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# Riparian and Terrestrial Issues in The Chesapeake

## A Landscape Management Perspective

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## Introduction

The Chesapeake Bay watershed covers approximately 64,000 square miles, including portions of six states and the District of Columbia. This vast hydrologic network has been profoundly altered by a gradual transformation of the landscape that started with changes in forests caused by native American populations and accelerated soon after European settlement of the watershed three hundred years ago.

The transformation of the watershed was accomplished without forethought or planning, by the cumulative effects of millions of decisions made by tens thousands of landowners. Settlers cleared fields for homesteads, foresters harvested timber, builders constructed houses and towns, businesses built mills, warehouses and factories, farmers planted tobacco and small grains. Individuals, acting in response to what they thought best, within the institutional frameworks of their day, have transformed the land, and transformed the Bay. When European settlers arrived, the Chesapeake watershed was more than 95% forest. Today the watershed is approximately 58 percent forest, 33 percent agricultural lands, 8 percent developed land—including low, medium and high density residential; commercial; and industrial lands—and 1% water (Neumiller et. al. 1994). Only about one half of the region's original wetlands remain (Tiner et al. 1987). The decisions that led to these landscape changes were, and to a large extent continue to be, driven by human needs and wants on local spatial and short temporal scales, yet over time they have had profound effects at the scale of the Bay watershed.

Paleoecological information suggests that soon after the arrival of European settlers in the watershed, the ecology of the bay began to change (Brush, this volume). Sedimentary records suggest that sedimentation rates climbed as forests were cleared for agriculture. Anoxic conditions in the bay became more frequent, and signs of nutrient enrichment appeared in Bay sediments and ecosystems (Cooper and Brush 1991). A profound hydrologic alteration of the bay also occurred. Increases in surface runoff and decreases in evapotranspiration throughout the watershed, triggered by the removal of forests, caused an increase in freshwater flows to the Bay, reducing salinity in the upper Bay. The State of Maryland now mines oyster shell from once-productive oyster bars in the upper Chesapeake, where salinity in the water is now too low to support oysters, and places the shell in the lower Bay, where oysters can still survive.

The transformation of landscapes within the Chesapeake watershed not only continue, but have accelerated. The population of the watershed, slightly over 13 million people today, is expected to increase by about twenty percent in the next quarter century. But development patterns have changed dramatically in the last fifty years, and consumption of land will climb faster than population. New development consumes nearly twice as much land per capita as existing development has (2020 Panel 1988). Thus while forest loss in the Chesapeake watershed has slowed, and even reversed in some regions, urbanization and suburbanization have increased.

The potential implications of these trends for the Chesapeake and its tributaries are troubling. Without implementation of more sophisticated approaches to understanding and managing watershed-scale consequences of local land use decisions, continued loss of forest and wetlands, increased human populations, and more abundant roads, rooftops, parking areas and other "impervious surfaces" will increase flow of pollutants, especially nutrients, to the Chesapeake, and degrade both terrestrial and aquatic habitats. A variety of local environmental services, from provision of habitat for migratory birds and protection of human populations from flooding, are likely to be disrupted. And regional environmental services such as support of biodiversity, production of anadromous fishes and support of commercial fisheries will be increasingly strained. These reductions in environmental services represent real social costs of landscape change in the Chesapeake watershed, costs that in many cases could be reduced by consideration of landscape dynamics to guide policy and steer investments in environmental restoration and enhancement.

## Landscapes, Scale, And Land Management

Landscapes are hierarchically structured (O'Neill et al. 1986, Forman and Godron 1986). Larger landscapes (e. g. the Chesapeake Watershed) are composed of smaller landscapes (counties, sub-watersheds), which, in turn, are composed of smaller units. The hierarchical nature of landscapes implies a dependence of dynamics (patterns of change over time) at one spatio-temporal scale on those occurring at other scales. Local changes and changes at the landscape scale are necessarily linked, if only because landscapes are built up of local-scale features. Those linkages, however, take particular forms because differences in the characteristic frequencies or response times at successive levels in hierarchical systems partially insulates each level from adjacent (higher or lower) levels (O'Neill et al. 1986, Hollings 1992).

Phenomena occurring on landscape scales provide a slowly-changing background for events at smaller, local scales (O'Neill et al. 1986). Thus the Chesapeake Bay watershed provides a gradually changing context for phenomena occurring on individual land parcels. A decision to build a seafood processing facility or a commercial fishing pier, for example, is predicated on an abundance of fish, crabs, and oysters. As the bay's production of these resources has declined, commercial coastal lands have become available for marinas, vacation homes, and other uses not as dependent on abundant seafood. The landscape dynamics are slow enough, however, so that local events—whether land use decisions or changes in the abundance of muskrats—are predominately controlled by the current condition of the Bay, and only secondarily by how the condition of the Bay is changing.

Similarly, rapid changes at local scales are often attenuated by the slow response times of landscapes. For example, the annual decisions farmers make selecting among commodities to produce on their farms induce short-term fluctuations in land cover and land use. These fluctuations, however, have only limited effects on the Chesapeake watershed as a whole. The watershed is too large and changes too slowly to respond to such short term, local fluctuations.

The cumulative impacts of local land use decisions on watershed or landscape processes can be profound (Bedford and Preston 1988). The relationship between the health of a landscape and the health of component ecosystems, lands, and habitats, however, is a complex one. Both the *scale* of changes in land condition and the *location* of lands so affected are important for determining overall landscape response. A limited degree of agricultural or suburban development is possible within larger landscape units without serious impairment of landscape processes (Klein 1979, Schueler and Galli 1991). However, there are limits to this flexibility. When dynamically important lands within a landscape (e.g., wetlands, riparian areas, floodplains) are disturbed, or when ecological processes are altered or disrupted on a sufficient proportion of less sensitive lands, landscape-level processes and thus landscape-level environmental services may be impaired.

Current efforts to institute "ecosystem management" are, in part, efforts to recognize landscape-scale ecological and social processes that have traditionally been outside the range of consideration of land managers (Grumbine 1994, Lackey 1994).

**Scale and the Management of Landscapes**

Land managers operating at different spatial scales perceive different incentives for management action, and are capable of effectively managing different resources (Bohlen and King 1995). Land owners' primary management focus tends to be on-site resources. Local governments perceive the effects of development decisions on the local landscape, including effects on tax revenues, human health, costs of county services, aesthetics, and local environmental effects. Federal managers are charged with protecting resources at national scales, and attend to interstate resources such as migratory birds and major rivers, that local and state governments are unable, or unwilling to manage effectively.

The scale of environmental management necessary for supporting or enhancing environmental benefits depends on the particular benefit under consideration. Landowners, for example, are capable of effective management for timber, because most management actions to increase timber production can be carried out without reference to practices on adjacent lands. Since landowners also receive many of the benefits of managing their lands for timber (see figure 1), investments in timber management are freely undertaken (provided harvest is not too far in the future). In contrast, managing a wetland or a stream reach to support stocks of anadromous fishes is impossible for most landowners. Even a high quality stream reach or wetland in a watershed that provides poor habitat for anadromous fishes will support few fish. In addition, many of the benefits of efforts to support anadromous fishes will accrue many tens of kilometers from the stream reaches in which the fish reproduce. Therefore land managers (like many landowners and local governments) who focus on local environmental benefits would have difficulty protecting anadromous fishes, but equally important, they may perceive weak incentives to do so, since they or their constituencies would receive only a small share of the benefits.

