a threshold beyond which it cannot adequately provide the services on which we depend. It is in our interest to maximize the ecosystem resilience of our watersheds.

KEY WATERSHED SERVICE PLANNING CONCEPTS

Tools for Planning to Protect Watershed Services

It is one thing to recognize in general the value of landscapes that provide watershed services. It is another thing to protect that value. Tools are needed to connect watershed services to land use planning in recognizable, measurable ways. Below are a few key concepts available as starting points for protecting watershed services.

Impervious Surface: An Integrating Concept

It can be overwhelming to consider and analyze the many variables that affect watershed services. One useful concept that integrates many variables is impervious surface.[31,32] As watersheds are developed, more roofs, parking lots and roads are constructed. Such surfaces are absolutely impervious. One can estimate the percentage of a watershed that is covered with absolutely impervious surfaces. Taking things a step further, a measure called "effective impervious cover" may be more appropriate as a summary statistic for a broad range of land uses in large watersheds.[18,31,33] In contrast to "absolute impervious cover," effective impervious cover accounts for partially impervious land cover in addition to absolutely impervious cover (Table 2). Such land uses reduce the ability of the ground to absorb water without eliminating permeability entirely. As described above, lawns, croplands, and pastures are less permeable than forests because of soil compaction and other changes.[9]

Table 2. Comparison of the terms "Absolute Impervious Surface" and "Effective Impervious Surface"

Comparisons	Absolute Impervious Surface	Effective Impervious Surface
Definition	Percent of land covered by roofs, pavement, etc. that are impervious to all infiltration	Percent of land covered by roofs, pavement, etc. (absolute impervious surface) plus partially impervious covers like lawns, cropland, pasture, etc. converted to their equivalent in absolute impervious surface
Appropriate application	Quick analysis of small urban and suburban sites	Large, diverse watersheds that include agricultural use; used for smaller sites to practice "Low Impact Development"
Difficulty of calculation	Fairly simple for small areas but somewhat complex for large watersheds; can be done with a planimeter on small sites	More complex; best with computer mapping; need reasonable assumptions about the imperviousness of various land uses
Ballpark threshold at which stream communities are believed to decline significantly	10%[32]	No such estimate, but would be somewhat higher

While the effects of partial impervious cover may be less intense, the land uses may be more widespread. For instance, one acre of typical residential lawn may be equivalent to 0.1 acres of pavement in terms of runoff characteristics but lawns might make up a much larger portion of a residential area. Effective impervious cover can be thought of as the condition of the watershed on a scale ranging from completely forested (0% impervious) to completely paved (100% impervious).As an example, the effective impervious cover was calculated for the entire Rivanna River Watershed, including the

South Fork Rivanna Reservoir Watershed, using land cover data from the early 1990s (Figure 4).[33] The work, originally done by the Rivanna Basin Roundtable, has been revisited here to estimate and compare absolute impervious cover to effective impervious cover (Table 3). The absolute impervious cover numbers are lower than the effective impervious cover numbers because they don't include partially impervious land uses.

Table 3. Comparison of estimated values for "Absolute Impervious Surface" and "Effective Impervious Surface" in the South Fork Rivanna Reservoir Watershed of Albemarle County, VA.

	Buck Mt. Cr.	**Ivy Cr.**	**Mechums R.**	**Moormans R.**	**Small Tributaries Along SFRR**	**SFRR Total**
Absolute Impervious Cover (%)	1.3	2.3	2.0	1.1	2.1	1.7
Effective Impervious Cover (%)	5.5	7.8	6.5	3.6	7.0	5.7

Changes in land use that create an increase in impervious surface are expected to have negative water quality as well as quantity impacts[34]. The concept of impervious surface serves as a general watershed health indicator, but the water quality issue is more complex than the hydrological issue. While an increase in runoff (hydrological impact) from new impervious areas is relatively well understood, water quality impacts can vary depending on pollutants of concern and management practices. For instance, a small amount of residential land use can have a significant water quality impact while having limited hydrological impact according to some models[35]. This complexity does not disqualify impervious surface as an indicator, but it indicates that attention to the details of the specific land uses and watershed services of concern is needed.

