A Context-based Approach to Shoreline and Critical Areas Management

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Current environmental protection strategies used by many jurisdictions in the Puget Sound region tend to be dominated by approaches that can best be described as legalistic or prescriptive. That is, rules and standards are prescribed in development codes and are generally assumed to be adequate and sufficient for achieving the desired level of protection for the particular environmental attribute in question—a stream, a wetland, or a shoreline, for example (critical or sensitive areas). These rules and standards are assumed to be applicable across the jurisdiction despite the variety of geographic, environmental and land use conditions encountered. Variations from the general code provisions are allowed when the provision or standard either cannot be met on a site or is too burdensome for the allowable use of the site. Environmental codes of this type tend to be quite complex. Questions of applicability invariably arise and in many cases, the provision or standard will probably over-regulate some areas and under-regulate others. Codes of this sort tend to work best when the activity or system that is regulated is stable, when the method or standard is well understood, and uncertainty in the system is low. When the system under scrutiny is dynamic (socially and ecologically), and uncertainty is high, an alternative approach may be called for to assure effective protection and management

Introduction

The importance and influence of the surrounding landscape to the structure and function of aquatic ecosystems has been well established. There has been considerable research on the effects of land use and land management on streams, lakes, and wetlands and new work gains impetus from the growing realization that large-scale human alterations of the landscape have implications for the well-being and sustainability of these ecosystems (as well as our own). Human activities that alter land cover, hydrologic pathways, migratory pathways and other land-water-biota interactions affect processes that operate at scales from the local to the regional, with important implications for how we go about managing these systems. In many cases, our management schemes have not kept pace with our knowledge and experience.

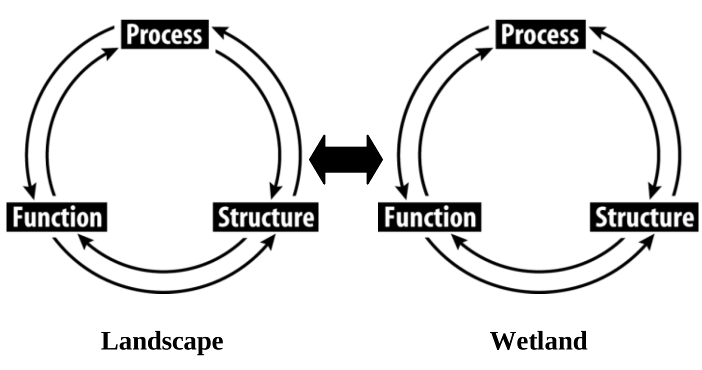
Given the many and complex interactions that occur between land and water across large spatial scales and over many years, and recognizing the dynamic nature of land use and ecosystems, it is somewhat surprising that our management remains so closely tied to a single, dominant strategy—the vegetated buffer. However, this management tool is at once simple and elegant, a kind of "living fence" intended to shield the stream or wetland from the vagaries of the surrounding area; at the same time, the buffer provides some value of its own as habitat for many plants and animals. Buffers around wetlands and other critical aquatic systems can do much to protect the functions and ecological condition of these ecosystems (Adamus 2007). Nevertheless, there are limitations to the use of this approach.

Determining the necessary width and composition of the buffer in order to provide the protective functions to the wetland and assure the longevity of the buffer itself is both scientifically and administratively complex. Other common complaints are that some buffers will be too large and others too small for their intended purpose--they take up significant area on some sites, reducing the use of property with little environmental gain, and their cumulative effectiveness is unpredictable. All are valid complaints and a variety of strategies have been developed to address them, all within the basic assumption that the vegetated buffer is the proper management choice. But perhaps the greatest ecological criticism of the current buffer approach is that this strategy tends to be somewhat oblivious to the surrounding landscape and is largely ineffective at protecting functions that are driven by processes that lie well outside the buffer, in the greater watershed or landscape beyond. This may be especially the case where the surrounding landscape is composed of a variety of land uses, is degraded or has been degraded in the past (land use legacies), and where the wetland and its buffer are, themselves, degraded, or where the opportunities for applying an effective buffer are absent.