Larger scale (regional, or national) managers, on the other hand, serve larger constituencies that include those who benefit from improved commercial and recreational fishing downstream. Thus regional or national authorities are more likely to invest in protecting them.

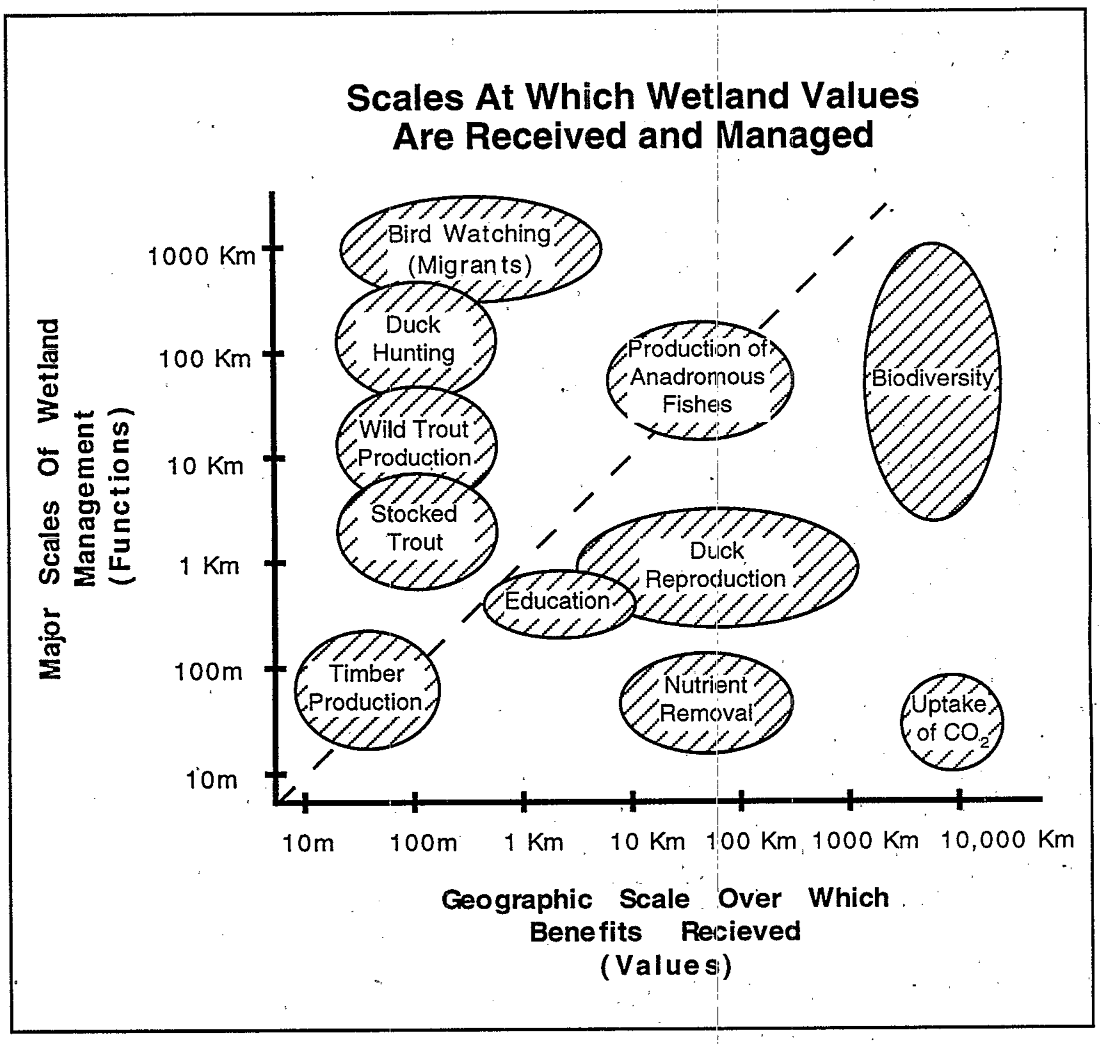


**Figure 1:** Scale over which site-specific resources such as wetlands can be managed do not always match the scales over which resulting benefits are realized. Externalities beyond the control of any single decision maker are common (Modified from Bohlen and King 1995).

The scale on which resources need to be managed does not always match those on which the benefits are most readily received, leading to resource conflicts. Resources that fall above the dotted line in figure 1 are hard for individual land owners to manage, even if they want to, because local benefits are supported by ecological processes occurring outside the local area. In the presence of institutions such as elected governments, markets, and voluntary associations that are capable of aggregating preferences of scattered individuals, cooperative, minimally coercive management may be possible (e. g. , bag limits on waterfowl). Management may be minimally coercive in the sense that many local decision makers will receive benefits from management actions, and coercion is needed primarily to discourage "free riders".

Resources below the diagonal line, on the other hand, present fundamental conflicts of interest between landowners and others in society. The resources generally must be managed at small scales (often at cost to landowners), but they produce benefits that accrue primarily to others. Thus landowner-dominated decisions generate externalities, and there may be calls for regulation in order to protect others' interests. Resulting regulations are coercive in the sense that they impose real costs on local decision makers, thus engendering non-compliance and political opposition. This conflict between local and regional benefits underlies much of the current political controversy over regulation and property rights.

## Landscapes in the Chesapeake Region

In this paper we focus on two contrasting landscapes in the Chesapeake Watershed. The two landscapes are (1) rapidly suburbanizing Anne Arundel County, Maryland, and (2) the largely agricultural Nanticoke river watershed of Maryland and Delaware. Neither landscape can be considered "natural". Both are products of a long history of human management. The Nanticoke watershed is highly agricultural. Anne Arundel county is a county in the midst of a suburban transition.

### Case 1: Anne Arundel County

Anne Arundel County, Maryland is a suburbanizing county located east of Washington D. C. and south of Baltimore. North of Annapolis, the county is highly suburbanized, while "south county" retains much of its rural character. Most of the county is now within an hour's drive of either Washington D. C. or Baltimore, making the entire county attractive for suburban development. The county is underlain by deep, poorly consolidated coastal deposits. Soils tend to be sandy and easily eroded. The Patuxent river, which forms the western boundary of the county, is the only large non-tidal river in the county. Most streams are small, and drain to tidewater within a few miles of their headwaters, either to the tidal Patuxent, or to one of several tidal rivers to the east. Stream valleys are often steep-sided, with narrow, but well developed riparian areas. Extensive forests remain in the central and western part of the county, with a few large forests in the north, and abundant small woodlands to the south.

