THE WOODLANDS, TEXAS: A RETROSPECTIVE CRITIQUE OF THE PRINCIPLES AND IMPLEMENTATION OF AN ECOLOGICALLY PLANNED DEVELOPMENT

by

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ABSTRACT

This thesis critiques the planning and development of The Woodlands, a "new town" development north of Houston, Texas. When it was designed in the early 1970s, The Woodlands was hailed by its planners as the first ecologically planned city.

The thesis seeks to evaluate how successful ecological planning has been in The Woodlands relative to its original goals and contemporary conservation concerns. It does this by first determining to what extent the original ecological principles have been applied during implementation. Recent research from the discipline of landscape ecology is then drawn on to assess the relevance of these principles for addressing current conservation concerns. The implementation phase is similarly critiqued. The purpose of this critique is to use The Woodlands experience to gauge the capacity of ecological planning for achieving ecological protection in contemporary suburban developments.

The thesis concludes that ecological planning in The Woodlands has not worked for several reasons. Several of the ecological principles that underscored the planning phase are flawed by today's standards, and would have been counterproductive to the achievement of contemporary conservation goals. In addition, the Ecological Plan that derived from the planning phase was difficult to implement. It was inflexible to change, and provided insufficient detail to facilitate implementation at the scale required by the plan's executors. For their part, The Woodlands Corporation, the developers of The Woodlands, failed to pursue the ecological vision encapsulated by the early planning phase. As a result, The Woodlands of today is not significantly different from a conventional suburban development in its capacity to provide protection of the site's principle ecological functions.

The Woodlands case demonstrates that a higher level of ecological integrity can be maintained by ecological planning, but that planning must be significantly more comprehensive than that undertaken in this instance. Commitment following the planning phase is also essential.

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INTRODUCTION

Since the 1970's, The Woodlands, north of Houston, Texas has been described in numerous books and articles as a model of ecological planning (Everhart 1973, Anon. 1974, Juneja and Veltman n.d., McHarg and Sutton 1975, Dunne and Leopold 1978, Spirn 1984, Malone 1985, Steiner et al. 1988, Holmes 1992, Smith 1993). Steiner et al. (1988 p.36), for example, state that "the planning for The Woodlands is noteworthy for its success." Spirn (1984) also offers plaudits for The Woodlands, based on its original design and the early success of its innovative natural drainage system in the first neighborhoods constructed. Most of the assertions about The Woodlands' success appear to have been based on its original development plan, because there has been minimal monitoring of the ecological performance of The Woodlands since construction commenced in 1973. There has also been no evaluation of how the original design guidelines have or have not been followed. Robert Heineman, The Woodlands Corporation Vice President of Planning (1993) states that there is little printed material describing the performance of The Woodlands relative to original goals. Only one critical assessment has been conducted (see Girling 1994).

My goal in this thesis is to examine The Woodlands twenty years after it began; to look at how the original concepts have been applied and to determine the types of ecological impacts (beneficial and negative) the development has created. Impacts are assessed against the ecological goals and expectations of the original design plan and the conservation concerns of contemporary landscape ecologists to determine the ecological appropriateness of the original approach and any subsequent deviations from this approach.

The purpose of this examination is two-fold. First, I want to use my assessment of the ecological impact of The Woodlands development to determine the worth of their approach for achieving ecological protection in contemporary suburban developments. Second, I want to evaluate the practicalities of integrating the natural environment with suburban development, i.e. to determine what level of ecological integrity can realistically be preserved.

Research for this thesis was undertaken through a review of relevant literature pertaining to The Woodlands and the discipline of landscape ecology, and by interviews with individuals involved in or otherwise familiar with the planning and development of The Woodlands.

THESIS OUTLINE

The thesis is structured in the following way.

Chapter 1 introduces the issue of integrating urban development and ecological protection. It discusses why there is a need for integration (why natural areas are important in urban areas), and how integration has been considered during recent history.

Chapter 2. reviews the current literature in the field of landscape ecology relevant to understanding (a) the ecological impacts of suburban development on extant natural systems, and (b) the ecological issues that need to be considered when designing for optimal integration of development and ecological protection.

Chapter 3 is a case study analysis of the ecological planning process used by the planning firm of Wallace, McHarg, Roberts, and Todd (WMRT) at The Woodlands. The early planning history and ecology of the site are briefly described to provide context for discussion on the ecological design philosophy and techniques that created an Ecological Plan for The Woodlands. The role of this plan in shaping the first development plan for The Woodlands is also discussed.

Chapter 4 assesses implementation of the Ecological Plan by The Woodlands Corporation.

Chapter 5 applies the landscape ecological concepts and current conservation concerns discussed in Chapter 2 to a critique of the ecological planning process employed by WMRT, and its implementation by The Woodlands Corporation.

Chapter 6 draws conclusions about the success of the ecological planning approach employed at The Woodlands relative to the original goals and expectations of WMRT and The Woodlands Corporation. Contemporary environmental concerns are also used to evaluate the development's success. The Woodlands experience is analyzed to assess the opportunities and constraints that confront the integration of ecological goals with suburban development.

CHAPTER 1

ECOLOGY IN URBAN PLANNING

1.1 Protection of Natural Areas in Urban Environments

Numerous authors have recognized the positive contribution made by the protection of natural areas to the ecological and anthropogenic functioning of suburban environments (McHarg 1969, Gill and Bonnett 1973, Laurie 1979, Jackson and Diamond 1981, Spirn 1984, Kaplan and Kaplan 1989, Goode 1990, Hough, 1990, Smith 1993). Attention to the protection of natural areas has been shown to enhance local economies by improving property values and market appeal, and reducing city stormwater maintenance costs (Moll 1985, Ebenreck 1988).[1] The positive impact of trees and natural areas on the quality of life and psychological well-being of urban residents is well documented (Kaplan and Kaplan 1989, Ebenreck 1988). Retention of natural areas and trees greatly improves ecological functioning within urban environments through positive effects on surface and ground water quality, flooding, groundwater recharge, air quality, microclimate, species diversity, and noise reduction (Laurie 1979, Spirn 1984, Smith 1993, Moll 1985, Ebenreck 1988).

Spirn (1984) states that

> "tradition has set the city against nature, and nature against the city. The belief that the city is an entity apart from nature and even antithetical to it has dominated the way in which the city is perceived and continues to affect how it is built. This attitude has aggravated and even created many of the city's environmental problems: poisoned air and water; depleted or irretrievable resources; more frequent and more destructive floods; increased energy demands and higher construction

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[1]Moll (1985) assessed the economic contribution of a single urban tree over a 50 year time span to be around $57,000, based solely on its contribution in reducing air conditioning costs, erosion and stromwater control, wildlife shelter, and air pollution amelioration. Moll (1985) suggests trees improve real estate vaues by an average 5-7%.

> and maintenance costs than existed prior to urbanization; and in many cities, a pervasive ugliness..............As cities grow, these issues have become more pressing. Yet they continue to be treated as isolated phenomena, rather than as related phenomena arising from common human activities, exacerbated by a disregard for the processes of nature. Nature has been seen as a superficial embellishment, as a luxury, rather than as an essential force that permeates the city."

In the U.S, 8,800,000 ha (22,000,000 acres) of land were developed for urban purposes between 1959 and 1982, an area the size of Maine (Heimlich and Anderson 1987). Lowe (1991) cites the example of the New York metropolitan region which, though only growing by 5% in population since 1965, expanded its developed area by 61%. Approximately 80% of the U.S. population now lives in urban areas (Goode 1980). Urban land demand directly impacts on natural areas through development of diminishing or threatened ecosystems, pollution impacts, natural systems fragmentation, and increased urban-natural interface (edge effects). Less directly, larger numbers of urban residents place an additional, and much greater burden on natural resources outside their boundaries.

The increasing loss of habitat to urban development reduces local biodiversity, and contributes to declines in diversity at larger scales. An increasing number of endangered species are now threatened by urban development. For example, the City of Austin, Texas has prepared a habitat conservation plan (in accordance with the provisions of the Endangered Species Act, 1973) to protect seven species listed as endangered by the U.S. Fish and Wildlife Service, eight species that are candidates for listing and a further 28 rare species threatened by urban development (City of Austin *et al.* 1993). Harris (1989) in reference to the impacts of development on Florida ecosystems states that "fragmenting landscapes into disjunct patches and restricting and isolating wildlife populations by amplifying the risks associated with movement have drastic consequences for the preservation of biological diversity." Recher and Serventy (1991) have stated that "with the continuing fragmentation and isolation of areas of native vegetation, proper management of small reserves is critical for the conservation of an increasingly large proportion of the world's plants and animals."

Diminishing biodiversity has become a major concern for many scientific disciplines, both for anthropogenic (economic) and philosophical reasons. It may be most important because of the uncertainty attached to its impacts. There is increasing concern that the presently inadequate understanding of the functional interdependencies between species will lead to the loss of keystone species[2] on which both the sustainable function of natural ecosystems and human ecosystems are dependent (Westman 1990).

Traditional urban design has emphasized provision of the built infrastructure necessary for human habitation. Though there has been increasing recognition of the contribution provided by open space to the urban environment over the last two hundred years, for the most part, open space remains an afterthought in the planning process. It is frequently provided only because it is mandated by municipalities and is usually not an integral element of the planning process. The provision of natural open space is

[2]The loss of some species seems to have no discernable effect on the overall function of particular ecosystems, with no other species unduly affected by their loss. However, keystone species play a vital role in supporting ecosystem functioning. Their loss can result in the consequential loss of several or numerous other species. In some instances a domino effect may result - leading to a complete breakdown of the original ecosystem and the loss of complete assemblages of interdependent species. Ecological gaps may be filled by invasive exotics that can result in further system degradation. Top predators often play a keystone role, as do decomposer organisms. But keystone species are not always easy to identify. For example, the Australian cassowary has been found to be the vital link in the germination of over a hundred rainforest trees

especially poorly provided for. Natural areas are often assigned on the basis of which land is least suitable for development, not which land is most suited to optimizing the protection of important ecological features. Moreover, little attention is given to the ecological impacts of suburban development and the integration of ecological protection in urban design.

For the largest part of their lives, most people's exposure to nature will now occur - or not occur - in the urban context. Kaplan and Kaplan (1989) have studied the psychological relationship of humans with natural environments and attest to the positive "restorative" impact of natural settings on human well-being and residents' level of satisfaction with their neighborhood. The way urban residents view their relationship with nature, and so understand their ultimate dependence on the healthy functioning of local, national and global environments, may to a large degree depend on the quality of their urban-natural experience (Gill and Bonnett 1973). This is an important point, because peoples' recognition of their dependence on nature could significantly influence their decision-making about how they live and therefore how they impact on natural ecosystems and ecological processes.

1.2 Recent History of Ecological Considerations in Urban Design

The earliest attempts to integrate natural features in urban design are attributed to Frederick law Olmsted in the late nineteenth century and Ebenezer Howard with his Garden City concept in 1902 (Falos et al. 1968, Spirn 1984, Smith 1993). However both Olmsted and Howard were interested primarily in aesthetics and using natural systems to benefit people, not protecting ecological features and functions.

Consideration of ecology in urban form and function may have infiltrated urban design thinking as a spin-off of the conservation/wilderness protection movements sparked by naturalists and nature writers Emerson, Thoreau, Muir, and Leopold. Thoreau, somewhat conservatively, proposed the inclusion of 200 to 400 ha (500 to 1,000 acres) of wilderness for every city (Laurie 1979). Awareness of the importance of natural areas was not foreign to the American public and policy makers of the late nineteenth and early twentieth centuries, but by way of action, conservation was still not considered to have a role in the urban environment.

Communion with nature was viewed as something that could be done on vacation or on the weekend, away from the city, but not in the city. This separation actually became culturally institutionalized as many American families established weekend residences and summer homes in the country. There was some application of the Greenbelt concept by Tugwell and MacKaye (Smith 1993) but for the most part, city and country remained separated. This separation of worlds was compounded by the dramatic growth in private car ownership, which allowed people to commute between the two according to need.

For much of its history, planning has consisted of little more than overlaying a grid pattern on the land and then re-forming the land to contend with the constraints imposed by the grid. Minimal consideration was given to the natural constraints and opportunities provided by the land, as watercourses were channelized, wetlands and floodplains filled, stormwater removed by ditches and pipes, existing vegetation removed, and cut and fill used to mold infrastructure and buildings to the land (Lahde 1982).

In the 1950s and early 1960s, some more innovative approaches to open space planning began emerging. Numerous local conservation groups began forming and for the first time, some planners and public officials began to seriously consider environmental impacts in planning design. Often, this was in response to pressure from community groups. One such example of innovative planning was a plan for lake-front development devised by Philip Lewis, a consultant landscape architect to the Wisconsin Department of Resource Development (Lewis 1964).

In the 1950s, the boom in the U.S. economy had fostered a rush of development along the Lake Superior shoreline. The Wisconsin government, concerned at the "stringtown" style of cottage development that was occurring, engaged Lewis to develop an alternative approach that would permit shoreline development but with reduced impact on shoreline aesthetics and public accessibility.

Lewis' primary focus was on recreational planning, but he also recognized that recreational opportunities stemmed largely from a healthy environment, and a healthy attitude to the environment. In his view, it was the natural features of the land that tied the land together and determined where and how development could occur (Lewis 1964). In developing a compatible mix of development and protection of sensitive aspects of the natural environment, Lewis emphasized the physical nature of the shore, local hydrology, vegetation, wildlife habitat, and soils. Lewis overlaid these features to determine the tolerance of the land to development. His solution in this instance was a form of cluster housing. Beyond the Lake Superior shoreline though, Lewis' recognition of the importance of corridor protection resulted in the adoption of a regional land use plan in the southeastern part of the state that protected an extensive network of corridors. Corridor protection and acquisition also became a State priority as Wisconsin moved to establish a statewide trails plan (Smith 1993).

Lewis' use of overlays in planning was nothing new, having been employed in various forms since 1912 (Steinitz et al. 1976). However, its use for integrating environmental and development goals was new, constituting an important step towards the more widespread adoption of a comprehensive approach to planning.

The use of overlays for comprehensive planning was popularized by the Philadelphia firm of Wallace, McHarg, Roberts and Todd (WMRT), and Ian McHarg in his other capacity as Chairman of the Department of Landscape Architecture and Regional Planning at the University of Pennsylvania. During the 1960s and 1970s, WMRT used overlays for many of their urban planning projects. WMRT's approach began with inventorying the natural and existing human elements of the landscape that would affect, or be affected by a change in land use intensity. Each element was assessed to determine the opportunities and constraints it presented with respect to the proposed land use changes. "Suitability maps" were then mapped for each element in shades of gray or various colors. (McHarg 1969) Overlaying these individual maps demonstrated how the different elements interacted with each other and illustrated where development of particular intensities could be accommodated with the least impact, as well as where development was to be avoided. The approach was simple but effective, in approximating the most environmentally and socially optimal land use decisions. This comprehensive approach to planning has also been described as ecological planning (WMRT 1974d p.1, Giliomee 1977).[3]

WMRT's approach, however, is not without its problems. Foremost, it depends on the inventory phase being accurate. The overlays are also only a snapshot in time - inadequate for representing much more than the short term fluctuations, flows, interactions and interdependencies that characterize a normal dynamic ecosystem. More often than not it seems WMRT failed to place much emphasis on weighting the importance of each of the overlaying elements. For example, in the use of overlay analysis for determining the optimal route for the Richmond parkway in New York, shading for each of the elements were accorded equal importance (McHarg 1969). Even in cases where WMRT did use weighting, there remained room for significant subjectivity in assessing the importance of some of the less tangible elements considered. WMRT recognized this flaw but were usually constrained by time and finances so opted for the approximate approach (McHarg 1969). From Ian McHarg's account in his book Design with Nature (1969), this was enough to sway clients to accept the results of the approximating overlay.

Design with Nature seems to have been an important catalyst in promoting the adoption of a more holistic, ecologically based approach to planning in urban areas. Importantly for the focus of this thesis, Design with Nature was read by George Mitchell, and provided some of the impetus for his emphasis on environmental goals in the construction of The Woodlands.

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[3] For a more detailed description on the ecological planning technique employed by McHarg, see Giliomee, J.H. 1977. "Ecological Planning: Method and Evaluation" Landscape Planning, 4:185-191.