Alternatively, a context-based approach relies on integrating environmental and landowner goals with the conditions of the landscape and the sensitivities of the critical area. This approach recasts the notion of "buffer" broadly, as any management practice or action that can be tailored to environmental objectives and prevailing conditions. In this approach, even the mainstay of critical areas protection in the Northwest--the traditional vegetated buffer--becomes one of many available management actions that can be applied where appropriate to meet environmental objectives. More a process than a prescription, context-sensitive management enlarges the available management options to include preventative, protective, and restorative actions at locations and scales that are likely to be most effective and efficient.

The Context of Management.

In the words of one landscape ecologist "Context is often more important than content" (Bailey 2003). The objective of context-based management is to place the object of our management—a wetland, shoreline, a parcel of land—in a proper ecological and social setting so that we might understand the relationship between the internal characteristics of the feature and the characteristics of the surrounding area that influences those characteristics. By doing so, we can craft management strategies and actions specific and appropriate to the feature and its setting.



Pattern, Scale and Distance

Wetlands (and other critical ecological areas) are embedded in landscapes (**Image 1**). In the decades since the late 1960s, the realization that habitats and ecosystems from wetlands to rivers to forests are strongly influenced by processes and conditions outside their boundaries has grown exponentially. Furthermore, the development of ecosystem and landscape ecology and the application of ecological principles to land use planning and management have provided new insights into the relationships between ecological processes and human activity of many kinds but especially land use and management (McHarg 1967; Forman 1995; Dale and Haeuber 2001; Ndubisi 2002; many others)[1].

Increasingly, the work carried out by investigators in these disciplines is demonstrating that the conditions of the landscapes surrounding wetlands and the attributes of the catchments that give rise to streams are major drivers of the conditions—habitat quality, water quality, even biota--within these same wetlands and streams. In particular, human-dominated land uses, especially the intensity of the land uses, affect ecological communities through direct, secondary, and cumulative impacts (Brown and Vivas 2005). Generally, the more intense the activity, the greater the affect on ecological processes. The effect tends to diminish with distance.

The advent of watershed management in the late 1970s and early 1980s in the Pacific Northwest provided the impetus to clarify some of the significant relationships between land use and its effects on stream and wetland structure and function, particularly the effects of altered watershed hydrology from increasing urbanization. The work of Booth (1991), Booth and Jackson (1997), and Horner, Booth, Azous, and May (1997) provide evidence for changes in hydrology due to the effects of land use change occurring throughout the contributing watershed. The effects appear to increase as the land use intensifies across a forest to urban gradient. In *Wetlands and Urbanization* (Azous and Horner, eds. 2001), a summary of the work of the Wetlands and Stormwater Management Research Program, parallel results were obtained for wetlands in urban and suburban settings. The hydrologic regime of wetlands in the study was altered in proportion to the land use intensity within the wetland's contributing catchment.

Since hydrologic regime is a main driver of both stream and wetland processes and functions, the conditions in the catchment cannot be ignored in crafting management strategies for protecting stream and wetland functions.

As land is altered from native cover to human uses, by forestry, agriculture, or urbanization, both the area and continuity of native vegetation is modified (**Figure 1** graphically describes this process) and transformed from the original composition and arrangement to an alternative structure and function (Forman 1995). This generally represents stages in the transformation process from one type of landscape or patch to another. The process usually begins with *perforation*—the creation of "holes" in an otherwise homogeneous land or habitat area. This may result from carving out a small portion within the original landscape for a homestead or farm, or it may be the result of a natural disturbance within a larger forested landscape. D*issection* may occur as a road or rail line splits the landscape into sections; *fragmentation* occurs as the original landscape is further broken into unconnected pieces. *Shrinkage* is the decrease in size of any

[1] These insights were presaged late in the 19th century though. George Perkins Marsh (1802-1882), sometimes called the Prophet of Conservation, revealed much about the relationships between the environment and land use in his book Man and Nature, published in 1864.

habitat or patch; *attrition* is the disappearance of habitat or patch types and leads, ultimately, to the *substitution* of a new landscape for the original one.