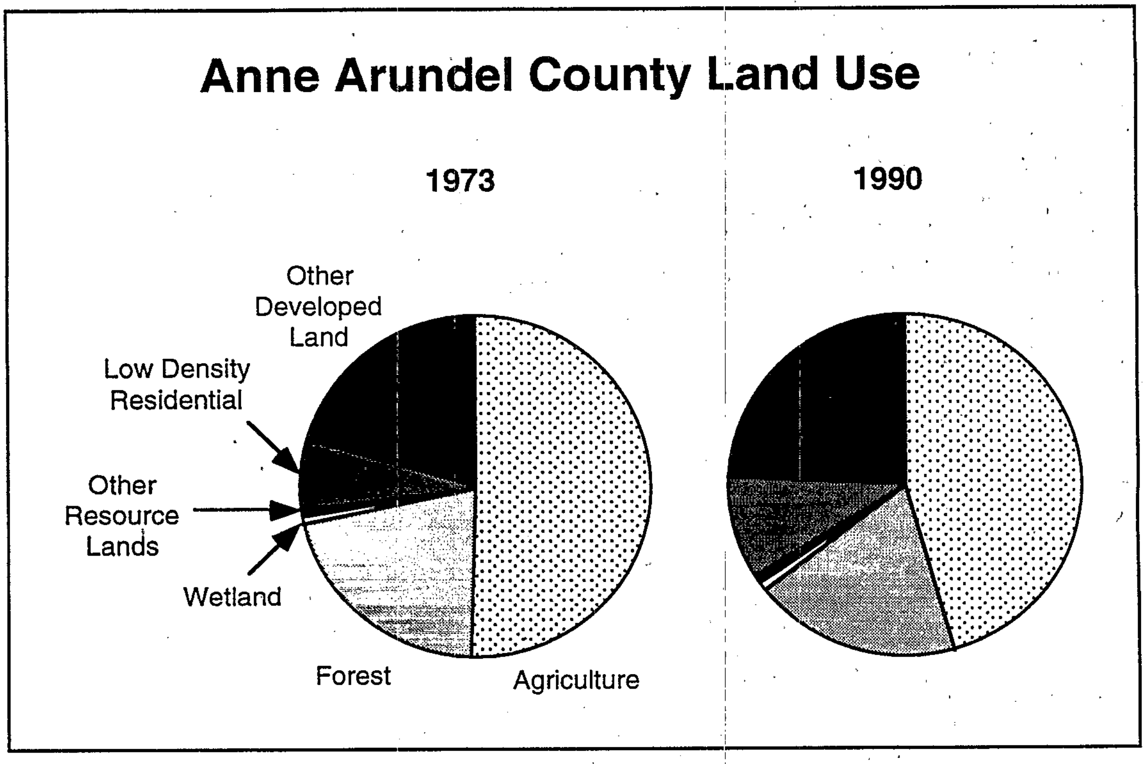


**Figure 2:** Land use in Anne Arundel County, Maryland, 1973 and 1990. Agricultural and forest lands have declined, low density residential lands and other developed lands have increased. (Based on data From The Maryland Office Of Planning).

Land use changes in the county over the last twenty years have been profound (Figure 2). Between 1973 and 1990, total developed land in the county increased from 28% to 35% of county land area. Low density residential development (which increased by almost 50% over the period) accounted for almost half of that increase. Over the same period, forest lands and agricultural lands declined by 10%. Almost half of the loss of forest and agricultural lands occurred in the last five years of the period, from 1985 to 1990 (all statistics on land use from Maryland Office of Planning 1991).

These statistics are a symptom of a general acceleration of land consumption both in Anne Arundel county, in Maryland as a whole, and in the Chesapeake Bay watershed (Maryland Office of Planning 1993, 2020 Panel 1988). The population of the state, while growing overall, has been abandoning developed areas and moving into newly suburbanizing areas. From 1970 to 1990, Maryland's urban and inner suburban areas have shown declines in population. The (mostly urban) areas of the state that declined in population over that twenty year period witnessed a 21% loss in total population, despite state-wide population growth. In contrast, newly suburban areas of the state have shown strong population increases. Existing suburban areas and most rural areas have had slight population increases (Maryland Office of Planning 1993). Per capita land consumption has increased substantially in the last few decades. As of 1950, an average of 0.18 acres of land had been developed per person in the Chesapeake Bay Watershed. By 1980, land intensity of development had increased to the extent that 0.65 acres of land were being developed per new Maryland resident (2020 Panel 1988).

**Consequences of Suburbanization**

Clearing of forest and the transformation of agricultural land into lawn, roads, and buildings triggers profound hydrological, physical and chemical changes at the landscape scale.

Abundant impervious surfaces in urban and suburban landscapes (roads, parking lots and roofs) prevent water from infiltrating into the soil. Infiltration on what pervious areas remain is reduced in comparison to that which occurs in forested or even most agricultural landscapes. Little water falling on suburban landscapes finds its way into the ground water, where water flow rates are slow, and opportunities for biological and physical removal of pollutants, great (figure 3, Schueler 1987).

Under pre-development conditions, a substantial portion of precipitation enters the groundwater, which slowly drains to streams over weeks or months. Flow paths to surface drainage networks are long. Natural ephemeral and low order streams dissipate a substantial proportion of the energy of falling water in turbulent flow and friction, slowing water movement. Thus water levels in streams remain higher between precipitation events, maintaining sufficient base-flows to protect aquatic organisms, and the pulse of water that reaches the stream after a storm event (arrow in the figure) arrives slowly, spread out in time, resulting in a relatively low peak discharge.

Developed landscapes, on the other hand are "flashy". Structurally complex natural drainage networks are replaced with simpler storm drain systems, in which turbulent flow and friction are reduced. Water moves via engineered surface water conveyances, instead of via a combination groundwater, surface sheet flow, and natural channels. Flood pulses are rapid and high, but between-storm flows are low; most of the stream flow occurs in brief flashes immediately following rainfall events.