At the same time WMRT was applying its comprehensive planning approach in the 1960s and 70s, interest in environmental issues was growing rapidly (Kaplan and Kaplan 1989, Spirn 1964, McHarg 1969). Though much of the environmental concern was focused on risks to health (from air and water pollution for example), the declining quantity and quality of natural features within urban areas also attracted attention.

Interest in the ecology of urban areas has also begun to attract more attention from scientific researchers, especially over the last twenty years. Scientific awareness of the functioning of urban ecosystems is still deficient in many areas, but is nevertheless considerably advanced on what was known 20 years ago. It is this base of knowledge that I will draw on to critique the ecological planning principles that laid the foundation for The Woodlands' first General Plans, and The Woodlands Corporation's application of those principles.

CHAPTER 2

LANDSCAPE ECOLOGICAL PRINCIPLES AND CONSERVATION GOALS IN A SUBURBAN CONTEXT

2.1 Introduction to Landscape Ecology

Over the last three decades interest in understanding the ecological impacts of urban development, and determining ways to minimize or mitigate impacts has grown substantially. One of the key catalysts and informants to this growth in interest has been the emerging science of landscape ecology.

Landscape ecology recognizes that human activities and ecosystem functioning are inextricably linked, in contrast to traditional ecology's attempts to separate the two. The value of landscape ecology therefore lies in its bridging nature, in its capacity to enable an understanding of the functioning of human-dominated landscapes.[4]

Landscape ecologists look at the ecological processes that operate in landscapes, how they drive the landscape, and how they determine, or are determined by the form and function of the landscape.[5] Landscape ecologists pay particular attention to how form, function, and process may be altered by human activities and natural[6] events. Forman and Godron (1986 Preface) describe

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[4] Landscape ecology cuts across many traditional scientific disciplines, including ecology, hydrology, geomorphology, pedology, wildlife biology, botany, and geography. It also considers human activities that intersect with the landscape, such as landscape architecture, urban design, planning, forestry, and agricultural science. All disciplines concerned with studying or altering components of the natural and human ecosystems benefit from an understanding of landscape ecology principles.

[5] Landscape form describes how the landscape is patterned. Function describes the ways in which the different elements of the landscape interact.

[6]As used in this thesis, "natural" is defined as an ecological condition or process that is minimally impacted by human activities or influences. It assumes a condition as near to a

landscape ecology as exploring "how a heterogeneous combination of ecosystems---such as woods, meadows, marshes, corridors and villages---is structured, functions and changes." According to Forman and Godron (1986 Preface) landscape ecology focuses on:

- the distribution patterns of landscape elements or ecosystems;
- the flows of animals, plants, energy, mineral nutrients, and water among these elements; and
- the ecological changes in the landscape mosaic over time.

Although the development of landscape ecology as a science is largely rooted in non-urban (rural and natural) landscapes, landscape ecology principles are likely to be equally applicable to understanding the interaction of ecological functions and human activities in the urban environment. To this end, research is increasingly being directed to specific application of landscape ecological principles in urban areas (Dickman 1987, Tilghman 1987, Cicero 1989, Catterall et al. 1991, DeGraaf 1991).

2.2 Landscape Ecology and Conservation Goals

The negative ecological impacts of new housing developments result from:

1. Direct loss of habitat,
2. Fragmentation and loss of connectivity in remaining habitat, and
3. Increased degradation of natural habitat.

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pre-colonial condition as possible, including the effects of natural fluxes induced by floods, fires, etcetera. Ecological processes are the dominant influence on habitat form, functions, and flows. For example, a natural forest condition is one where the forest structure is intact, and species composition, abundance, behavioral patterns, and interspecific interactions are as near as possible to those which occurred prior to colonial influences.

The most fundamental impact resulting from the loss of preferred habitat is a decline in the populations of floral and faunal species. For particularly sensitive species, this decline can result in local or global extinction. Species which are either wide ranging (large home ranges), or are restricted to very specific habitats are especially vulnerable.

Fragmentation results from conversion of natural systems to agriculture, urban/suburban areas, construction of roads and other infrastructure, and shorter temporal disturbances such as those created by logging. Fragmentation isolates habitat patches and disrupts natural flows of energy, biota, and nutrients. Isolation effects are manifested when the distance between patches, or between a patch and a large area of habitat, becomes so great as to effectively limit or prevent species interchange between patches. The resistance of the intervening matrix to the dispersal of individuals of particular species is also an important determinant of isolation.

Habitat degradation results from changes to forest structure, species composition, and soil conditions (compaction and nutrient levels). Degradation is caused by logging, understory thinning, cattle grazing, recreational use, waste dumping, increased nutrient input from stormwater runoff, introduction of non-native plants, and altered natural disturbance regimes (fire and floods). Degradation can affect the viability of many species dependent on particular microhabitats, .

This chapter will focus primarily on fragmentation, because of the fragmenting effect of suburbanization, and recent research that indicates fragmentation may be responsible for declines in the abundance of many bird species, especially neotropical migrants.

Numerous authors have described the adverse ecological impacts that derive directly from habitat fragmentation (Harris and Gallagher 1989, Wilcox and Murphy 1985, Forman and Godron 1986, Freemark and Merriam 1986, Kareiva 1987, Temple and Cary 1988, Robbins et al. 1989). Harris and Gallagher (1989 p.13) believe habitat fragmentation, in combination with increased landscape resistance to animal movement,[7] has "drastic consequences for the preservation of biological diversity." Wilcox and Murphy (1985) contend that "habitat fragmentation is the most serious threat to biological diversity and is the primary cause of the present extinction crisis."

Fragmentation effects in the urban context have been addressed by Davis and Glick (1978), Recher and Serventy (1991), and Adams and Leedy (1987, 1991).

Harris and Gallagher (1989) describe four major consequences for wildlife resulting from habitat fragmentation. These are:

1. The loss of area-sensitive (so-called interior) species.
2. The loss of wide ranging species (species with very large home ranges, primarily predators).
3. The promotion of exotic species and native generalists which compete with, parasitize, or predate on native species.
4. Increased inbreeding depression and resultant population instability due to loss of genetic diversity.

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[7]Landscape resistance is a description of the degree to which the landscape (through barrier, and filter effects) restricts the passage of migrating fauna or vegetation (Knaapen et al. 1992).

The impacts of fragmentation on natural ecosystems can be understood through the following concepts (after Forman and Godron 1986, Forman in press):

1. Patch-corridor-matrix theory
2. Patch size and shape
3. Boundary and edge phenomena
4. Corridor width and connectivity
5. Network structure
6. Mosaic complexity and grain size

The above concepts apply to flows of organisms, energy, and materials within ecosystems. In addition to these, two important species related concepts are important for understanding fragmentation effects. These are:

7. Interior versus edge species
8. Minimum viable populations

These last two concepts will be discussed in the context of edge phenomena and patch size respectively.

Patch-corridor-matrix theory

This theory suggests that any landscape can be analyzed on the basis of whether the land cover forms part of the matrix (the dominant type of land cover), is a patch within the matrix, or is a linear section of habitat that interconnects patches (a corridor). In the suburban situation, the matrix is invariably the built environment, natural areas occur as patches, and corridors may be either natural (stream corridors for example) or constructed (for example, roads and transmission lines).

Patch size, shape, quality, and isolation

Opdam (1991) states that patches differ in the probability of being occupied as a result of different spatial characteristics: patch size, habitat quality, distance to other patches (isolation), and resistance of the landscape matrix.

Numerous studies have demonstrated a strong correlation between the number of species or species richness, found in isolated patches of habitat and the size of the patch (Moore and Hooper 1975, Forman et al. 1976, Stauffer and Best 1980, Ambuel and Temple 1983, Howe 1984, Lynch and Whigham 1984, Blake and Karr 1987, Robbins et al. 1989, Tilghman 1987, Bennett 1987, Bennett 1991, Opdam 1991). Figure 2.1 illustrates the relationship between the number of bird species in a given urban forest patch and the size of that patch. A similar relationship is reported in several of the other studies cited. Soule (1991) states that "in general, vulnerability to extinction within isolated patches is inversely related to their size." The majority of these studies have focused on birds, but studies of mammals (Dickman 1987, Bennett 1991), have shown similar relationships. Studies on invertebrates (Webb 1989) and plants (Game and Peterken 1984) are rare.

Figure 2.1
Relationship Between Number of Bird Species and Patch Size of Urban Woodlands

Source: Tilghman (1987 p. 488)

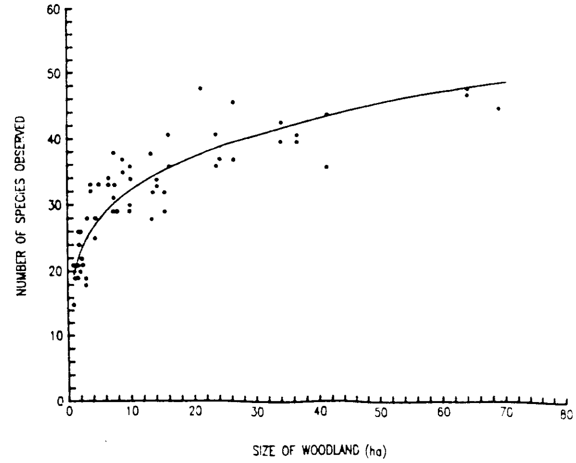


Figure 2.2
Probability of Sensitive Species Occurrence and Forest Patch Size
Probability curves drawn for 1, 2, 5, 8, 11, and 14 area-sensitive species.

Source: Robbins et al. (1989 p. 27)

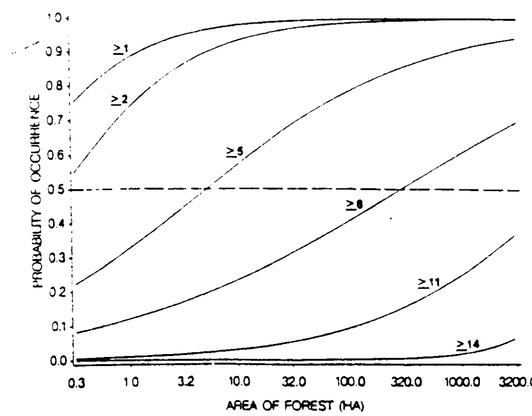
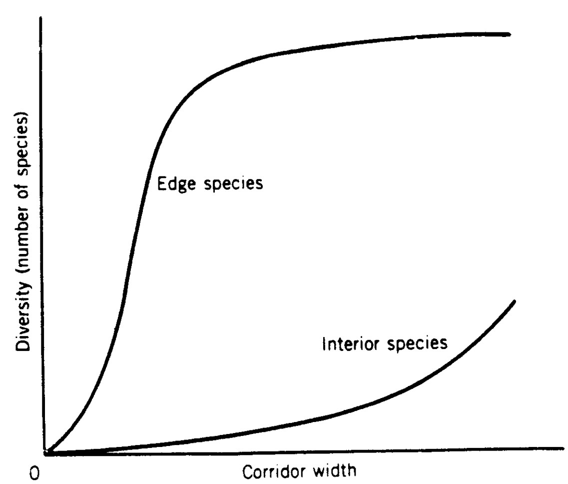


Figure 2.3
Hypothesized Effect of Corridor Width on Edge and Interior Species

Source: Forman and Godron (1986 p.145)



Robbins et al. (1989 p. 23) found a strong area-diversity relationship for neotropical migrant species, most species requiring "hundreds of hectares of contiguous habitat to reach their highest probability of occurrence". Figure 2.2 demonstrates the positive relationship between habitat area and the probability of detecting several species of area-sensitive birds. Howe (1984 p. 1596) states that "long-distance migrants . . . . generally exhibited low numbers in island (habitats)." Few neotropical migrant species were considered by Robbins et al. (1989) capable of breeding in patches less than 10 hectares. Conversely, they found that most short distance migrants readily used patches this size.

The principal reason for the strong, positive correlation between patch size and species diversity for fauna derives from variance in the habitat requirements/preferences of each species, and their tolerance to disturbance.

The question of how large a patch should be depends very much on what the objective of patch retention is. Contemporary ecological goals are directed at maximizing species diversity, i.e. retaining the maximum number of area sensitive or interior species.[8] Achieving this goal requires that patches be as large and circular as possible in order to minimize edge effects (Schonewald-

[8]Species richness is not considered a useful measure of ecological integrity, because fragmentation frequently has no effect on total diversity. In some cases, richness is actually increased in the short term because of the invasion of edge species (cowbirds for example), ubiquitous suburban species (sparrows and starlings for example) and, if ponds are created, several common waterbirds. Over the long term, the abundance and viability of many sensitive species can be expected to decline (Wilcox and Murphy 1985). Robbins et al. (1989) state that the generalist species which commonly occupy small and disturbed forests "need no special assistance", because these do well in any case . In some cases (such as with cowbirds) they counteract goals of protecting interior species Terborgh (1992).

Cox and Bayless 1986 p. 315). Ideally they should also be connected in some way (see discussion on corridors below). Butcher et al. (1981) and Robbins et al. (1989 p. 28) argue strongly for large reserves instead of several small reserves.[9]

Opdam (1991) maintains that some species can be maintained in small patches if they are capable of moving between patches, therefore forming a metapopulation.[10] Robbins et al. (1989) suggest that smaller forests may accommodate breeding pairs of rare species if other habitat attributes (such as streams) are considered.[11] They also postulate (with a qualifying caution) that smaller tracts in close proximity to large forest areas may attract some area-sensitive species.

Some of the recommended or empirical indicators for patch size are listed in Table 2.1. These are provided as an indication of the variability associated with predicting minimum area requirements for maintaining species diversity and as an argument for acquiring local understanding of species autecologies and system dynamics before undertaking fragmenting activities. With an understanding of the likely impacts of fragmentation on particularly sensitive species, planning can be more precisely oriented to minimizing species loss.

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[9]Maximizing diversity is dependent on retention of wide ranging, area sensitive species that would be lost in a several small reserve approach. Maximizing local richness, if repeated ad nauseam in relatively small precincts would have the effect of supporting close to the same suite of generalist, human disturbance-adapted species across the country. This broad scale homogenization would have a devastating national effect on diversity. This is why Robbins et al. (1989 p.1) emphasize the need to target area-sensitive or rare species when designing for wildlife conservation.

[10]A metapopulation can be characterized as an aggregate population of several disjunct, but interacting smaller populations.

[11]Instead of focusing only on area, if the preferred habitat elements of the species are provided, a speices may be able to be accommodated within a smaller reserve.

Table 2.1

Relationship Between Patch Size and Presence of Interior Species

Author	Recommended area (hectares)	Qualifying comments
Robbins et al. 1989 (p.31)	3,000	Will retain all species of forest-breeding avifauna [a]
Butcher et al. 1981 (p.36)	> 23	23 ha stated as being "hopelessly small for the effective preservation of forest interior birds"[b]
Forman et al. 1986	> 40	Number of species continued increasing through 40 ha[c]
Howe 1984	at least greater than 7	Forest patches 0.1-7 ha considered unsuitable for avian habitat preserves[d]
Wilcove 1985 (p. 1214)	≥ 900	This may eventually result in "declines in breeding populations of migratory songbirds."
Recher et al. 1987 (p.191)	>50-100	Patches smaller than this size considered too small for some fauna.
Tilghman 1987 (p. 491)	> 69	Patches in study (all < 69 ha) considered "much smaller than would be recommended for a nature reserve."[e]
Blake and Karr 1984 (p. 178)	> 600	Number of forest interior species continued increasing through 600 ha[f]
Askins et al. 1987 (p. 144)	23 - 647	Minimum patch areas specified for occurrence of several species.[g]
Soule and Simberloff 1986 (p. 32)	as large as possible	Also adds that there should be many of them.