Image 1. Wetlands in a variety of landscape settings. The effects on wetland functions reflect the surrounding land uses, their intensity and proximity. Wetlands in forested settings, for example, are "buffered" by the overall condition of the surrounding area. Wetlands surrounded by multiple land uses are subject to a variety of stressors and are influenced differently by each distinctive land use.

The first three processes are largely the result of transformations that began in the mid-19th century throughout Puget Sound and reached their zenith around the turn of the century. Although no longer the result of agricultural activity, these transformation processes continued through the 20th century and into the present as agricultural and forested landscapes continue to be transformed to suburban and urban ones.

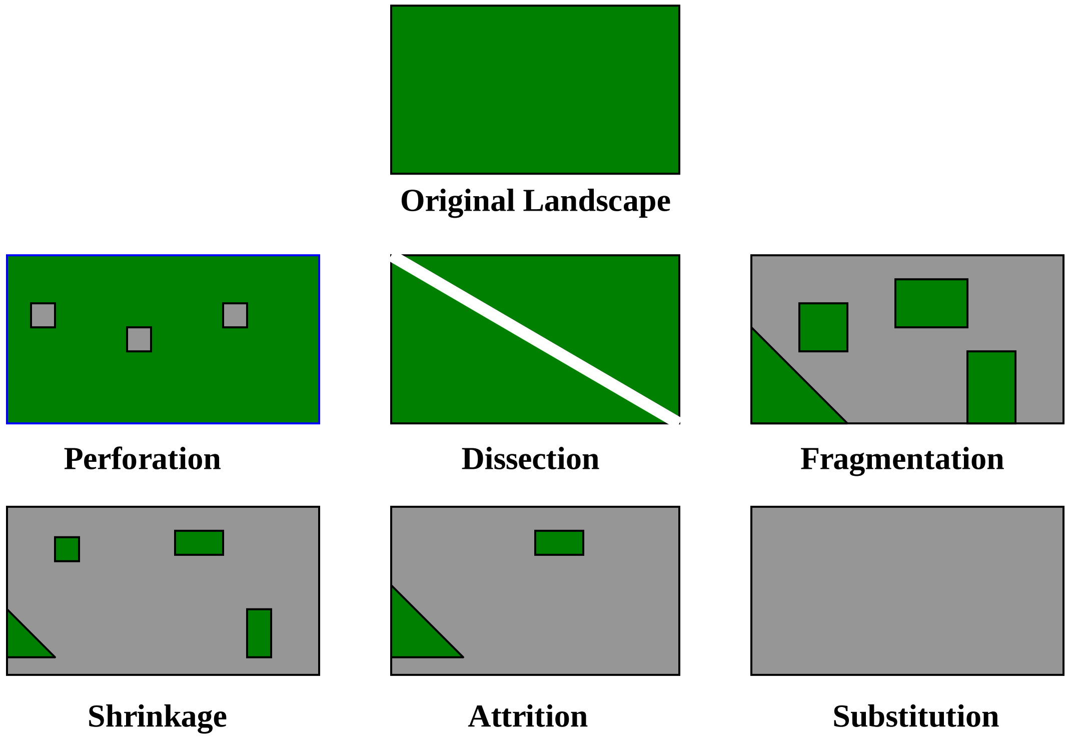


Figure 1. Spatial Processes in Land Transformation

Each of the spatial processes described above and illustrated in Figure 1 has distinctive attributes, and each exerts some unique effects on a range of ecological characteristics from habitat structure to biodiversity to erosion to water chemistry. Perforation, dissection and fragmentation may affect the whole landscape or a patch within it; shrinkage and attrition apply mainly to a patch or corridor within the larger landscape. Substitution, the ultimate result of attrition, results in conversion from the original condition to a wholly new one, and applies mainly to the landscape but is sometimes said of a habitat or patch as well. In **Table 1**, we see the effects of each process on four landscape attributes. As each attribute of the landscape is altered, the relationship among the various processes and functions that support critical areas is likewise altered. For example, wildlife processes and functions such as migration patterns, reproductive success, exposure to invading species and predators are modified as landscape elements are split and isolated.