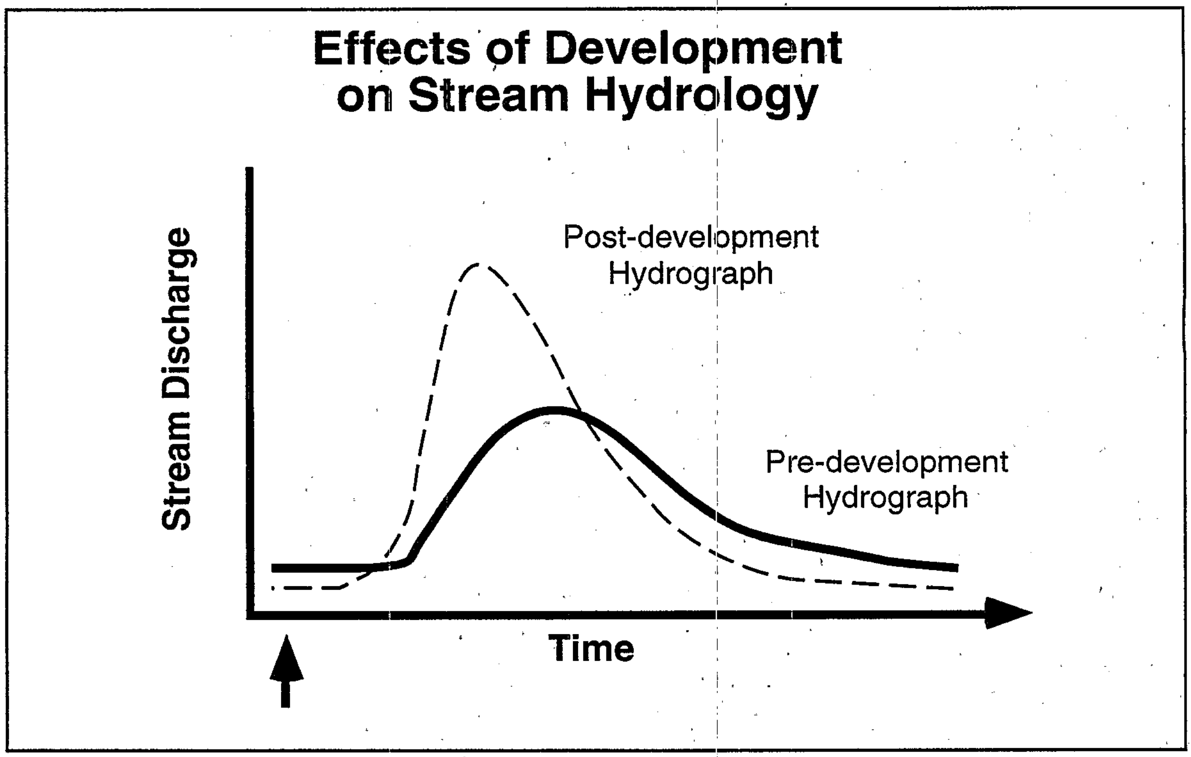


**Figure 3:** Idealized Pre- And Post-Development Hydrograph For Maryland Streams (Modified from Schueler 1987).

The ecological and geomorphic consequences are substantial. First, flashy streams are erosive streams. High discharges and associated high water velocities in streams move soils and sediments much more effectively than do low velocity flows. The resulting stream bed erosion in suburban and urban streams in Anne Arundel county is sometimes severe enough to turn streams into biologically depauperate gullies. In one extreme case (the west branch of Weams Creek on the outskirts of Annapolis) the stream has cut a gully over 3 meters deep in places (personal observation). Sediments from downcutting are also transported downstream where they go on to harm other aquatic ecosystems, and trigger dredging and other activities to ameliorate their effects on waterfront land owners.

Second, urban and suburban streams are often unable to support normal riparian communities. Riparian areas and associated wetlands trap sediments and remove nutrients thus protecting downstream water quality. Riparian areas are also important to a variety of landscape-scale processes including creation of high quality aquatic habitats, water storage and support of biodiversity (Peterjohn and Correll 1984, Welsch 1991, Schlosser 1991, Richardson 1994, Bohlen 1992, Lowrance et al. 1995). Downcutting of streams can dry out adjacent riparian areas and wetlands, reducing water quality and other values. Even where downcutting has not been severe, flashy conditions and reduced infiltration shrink the residence time of waters in riparian areas, lessening opportunities for biological processing of nutrients.

Third, urban and suburban streams provide poor habitat for most aquatic organisms. Abundance, number of species, and total diversity of stream fish and invertebrates generally declines with watershed imperviousness, which is highly correlated with the abundance of urban and suburban lands within the watershed (Klein 1979, Schueler and Galli 1991). With even moderate levels of suburban development and extensive use of urban BMP's (Best Management Practices), few species of fish survive, and those that do survive are generally of little recreational value. The biotic integrity of urban and suburban streams is generally low (Karr et al. 1985, Hall et al. 1994)

In addition to its physical effects, suburbanization also increases the flow of various pollutants to receiving waters. Urban and suburban landscapes release substantial quantities of nutrients, sediments, hydrocarbons, metals, and other pollutants into surface waters (EPA 1991, Schueler 1987, Ailstock and Horner 1989, Olsenholler 1991). Flows of nutrients have been especially problematic in the larger context of the Chesapeake restoration effort. The Chesapeake Bay Program adopted in 1987 an ambitious goal of reducing nitrogen and phosphorous flows to the Bay by

40% by the year 2000 (Chesapeake Bay Program 1994). Suburbanization increases nutrient flows in a number of ways.

(1) Nitrogen and phosphorous are released from suburban landscapes simply because of their large human populations. Large quantities of nutrients are imported into the Chesapeake Watershed in food. Those nutrients are seldom exported from the region, but are released into ground and surface waters via septic tanks and sewage treatment plants.

(2) Maryland now has more acres in lawn than in corn production (Horton and Eichbaum 1990). Grass for ornamental purposes is thus one of the state's major "crops". Many lawns receive high levels of fertilizer, and leaching of nutrients can be significant.

(3) Approximately a quarter of the total nitrogen entering the Chesapeake Bay is derived from atmospheric sources (MDE 1992, Hinga 1991). Of that, about one third is thought to be derived from automobiles (Waheed 1994). In suburban landscapes, people are widely scattered and residences are far from shopping and work. Although emissions per vehicle mile traveled have fallen, increased travel (in part encouraged by suburban development patterns) has more than made up for the difference.

(4) Loss of forest also contributes to increased nutrient loadings since forests are both the region's least polluting land use, and highly conservative of nutrients. Suburbanization replaces a non-polluting land use with a much more polluting one.

Sediment releases from suburban landscapes and from development sites also cause problems for aquatic ecosystems. Sediments fill navigation channels, reduce light penetration in the water column, bury benthic communities, reduce feeding efficiency of suspension feeders, and cause physical damage to gills and other delicate biological structures. In streams and rivers, sediments may also alter water flow patterns, sediment transfer processes, and stream bottom properties in ways harmful to fish and other desirable aquatic life. The impacts of sediments may be further exacerbated because phosphorus and a variety of toxic chemicals often travel adsorbed to sediment particles.

## Case 2: The Nanticoke Watershed

The Nanticoke watershed drains approximately 400,000 acres in Caroline, Dorchester, Wicomico and Somerset counties in Maryland, as well as approximately 315,000 acres in Sussex and Kent counties, Delaware (Nature Conservancy 1994). Agriculture accounts for approximately 42% of the watershed by area. Forests, many intensively managed, cover an additional 45% of the watershed. Less than 2% of the watershed area is in urban lands.

The landscape is one of low topographic relief, developed on a variety of unconsolidated sediments, mostly derived from sandy and silty coastal plain deposits. With little elevation change, water potential gradients are low, so both ground water and surface water flows are slow. In particular, without artificial drainage, water drains slowly and ponds extensively. Extensive wetland complexes were once found along drainage divides throughout the region where topographic gradients are low, and drainage patterns ill-defined. In the upper, Delaware portion of the watershed substantial areas were drained for agriculture, many of them as WPA projects during the depression.