Table 2.1 Footnotes

a) This estimate applies to the Middle Atlantic States. However, Noon et al (1980 p.242) state that "the habitat requirements of most forested bird species, although quite specific for each species, apply generally throughout their breeding ranges". Many of the species found in The Woodlands also occur in the Middle Atlantic states so that empirical data on area requirements from East coast studies, or the northern states may serve as a good first approximation of area requirements in The Woodlands.

b) Study undertaken on upland site in Connecticut.

c) Increase in number of bird species "due to progressive addition of carnivorous species with increasing minimum forest size requirements." (Forman et al. 1976 p.1)

d) Based on studies undertaken in southern Wisconsin and New South Wales in Australia.

e) Study was undertaken in Springfield, Massachusetts on 32 forest patches from 1-69 ha. Species diversity in urban woodlands continued to increase up to 69 ha (largest area sampled). Most rapid increase occurred between 1-25 ha.

f) Study conducted in east-central Illinois in 12 patches ranging from 1.8 to 600 ha.

g) Species cited were Hermit thrush (minimum area of 323 ha), Brown creeper (50 ha), Blue-gray gnatcatcher (50 ha), Yellow-throated vireo (347 ha), Black-throated green warbler (187 ha), Cerulean warbler (647 ha), and Worm-eating warbler (23 ha). All but the Black-throated green warbler and the Cerulean warbler have been recorded on The Woodlands.

Patch Shape

The optimal patch shape is generally considered to be circular, because this minimizes the ratio of perimeter (edge) to area (interior habitat), and therefore the magnitude of the edge effect (Diamond 1975, Butcher et al. 1981, Forman and Godron 1986, Schonewald-Cox and Bayless 1986). As discussed below, edge effects are considered detrimental to regional biodiversity.

Patch Quality

Recher and Serventy (1991) stress the impacts that structural alterations to forests have on avian diversity, especially removal of the understory. They found that removal of dense understory and ground vegetation has a major impact on avifauna. Tilghman (1987) stresses the importance of structure and the maintenance of the shrub layer in determining avian diversity in urban forest patches. Cicero (1989) refers to the strong correlation between the composition and diversity of urban avifaunas and habitat structure, availability and quality of food resources, and the degree of disturbance. Harris (1984, p.129) points out that the habitat value of a particular patch is determined by its structural characteristics (vertical zonation), and the matrix within which it occurs (its context).

Isolation Effects

Isolation effects are created when natural areas are separated from like habitat by human disturbance patterns, becoming in effect habitat islands. Quinn and Harrison (1988), Butcher et al. (1981), and Howe (1984) point to the negative correlation between increasing patch isolation and species richness. Opdam (1991) also refers to the negative impacts of isolation but adds that area is a much more important determinant. In Opdam's view the relative importance of scale and isolation seem to be dependent on scale and the dispersal capacity of species. Oxley et al. (1974) and Van Dorp and Opdam (1987) believe isolation effects are most pronounced when patches are surrounded by open areas of several kilometers.[12]

Minimum viable populations

Shaffer (1981 p.132) states that "A minimum viable population for any given species in any given habitat is the smallest isolated population having a 99% chance of remaining extant for 1000 years despite the foreseeable effects of demographic, environmental, and genetic stochasticity, and natural catastrophes." Gilpin and Soule (1986) maintain that though somewhat simplistic, a population of 500 breeding pairs is about the right order of

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[12]These studies were undertaken in rural landscapes. Their relevance to the urban environment would need to be confirmed.

magnitude for a viable population. The size of the habitat patch required to support a minimum viable population depends on the habitat requirements of individuals, and the manner in which they interact.

Boundary and edge phenomena

Edge effects are created when two different habitat types adjoin. Edge is created naturally by fires, tree blow-down, and other natural disturbance processes. Edge effects are also created when natural habitats are fragmented by human activities. Yahner (1988 p.336) states that "Induced edges are often characterized by abrupt differences in vegetative structure and composition between two contiguous landscape elements." Vegetation changes in the edge zone result from increased light, nutrients, and dominance by early successional species (including many exotic species). The edge zone is also characterized by the presence of generalist (opportunistic) fauna, both native and introduced.

Harris (1988), and Harris and Gallagher (1989) contend that the dramatic increase in the area of edge habitat created by human activities has resulted in negative impacts on the abundance of many U.S. species sensitive to edge effects. Virtually all the literature in this area focuses on edge effects as they impact birds, especially their breeding success, though it is highly likely that edge effects have a similar negative impact on some percentage of the total fauna.

To understand edge effects on faunal diversity it is important to understand the distinction between what are commonly referred to in the literature as interior and edge species.

Interior versus edge species

Harris and Gallagher (1989) characterize interior species as those whose "occurrence and successful reproduction are highly dependent on the size of the habitat patch in which they occur." Interior species are frequently referred to as area sensitive species. Species intolerant of human presence or disturbance are also characterized as interior species.

At one end of the spectrum of fauna commonly labeled as "interior species" are the wide ranging species that require large areas of undisturbed habitat to breed, forage for food and satisfy other behavioral characteristics. Examples in this category typically include species at the top of the food chain, such as wolves, bears, cougars, and spotted owl. These species require several thousand hectares to support an individual animal.[13] Maintaining a viable breeding population requires several hundreds or thousands of square kilometers. These are not species that can be accommodated within an urbanized or otherwise fragmented landscape.

Harris and Gallagher (1989) maintain that the loss of these wide-ranging animals significantly weakens the functioning of natural systems because of the removal of their regulatory effect on prey species. Harris and Gallagher

[13]Landers et al. (1979) radio-tracked a male black bear in North Carolina with a range of over 18,000 ha. Harris and Gallagher (1989) cite individual home ranges of 6,000 ha (15,000 acres) for black bear, 2,000 ha (5,000 acres) for bobcats, and 60,000 ha (150,000 acres) for cougars.

also found that declines in the populations of the top carnivores and large wide ranging species[14] in Florida has allowed smaller, omnivorous, and more generalist species[15] ("meso-mammals") to increase in abundance[16] This increase has changed the dynamics within the food chain below the top predator level, significantly altering the abundance of species preyed on by meso-mammals (Harris and Gallagher 1989).

Generalist or edge species are the converse of interior species. These are species that occupy much wider niches, and are adapted to surviving in more than one habitat type. In an urban context, these are species that are either tolerant of, or favored by the types of habitat disturbances created by humans, for example, squirrels and cardinals (Tilghman 1987).

To a large degree, the extent and magnitude of the edge effect is very much determined by the behavior of the generalist species that occupy the edge zone. Several meso-mammal edge species (raccoons and opossums for example) are ground nest predators, and "have been identified as a critical factor in the decline of several species of migrant songbirds" (Harris and Gallagher 1989, p.26). Harris and Gallagher (1989) further suggest that predation and nest parasitism (by mammals and birds) are the main negative manifestations occasioned by species frequenting the edge zone. Small and Hunter (1988), Wilcove (1985), and Andren and Angelstam (1988) documented much higher rates of nest predation in smaller forest patches than occurred in large patches, with the rate of predation decreasing with distance from the edge.

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[14]Black bear, Florida panther, red wolf, bobcat, otter, mink, and weasel.
[15]Raccoons, coyotes, skunks, grey fox, red fox, opposums and armadillos.
[16]Prior to disruption of the natural dynamic by colonial settlement, these species were probably either unable to compete with the larger predators, or their populations were limited by predation from larger animals.

Several authors (Brittingham and Temple 1983, Serraro, 1985, Robbins et al. 1989, Harris 1988, Terborgh 1992) have pointed to the negative impacts of nest-parasitic cowbirds on nesting songbirds[17]. Increased nest predation by raccoons has been noted by Harris and Gallagher (1989); by blue jays (Serraro 1985, Wilcove 1985); by grackles (Ambuel and Temple 1983, Serraro 1985, Wilcove 1985); and by crows (Yahner and Wright 1985, Wilcove 1985). Wilcove (1985) also noted that avian predators such as crows and blue jays may be more common along forest edges than in the interior.

Catteral et al. (1991), and Recher and Serventy (1991) cite aggressive behavior as another important characteristic of edge species. Competition for nest sites has been observed by Butcher et al. (1981), and Catteral et al. (1991). Catteral et al (1991 p.254) state that the "junction between suburb and forest appears to provide a favorable combination of resources needed for feeding, perching and breeding of such (edge) species." In their study within an Australian suburb, edge species were characterized by relatively large body size and aggressive behavior. Furthermore, the relatively small size of most forest birds may make them "particularly vulnerable to processes involving behavioral interference competition" (Catteral et al. 1991 p.254).

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[17]Brittingham and Temple (1983) found that cowbirds parasitized 65% of nests located within forested edges in southern Wisconsin forest patches. This figure dropped to 18% 300 meters from the edge. Terborgh (1992) describes another study by the Illinois Natural History Survey which recorded population declines of over 50% in 7 out of 13 neotropical migrants in an area near Shelbyville, Illinois during a five year period from 1985 to 1989. In this instance 80% of clutches were lost to predation, and of the remainder, 76% were parasitized by cowbirds. See footnote 18 for comparison with predation rates in interior forest.

Serraro (1985) and Terborgh (1992) assert that increased edge effects in combination with losses of habitat[18] have initiated dramatic declines in the abundance of many species of single-brooding, low nesting neotropical migratory birds. Since more than a third of breeding bird species in the U.S. are neotropical migrants (Serraro 1985), these declines have serious implications for species diversity at all spatial scales.

Neotropical migrants are particularly vulnerable to edge effects because they tend to lay fewer eggs[19], in open cup-shaped nests on or low to the ground, and produce only one brood a year (Brittingham and Temple 1983, Serraro 1985, Robbins et al. 1989). Their reproductive success is therefore much more susceptible to nest predation and parasitism than species that nest higher up, or in cavities, and produce more than one brood per year. Robbins et al. (1989) suggest that increased predation and parasitism in combination with isolation effects may reduce both the rates of return of adult birds and colonization by first-time breeders.

Most of the literature on edge effects describes just two specialist groups of species - interior and edge species (for example, Forman et al. 1976). Catteral et al. (1991), in a study of habitat use by birds across a forest-suburb interface, describe three specialist suites of species adapted to particular habitat types: forest, edge, and suburb. Most species are classified as "behavioral macrohabitat specialists" adapted to each of these habitat types. A differentiation is also made between edge and a small group of generalist

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18 Habitat loss in this instance is exacerbated because it is happening in both the U.S. and wintering grounds in Latin America and the Caribbean.

19 Terborgh (1992) specifies an average clutch size of 3-4 eggs for neotropical migrants versus 5-6 for non-migrants.

species, the latter occurring across all three zones. Catteral et al. (1991) found little movement of either forest or suburb species occurs across the interface or edge zone.

Goldstein et al. (1986) also found that bird presence and abundance fell into three principle groups: edge and generalist species that are little affected by vegetation biomass[20] (18 out of 65 species), a larger group (25 species) that Goldstein et al. classify as "able to survive in suburban environments only when vegetation and other conditions are unusually suitable"; and a third group (19 species) of more sensitive species. Species in the second group occurred on average where vegetation volume was greater than it was for Group 1 species. Goldstein et al. (p. 384) contend that these species "are responsive to management, and can fairly predictably be added to a suburban avifauna where adequate vegetation volume is provided."

DeGraaf (1991 p.173) contends that suburbs "have great potential for supporting quite varied bird communities" as long as mature native shrubs are present and the canopy is comprised of native species. DeGraaf (1991 p. 178) found that suburbs built within woodland contained an "appreciable number of insectivorous species" in contrast to planted environments which could not match the habitat value of natural suburbs, no matter how mature the vegetation. DeGraaf (1991 p.179) believes that" urbanization need not eliminate insectivorous forest birds if fragments of native woodland are retained where possible," though DeGraaf and Wentworth (1986) still contend that suburbanization generally results in a decline in insectivorous species.

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[20]Goldstein et al (1986) use the term "volume" to denote biomass.

Edge effects decrease with distance from the edge, and the degree of impact is often enhanced over time if the edge is maintained, as is common in suburban landscapes. Catteral et al (1991) believe the edge effect in suburban Eucalypt forests in Brisbane may extend up to 250 meters. Brittingham and Temple (1983) found that cowbird parasitism extended over 300 meters into the forest, though the rate of parasitism declined with distance from the edge. Both Wilcove (1985), and Andren and Angelstam (1988) found predation rates leveling off to near natural rates[21] between 200-500 meters from the forest edge, but still extending up to 600 meters.

Edges as a factor in urban pond design

Cicero (1989) contends that avifaunal richness and diversity in areas adjacent to urban ponds is mostly determined by the width of adjacent vegetation, and the habitat structure of vegetation around the pond and within the buffer zone. Based on this finding, Cicero recommends the following guidelines for "designing and maintaining pond habitats to enrich bird communities in urban parks," (Cicero (1989 p.221):

1. Construct ponds (preferably > 1 ha) as far as possible from adjacent urban development,
2. Maintain a complex vertical structure of vegetation within the buffer zone surrounding the pond,
3. Establish shrubby vegetation interspersed with bare ground and trees immediately adjacent to the water,
4. Provide irregular shoreline shapes,
5. Maintain overhanging vegetation,

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[21] The lowest predation found by Andren and Angelstam (1988) in their study was around 8%, in comparison with 6% in interior forest areas.

6. Provide islands,

7. Maintain standing dead trees (especially flooded).

Corridors

Natural dispersal of animals, plants, organic material and nutrients is one of the most fundamental ecological processes. Dispersal can be random or directional. It can take the form of annual migration or searches for food, water, cover and mates. Habitat fragmentation significantly affects natural dispersal patterns. To understand this impact it is important to understand the role of corridors in facilitating dispersal through landscapes.

The corridor concept holds that the movement of animals and plants across a landscape can be facilitated by avenues of preferred habitat (Harris and Gallagher 1989, Noss 1993).[22] The concept is especially relevant in landscapes where the mosaic (for example, housing development, or agriculture) is not favored by organisms trying to disperse. These avenues are commonly called corridors. Corridors may move individual organisms or genetic material (Bennett 1990a).[23] Corridors may be discrete, easily recognizable, linear landscape features, such as strips of riparian and roadside vegetation (Noss

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[22]My discussion confines itself to wildlife movement, because of the paucity of research on plant movement via corridors, and the greater applicability of existing empirical data on wildlife for assessing the functionality of corridors within The Woodlands.

[23]Bennett (1990) suggests that gene flow could be accomplished along a corridor incrementally, without individuals necessarily traveling its entire length. This would occur through resident populations interacting with adjoining populations along the length of the corridor. For example, a male deer at the northern limit of its home range could mate with a doe in the southern limit of its home range, the progeny of which could perform a similar function at the northern limit of its range. The rate of genetic flow by this manner is slower than by individual migration, but is nevertheless effective over ecological timespans. It is probably most relevant for flora and fauna with small home ranges, or which do not readily disperse.

1993), or they may be relatively heterogeneous, ill defined flow paths, that permit passage of species but do not constitute substantive habitat on their own.[24] (Noss 1987, Simberloff and Cox 1987, Soule and Gilpin 1991)

Numerous studies have stressed the value of corridors for biotic dispersion and maintenance of patch populations (Roff 1973, Harris and Gallagher 1989, Bennett, 1990, numerous papers in Saunders and Hobbs 1991, Noss 1987, Noss 1993, Forman and Godron 1986,). Harris and Gallagher (1989) maintain that the problems of fragmentation and isolation can be "largely alleviated through a series of greenbelts, habitat linkages, wildlife corridors, and riparian buffer strips connecting key parks, refuges and habitat islands." Noss (1993 p.43) points out that the "maintenance or restoration of habitat connectivity has become a central goal of biological conservation" in fragmented landscapes. Noss (1987 p.161) also stresses that corridors are not a panacea for resolving conservation problems, but are "one critical component of an integrated landscape conservation strategy."

The habitat function of corridors is particularly important where all other suitable habitat has been altered (Bennett 1991, Saunders and Hobbs 1991). Several authors have pointed to the value of riparian habitat for wildlife and other ecological functions, for example, water quality (Johnson 1989, Allen and Kennedy 1989, Naiman et al. 1993, Evans 1991, Harris 1984). The importance of corridors for facilitating the existence of metapopulations has also been emphasized (Wegner and Merriam 1979, Opdam 1991).

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[24] Prevett (1991) describes the movement of koalas across agricultural land using scattered remnant trees as stepping stones.