Table 1. Effects of land transformation. Major processes are listed in the first column and their effects on landscape attributes. **+** = increase; **-** = decrease; and a **0** = no change.

Spatial Process	Patch size	Connectivity	Habitat loss	Isolation
Perforation	-	0	+	+
Dissection	-	-	+	+
Fragmentation	-	-	+	+
Shrinkage	-	0	+	+
Attrition	+	0	+	+
Substitution	+/-/0	-	+	0

We can find such effects throughout the literature; many sources support the contention that the greater the transformation of the landscape, the greater the effects on process, structure, and function. In his excellent review of wetland science for Island County, Washington, Adamus (2007) references work that provides evidence for broad-scale influences on wetland structure and function. Four referenced studies will serve to illustrate this point.

1. A comparison of 80 watersheds with varying amounts of forest and agricultural land suggested that nutrient concentrations in streams was predicted by the percent of land cover in forest or agriculture throughout the watershed. Proximity of forest to stream showed no significant statistical relationship, however (Omernick et al. 1981).

2 In a rare study of the effects of landscape effects and plant diversity (Houlahan et al. 2006), found that the number of plant species in a wetland increased mostly as wetland size increased but also with increasing amounts of forest cover on adjacent lands. The effect of surrounding forest cover was most pronounced on diversity within forested watersheds although an increase also occurred in total plant species, native species, and perennial species.

3. In a study of a marsh bird community in a tidal wetland in Chesapeake Bay, land cover alterations occupying as little as 6% of the landscape influenced the species composition of the bird community even at distances of 3000 feet from the community (DeLuca, Studds, and Marra 2004).

4. Finally, in a study of amphibians in southwestern Ontario wetlands (Houlahan and Findlay 2003), amphibian species richness was positively correlated with wetland area, surrounding forest cover, and the amount of wetland on adjacent lands and negatively correlated with road density. In fact, there were demonstrable effects of increased land use intensity out to 3000 meters for species richness and out to 4000 meters for some individual species. The authors were quite clear in their conclusions from the study:

> "This means that the concept of "buffer zones" as a management technique for protecting amphibian communities is impractical because the size of an effective buffer zone would be prohibitively large. Effective management of wetland amphibian communities will require managing "communities" of wetlands rather than individual wetlands…"

Condition of the Surrounding Area

The condition of the sites and landscape surrounding a critical area is another element that must be considered in establishing context. Most critical areas that we seek to protect are no longer embedded in the historic, undisturbed landscape. Rather, they now occur in human dominated landscapes where land cover has been significantly altered and where land uses may range from forestry to agriculture to residential within a short distance. A single wetland, for example, may find itself embedded in a multi-use landscape where the effects of each land use on wetland functions are distinctly different from the other land uses (see Image 1). Thus, the spatial distribution of effects is likely to vary with the land use. Moreover, the intensity of use (and therefore the intensity of the effects associated with that use) may vary considerably, even within a single land use: agricultural land uses may vary from well-managed to degraded pasture, from no till to open row cropping, even within the same site. And the intensity will likely vary with the proximity of the use to the critical area--the nearer the use, the greater the effect. Each variation carries a distinct signature of effect and might be expected to alter the physical, chemical, and biological processes of the landscape and critical area slightly differently. The effects could, for example, vary in magnitude, frequency, duration, or timing, or in all these attributes at the same time.