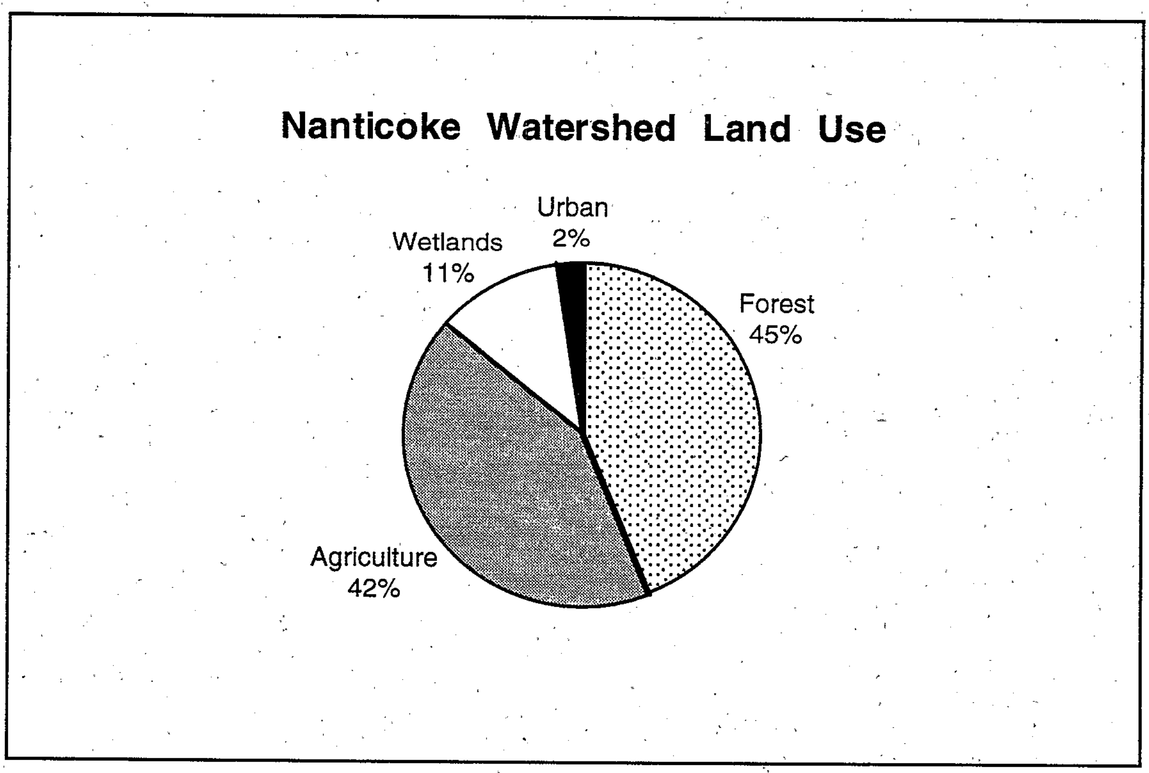


**Figure 4:** Land Use in the Nanticoke Watershed. Forested wetlands have been included in the "Forest" land use category. Total wetland area therefore is somewhat higher than this diagram suggests.

There has been little change in land use in the watershed over the last few decades. There has been only a slight increase in urban land over this period, although development of suburban strips along major roads has occurred around the watershed's larger towns and cities. Data from the Yearbooks of Agriculture (U.S. Department of Commerce 1954, 1959, 1964, 1969, 1974, 1982, 1987, and 1992) for Dorchester County Maryland and Sussex County, Delaware show that between 1948 and the present, total cropland area has remained more or less constant, or increased slightly. Simultaneously, the total number of farms has declined, and average farm size has risen (Figure 5).

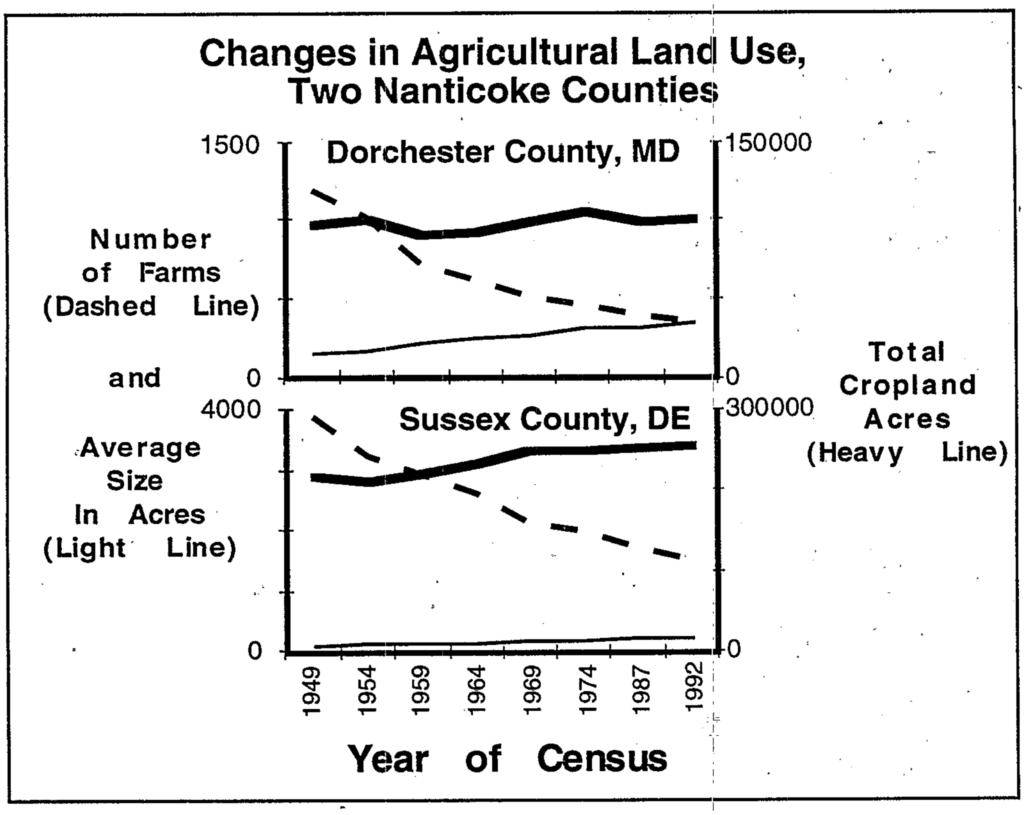


**Figure 5:** Changes in Land use in Two Nanticoke Counties, 1948-1992. Source: Census of Agriculture.

### Consequences of Agriculture

Much of modern agricultural practice is an effort to keep agricultural fields in early successional states. Repeated disturbances (in the form of plowing, disking, cultivating, applying herbicides, and harvesting) prevent the development of later successional ecosystems (e.g., forests) that would be undesirable for agricultural production. Early successional ecosystems generally show an excess of primary productivity over respiration. In many agricultural production systems, that excess is captured for human use in the form of crops (Odum 1969). Unfortunately, early successional ecosystems also tend to be leaky. Early successional or disturbed ecosystems retain nutrients and sediments less tightly than do less frequently disturbed communities (Odum 1969, Bormann and Likens 1979). Thus agricultural efforts to maintain early successional conditions in order to produce crops are associated with releases of sediments and nutrients to adjacent ecosystems. Careful agricultural management efforts can limit the losses, but they are extremely difficult to eliminate entirely.

On a landscape scale, agriculture increases nutrient flows to the Bay by importing nutrients into the Chesapeake watershed, especially in the form of fertilizers and animal feeds. Nutrients are also exported from the region in agricultural products, but because of nutrient losses within the agricultural production system, a portion of the imported nutrients remains within the watershed, increasing total loadings to the bay.