The functional capability of corridors is largely dictated by their width, integrity (quality of vegetation), connectivity and length. Width and connectivity are especially emphasized by Noss (1993). Width is important because the linear form of corridors exposes them to edge effects on two sides. To enable the passage of interior species requires that the corridor be at least wide enough to maintain a continuous strip of interior habitat (see Figure 2.3). Connectivity is a measure of the continuity of the corridor, that is to what degree it remains unbroken by disturbances and intrusions (such as roads, trails, utility line clearings, and drainage improvements). Variability in the quality of corridor vegetation may derive from edge effects, or from other edge independent disturbances (for example, cattle grazing or storm damage). Variations in vegetation will exclude species dependent on particular habitat conditions.[25]

On the importance of corridor length, Bennett (1990) states that the "effectiveness of corridors for dispersal by single animals depends upon the distance to be traversed." Corridor length could be important where species that would use a short corridor are less inclined to use one to travel much longer distances. Also, different animals have different speeds of dispersal, implying that if use of the corridor exposes dispersing individuals to risks (e.g. predation) greater than those found in their preferred habitat, then the longer they are in it the less successful they are likely to be at dispersing (Soule 1991).

25 This quality variation may be very subtle. For example, McFarlane (1994) states that Red-cockaded Woodpeckers are adapted to mature pine forests that are maintained free of hardwoods by regular fires. If fire were to be excluded from a corridor of this type, resulting in hardwoods invading the mid-upper canopy, the Red-cockaded Woodpecker would be less likely to use it. This would only be true though for corridors extending several kilometers, since Red-cockaded Woodpeckers would likely use corridors in different successional stage over shorter distances (McFarlane 1994).

Animals also have a learning capacity, and even if they successfully negotiate the corridor, they may be less inclined to use it again.

More fundamentally, the suitability of a corridor for moving wildlife is most dependent on the life histories of the species using it. Each species has certain behavioral characteristics that determine whether they will use corridors. For example, narrow corridors, constituting all edge, will exclude most, if not all interior species. Many species will only disperse through an unbroken corridor and so are prevented from dispersing by breaks created by roads, utility line clearings, drainage improvements, and other disturbances in urban environments.[26] Bennett (1990, p.109) contends that "for many faunal species, even small habitat discontinuities may pose a distributional barrier, or a severe limitation to free movement." Soule (1991) states that "the death rate of species in a corridor is the major criterion in determining its effectiveness."

Empirical data on optimal corridor widths for particular species or assemblages of species is limited. Stauffer and Best (1980) found a significant positive correlation between bird species richness and the width of forested riparian habitats. In modeling the impacts on bird densities of reducing woody riparian vegetation to narrow strips, they found that this action could provide favorable habitat for 12 species, but would eliminate 6 species, and might reduce the densities of a further 16 species. Several authors (Noss 1987, Noss 1993, Harris and Gallagher 1989) maintain that in the face of uncertainty about the dispersal behavior/requirements of particular species, that a policy of "the wider the better" is most prudent . Based on their estimates of edge effect,

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[26]Breaks function as barriers that filter out smaller, slow moving animals, animals unwilling to move into cleared areas, and animals that inhabit the forest canopy.

Catteral et al. (1991) recommend a corridor width of 500 meters to enable dispersal of forest bird species. Harris and Scheck (1991) attest to the need for corridors kilometers wide to cater to the movement of "entire assemblages of species." Noss (1987) states that "corridors several miles wide" would be necessary to enable the dispersion of carnivores such as cougars.

Network structure

Networks of corridors are important in that they provide redundancy, or multiple movement pathways, and mitigate against the destruction of any single corridor by catastrophic disturbance events (Forman 1983). Bennett (1991) stresses that networks of habitat corridors are essential components of conservation strategies in fragmented landscapes.

Mosaic complexity and grain size

Mosaic complexity is determined by landscape grain size; the finer the grain, the more complex the landscape. Landscape grain size is a measure of the average size of landscape elements (Forman and Godron 1986). A suburban landscape would be characterized as fine-grained, because each of its elements (parking lots, roads, houses, gardens etcetera) is quite small. Grain size is also applicable to organisms, although this is a different concept than landscape grain size. Forman and Godron (1986 p.217) describe organism grain size as "the area to which an organism is sensitive or uses."

2.3 The Suburban Mosaic

An assessment of landscape structure must consider more than individual landscape elements (patches, corridors etcetera): adjacency effects are also important. Patches adjoining a suburban matrix are subjected to different types and intensities of pressures than those in rural or heterogeneous natural landscapes.

Generalist species dominate urban areas, magnifying the edge effect in coterminous forested patches (Davis and Glick 1978). The negative edge effects occasioned by raccoons, grackles, blue jays and other edge species are often exacerbated by human activities. Wilcove (1985) found nest predation rates of 71% in suburban forested patches (4-12 ha) versus 48% in rural woodlots. Supplemental feeding of these species or just the unintentional creation of additional food sources (from garbage and roadkill) maintains these populations at higher levels than would exist on the edge without human presence. Terborgh (1992) points out that suburban resident raccoons and opossums typically occupy smaller ranges, grow faster, and attain greater body weights than they do in rural areas.

Some of the management practices of suburban forest patches reduce natural forest heterogeneity. For example, Stauffer and Best (1980) assert that removal of dead trees from wooded habitats drastically reduces potential nest sites for primary cavity-nesters. They add that the removal of dead limbs and general tree repair in urban trees can also affect secondary cavity-nesters. Management to reduce insect populations, and the use of non-native plants in suburban gardens result in reduced food availability for native insectivorous species (Goldstein et al. 1983). Insectivorous species are also the most sensitive group of birds affected by edge effects.

The negative impacts of invasive herbaceous plants on suburban forest patch fauna have been noted by Recher and Serventy (1991) These contribute to loss of floral diversity in natural systems by out-competing native species. Their vigor is also encouraged by increased moisture from impeded drainage, by increased nutrients in stormwater runoff and illegal waste dumps, and by increased light in forest edges and disturbed areas.

Other impacts are occasioned by the dumping of human refuse - miscellaneous garbage, car bodies, construction debris, Xmas trees, grass clippings, leaves, and prunings (Matlack 1993). These wastes can introduce exotic plant material, prevent native plant germination, harbor rodents, and increase nutrient levels (personal observation). Understory thinning, mowing and removal of desirable plants or flowers are common activities in suburban forest patches (Recher and Serventy 1991). Patches are sometimes "enhanced" by plantings of exotic species with bright foliage or flowers (personal observation). Matlack (1993) also cites substantial recreation impacts such as the construction of children's huts and campgrounds, hacking of vegetation, and firewood collection. Most, if not all, suburban forest fragments are bisected by formal/informal trail systems that further promote edge effects, in addition to increased erosion, trampling and compaction effects. Matlack (1993) noted that human impacts were often clustered around footpaths.

In a study of 40 forest fragments in suburban parts of Delaware, Matlack (1993) found that 95% of localized damage from human intrusion occurred in the first

82 meters from the edge, most within the first 30 meters. Matlack adds that "in terms of penetration of the forest and severity of damage, human impacts greatly exceeds natural edge effects for this community." He further adds that the severity of impact is linked to access. More access equals more impacts.

Suppression or promotion of fires can also have a dramatic impact on the dynamics of forest patches (Recher and Serventy 1991, Davis and Glick 1978). The biota and structure of ecosystems that have evolved in the presence of periodic fires, or other natural disturbances, will eventually be replaced by a different suite of dominant species if these natural disturbance regimes are suppressed by human activities.

2.4 Impacts Related to Scale

Noss (1983), Noss and Harris (1986), Turner (1989) have all emphasized the need to consider ecological protection goals at more than the local scale. Noss and Harris (1986) state that the present focus on practical conservation efforts is limited in scope (is too fine-grained), and that this narrowness has resulted in an inability to evaluate and manage phenomena that operate at large spatio-temporal scales.

Noss (1983 p.700) believes that "recent trends in species composition in fragmented landscapes suggest that a more comprehensive view is required for perpetuation of regional diversity. A regional network of preserves, with sensitive habitats insulated from human disturbance, might best perpetuate ecosystem integrity in the long term." Turner (1989 p.189) states that "the long term maintenance of biological diversity may require a management strategy that places regional biogeography and landscape patterns above local concerns." Turner (p.190) also stresses the tremendous necessity for "truly interdisciplinary cooperation among ecologists, geographers, landscape planners, and resource managers to develop an integrated approach to landscape management."

The spatial structure discussed in this chapter shows different patterns at different scales. The size of the land parcel being examined therefore requires analysis at different scales because landscape patterns change according to scale. For example, it is not possible to consider conservation of wide-ranging species (such as the Florida panther) at the scale of suburban developments, regardless of their size. The subject parcel must also be analyzed at the scale appropriate to this species, especially if that species is threatened by cumulative small scale developments as the Florida panther is.

2.5 Principles for Conservation of Wildlife in Urban Areas

Pickett and Thompson (1978 p.27) contend that the design of reserves in fragmented landscapes "should be based on 'minimum dynamic area", the smallest area with a natural disturbance regime which maintains internal recolonization sources and hence minimizes extinctions. Determination of minimum dynamic area must be based on knowledge of disturbance-generated patch size, frequency, and longevity, and the mobility of the preserved species."

The primary focus of designing suburban development to protect biodiversity must be focused on the protection of interior species. The most important guidelines for achieving this goal are summarized in Table 2.2.

Table 2.2

Ecological Principles for Suburban Design

Determine site's regional ecological context
Understand interior species' autecologies, especially rare and sensitive species[a]
Design patch (size, number, location) and corridor network to maximize interior habitat, minimize edge effects, and promote interior species viability
Patches should be as large and circular as possible: corridors should be continuous and as wide as possible
Protect areas with natural vegetation strata intact and in good condition
Maximize natural spatial heterogeneity to promote overall population persistence
Minimize negative impacts deriving from the urban matrix
Minimize human intrusion into interior habitat
Manage natural areas to support natural system dynamics
Monitor habitat condition and abundance of interior and redress negative impacts wherever possible
Provide buffers to preserved areas
Develop contingency plans to counteract stochastic population destabilizing events

Table footnote
a) The designer needs to know habitat requirements (cover, food, water, nesting sites), micro-habitat preferences, home range, natural behavior (for example, mobility and dispersal tendencies), fecundity, natural population stability (normal range of population swing), behavior in response to human disturbance and presence, and vulnerability to flow-on effects of fragmentation (i.e. predation, nest parasitism). (Davis and Glick 1978)

CHAPTER 3

ECOLOGICAL PLANNING FOR THE WOODLANDS

3.1 The Woodlands Pre-development History

In the 1960s, Texas oil millionaire, George Mitchell, spurred by concern for what he saw to be the social decay of many American cities, conceived the idea of creating his own community (Malone 1985, Morgan and King 1987, Holmes 1992). Mitchell had observed the riots of Bedford Stuyvesant in New York and Watts in Los Angeles and was concerned that the flight of the middle class and their allied tax base to the suburbs was promoting the collapse of the social and physical character of inner cities, which was in turn promoting a general fragmentation of society (Malone 1985). Concerned that the decline of northern cities would eventually affect his home town of Houston, Mitchell wanted to develop a community that would circumvent the problems he had observed.

His initial goals were to:

1. Provide a wide range of housing to accommodate a racial and socio-economic mix as close as possible to Houston's.
2. Provide enough employment to support a range of socio-economic groups and to allow people to live and work within the community.
3. Provide all the facilities and services a self sustaining community requires (Malone 1985, Holmes 1992, Morgan and King 1987).

Mitchell also believed his new town could alleviate many of the urban woes of the time; pollution, congestion, noise, social disharmony and general social blight (Morgan and King 1987) He was not interested in creating a large, traditionally planned subdivision: "his interest lay in creating a style which would make it the most attractive community within the Houston metropolitan area" (Malone 1985 p.14).[27]

Mitchell's move into real estate was not entirely driven by his community concern. He also saw this expansion of his portfolio serving as an in-house tax shelter in the short term and as a longer term diversification of his portfolio of oil and gas interests. During the 1960s and 70s Mitchell acquired approximately 26,400 ha (66,000 acres) within a 50 mile radius of Houston, including The Woodlands property. Much of this was purchased for "as little as $125 an acre" (Malone 1985). In the end, the 10,000 ha (25,000 acres) making up The Woodlands cost on average $1,688 an acre and required over 500 separate purchase transactions. Jim Wendt, Director of Residential Planning for The Woodlands Corporation (1994) estimates with more recent acquisitions, the total area of The Woodlands is now closer to 10,800 ha (27,000 acres).

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[27]The notion of creating a separate development to alleviate problems elsewhere in the city is paradoxical. By diverting resources that might have been used to provide needed infrastructure in problem areas to develop infrastructure for new areas, the problems targeted by Mitchell have been exacerbated. This satellite approach only benefits those with the resources to move.

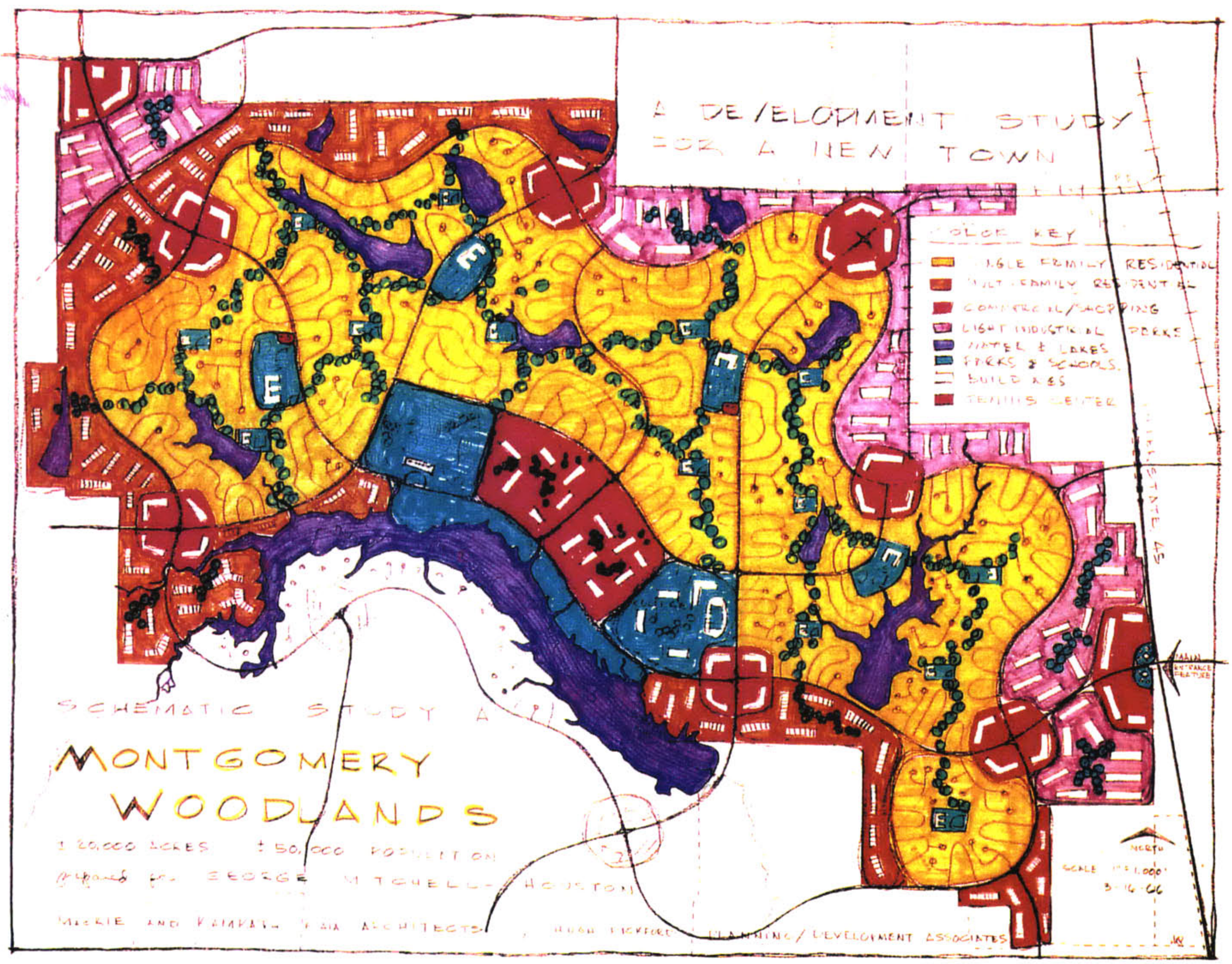

Figure 3.1 First Concept Plan for The Woodlands

Source: Malone (1985)

In search of a formula for a community that would avoid the problems he had observed, Mitchell asked Houston architect, Karl Kamrath in 1966 to develop an appropriate plan (see Figure 3.1). Dissatisfied with the lack of originality in the Kamrath plan, Mitchell eventually tried another Houston architect, Cerf Ross in 1969 (Morgan and King 1987), whose plan he submitted to HUD for aid under the Urban Growth and New Community Act of 1968 (Malone 1985). HUD rejected the plan, but gave approval to his pre-application proposal. Thus encouraged, Mitchell began to cast around in earnest for a team that could prepare a plan to suit HUD's requirements. Inspired by the new town concept, he also began visiting new towns throughout Europe and the U.S., including Columbia, Maryland (1967); Reston, Virginia (1965); and Irvine, California (1960) looking for ideas. He found Columbia to be particularly impressive (Holmes 1992).