Some authors have stressed the effects of past land uses as well—the so-called legacy effects. That is, the condition of the landscape and the trajectory of the land's response still bears the imprint of past land uses, sometimes far in the past. For example, in a study of land use effects on stream biodiversity, Harding and co-authors (1998) reported that land use from the 1950s was the best predictor of stream diversity in the 1990s. Riparian land use and current watershed land use (1990s) were comparatively poor predictors. They concluded that past land use activity resulted in long-term, persistent modification of diversity that was not so easily remediated by the recovery of streamside riparian zones. They did not conclude that riparian zones were unimportant, however. Only that some persistent land uses can have long lasting effects that are not so easily mitigated by our traditional approaches.

In a 2003 paper in BioScience, Foster and several co-authors emphasize the importance of land use legacies to ecological function and conservation. The authors make several points important for evaluating and developing land management and conservation strategies.

- The history of disturbance shapes the structure, composition, and function of most ecosystems and landscapes. Recognition of that can increase the effectiveness of management;
- Ignoring historical use and modification can lead to ill-conceived conservation and management schemes;
- Historical perspectives contribute to the identification of realistic goals and appropriate tools to achieve those ends;
- Historical perspectives may inject a sober reality into the planning and management process by highlighting constraints.
- The reintroduction of historic (natural) processes does not necessarily restore historic ecosystem conditions.

Their conclusion was this: past dynamics shape current conditions and constrain future responses.

Condition of the Critical Area

The sensitivity of wetlands and other ecological areas are based on their physical, chemical, and biological attributes (Adamus 2007). More sensitive wetlands are those that respond to stressors (natural and human-caused) more quickly and to a greater degree than less sensitive areas. Recovery from the stressor may take longer in these systems as well, and may be evidenced by abnormal changes in biological community structure or in other functions and processes (Brouwer et al. 1998). In critical areas that have been modified—or are being modified--by changes in surrounding land use or by direct activity within the critical area, some functions may have been altered and may have become increasingly sensitive to further disturbance. Previous impacts may have pushed some functions and processes close to some critical threshold. In these cases, the maintenance or recovery of these functions may depend on direct remedial action in the wetland or in the surrounding watershed. Like all ecological areas, the structure and function of wetlands varies over time as the system responds to variations in weather, climate, land use, and land management. Patterns of succession as wetlands age in the landscape modify other functions and processes and may require changes in protection strategies over time.

Given the scale and distribution of many of the attributes and processes that drive function in ecological areas, coupled with the variety of conditions, past and present, of the landscape surrounding critical areas, we can see that effective management requires us to be attentive to more than the internal composition and function of a wetland or other critical area. It is unlikely that a single approach or tool can suffice to address the varied factors that drive function and structure within wetlands, streams, or along shorelines. Our management approach should recognize the context described above and strive to address the many and complex factors as directly as possible and as near to the source of the effect as we can.

Current Management Strategies and the Landscape Context

As land is transformed from less intensive uses to more intensive ones, the stress on critical areas and other "natural" areas increases. Our current strategy for managing these stressors on critical areas primarily relies on a tool that, while probably effective in many situations (we do not have much field information to support our contentions), is unable to address the context that is so important to critical area conservation. Critical area buffers are a dual purpose strategy: first, the vegetative barrier "filters" the effects of surrounding land uses, reducing the effect of various stressors to a level that can be assimilated by the wetland, stream, or other critical area without a significant loss in function. Second, the buffer provides some elements to the critical area that are deemed necessary to its function—woody debris, leaf litter, nesting habitat, etc.—that are dependent on the structure and function of the buffer itself. All of these buffer functions also depend on the ecological integrity of the buffer itself. That is, is the buffer *resilient* enough to maintain its own processes, structure, and function in the face of the stressors from the surrounding area? Is it large enough to maintain ecological conditions within the buffer that provide important functions? Is the assimilative capacity of the buffer sufficient that it will not suffer degradation over time that compromises integrity? And, as land use changes and the buffer, itself, changes, how will its protective functions change?