It is important to distinguish the actual condition of the land from the description of the land use. From a watershed service perspective, what matters at any moment is the condition of the soil and the vegetative cover, not the land use label, ownership, or parcel size. Theoretically, a set of small house lots with low impact designs could maintain a lower level of effective impervious surface than a high impact farm or forestry operation. Similarly, a well-managed forestry or farm operation could have a lower level of effective impervious surface than a high impact residential estate. Converting land from forest to pasture potentially can increase stormflows and reduce baseflows more than converting land from pasture to certain residential uses, particularly if forest cover is increased in the residential land management scheme.

Still, parcel size does matter from a watershed management perspective. Overall, soil and land cover conditions can more easily be managed on large parcels to minimize effective imperviousness. Landowners can strive for management of large parcels in ways compatible with watershed services much more easily than can owners of small parcels. Large parcels provide more flexibility for protecting the critical resources in concert with other landowner goals.

While protecting large parcels seems generally in accord with historic Rural Area Plan goals, a purist view of effective impervious surface (i.e., favoring maximum forested area) presents some conflict with other traditional County values. The "pastoral" aesthetic landscape of wide-open fields with interspersed forest patches is highly valued in Albemarle. It is part of the defining character of the area and is featured on County publications. However, from a watershed services perspective, we could lower the effective imperviousness by having a much higher level of forest cover. These values will have to be balanced in establishing the County's policy goals.

Waterway Buffers a Special Case of Forest

(Except where noted, this section largely is summarized from Wenger 1999[29] *as well as National Research Council 2002*[36]*, Chesapeake Bay Program 1995*[37]*, and Austin 1999*[25]*.)*

A special case of the value of forests to water protection is the waterway buffer. Forests along waterways provide all the same benefits as other forests, but their importance is magnified. There are many functional connections between a stream and the land surrounding it (or riparian zone). Trees and other plants of the buffer zone are specially adapted to it (Figure 5). Streamflow results where the water table intersects a stream channel. By definition the water table near the stream is usually close to the land surface. During storms the water table rises, preventing infiltration. Much of the initial