Around this same time, Mitchell was introduced to Ian McHarg's book, Design with Nature by his director of planning and design, Robert Hartsfield (Morgan and King 1987). Hartsfield had been a student of Ian McHarg at the University of Pennsylvania. Considerably impressed by Design with Nature, Mitchell engaged McHarg's firm of Wallace, McHarg, Roberts, and Todd (WMRT) to undertake the ecological planning for his new town (Morgan and King 1987). Because the HUD review process had a strong focus on environmental factors, Mitchell knew that his success in garnering the $50 million HUD Title VII grant depended on the strength of the environmental component of his plan. McHarg and Sutton (1975 p.81) state that "It is fair to say that the ecological studies were contracted less with a profound conviction of their necessity than as a concession to public environmental consciousness."

Heartened by what he saw as the potential of new towns for achieving his goals, Mitchell added to his planning team with two consulting firms that had been involved in the planning of the new towns he had visited. These were William L. Pereira Associates, of Los Angeles, who had been involved in the planning and design of Irvine, and Richard P. Browne Associates, of Columbia, Maryland who had been engineering consultants to the Columbia development. Pereira was contracted to handle the master planning and design. Browne was to be responsible for development, engineering and HUD liaison. Gladstone Associates, of Washington D.C. were employed to handle the economics and marketing. Mitchell also poached many of the senior personnel and consultants associated with the aforementioned new towns for his own staff (Malone 1985).

Though the planning process went through many permutations over the next two years, the final design plan (Revised General Plan) was dominated by the influence of WMRT. Part of this was due to the quality of the work produced by WMRT, but a significant contributor was also the special rapport that formed between Mitchell and McHarg (Sauer 1993). The turning point in Mitchell's faith in the ecological design promulgated by WMRT came when McHarg outlined to Mitchell the advantages of his proposed natural drainage scheme over a conventionally engineered design. Because of the flat terrain on The Woodlands site, conventional drainage would have required substantial alteration of the landscape with the removal of a substantial proportion of the forest on site in order to facilitate the construction of large, unsightly concrete drainage channels. This approach did not meet with Mitchell's image of his new town, nor HUD's requirements. The most persuasive argument though was the estimated cost savings - $14.5 million in Phase 1 alone (McHarg 1993)[28].

3.2 Site Description

The bulk of The Woodlands site is located within Montgomery County, approximately 43 km (27 miles) north of Houston downtown (see Figure 3.2). A small area of several hundred acres falls within Harris County, on the southern side of Spring Creek.

Physiographically, The Woodlands lies on the Atlantic Coastal Plain, in the south west corner of the East Texas forest system, referred to in Texas as the Pineywoods. The site is essentially flat, with slopes greater than 5% encountered in only a few small areas (WMRT 1974d). The site is drained by three main watercourses - Spring Creek, Panther Branch, and Bear Branch. The 100 year floodplains of these creeks are depicted in Figure 3.3. The west branch of the San Jacinto River also cuts across the Trade Center area on the eastern side of I-45. Low, level depressions, referred to locally as Waller Ponds are also interspersed over the site. Waller ponds average between 0.4-2 ha (1-5 acres) and are formed on highly acid soils, with a very low mineral content. Vegetation is determined by the soils and inundation period.

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[28]Phase 1 is comprised of about 800 ha (2,000 acres).

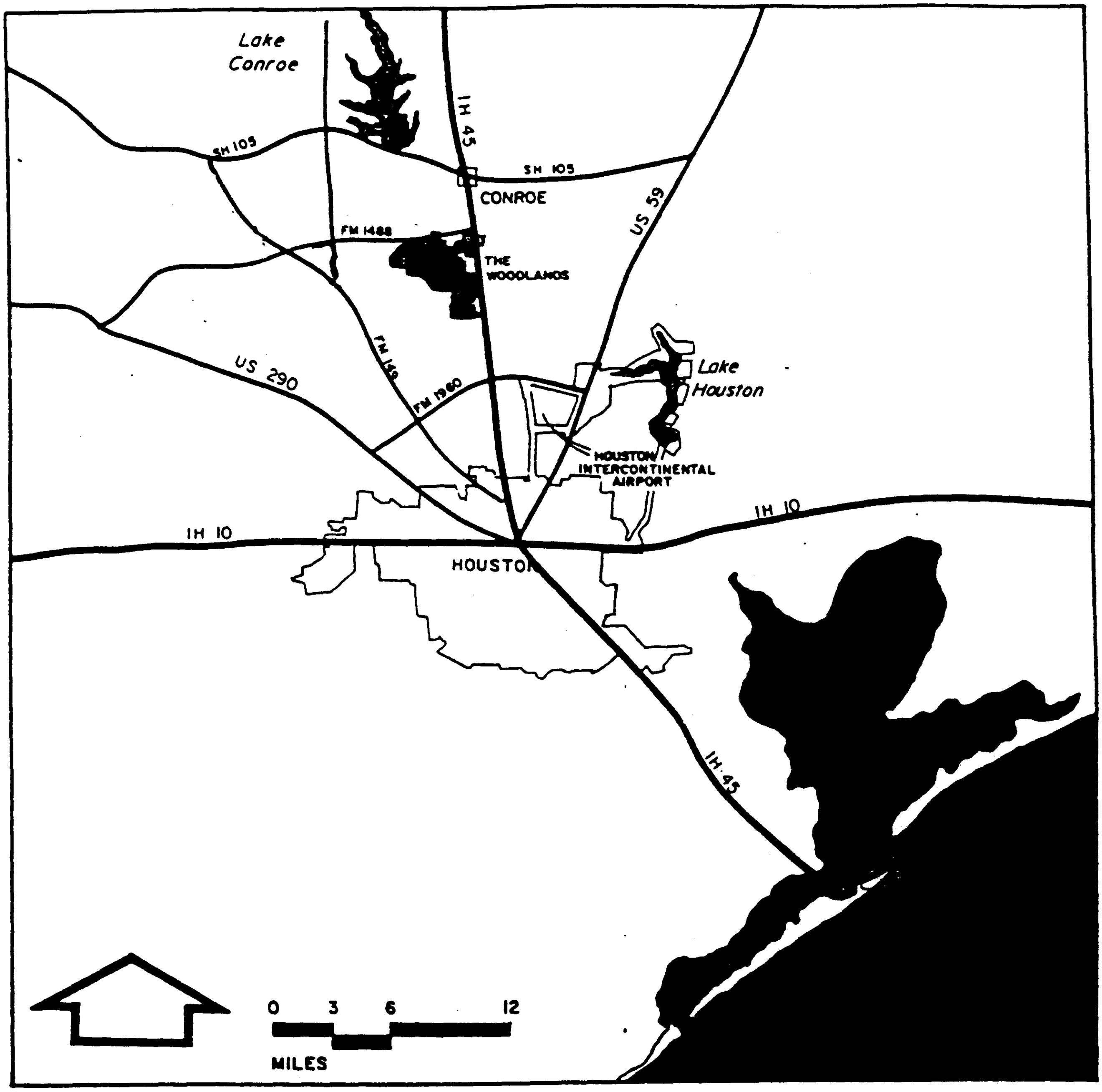

Figure 3.2 Regional Context of The Woodlands

Source: Mitchell/Southwest and The Woodlands Corporation promotional pamphlet

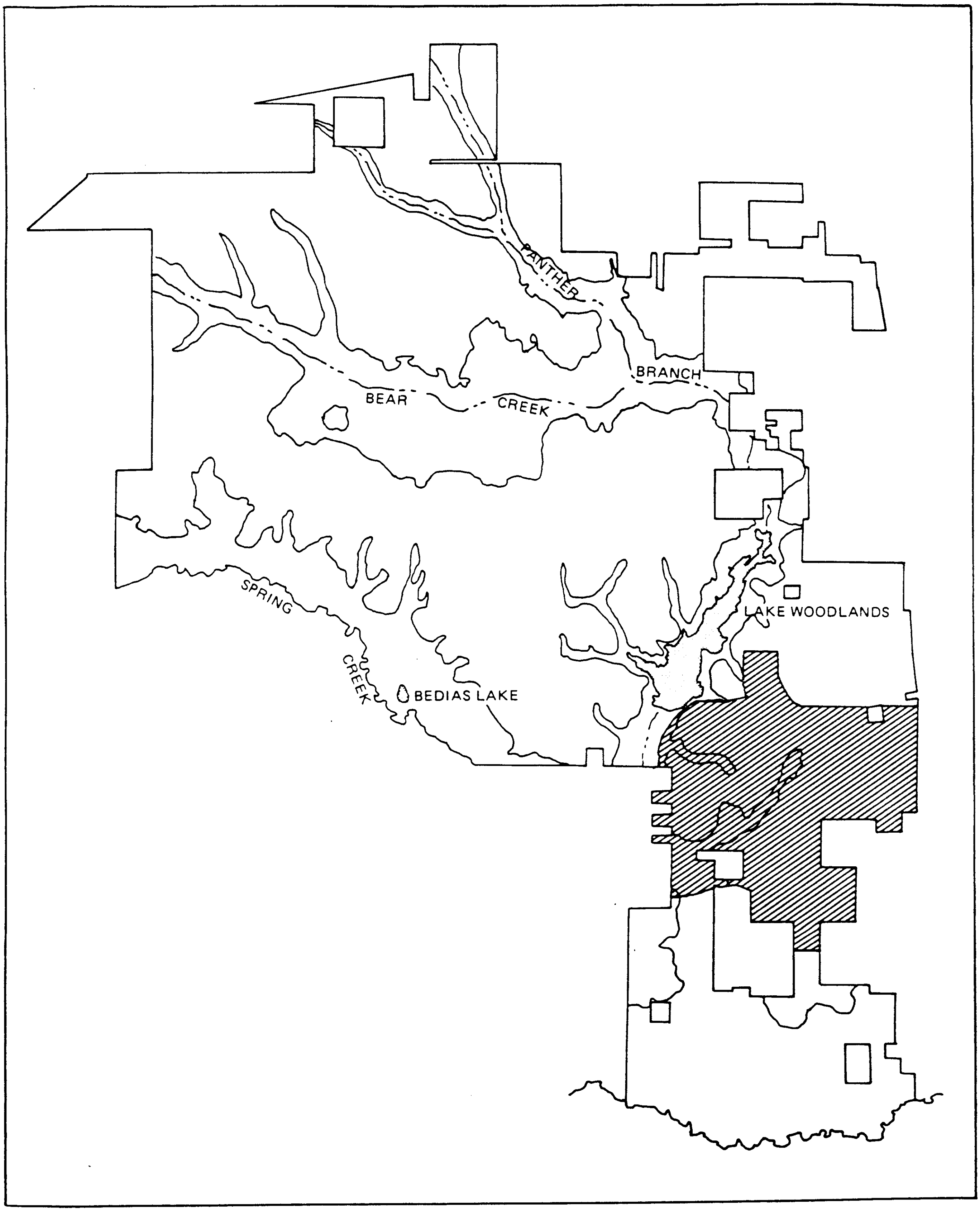

Figure 3.3 The Woodlands - 100 Year Floodplain

Source: WMRT (1973b p.13)

The climate is subtropical, with most of the rainfall occurring in thunderstorms. Average monthly rainfall is over 100 mm (4 inches). Climate is considered to have the greatest impact on soil formation (WMRT 1974a). Soil and hydrology are in turn the primary determinants of vegetation. Vegetation type and quality determine wildlife.

Soils are highly leached and sandy to loamy in texture, with a zone of clay accumulation. The sandy A horizon typically has a depth of 30-60 cm (12-24 inches), with the B horizon extending between 60-125 cm (24-50 inches) (WMRT 1974a p.30). Permeability varies significantly, although the more permeable soils are usually found in the floodplain and the impermeable soils on the uplands. Waller ponds are characterized by very low permeability, resulting in shallow ponding through much of the year.

Forest cover is comprised of a moist mixed woodland, dominated by loblolly pine (*Pinus taeda*) (WMRT 1974a). The mix of hardwoods and pine varies over the site in response to soil type and disturbance history.[29] WMRT's original Ecological Inventory described 8 major vegetation associations on site, as follows: (WMRT 1974a).

1. Shortleaf Pine-Hardwood
2. Loblolly Pine-Hardwood (the largest and most varied vegetation type mapped)
3. Loblolly Pine-Oak-Gum
4. Pine Oak-Oak
5. Mixed Mesic Woodland
6. Pine Hardwood

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[29] Differentiation between forest types is weak (WMRT 1974a).

7. Floodplain

8. Wet Weather (Waller) Pond

This breakdown was expanded to 11 types when detailed planning began for Phase 1 construction in Grogan's Mill (WMRT 1974d). Dr. Claude McCloud[30], who undertook the initial vegetation inventory characterized the site's vegetation as "reasonably complex", because of the diversity of different forest communities. (WMRT 1974a p.37).

Oaks (*Quercus spp.*) dominate the hardwoods, in association with sweetgum (*Liquidamber styraciflua*), hickories (*Carya spp.*), tupelo gum (*Nyssa sylvatica*), occasional elms (*Ulma spp.*), magnolia (*Magnolia grandiflora*) and sycamore (*Platanus occidentalis*). Short leaf pine (*Pinus echinata*) may replace loblolly as the dominant pine with an associated shift in associated hardwood spp. on the drier, more elevated soils. The predominant understory shrub is Yaupon (*Ilex vomitora*). More detailed vegetation descriptions can be found in An Ecological Inventory (WMRT 1974a).

The site has been subjected to several types of disturbance since the area was settled by non-Native Americans. McCloud (WMRT 1974a) states that these disturbances have "radically altered" the original vegetation structure Disturbances have resulted from repeated harvesting of mature pines and hardwoods, the construction of roads, oil and gas drill sites and pipelines, pockets of cultivation, increased deer grazing, some urban development, and

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30 McCloud, Assistant Professor of Biology at Sam Houston State University, was the plant ecology consultant to WMRT during the first phase of resource inventorying.

forestry practices favoring the pines (WMRT 1974a). The site has also been extensively grazed by cattle (WMRT 1974a).

Another more subtle but nevertheless substantial disturbance has been the exclusion of fire. Fire had been absent from The Woodlands site for at least 30-40 years prior to the commencement of planning (WMRT 1974a). There have also been no significant fires over the last 25 years. This exclusion has favored the growth of fire intolerant hardwoods, leading to their increasing representation in the canopy and mid-story. Fire exclusion has also contributed to the growth of a diverse understory of smaller trees, shrubs and vines. Historically, fire is thought to have been a much more pervasive influence on the East Texas forests prior to European settlement (McFarlane 1994).

3.3 The Development of an Ecological Plan

WMRT's philosophy towards planning for The Woodlands was relatively simple. The "landscape and its natural processes offer opportunities and constraints for land utilization (WMRT 1974d p.1). By identifying and interpreting explicit natural phenomena which contribute to a balanced ecosystem, the planner is able to specify the most and least suitable use for a particular landscape. Using this information he is able to determine more accurately the consequences of alternative actions and he can also measure the degree to which compromises can be made when objectives are in conflict" (WMRT 1974d p.1). In their view, inattention to the natural environment and ecological processes during the planning/development process creates high economic, social and ecological costs (WMRT 1974d). "From its inception, the comprehensive planning approach for The Woodlands New Community was intended to counteract this tendency" (WMRT 1974d Preface).