Managers are well aware of the limitations of vegetative buffers as a single management tool. In a review for the National Agroforestry Center, Helmers et al. (2008) discuss some of the limitations of vegetative buffers in agricultural areas and emphasizes the importance of intentional buffer design. In their review, the authors note the significant range in the performance of buffer systems for water quality benefits. The performance depends on the field, topographic, and climatic conditions on the site and throughout the contributing watershed. Loading rates may be dependent on land uses far from the wetland and buffer and may, in some cases, overwhelm the assimilative capacity of the buffer.

As noted above, the functions of buffers for wildlife conservation are often compromised by the life history and habitat requirements of many species. Despite their affinity for wetlands, for example, many amphibians require terrestrial habitats well beyond the wetland and buffer boundary. In such a case, the habitat function of the wetland may degrade, despite the buffer, as the landscape between the wetland and terrestrial habitat is altered by development.
In a brief argument for expanding the concept of wetland management to the surrounding catchment, King County (1996) suggested three limitations to buffer-based management:

1. Buffers (as they are applied) do not account for functional attributes of wetlands which are typically variable over time and dependent on processes that are external to the wetland;
2. Buffers often do not account adequately for differences among types, size, and complexity of wetlands and;
3. Buffers do not typically account for differences in the structural and functional complexity of the buffers themselves.

This is not to say, of course, that vegetated buffers are unnecessary or ineffective for the protection of wetlands and other critical areas. However, in built or developed environments, the effectiveness of buffers alone, and even the opportunity to implement sufficiently sized and designed buffers, can be severely limited. The conditions of the prevailing landscape often mitigate against this strategy. The evidence seems to suggest that wetland (and other critical area) protection will only be realized if traditional buffers are integrated with other management practices that are designed to address the variety of processes that often originate far from the critical area and are greatly changed in rate, magnitude, frequency, and even in location.

A Context-based Management Alternative

An alternative approach may be described as place-based (spatially explicit), context sensitive, and adaptive; an approach that relies on integrating environmental goals and sensitivities with the conditions that influence and affect them (the prevailing social and ecological context), and is responsive to both uncertainty and changing conditions (adaptive). This approach relies less on general rules and more on specific management strategies and actions to achieve the environmental objectives in particular areas. This approach has been termed “context-based environmental management” or simply, integrated environmental management and is especially appropriate as an approach for management in areas that are mainly in private hands and already developed. In this approach, there are few (if any) hard and fast rules or traditional standards; rather, all prescriptions, prohibitions, and standards are considered to be variants or types of management activities that can be tailored to environmental objectives (performance), prevailing conditions, and sensitivity. Even the mainstay of environmental protection in the Pacific Northwest—the vegetated buffer—becomes a management action (or BMP) to be applied where appropriate and where it is likely to be effective at protection or at providing some important function. In an important way, this brings the regulated buffer back within the generic definition of buffer: “…to cushion or protect; to lessen the adverse effect of” (Webster’s Collegiate) and enlarges the management options available for environmental protection and management. This avoids two important criticisms of the buffer method: no longer does “one size fit all”; and, in a damaged landscape or shoreline, the buffer does not institutionalize the existing condition. Moreover, by widening the management strategies available to the resource manager and the landowner, the likelihood of effective protection actually increases. In doing so, we can be assured that we are (at the moment) doing as well as we can for the protection of the functions and values of the ecological area.

Two further advantages of an integrated approach are that it can be both forward-looking and adaptive. That is, management actions can be contemplated that could ameliorate some existing conditions on the critical area and in the areas affecting function consistent with ecological recovery[2], and these same actions can, and should, be modified and adapted as conditions change or as recovery proceeds. A third advantage of this approach is that it is necessarily collaborative, engaging citizens in the development of goals and management activities.