The agricultural community has, for years, worked hard to reduce soil erosion and the export of nutrients from agricultural lands. Various management practices, from fertilization practices, to strip cropping, to low-till or no-till farming systems can increase or decrease the loss of nutrients and soil from agriculture. A variety of federal and state agencies have worked with farmers to develop management techniques to reduce the loss of sediment and nutrients from farm fields. Maryland now requires many farms within the 1000 foot "critical area" adjoining the Chesapeake and its tidal tributaries to have detailed nutrient management plans. These plans, which vary in their complexity, represent a concerted effort on the part of farmers to reduce the loss of nutrients from agriculture. The Soil Conservation Service worked for decades with farmers to implement agricultural Best Management Practices (BMPs) targeted on reducing soil loss. The SCS's mission was gradually broadened by legislation and policy to incorporate a wider and wider range of resource protection issues, including protection of water quality, the reduction of nutrient runoff, wildlife conservation, and wetland protection. Near the end of 1994, the agency's name was officially changed to "Natural Resources Conservation Service" in order to reflect its broader mission.

Despite these and related efforts, agriculture remains a major source of nutrients to surface and ground water. Water quality in the tidal fresh portion of the Nanticoke river reflects the impacts of agriculture. The consequences are shown in water quality monitoring records collected between 1985 and 1989 at the tributary water quality monitoring station on the tidal freshwater portion of the Nanticoke river, near Sharpstown, MD (MDE 1994). Dissolved inorganic nitrogen (sum of nitrate, nitrite, and ammonium concentrations) was routinely available in excess, and sometimes in tremendous excess of levels limiting to phytoplankton growth. Ratios of the concentrations of total nitrogen to total phosphorus were also very high, indicating that phytoplankton growth was generally limited by available phosphorous. Chlorophyll A concentrations (a measure of phytoplankton abundance) were high, and Secchi depths (a measure of water clarity) were low. Conditions were poor enough to preclude growth of submerged aquatic plants, which grow best when waters are clear. Ecologically, the Nanticoke is suffering negative effects from nutrient enrichment, especially enrichment by nitrogen.

The USGS has found that agriculture on the Delmarva peninsula also contributes nitrate to ground water. Detectable levels of nitrate were found throughout the upper portions of the Nanticoke watershed, but concentrations of nitrate exceeded EPA drinking water standards (10 mg/l, approximately 15 times the level at which phytoplankton growth would be limited) only in a few hotspots (Hamilton et al. 1992). Over time (sometimes measured in decades in the flat Nanticoke watershed) this nitrate-enriched ground water will flow to streams and other surface water systems, eventually increasing nitrate loadings to the Chesapeake.

**Consequences of Drainage**

The construction of drainage systems throughout the upper portion of the Nanticoke represents a significant change in landscape dynamics, and has had a series of ecological consequences.

Construction of drainage ditches successfully sped the removal of water from the landscape, thus allowing expansion of agricultural production. The same increase in the speed with which water drains off of the landscape, however, changes the patterns of water flow entering downstream ecosystems. Construction of drainage systems removes surface water, and in the sandy soils that predominate in much of the Nanticoke watershed, can lower the water table aquifer as well. The net effect is to reduce the ability of landscape to trap and store water. Rainfall from storm events, instead of being stored within the upstream portions of the watershed is now passed downstream, increasing peak discharge following storms, and increasing the variability of the salinity and other chemical characteristics of estuarine waters downstream.

Drainage has resulted in the loss of substantial areas of wetland and the degradation of riparian areas. Wetlands and riparian areas can be remarkably effective at removing, transforming, or neutralizing sediments, nutrients and certain other common agricultural pollutants from surface and groundwater flows (e. g. Moshiri 1993, Peterjohn and Correll 1984, Welsch 1991, Lowrance et al. 1995). The potential water quality benefits of these areas have been reduced because (1) the area of wetland and riparian forest within the landscape has been reduced, (2) ground and surface waters draining agricultural areas and carrying heavy loads of pollutants are now more likely to bypass riparian areas, and (3) those waters that do pass through a riparian area are likely to flow through the biologically active zones of the soil more quickly under the increased hydraulic gradient provided by drainage systems. These changes reduce the extent of denitrification, physical trapping of sediments, and biological uptake of nutrients within the upper portions of the watershed.

It is possible, although not yet proven, that hydrologic changes in the river have exacerbated the impacts of acid deposition on rockfish (*Morone saxitalis*). Rockfish larvae are unable to survive in the Nanticoke river, apparently because of low pH and elevated levels of aluminum in the water (Hall et al 1985). The shorter time that water from storm events resides on the landscape reduces the extent to which storm waters are mixed with less acidic groundwater. Moreover, decreased contact of storm waters with wetland and riparian systems may limit biogenic buffering processes capable of reducing the detrimental effects of the acid deposition. Thus hydrologic modifications may have increased the severity of acidic "flashes" that follow precipitation events, indirectly limiting rockfish recruitment, and reducing populations of other acid-sensitive fish species (Hall et al. 1994)

## Landscape Management

### Management Of Landscapes Via Natural Vs. Cultural Processes.

Landscapes maintain and change their physical structure through endogenous (ecological and physical) processes, through maintenance processes carried out by humans, or through some combination of the two. In human-dominated ecosystems, maintenance processes may derive from government expenditures, general economic activity, engineering, or other human behaviors. In unmanaged landscapes, ecological maintenance processes predominate. These non-anthropogenic maintenance processes are known as "functions" in the wetlands science and policy literature (Richardson 1994). We use the term "ecological processes" to emphasize that these phenomena need not have any utilitarian benefit to be significant from the perspective of landscape dynamics.

The choices land managers face can be depicted schematically in a Landscape Management Ternary Diagram (figure 4). Human activity may sever or alter one or several of the environmental processes that maintain the ecological and physical structure of an unmanaged landscape. The resulting landscape change may be perceived either as beneficial (e. g. , when agriculture is established) or as detrimental (e. g. , when suburbanization leads to degradation of stream ecosystems). When humans like the landscape changes, cultural processes develop or are established that maintain the landscape in its new, desirable form. Therefore, the landscape moves from the lower right region of the ternary diagram labeled "Maintained by Ecosystem Processes" toward the top of the diagram, labeled "Maintained By Cultural Processes" to reflect the increased importance of human activity in maintaining the structure of the landscape. If humans do not like the landscape changes, two outcomes are possible. First, cultural management may not develop, and the landscape moves toward the lower left part of the diagram, labeled "Low Environmental Quality". Second, human societies may undertake defensive expenditures to resist the landscape changes, again increasing the degree to which the landscape is maintained by cultural processes, and moving toward the upper portion of the ternary diagram.

The landscape management ternary diagram depicts, in a schematic way, the relative intensity or importance of cultural and ecological processes in structuring landscapes. A healthy urban landscape, for example, might rest somewhere near the "1" on the diagram. A wilderness area, somewhere near the "2". An agricultural landscape dominated by conventional agricultural practices might lie at "3", while a small, heavily managed nature reserve in a suburban landscape might lie somewhere near the "4". More generally, the diagram represents a state space over which landscapes evolve as they are disturbed, managed, and abandoned by humans. The diagram provides a framework for understanding a variety of land management decisions.