WMRT were involved in ecological planning for the original and revised Woodlands general plans; planning and design for the first phase of the development - the Village of Grogan's Mill; the development of general site planning guidelines; design of a housing cluster in Grogan's Mill; and the development of suggested housing prototypes to match specific environmental site conditions.[31] WMRT considered the scope of this participation to have "provided a rare opportunity to apply a consistent methodology of environmental evaluation, planning and design from the scale of the General Plan to site planning and housing prototypes." (WMRT 1974d p.1) It was from their perspective, "a unique experiment."(WMRT 1974d p.1)

The primary objectives of WMRT's planning process were:

- *To use the latest scientific data to determine land planning and management recommendations;*
- *To employ these recommendations to discover the best environmental accommodation between land-use impacts and the physical characteristics and landscape tolerances of the site;*
- *To relate environmental, social and economic programming data to a common face so that design decisions could be made with a more complete understanding of the costs and benefits involved;*

[31]WMRT's relationship with The Woodlands extended over 4 years between 1971 and 1974.

• *To demonstrate that the ecological approach could exercise a positive physical, social, and financial influence in The Woodlands New Community at all scales of planning and design.* (WMRT 1974d p.2)

The ecological planning process was similar to that employed in previous WMRT planning efforts (McHarg 1969). In The Woodlands case this was comprised of eight steps,[32] as described in Table 3.1.

Table 3.1

Ecological Planning Steps Employed by WMRT

(From WMRT 1974d p.6)

Inventory and mapping of ecological data
Interpretation of data
Determination of landscape tolerances based on the data
Determination of development intensities for various land uses
Establishment of a design synthesis
Matching of development intensities with landscape tolerance
Creation of land and site planning guidelines
Preparation of a master land use plan responsive to environmental as well as social, economic and financial objectives (as in the case of Phase 1)

The inventory phase examined the following site features (WMRT 1974a):

Geology and Ground water
Surface Hydrology
Limnology
Pedology
Plant Ecology

[32]These are explained in more detail in WMRT (1974d pp.6-7).

Wildlife
Climate

WMRT (1974d pp. 2-3) considered The Woodlands site to present several major problems for planning.

1. The site was almost completely forested, which in their view, made it a difficult environment to build in.

2. The site is flat - a substantial problem in terms of draining the site.

3. Most of the soils on site are very poorly drained.

4. On-site streams are characterized by very low base flow and very high peak flows resulting in very broad and shallow floodplains. Almost one third of the site lies within the 100 year floodplain of the three main watercourses on site; Panther, Bear and Spring creeks.

An important, additional constraint not listed by WMRT, but part of their directive from The Woodlands Corporation, was to ensure no significant increase in stormwater outflow from the site (McHarg 1993). Though, no county/regional regulations to this effect were in place, the unwritten code amongst developers in the Houston area at the time was that any new development had to ensure it did not exacerbate downstream flooding problems for existing developments (McHarg 1993). Heineman (1994) states that stormwater discharge is in reality controlled by the potential for liability suits arising from the flooding of downstream property owners.

Based on these constraints and their synthesis of inventory data, WMRT concluded that water was the "integrating process that explained the nature of the site" (WMRT 1974d). Though they were primarily concerned with accomodating drainage, WMRT also wanted The Woodlands to be as benign as possible in its impact on the pre-development ecology of the site. To this end, they strongly emphasized maintenance of water quality in existing streams, Waller ponds and constructed lakes and ponds, and the protection and recharge of groundwater. Promotion of groundwater recharge tied in with resolving the off-site stormwater problem. It was also intended to meet WMRT's goal of achieving hydrologic equilibrium for the development by offsetting withdrawal with recharge.

A Natural Drainage System for The Woodlands

To permit development of The Woodlands, an orthodox approach to drainage would have required considerable expense in the construction of large open drains and underground piping. This approach would have also necessitated the destruction of large areas of forest (WMRT 1974d). Since protection of the forest was considered essential for ecological and marketing reasons, an alternative approach to resolution of the drainage problems was sought. WMRT concluded that the answer lay in the use of a natural drainage system.

A natural drainage system would utilize existing drainage patterns, with existing forest coverage. No ditching was considered necessary. The primary objective of WMRT's natural drainage system was to impede the flow of water. Keeping stormwater within The Woodlands resolved downstream flooding problems and facilitated ground water recharge. The system was intended to cope with a 25 year storm. Runoff from high frequency storms (25 mm or 1 inch in 6 hours) was intended to be recharged entirely on individual development parcels (WMRT 1973c p.20). WMRT's approach was the exact opposite of orthodox drainage schemes which seek to facilitate the quickest possible removal of water from developed areas.

WMRT's assessment of the benefits of a natural drainage system are described in Table 3. 2.

Table 3.2

Benefits of The Woodlands Natural Drainage System

Meet site drainage requirements
Save money in construction
Protect forest
Sustain high site amenity
Increase development marketability
Reduce erosion and runoff
Maintain water quality
Protect and recharge groundwater
Decrease maintenance costs
Provide recreation potential
Increase base flow in streams
Increase land values
Maintain wildlife habitat

(WMRT 1974d pp.14-15)

Both George Mitchell and the engineers were skeptical of the feasibility of such an approach. Mitchell was convinced when his engineers' calculations showed not only that it would work, but more importantly that it would incur substantial savings - $14,478,900 on Phase One alone (WMRT 1974d)[33]

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33 The cost for a conventional drainage system was estimated at $18,679,300. The natural drainage system had an estimated cost of $4,200,400 (WMRT 1974d).

This decision to adopt a natural drainage system was perhaps the most important decision enabling the adoption of an environmentally sensitive approach to the development of The Woodlands. Having been shown the economic benefits attached to an ecological approach on drainage, Mitchell also became more amenable to many of McHarg's other environmental recommendations. This is reflected in the detail to environmental protection contained in WMRT's synthesis report, An Ecological Plan (WMRT 1974d).

The natural drainage scheme was to function by:

- Using the existing drainage pattern to both direct and detain stormwater flow,
- Directing development to the most impermeable soils where it would have the least impact on recharge,
- Retaining the most permeable soils in an undisturbed state to maximize the potential for recharge, and
- Promoting recharge by directing runoff from built areas and areas of impermeable soil to areas of permeable soil.

The primary determinants of the drainage system were soil permeability and the location of existing drainage patterns. Existing drainage patterns formed the foundation of the natural drainage system. Soils, because they determined runoff and recharge, played a major role in dictating where development could go and at what intensity. Twelve main soil groups were differentiated by WMRT on the basis of "drainage, permeability, topographic position, and susceptibility to ponding or flooding" (WMRT 1974d).

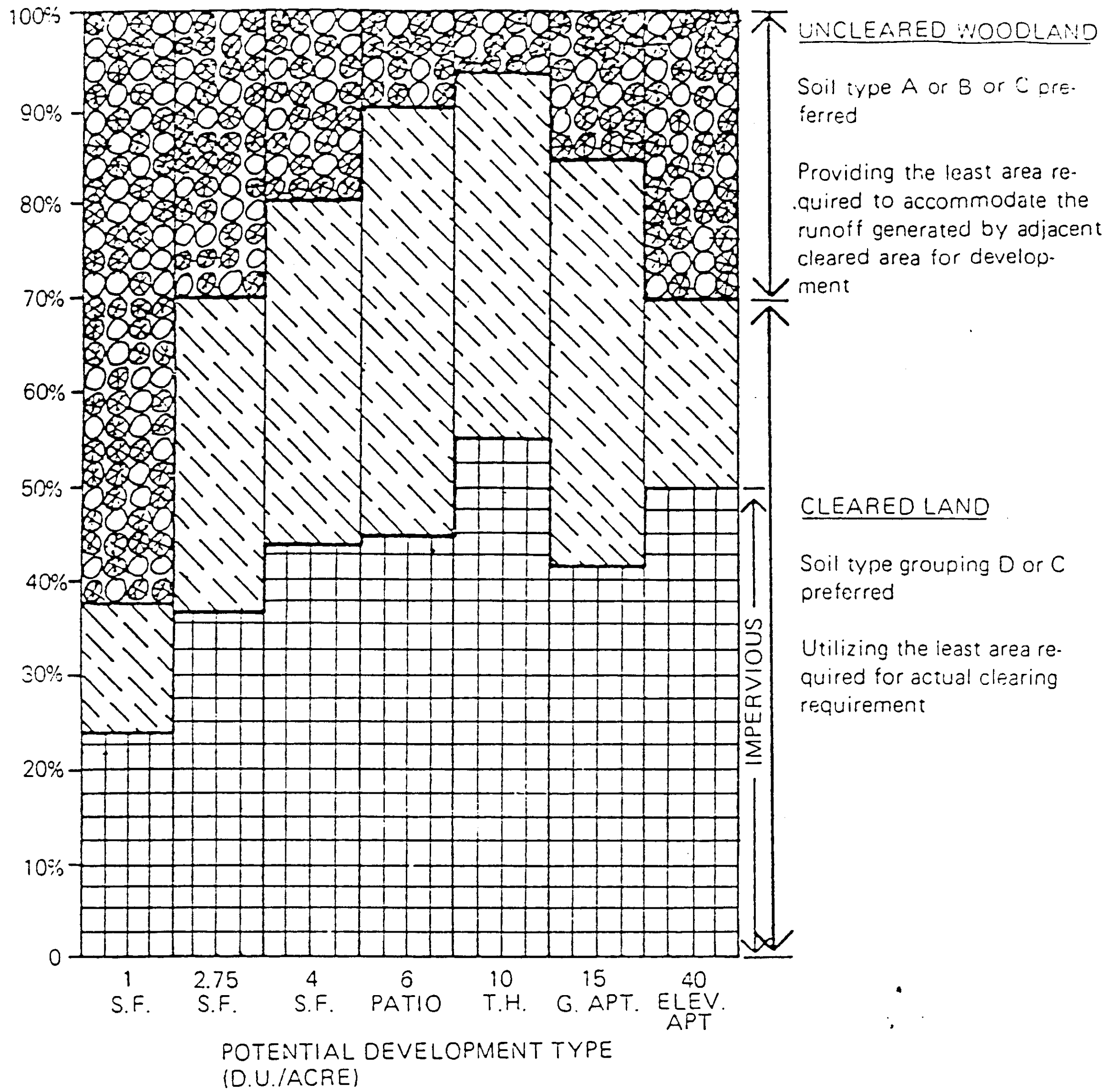

Figure 3.4 Relationship Between Soil Type, and Permissible Site Clearance and Development Density (for Grogan's Mill development)

Source: WMRT (1973b p. 59)

Soil permeability and vegetation quality[34] were the most important determinants of permissible vegetation clearance and site coverage (see Figure 3.4). Because the natural drainage system was designed to operate at all scales, a fine grained knowledge of the soils and hydrology of the site was required.

The most important elements of the natural drainage system are as follows:

- the protection of existing primary (100 meters wide) and secondary (32 meters wide) drainage channels as the primary conduits and recharge areas for stormwater. These channels were to be retained in their natural vegetated state, the vegetation helping to slow water flow and promote recharge. Importantly, existing drainage channels were also where the most permeable soils could be found.
- the retention of natural swales to support the primary and secondary drainage channels.
- the retention of Waller ponds as temporary stormwater storages. WMRT specified that Waller ponds were not to be used as permanent storage ponds, though their temporary storage capacity could be enhanced by the construction of small levees with trickle tubes installed to allow the stormwater to escape after flood peaks.
- Use of check dams and berms to hold water during high runoff periods, and to direct runoff to soils with excess storage capacity.
- Elevation of roads and trails on impermeable soils to facilitate runoff towards permeable soils
- Use of innovative housing styles (for example, post and beam) to minimize surfacing of permeable soils.

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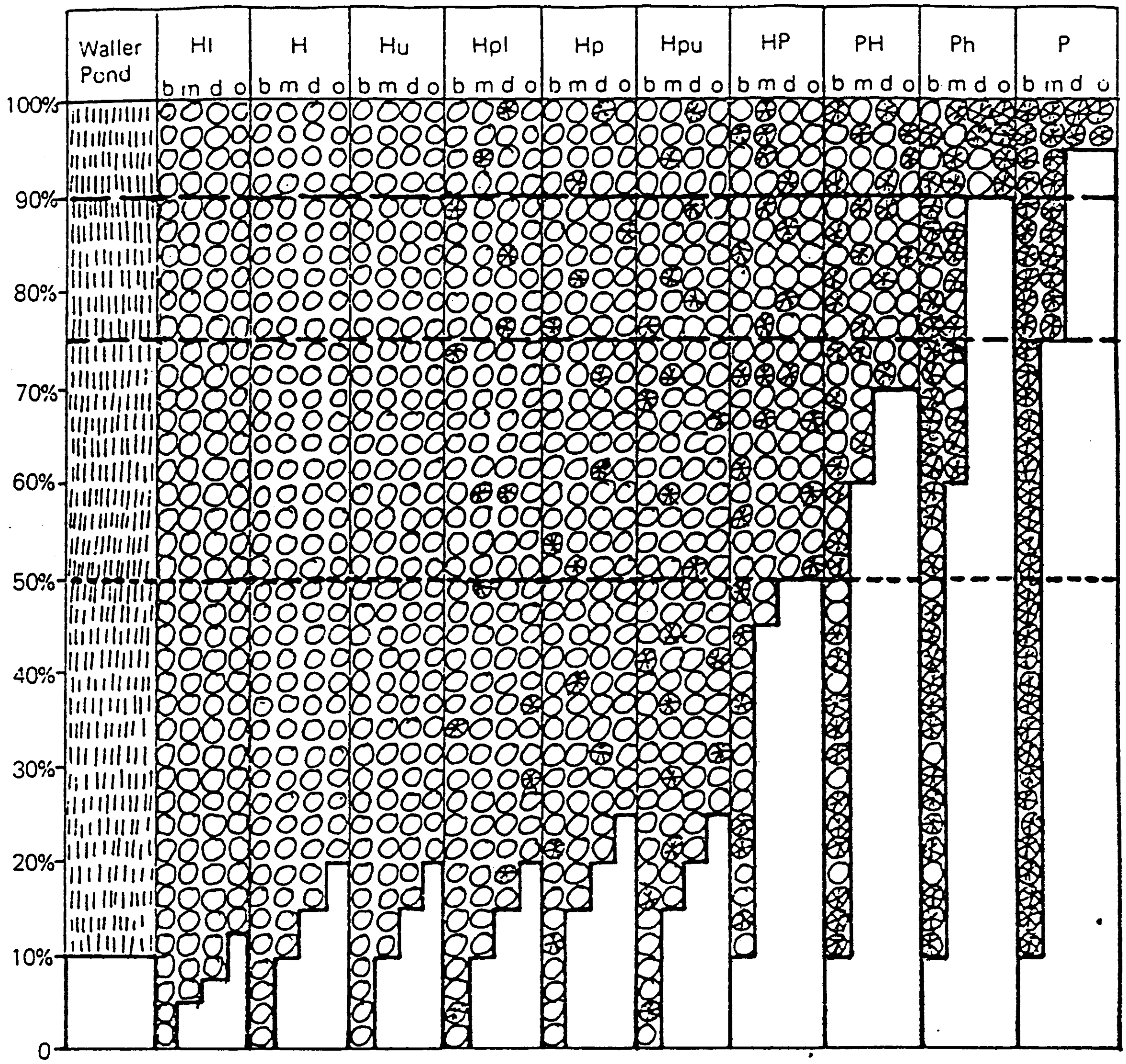
[34]Vegetation quality was based on structural integrity, botanical representativeness, the presence of rare or uncommon species, and value for wildlife habitat.

Vegetation

Vegetation was mapped from ground surveys by McCloud, and infrared air photograph interpretation (WMRT 1974d). The infrared analysis was conducted by WMRT planners (WMRT 1973b p.28) and was considered accurate to about 13 meters (40 feet). This was considered adequate for determining carrying capacities for dwelling units. It was expected that areas of special interest would be more precisely refined with additional field work. Mention is also made in Phase 1: Land Planning and Design Principles (WMRT 1973b) of a study to locate exact tree locations within a 60 cm (two foot) radius margin of error. It is not known if this study was completed, but it was never applied to WMRT's planning.