Other Aspects of the Approach

- Since management practices can be tailored to conditions, context, and goals, the certainty of achieving the protection goal is likely to increase;
- Implementation can be sequenced and scheduled more effectively;
- Monitoring and adaptive management can be tied more closely to goals and strategies through this approach;
- There can be a recognition of ongoing landowner stewardship;
- Where landowner participation is required for effective management, resources can be targeted;
- Resources and capabilities for protection, recovery, and acquisition can be targeted effectively.

What is required to develop and apply this approach?

This approach has its origin in the ecological design methods advocated by McHarg (1967), Steiner (1991), Lyle (1985) and others. In effect, we are seeking to (re)design a built landscape for the protection of important ecological areas. To do so, we must have some information about the state of the ecological area--its condition, its sensitivities and vulnerability; we must have some knowledge of the condition of the landscape that influences the ecological area—its management, land use history, its suitability for use and sensitivities to that use; we must have some idea of environmental goals and objectives for the ecological area; and, not least, we must have some idea of the goals and objectives of the landowner(s) for the landscape(s) that influence the ecological area. By combining these elements in a logical and structured manner, we can develop a suite of integrated management practices that may remediate landscape conditions (to the benefit of the landowner), reduce land use effects of proposed activity, recover critical ecological attributes, and make critical areas more resilient in the future.

[2] Even though "no net loss" is the putative standard by which environmental protection and management is measured, the history of use and development of our shorelines and the time lags between effect and outcome has created a "debt" on the landscape that will become greater even if the degrading effects were immediately halted. To assure "no net loss", some recovery of structure and function is required. In conservation biology, for example, extinction of many species lags behind habitat loss by a considerable time. In order to avoid extinction, the "debt" must be repaid—habitats must be recovered before the extinction curve steepens to irreversibility.

There are two commonly accepted methods to accomplish these ends. The first is employed by the City of St. Cloud, Minnesota (among others) and involves a review team made up of landowners, developers, city engineers, city planning staff, and perhaps, most notably, a group of volunteer scientific specialists (see appendix). This team works together to reach consensus on a Concept and Natural Resource Management Plan prior to he preparation of preliminary design for any development. These are a set of management practices that will protect the sensitive natural resources of the site while allowing the landowner's development and management goals to be met. Crucial to this process is a valid and dependable inventory of the resources to be protected. Also critical to the success of this process is the participation of the landowner/developer and a clear set of environmental goals and objectives (MN Department of Natural Resources 2002).

A second method for arriving at suitable management practices is the use of a more formal suitability and sensitivity analysis coupled to a system that uses the analysis to develop appropriate management practices. Such suitability analyses have a history in agricultural land use (USDA's Land Evaluation and Site Assessment) and in general land use planning (see Ian McHarg's *Design with Nature* and John Tillman Lyle's *Design for Human Ecosystems*). Such a system was developed for King County's Rural Stewardship Program in 2005 with the added element of a sensitivity analysis (see appendix). Adding the sensitivity analysis allowed the users to evaluate the effects of the proposed land use action on both the land itself, on the sensitive area that was the object of protection, and on other environmental objectives that were off site but influenced by the activity. From these analyses, management practices could be formulated that benefited both the landowner and the environment in unexpected ways. The system was designed to be user-friendly in so far as it could be used easily by both landowners and planners, and could be iterative. As in the St. Cloud example above, a thorough inventory of the landscape and sensitive area is required. Management practices were developed through a collaborative process with ecologists, planners, and landowners. Each of these methods, and those outlined in the planning references above, make few *a priori* assumptions about the nature and application of management practices.

Why Suitability and Sensitivity[3] Analysis?

In order that we choose appropriate Best Management Practices (BMPs) and apply them effectively, we must derive the BMPs as directly as we can from the likely effects of the landowner's actions on the set of environmental conditions or features we are attempting to conserve or protect.