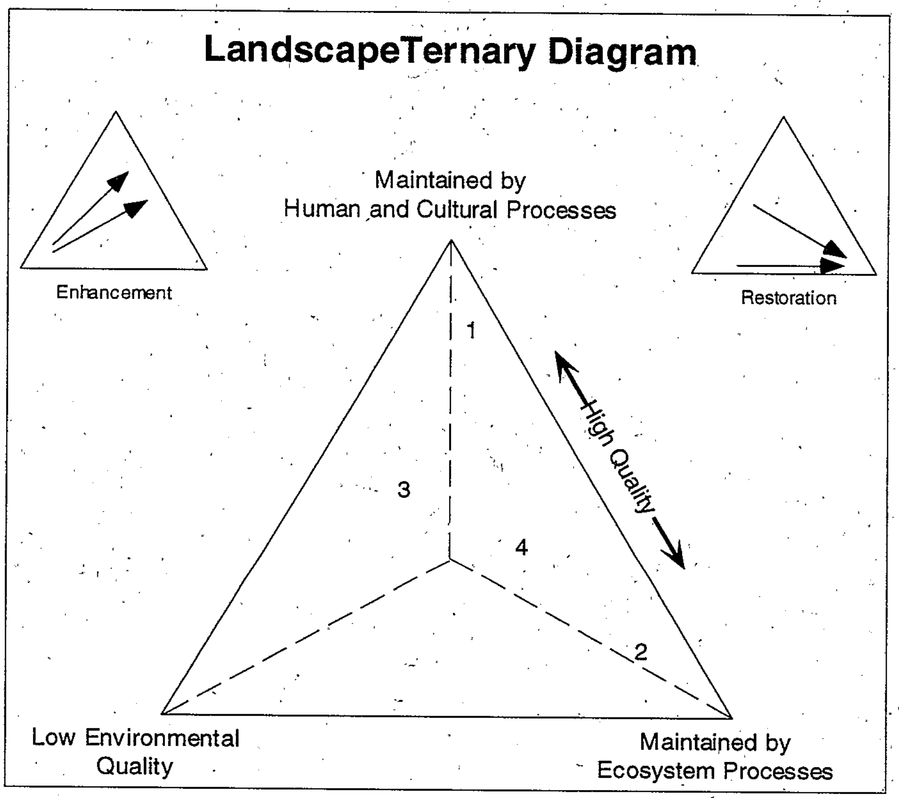


**Figure 6:** The Landscape Management Ternary Diagram.

It is important to point out that both high quality and low quality lands may be maintained predominately by either cultural processes or ecosystem processes. The relative importance of cultural and ecosystem maintenance is not, in general, related to any subjective evaluation of environmental quality. Relatively stable, culturally dominated landscapes—of both low and high quality—have existed in Europe and Asia for a millennium or more. Moreover, the conceptual separation we are using between cultural and ecosystem processes is in no way an effort to separate humans from nature. In fact, it is in large part motivated by an effort to develop analytic alternatives to a simplistic dichotomy between natural landscapes and other (unnatural?) landscapes. If such a dichotomy ever had any validity, it certainly has little in a world in which even the global radiation budget has been altered by human activity (McKibben 1989). Essentially all landscapes today are maintained or altered by some combination of ecosystem and cultural processes.

Indeed, land managers, in deciding how to achieve environmental and social goals may rely primarily on cultural processes or on ecological processes to maintain, restore, or enhance landscapes. The resulting landscapes would be very different (city versus forest) and would therefore provide different combinations of environmental and economic benefits, risks, and opportunities. Direct maintenance costs for landscapes maintained by ecological processes are, by definition, low. The direct costs of maintaining a landscape by cultural processes will be higher. In general, reliance on cultural processes will require ongoing effort (and expense) to prevent succession, decay, erosion, sediment deposition, and other ecological or physical processes from changing the landscape in undesirable ways. In addition, landscapes maintained primarily by cultural processes often change the rate of flow of sediments, nutrients, water, and other chemicals to adjacent ecosystems, perturbing them in unplanned, and often undesirable ways. Thus human-dominated landscapes often induce environmental externalities.

To understand why externalities arise, it is necessary to consider landscapes as hierarchical systems. Landscapes have usually been managed primarily at small scales; less attention has been paid to the effects of small-scale land use changes on larger-scale landscape and watershed processes, perhaps because the benefits to be derived are often public goods. The intercalation of cultural processes into the landscape hierarchy therefore is dominated by social, economic, and behavioral processes occurring at certain characteristic scales. At larger scales, we just do not pay much attention until some sort of a problem develops.

Within a dynamic hierarchy, however, changes in dynamics at specific scales are communicated up and down the hierarchy. Altering dynamic processes at one scale will trigger unplanned effects at other scales. One manifestation of this is that landscapes maintained predominately by cultural processes often export environmental problems to other landscapes with which they are linked (for example the agricultural landscape of the

Nanticoke exports nutrients to the estuary). These problems represent conditions imposed on adjacent ecosystems inconsistent with their previous ecologically-driven dynamic regimes. Establishment of culturally-maintained landscapes at one scale often has the effect of disrupting ecosystem maintenance processes at larger scales. At the smaller scale, culturally-controlled landscapes may be of high quality (toward the top and right of the ternary diagram), yet at the next higher level in the landscape hierarchy, the landscape will begin to change. At least in the short term, it is likely that at some of these unplanned and often unanticipated landscape changes will be undesirable.

In the Chesapeake watershed, small-scale landscape transformation has been going on for centuries, with different results in different areas. In suburban or agricultural landscapes, as elsewhere, we have just begun to institute cultural processes aimed at maintaining the larger (watershed scale) landscape system. It should, therefore, not come as a surprise that the Chesapeake watershed shows signs of dynamic instability and functional change. In this case, many of the changes we see have been unpleasant, with the result that a concerted effort has developed to manage the bay to maintain more of its environmental benefits, either by shoring up disrupted ecosystem processes, or by implementing new cultural processes to partially replace them.

## Management Of Chesapeake Landscapes

Consider the management options faced by managers of the Chesapeake Bay and its watershed hoping to restore environmental services once provided by the Chesapeake. (1) The Bay may be managed in a manner that relies on cultural processes to assist in the production of desired environmental outputs (for example, oyster aquaculture, rockfish hatcheries). We would call this approach environmental enhancement, since it would not be restoring the Bay system to previous dynamic conditions, but instead working to replace them with a new dynamic regime. Such a strategy is likely to become increasingly difficult and expensive as ecosystem services of the Bay watershed continue to decline. (2) Alternatively, the Bay could be managed to reinstate fundamental ecological relationships that previously produced desired environmental benefits. This approach could be called environmental restoration because it focuses on restoring ecological processes that previously dominated the dynamics of the watershed. Environmental restoration, in this sense, may place more stringent limits on the scale or character of human activities within the Chesapeake watershed, inducing a variety of social costs. Different approaches or combinations will be most feasible in each landscape.