Soils and hydrology - as the primary determinants of the natural drainage system - were the most influential elements in determining the scale and location of development. However, maximizing the retention of vegetation was considered no less important a goal by WMRT, because of its role in detaining stormwater in drainage swales, in defining the character of The Woodlands, and for supporting wildlife. Vegetation was assessed for type, quality, tolerance to compaction, understory density, landscape value, and value for wildlife (WMRT 1973c, 1974a,d). On the basis of this assessment, priority areas for vegetation protection were established and rates of permissible clearance determined according to vegetation type (see Figure 3.5). The processes by which preferences for vegetation preservation and rates of clearance are determined are explained in "Guidelines for Site Planning" (WMRT 1973c).



UNCLEARED VEGETATION

O HARDWOOD

⊛ PINE

||||| HERBACEOUS

—— MAXIMUM PERMITTED CLEARANCE FOR A SOILS*

— — MAXIMUM PERMITTED CLEARANCE FOR B SOILS*

- - - - MAXIMUM PERMITTED CLEARANCE FOR C SOILS*

Hl LOWLAND HARDWOOD
H HARDWOOD
Hu UPLAND HARDWOOD
Hpl LOWLAND HARDWOOD WITH OCCASIONAL PINE
Hp HARDWOOD WITH OCCASIONAL PINE
Hpu UPLAND HARDWOOD WITH OCCASIONAL PINE
HP HARDWOOD–PINE
PH PINE–HARDWOOD
Ph PINE WITH OCCASIONAL HARDWOOD
P PINE

b VERY LARGE TREES
m MEDIUM SIZE TREES
o OPEN, WITH FEW TREES
d DENSELY SPACED TREES

*If recharge of runoff is to be achieved

Figure 3.5 Vegetation and Soil Types as Determinants of Permissible Site Clearance (for Grogan's Mill development)

Source: WMRT (1973b p. 51)

General vegetation protection was to be achieved in three main ways:

1. Within the primary open space system, which was to include major floodplain areas, vegetation of exceptional quality, and other areas of ecological importance to drainage, vegetation, and wildlife,
2. Within the natural drainage system (for slowing water), and
3. Within development parcels, according to permissible rates of clearance; preference to be given to hardwood retention wherever practicable.

Wherever possible, vegetation retention was to aim for the preservation of the forest in a circular form. Where linear areas are required, these were recommended to have a minimum width of 100 meters (300 feet). WMRT (1973b p.29) also advocated the maintenance of an uneven edge on protected vegetation areas to "maximize the edge condition." To protect individual trees and stands of trees from compaction during development, buffer zones of at least one crown width were recommended (WMRT 1973b p.30). Because of their greater tolerance to disturbance, pines were considered to be better suited to thinner linear strips; 16 -32 meters (50-100 feet) being considered viable (WMRT 1973b p. 30).

Priority conservation areas were considered by WMRT to be:

1. Waller Ponds.
2. Areas of exceptional quality - those with high diversity, exceptional botanical integrity and outstanding landscape value.
3. Areas of prime vegetation, these being stands of pure hardwoods of "medium spaced and very large trees."

McCloud, McHarg and Mitchell all express a strong bias for the protection of hardwoods (Sauer 1993, McHarg 1993, McFarlane 1994). McCloud (WMRT 1974a) frequently refers to the attractiveness of the hardwoods. This hardwood favoritism is pervasive through the WMRT reports.[35]

Hardwoods were favored primarily on aesthetic grounds for landscaping purposes, but also because they were "less common" (WMRT 1973b p.27). They were also considered to provide a greater botanical diversity and better food resources for wildlife (WMRT 1973b, 1974a). Hardwoods are more sensitive to disturbance, and are much slower growing than pines, taking a long time to reestablish following disturbance.[36] Because pines are quick to reestablish, WMRT and The Woodlands staff (WMRT 1973c, Kendrick 1994) felt they did not require as much protection during development. Facilitating the natural regeneration of hardwoods is also why The Woodlands Residential Development Standards and educational brochures emphasize the protection of the understory during development. The value of the understory to foraging birdlife is given less emphasis.

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[35] For example, in discussion of mapping for Phase 1 construction in Phase 1: Land Planning and Design Principles (WMRT 1973b), mention of "special care" having been taken to delineate hardwood stands. Some of this predilection towards hardwoods may stem from acceptance of McCloud's work by the WMRT team: some may stem from belief in the ecological superiority of hardwoods over pines prevalent amongst biologists at the time, or an aesthetic bias towards hardwoods on the part of the WMRT team. Undoubtedly, McHarg's personal aesthetic preference for hardwoods also strongly weighted vegetation conservation towards hardwoods (McHarg 1993).

[36]The slower relative growth of hardwoods is true for The Woodlands site, but does not necessarily hold for other parts of the country, especially further north.

Waller Ponds and Areas of Exceptional Value

McCloud recommends the protection of several areas for species diversity, high quality, stability, and uniqueness (WMRT 1974a). Two of these areas occur within the dominant Loblolly pine-hardwood forest. These are cited for their outstanding quality.[37] He also recommends special attention be paid to the protection of an area containing several hundred "really fine" old hardwoods in upper Bear Branch Creek. He states that this area is "almost unique in its beauty, tree species balance (and) wildlife possibilities" (WMRT 1974a p.45). Two areas adjacent to Panther Creek are recommended for protection. One of these he describes as a "truly remarkable botanical entity (that) should by all means be saved" (WMRT 1974a p.48). These areas were mapped by McCloud.[38]

McCloud recommends that "careful thought" be given to the Waller Ponds before filling or draining them because of their "unique" aesthetic possibilities for the development program or wildlife preservation" (WMRT 1974a p.47).

Spring Creek is described by McCloud as a "valuable stream", seemingly because of the contiguous association of Loblolly pine-oak-gum, a forest type which supports the highest canopy of Loblolly and associated hardwoods on the site (WMRT 1974a p.41). Notably, McCloud recommended acquisition of further areas of this forest type associated with Spring Creek.

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[37] Quality was determined on the basis of the botanical integrity of the site (tree age and height, understory vigor, and absence of human disturbance); uncommon assemblages of plants, and value for wildlife (nest cavities, cover, and mast production). (WMRT 1974a)
[38] I was unable to locate these maps.

Wildlife

Wildlife was surveyed independently by Robert Maestro, a consultant wildlife biologist, and Richard Poche, a graduate student from Texas A&M.

Maestro states that the scope of his investigations prevented the compilation of a detailed inventory of all species (WMRT 1974a). Poche's investigations were apparently more thorough. Supervised by Dr. David Schmidley from the Department of Wildlife Sciences at Texas A&M, Poche undertook what was considered a standard wildlife survey for that time (Schmidley 1994).

Most of the recommendations concerning wildlife in the WMRT reports derive from Maestro's work (pp. 59-65 in WMRT 1974a). Species lists derived from Poche's work are appended to "Phase 1: Land Planning and Design Principles" (WMRT 1973b). Unless otherwise specified, citations in the following discussion on wildlife are taken from pages 59-65 in An Ecological Inventory (WMRT 1974a).

The main recommendations and observations relating to the maintenance of wildlife on the site are as follows:

Scope of Inventories

Maestro's wildlife inventory is limited to a sampling of birds (including a subset of game birds) and mammals.[39] Poche's investigations were more comprehensive in terms of both the numbers of species recorded and the range

[39] Maestro (WMRT 1974a p.59) asserts that the scope of his work did not allow a comprehensive assessment.

of biota surveyed. Poche provides lists of mammals, birds, reptiles and amphibians. However, these are only listed and no reference is made to conservation measures that may be required to maintain species diversity and abundance.

Sensitive Species

Maestro states that it will not be possible to sustain species that are extremely sensitive to human presence, and that the open space system should not attempt to do so. He adds that individual variations in sensitivity and the pattern of development will determine which species remain. Table 3.3 is an adaptation of Maestro's characterization of species sensitivity.

Table 3.3

WMRT Estimates of Wildlife Species Sensitivity

(after Maestro in WMRT 1974a p.60)

	deer					mourning
	gray fox		raptors		waterfowl	dove
	coyote		bobwhite		opossum	squirrels
turkey	bobcat	raccoon	rabbits	quail	armadillo	song birds

MOST SENSITIVE LEAST SENSITIVE

The species Maestro cites as unlikely to remain after development are bobcat, red wolf, black bear, and turkey.[40] WMRT (1974b p.35) express concern that predators will be the most affected by development, and recommend that their

[40] Sightings of Red Wolf were considered suspect by wildlife biologists at the time. Black bear sightings were second hand reports from hunters and were also never verified (WMRT 1973b).

maintenance is important for achieving a self sustaining system. Deer and foxes are considered the most sensitive species with a chance of survival. Songbirds are lumped together and described as relatively insensitive to human disturbance. Maestro adds that development will benefit these species, and recommends the establishment of lawns and landscaping, and the promotion of edge to encourage their presence.

In Phase 1: Land Planning and Design Principles, WMRT suggest that further inventory work on the habitat requirements of those species expected to remain after development will dictate minimum open space requirements to support viable populations; minimum corridor widths; and the sizes of buffer zones around ponds and water courses.

Corridors

Maestro uses the habitat requirements of deer as his baseline for establishing corridors. He suggests a corridor averaging approximately 200 meters (600 feet) wide should be enough to "contain" deer. This width he asserts "should also contain species of equal sensitivity to human disturbance (*the vast majority of species on the site*)." (author's emphasis) Maestro does not identify which species are encompassed by this assertion. He further suggests that if maintaining deer and similarly sensitive species is not desirable, "a corridor of approximately 65 meters (200 feet) should be sufficient to maintain the remaining species". Maestro also suggests that corridors could support some open space activities, including golf courses, playing fields, and bridle paths. WMRT (1974b p.34) recommend linkage of The Woodlands open space system with Jones State Forest by two 200 meter (600 foot) wide corridors.

Game Species

The emphasis on wildlife protection is very heavily weighted towards management that will enhance populations of game species. In the introductory section to the discussion on wildlife in "An Ecological Inventory" (WMRT 1974a), Maestro begins by suggesting that wildlife is most important as an economic consideration because of its "value for *hunting*" (Author's emphasis). He states that "Although it is desirable to maintain a maximum diversity, it is impractical to attempt to manage for all species properly. Management efforts should be concentrated towards those species of *major importance*." (author's emphasis) He then lists "deer, quail, mourning dove, squirrels, song birds, waterfowl, and other aquatic birds and fish." The majority of these are game species. In Maestro's opinion, management to support these species will also maintain most other species. (WMRT 1974a). As an example of management, Maestro advocates the planting of "weed" species to promote game species, i.e. quail.

The development of shooting preserves is recommended as a "very desirable form of outdoor recreation." One of the few adverse effects of development cited by Maestro is that hunting would be limited by the close proximity of people to "put-and-take preserves and trap shooting."

Wildlife "amenity" is also "valued", Maestro suggesting that the value of residential lots is enhanced by "aesthetic contact" with such species as squirrel, bobwhite quail, mourning dove, and particularly, deer." Coincidentally, these are some of the most important game species in the state.

Endangered Species

Maestro makes no mention of rare, threatened or endangered spp, though these are described in a "Special Considerations" section in Phase 1: Land Planning and Design Principles" (WMRT 1973b pp.34-35).[41] In this section, the protection of mature pine forest is recommended to serve as breeding and nesting areas for the federally endangered Red-cockaded Woodpecker (RCW)[42]. Black bear and red wolf (if present) are recommended for protection only so long as they "choose" to remain on site. Protection of floodplains and ponds on site was suggested as sufficient to retain the Louisiana Water Thrush. A further suggestion is made that particularly significant areas may be included in the open space system to accommodate endangered species (provided these are found on the site).

Promotion of Edge

Increasing the amount of edge is strongly promoted by Maestro to increase species diversity and abundance. The "best way to maximize for wildlife is to provide for a good edge" (WMRT 1974a). Conflicting with his comments about some species sensitive to human disturbance being adversely affected by development, Maestro states that the large amount of edge created by opening the forest canopy to development would benefit "*all* " species on site (author's emphasis). He also recommends that corridor borders be managed to provide a diffuse edge, since "the more diffuse the edge, the more favorable the habitat" (WMRT 1974a). WMRT (1973b) state that including "as much edge as possible, both natural and managed, is a worthwhile objective."

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[41] This is apparently based on Poche's work.

[42] The Red-cockaded Woodpecker has been listed on the U.S. Endangered Species list since 1971.

Management

Maestro recommends that a management program "must be established" to maximize diversity and abundance. Maestro emphasizes the need to maximize diversity, in order to sustain a "well maintained" and "stable" environment. However, his suggestions primarily relate to altering the existing environment to favor game species. Maestro states that parts of the site are too densely vegetated to support "desired" wildlife. He is concerned that a cessation of logging and grazing will create similar conditions in protected vegetation and so advocates management to emulate the thinning effects of these activities. He does not specify what this management might comprise. He recommends that "wildlife and vegetation management programs should be established......well in advance of site development." Some of Maestro's specific recommendations for management to promote "desired species" include:

- Extending the edge effect by selectively clearing 10 meters (30 feet) along edges of corridors (recommended for deer, mourning dove, rabbits, quail and songbirds),
- Supplementing the food supply for quail, deer, mourning dove, rabbits,
- Selectively opening the canopy (recommended for squirrels, rabbits, deer),
- Increasing the number/diversity of hardwoods (squirrels and deer),
- Establishing lawns and landscaping to encourage songbirds,
- Encouraging weed growth along pipelines as a food source for quail and mourning dove,
- Using cattle temporarily to maintain desired vegetation density and diversity.

Pond Construction

Maestro suggests that the development of an impoundment would greatly benefit aquatic spp. Game species, namely waterfowl and sports fish are emphasized. He also suggests that an impoundment would benefit avian and terrestrial species through increased habitat diversity. To attract resident and migratory waterfowl, he recommends the maintenance of a constant water level and shallow edges.

Establishment of Reserves

Maestro recommends the protection of two areas that he considers to have special value for wildlife. One of these appears to be the same area on upper Bear Branch that was recommended for protection in McCloud's vegetation survey (WMRT 1974a p.45). The other site is identified as being south of Panther Creek, approximately mid-site. This site may or may not correspond with another of the areas recommended for protection by McCloud (WMRT 1974a p.48). No map is provided in the WMRT reports, so it is impossible to discern whether these sites have or have not been developed since construction on The Woodlands site began. WMRT (1973b p.34) further recommend the protection of Bedias Lake (within the Spring Creek floodplain) and Mooney Pond. WMRT (1973b p.34) also recommend the protection of Waller Ponds for wildlife habitat and suggest that "at least a few should be surrounded by 20-30 acres of open space" and, where feasible, connected to the open-space system by 32 meter corridors.

Additional Studies

Maestro recommended that additional studies be undertaken before development to "insure proper consideration for wildlife (sic)." He stressed the need to establish a wildlife baseline to enable appropriate management post construction, and to evaluate the response of the natural systems as development proceeds. He also called for the preparation of definitive wildlife-vegetation maps and a detailed study on the use of corridors and unique habitat areas. He believed this additional data gathering (which the scope of his study did not allow) was essential for enabling managers to determine what actions were required to maintain desired wildlife species (i.e. game species). Particular questions he considered could be answered by additional data were:

- whether golf courses could be designed to coincide with wildlife movement,
- to what extent and where could corridors be traversed by roads,
- if and where alterations could be made to the 200 meter corridor width, and
- what development controls would be necessary to maintain unique vegetation-wildlife habitats.

Recreational Use of Wildlife Habitat

WMRT (1973b p.35) advise that active recreational use of primary wildlife open space is to be avoided. They recommend locating bridle and nature trails along the periphery of such areas, and that barrier fencing created from natural, bushy vegetation be used to limit access.

Other Environmental Considerations of the WMRT Plan

In addition to the detail provided on drainage, WMRT prepared comprehensive guidelines to adapt development to the Coastal Plain climate (for example, to maximize the effect of cooling breezes), and to minimize off-site sediment loss from construction sites. Housing prototypes were developed to protect permeable soils and prime vegetation. Cluster housing and grouped parking were also advocated as ways of minimizing development impacts on the forest.[43]

Design Synthesis

Figure 3.6 depicts a synthesis of all the major physical constraints on The Woodlands site: the 100 year floodplain, drainage easements, primary open space vegetation, and primary and secondary recharge soils. In its composite form, this map illustrates the open space system for The Woodlands (see Figure 3.7).