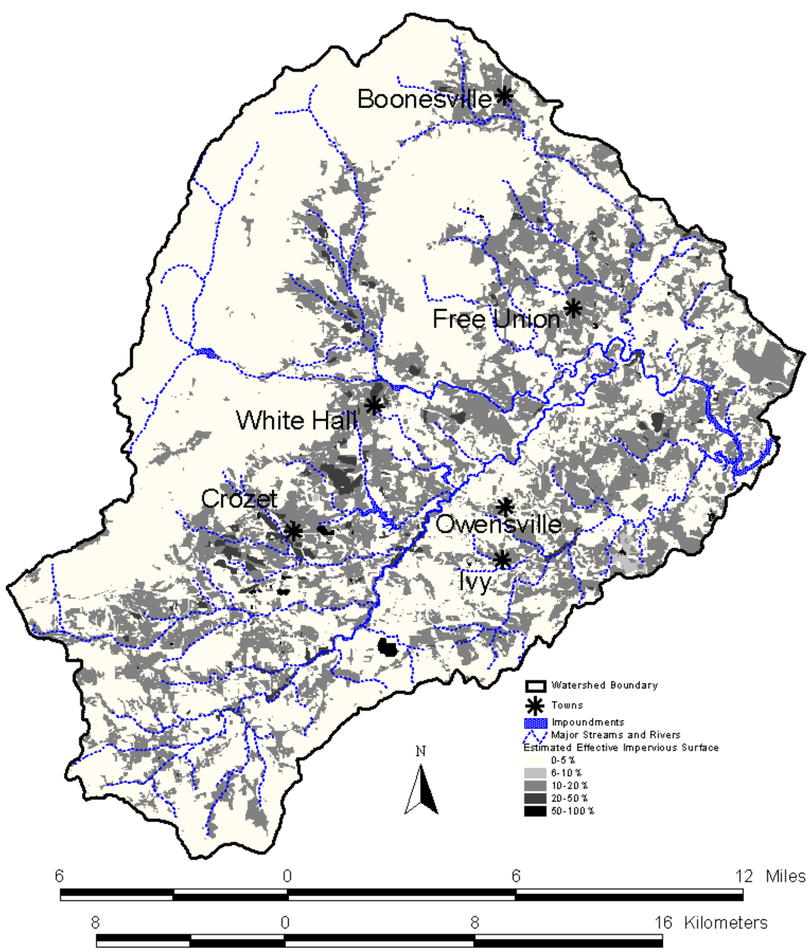

Figure 4. Effective impervious surface (estimated for the early 1990s) by percentage categories in the South Fork Rivanna Reservoir Watershed of Albemarle County, VA.

storm flow comes from areas adjacent to the stream.[38,39] The roughness of the vegetation near streams slows and delays floodwaters and traps sediment. Over years, deposits from flooding streams produce floodplains and create complex topography resulting in habitat diversity. Because the water table is close to the surface, the likelihood is higher that the roots of plants near a stream will tap the water table, using nutrients from the water, and contributing to groundwater cleaning. Microbial activity in this zone is a major factor in nutrient removal as well. Vegetation near streams holds stream banks and riparian sediment in place. Branches and leaves from near-stream vegetation provide structural habitat and food to stream organisms. Shade from streamside plants helps keep streams cool. Riparian areas often have much greater species diversity than surrounding landscapes. Buffers can help people connect to streams and find refuge in a natural setting serving as corridors for private or public pathways.

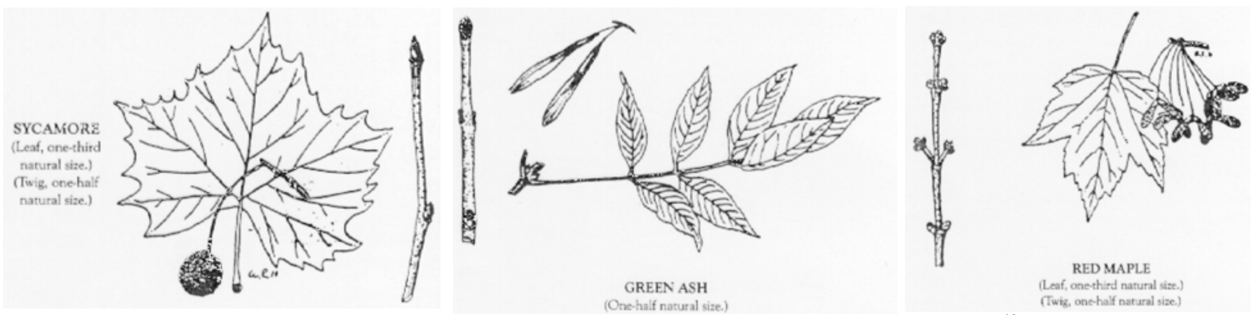

Figure 5. Examples of streamside trees important to watershed services in Albemarle County.[40]

Given all these connections, waterway buffers provide a great deal of service in water protection, particularly in moderating flooding, maintaining water quality, protecting plants and animals, and providing for low-impact recreation. One group of scientists has estimated the value of water-related services from swamps and floodplains as $6,867/acre/year.[2] The width of waterway buffers depends on the management goals. The common wisdom is that buffers should include the entire floodplain, a 100-foot distance from the stream bank, or the width necessary to achieve the management goal. As far as which streams should have buffers, the more the better. Buffers on small (even intermittent and ephemeral) streams can provide services as important as those provided on large rivers. Management of the buffer might vary based on neighboring land use, but the core and majority of the buffer should be forest (Table 4). Waterway forests are among the most valuable forests in the watershed. However, waterway forests can't compensate for a heavily impacted watershed.