Environmental restoration is likely to play a significant role in agricultural landscapes such as the Nanticoke, where land use is relatively stable, and the physical structure of the watershed is less profoundly disturbed. Impervious surfaces are not widespread in the Nanticoke watershed. The basic topographic structure necessary to reestablish ecological linkages between agricultural fields, drainage systems, and largely intact (but dewatered) riparian area remain in place. Restoration of wetlands and riparian areas would reestablish biological processing of nutrients and other chemicals. Such an effort would require that water be retained on the landscape for longer periods of time than is now the case. Increased retention would increase the exposure of both ground and surface waters to biological processing, and reestablish and maintain conditions in the soil conducive to denitrification. While restoring the hydrology of the Nanticoke watershed to something resembling its historical condition may be technically feasible, such a change would be expensive and probably unacceptable to local inhabitants. To be practical, restoration of landscape functions must be carried out in such a way that farmers' and other residents' need for drainage can continue to be met, while simultaneously retaining more water on the landscape, at least at some locations and at some times of year.

Much of the Nanticoke watershed once consisted of seasonal wetland systems, wet in the late winter and spring, but drier once evapotranspiration of growing trees and other plants removed water from the poorly drained soils. A major goal of many drainage systems thus was to remove water early in the growing season in order to ensure that agricultural lands could be planted. Ironically, some areas are now irrigated during the summer because they lack sufficient water to maintain plant growth. The ditches that remove water in the spring also reduce the availability of water the rest of the year.

Thus while full restoration of natural hydrology is impractical for the Nanticoke, partial restoration of ecological functions may be possible. Using simple water control structures that can be opened a certain times of year, and closed at other times. Installation of such structures within selected ditches may allow removal of water from these lands in the spring (when the control structures are open), while permitting increased retention of waters in the floodplains during the remainder of the growing season, when agricultural as well as riparian and wetland areas could benefit.

In contrast to the rural landscapes of the Nanticoke watershed, few opportunities for large scale landscape restoration are likely within urban and suburbanizing landscapes such as those in Anne Arundel County. Tree plantings and other typical urban and suburban restoration efforts build public awareness of environmental issues, but often have only marginal impacts on landscape-level processes. Larger-scale efforts at restoration are generally precluded because they would require the displacement of high-value land uses and removal of existing structures. Instead, most opportunities for managing landscape processes in suburban landscapes rely on enhancement of environmental functions with engineered structures like stormwater management devices.

Over the last two decades, stormwater management has increasingly been used to protect streams and surface waters from the consequences of local land use change (e. g. Schueler 1987). Infiltration, detention and retention basins have become a fixture of the Maryland landscape, found wherever recent development has occurred. Stormwater management substitutes engineered structures designed to provide particular hydrologic and water quality services for physical and ecological processes disrupted by development. Installation of stormwater management structures represents a prime example of a landscape being managed to achieve environmental purposes in a way that increases reliance on cultural processes.

The potential value of stormwater management is great, but it comes with substantial costs. The engineered structures being used for stormwater management are costly, and require ongoing maintenance to protect their environmental function. Maintenance shortcomings are common (Roberts and Lindsey 1990). Even when properly maintained, most stormwater management structures have a variety of unintended side effects (Schueler and Galli 1991). Infiltration devices, for example, not only infiltrate water, but also inject dissolved pollutants into the ground water, where biological contact and treatment are low. Detention and retention basins increase surface water temperatures. In general, high maintenance requirements and a variety of environmental side effects are to be expected whenever cultural maintenance processes substitute for ecological ones.

Recent developments in stormwater management have tried to reduce or eliminate many of these problems (Schueler and Galli 1991). One answer has been to design stormwater management structures as shallow, vegetated wetlands (Moshiri 1993, Schueler 1992). These basins not only provide the water quality and quantity control required of stormwater management devices by state laws, but also provide an artificial context for ecological processes in a largely human-dominated landscape where such processes would otherwise be rare. Using artificial wetlands in this way reflects a growing understanding that environmental technologies can be most effective when built to exploit, rather than resist ecological processes (Mitsch and Jorgensen 1989). On a larger scale, these artificial wetlands represent an effort to build a hybrid landscape that is neither natural nor artificial, but in which important natural processes are sustained in the context of a landscape that provided for human wants and needs. Such hybrid management systems, part nature, part culture, will, we suspect, become ever more common, as our society learns to reconcile the self-sustaining character of ecosystems and the focused functionality of manufactured artifacts, and equally important, as we learn to recognize how human activity affects landscape-scale systems.

## Conclusions

Residents of the Chesapeake Bay watershed have made, and continue to make, many land management decisions based on local benefits and short-term needs. Cumulatively, these decisions have provided food, housing, and other direct benefits for many, but have simultaneously altered landscape systems and initiated changes in landscape functions that reduced other benefits provided by the Bay, its watershed and its tributaries.

We suggest that long term restoration and protection of the Chesapeake Bay and its many values will require recognition of the hierarchical properties of landscapes. In the long run, successful management of the Chesapeake will require tools and approaches to environmental management able to assess landscape functions at various scales and able to recognize cumulative effects of apparently isolated decisions. Efforts should be expanded to inform individuals how their actions impact the landscape, as well as to communicate what can be done to achieve individual land management goals while avoiding or mitigating negative impacts on landscape systems. Landscape-scale management should also provide feed-back to individuals and local governments so that their actions can be better coordinated to reduce threats to landscape functions. In the long run, economic, legal and other incentives and disincentives may have to be tailored to reduce local activities that create negative externalities at landscape scales, and encourage those that support landscape processes.

Some landscape-centered management approaches already exist. For example, Local governments and soil and water conservation districts which oversee land management within political boundaries have initiated various programs to promote land management practices that help to maintain landscape-level functions. Federal, state, and local regulations have also been adopted that coerce land managers to reduce certain impacts on landscape-scale systems and to provide mitigation for impacts that do occur. Such regulations, however, are facing strong opposition because they generally impose direct costs on individual land owners.

Interestingly, recent changes in efforts to manage Chesapeake watershed also reflect the need for management that better reflects the hierarchical nature of landscape dynamics. The Chesapeake Bay Program, a regional cooperative effort to study and manage landscape-scale was established by the federal government and the main Chesapeake Bay states, (Pennsylvania, Maryland, Virginia, as well as the District of Columbia) as a way to better study and manage landscape-scale problems that have led to loss of benefits from the Bay. Recently, leaders of the Chesapeake Bay Program initiated the "Tributary Strategies" which decentralize the watershed restoration effort, and focus attention on the peculiarities of the different sub-watersheds of the Chesapeake. Coalitions of citizens, local governments, and soil and water district officials have been created to evaluate specific problems within the watersheds of the major Chesapeake Bay tributaries, and to promote regional management at a landscape scale. A major component of this initiative is education of residents so that they may make land management decisions informed by how they impact the larger landscape system.

In the Chesapeake Bay watershed, re-establishing landscape processes able to support a healthy, more productive Bay will require recognition of and investment in landscape-scale processes. We will have to be far more sophisticated landscape and watershed managers than we are today if we are to support anticipated human populations of 15 million or more in the watershed by the year 2020 without causing further declines in the physical, chemical, and biological integrity of the Bay and its tributaries. In the future, management efforts that focus explicitly on enhancing or restoring watershed- or landscape-scale processes must become a central part of all efforts to protect the environmental benefits of the Chesapeake. Otherwise, the combination of the landscape-scale externalities associated with land use decisions and the limited ability of markets to efficiently allocate public goods will lead to continued deterioration of the Chesapeake watershed, unnecessarily impoverishing the region.

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