Our tasks are threefold: Assuming the landowner's goals and objectives for his or her tract of land can be known, **derive the activities necessary to realize those goals and objectives**, and **evaluate the impact of the activities on the environmental objectives**. Having accomplished these tasks, **develop management practices to alleviate any harmful effects** (of the activities). Management actions should be thought of broadly here and may range from modification of the

[3] We define **suitability** as *the fitness of a tract of land for a defined use* and **sensitivity** as *the responsiveness of an attribute (of the site of larger landscape) to an action or activity*.

landowner's objectives to avoid an effect, to modification of the activity necessary to reach the objective, to remediation of the effect once the activities are carried out. It is the second task that is most crucial. Without a clear idea of the effects of the actions, we cannot specify effective management practices with any confidence. But this task is also the most difficult and perplexing, and is where suitability and sensitivity analyses can provide the framework to evaluate effects and therefore craft appropriate management actions.

Both suitability and sensitivity analyses make use of biophysical and sociocultural information collected at the site level and at larger scales, in order to place the actions in the context of the surrounding area and at the proper scale(s). This context is particularly important for wildlife and hydrologic effects. **Suitability analysis** seeks to determine the fitness or appropriateness of a tract of land for a particular use or objective, for example, forestry or agriculture, and may even assist in determining the most appropriate tree species and crop types and where on the site they should be grown. This is often done by examining soil characteristics, slope and aspect, climatic factors such as rainfall and seasonal temperature, and the management history of the site. **Sensitivity analysis** attempts to determine the responsiveness of the same tract of land or of selected attributes to the actions and activities of the landowner. A tract of land may be sensitive to vegetation removal because it possesses a combination of soils and slopes that are easily eroded when exposed to wind or water. As in suitability, areas of a tract may differ in their sensitivity (responsiveness) to a particular action. Generally, the greater the responsiveness of an attribute, the greater the sensitivity and the greater the vulnerability.

In many cases, sensitivity will be the inverse to suitability; a tract with soils highly suitable for agriculture may be relatively insensitive in some ways to agricultural operations. This is not always the case, however, and we often find that soils suitable for some objectives—soils highly suited for forestry, for example—may still be quite sensitive to the operations and actions associated with reaching the objective. The very same attributes that make a soil well-suited to growing trees—porosity, a deep surface organic layer (duff)—also make the soil highly sensitive to compression and rutting from vehicles.

This suitability/sensitivity approach to the evaluation of a tract of land (or even a landscape) is a central method in ecological planning which, itself, began in earnest in the United States during the late 1960s with the writings of landscape architects Philip Lewis and Ian McHarg (see especially *Design With Nature*). Advances in ecological planning continued throughout the 1980s with Anne Spirn, Jon Berger, John Tillman Lyle, and French geographer Jean Tarlet; most recently, Fredrick Steiner has championed this approach in his excellent book *The Living Landscape*. Christopher Alexander has defined this same ecological approach for human landscapes in two works entitled *A Pattern Language*, and *A Timeless Way of Building*, and in his most recent four volume work called *The Nature of Order*.

The ecological planning method, according to Steiner, "is primarily a procedure for studying the biophysical and socio-cultural systems of a place to reveal where specific land uses may best be practiced". Suitability and sensitivity analyses provide the basic information to link the attributes of the landscape to the objectives of the landowner (or planning entity) and to the limitations the landscape imposes on those objectives. Although usually carried out at large scales (many 10s of square miles), the concepts of ecological planning are applicable at multiple scales. Arthur Johnson (1981) explains:

> *"Such an approach is not limited by scale. It may be applied to locating plants within a garden as well as to development of a nation."*

Our purpose is fundamentally no different than either McHarg's or Steiner's in that we are attempting to find, on a tract of land, the areas of suitability for the landowner's goals while protecting the sensitivities of the environmental attributes on the tract and in the adjacent landscape should they be interrelated. Suitability and sensitivity analysis allows us to examine the landscape and more directly link management to the environmental attributes of the landscape at multiple scales. Once we have accomplished this work, we may be assured that we have done our best to protect our important ecological areas and accommodate the goals of those living on the land. For a look at the method and the expert system that accompanies it, see the appendix.

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