Other Watershed Service Tools

There are other basic tools available for guiding watershed service protection. Tracking and setting goals for the simple statistic of percent forest cover in a watershed could be quite useful. Similar measures based on parcel size or percent open space could be helpful. Some of these measures are already used in County planning, but not necessarily with explicit recognition of their connection to watershed services. If the County chooses to protect the watershed service value, science-based planning and monitoring tools will have to be developed, refined, and applied to the problem.

Table 4. Watershed services of forested waterway buffers.[29]

Watershed Service	Short Term Value	Long Term Value	Width to Provide Service	Notes
Sediment Trapping	Significant	Significant with greater width	30-100’	Wider on steep slopes. Grass strip outside forest area desirable.
Bank Stabilization	Significant	Significant, but won’t stop channel migrating	?	Width is site dependent.
Phosphorus	Significant	Questionable, may dampen, but not reduce long term P	50-100’	On site reductions still important. Removing vegetation (and thus nutrients) in outer zone of buffer may help.
Nitrogen	Significant	Significant	50-100’	Dependent on pathway of groundwater to stream
Fecal Coliform	Some	?	>30’	Saturation possible
Biological Oxygen Demand	Some	Some	?	
Pesticides	Some	Some	>15’	
Metals	Some	?	>15’	Saturation possible
Shade for Stream	Significant	Significant	30-100’	Greatest impact on smaller streams
Food and Habitat for Stream	Significant	Significant	50-100’	
Habitat for Terrestrial Organisms	Significant	Significant	=>300’	
Wildlife Corridors	Debated		?	
Flood Moderation	Significant	Significant	Entire floodplain	

RECOMMENDATIONS FOR COMPREHENSIVE PLANNING FOR WATERSHED SERVICES

The following are recommendations for understanding the value of watershed services in a technical sense and explicitly incorporating their value in land use planning.

- Value watershed services and other ecosystem services in comprehensive planning through the same process by which we value preservation of agriculture, forestry, historic resources, the pastoral aesthetic, biodiversity, etc. The weight and rank of these values may not be consistent across the County. In this case, the weight and rank could be determined individually for Rural Area planning zones in which the County's ranking of values and goals was reasonably homogenous.
- Seek mechanisms (such as Rural Preservation Developments, land use taxation, easement donations, and acquisition of conservation easements) for preserving large parcels of land on which it is more likely that characteristics needed for watershed services (healthy forests, soils, and waterway buffers) can be maintained.
- Seek incentives (through education, cost-share programs, land use taxation, Acquisition of Conservation Easements, etc.) that promote land use practices (specifically land covers) that protect watershed services.
- Seek incentives (through land use taxation, acquisition of conservation easements, etc.) to encourage forested waterway buffers on as many streams miles as possible.
- Develop baselines and measurable objectives for characteristics that preserve ecosystem services. The next update of the Comprehensive Plan chapter on Natural Resource and Cultural Assets might be an appropriate time to develop such objectives. These objectives might include miles of streams with buffers, percent forest canopy, and/or percent effective impervious cover. To the degree possible they could be based on simple models of the effects of land use change and land management on watershed services. The objectives could be established for the entire rural area, by rural area planning zone, or by watershed.
- Consider estimating the local economic value of some key watershed services to serve as an educational and policy tool (with the caveat that estimates accurate enough for direct cost-benefit analysis might be unachievable). Water supply benefits might be an appropriate starting point.
- In the Designated Development Areas, preserve watershed services to the maximum degree possible while recognizing that a County goal is to use the Development Areas to preserve watershed services and other values in the Rural Areas. In the Development Areas, watershed service protection can be addressed through the planning process and the application of "Low Impact Development" (LID) concepts in site design. LID essentially is a set of site design and engineering methods for maximizing infiltration. The degree to which these concepts can be applied based on our soils, topography, and other objectives of the Neighborhood Model must be evaluated.

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