Development opportunities on the balance of the site were determined mostly on the basis of soil permeability and vegetation type. This is the sixth step in WMRT's Ecological Planning process - matching development intensities with landscape tolerance (see Table 3.2). On this basis, WMRT calculated that the 6,800 ha (17,000 acres) comprising The Woodlands at the time of the WMRT consultancy had a carrying capacity of 47,000 dwelling units, housing a population of 150,000. This was considered the "least cost-greatest benefit solution."

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43 See Phase 1: Land Planning and Design Principles (WMRT 1973b), Guidelines for Site Planning (WMRT 1973c), and An Ecological Plan (WMRT 1974d).

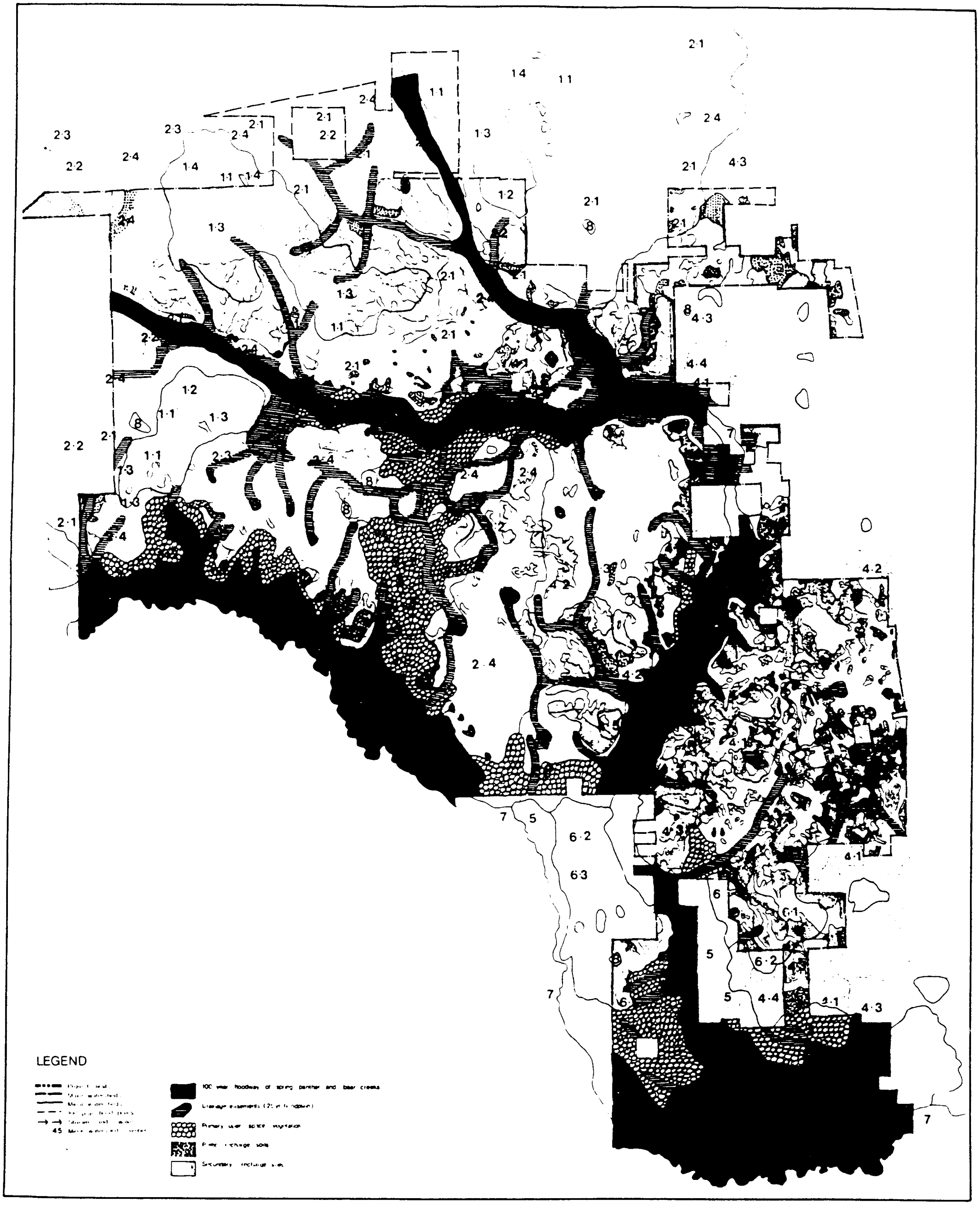


Figure 3.6 Synthesis of Development Constraints

Source: WMRT (1974d p. 35)

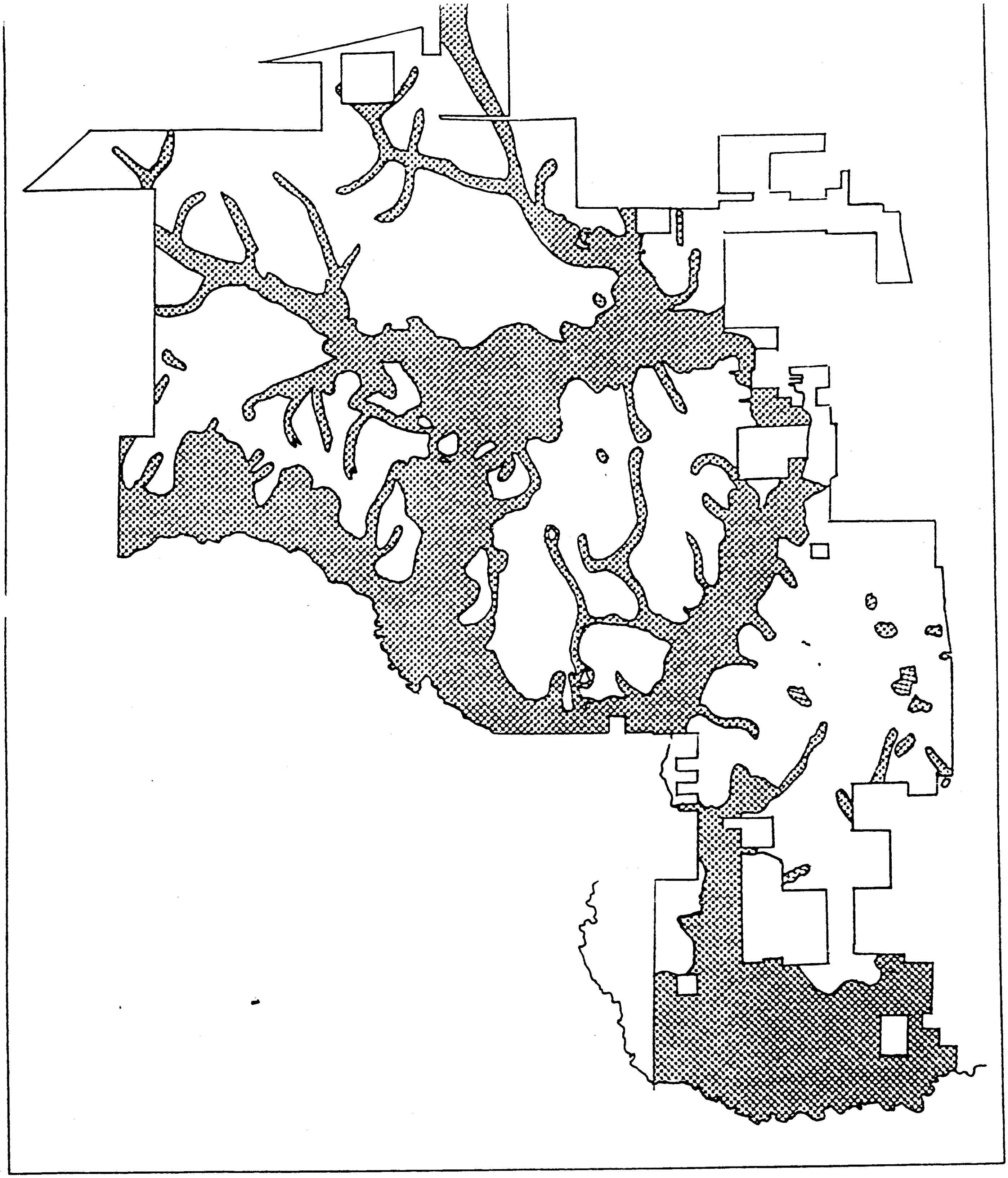


Figure 3.7 Ecologically Planned Determination of Primary Open Space in The Woodlands

Source: WMRT (1973b p.40)

WMRT Reports

The end result of WMRT's investigations was a series of four reports. These detail the physical nature of the site, the constraints and opportunities that derive from the physical aspects of the site, and detailed design guidelines that conformed to these constraints and opportunities to derive the least cost-greatest benefit development plan for the site.

The first of these reports, "An Ecological Inventory" (WMRT 1974a) details the biological and physical characteristics of the site. The last part of this document discusses how these elements interact to form The Woodlands landscape. Inventory data is also evaluated to determine what opportunities and constraints the site provides for development with the least environmental impact.

The second report in the series, Guidelines for Site Planning synthesizes the inventory into a plan for development, using a similar overlay methodology to that described in Design with Nature (McHarg 1969). It provides guidelines for development that best accommodate the constraints imposed by each site characteristic. For example, it suggests the appropriate amount of clearance which could be permitted according to soil and vegetation types, and development approaches that accommodate natural drainage objectives. The guidelines are applied to design a subdivision prototype within Grogan's Mill.

The third report, Phase 1: Land Planning and Design Principles applies the design synthesis approach to develop design principles for development of Grogan's Mill as the first phase of development.

The fourth report, An Ecological Plan, is a synthesis of the design principles and recommendations developed in the preceding three reports. The Ecological Plan is a plan for the development of The Woodlands.

3.4 The Ecological Plan and Development of The Woodlands

WMRT's Ecological Plan formed the framework of The Woodlands first and revised General Plans, and Development Standards. The General Plan and all revisions within the timeframe of WMRT's involvement, as well as the development standards were prepared in accordance with the following four primary objectives (WMRT 1973c p.1, 1974d p.1):

- Preservation of a woodland environment;
- Employment of a natural drainage system that utilizes existing floodplains, drainage channels, ponds, and recharge soils;
- Preservation of certain areas of vegetation noted for species diversity. high quality, stability, and uniqueness;
- Provision for wildlife habitats and movement, so that wildlife now living on the site may remain.

Other objectives that are stressed throughout the WMRT reports (WMRT 1973b,c, 1974d) are:

- Protection of permeable soils to maximize recharge, and maintain the water table;
- Reduction of runoff and retardation of erosion and siltation;
- Increased base flow of streams;

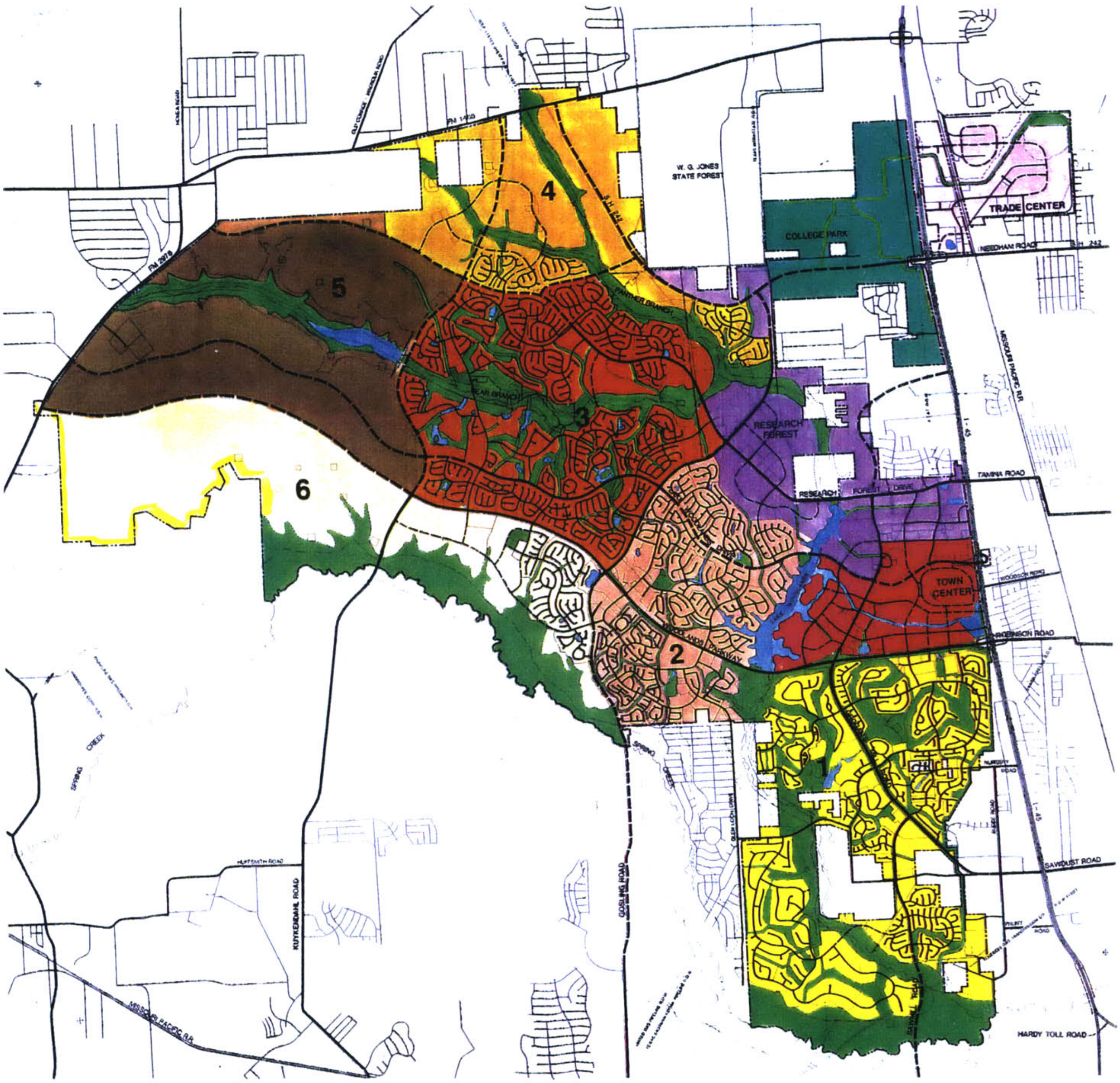
These objectives were meant to apply at all scales of development. Initially they were used to drive the detailed planning for construction of Phase 1: Grogan's Mill Village, an area of approximately 800 ha (2,000 acres). Completion of the planning for Phase 1 also heralded the end of WMRT's active involvement in planning at a scale less than the whole development. Implementation of the Phase 1 plan, and planning for subsequent villages became the responsibility of The Woodlands Corporation. As Chapter 4 demonstrates, the changeover of responsibility set in motion a series of changes to the foundations of the Ecological Plan.

CHAPTER 4

IMPLEMENTATION OF THE WOODLANDS ECOLOGICAL PLAN

The corporate philosophy of The Woodlands ostensibly remains the same today as when the development began twenty years ago - one of creating a community within the forest, living in harmony with the environment (TWC 1993b,c,d,e,g). As is stated in The Woodlands Residential Development Standards (TWC 1993c - 2.12 p.2), "the environment of The Woodlands is conceptually that of a natural forest." This philosophy is emphasized in all promotional materials for The Woodlands.

In reality though, the approach to development today is considerably different from that specified by the goals of the original Ecological Plan. Several major shifts in direction and numerous incremental changes, have substantially altered the physical structure and appearance of The Woodlands from what the original general plan had suggested. Figures 4.1 and 4.2 respectively depict the General Plan for The Woodlands (July 1993), and the extent of existing development. As Chapter 5 will describe, the cumulative ecological impact of these changes has also been substantial. The most significant changes are summarized in Table 4.1.



LEGEND

VILLAGE 1 (GROGANS MILL)	TOWN CENTER
VILLAGE 2 (PANTHER CREEK)	RESEARCH FOREST
VILLAGE 3 (COCHRANS CROSSING)	COLLEGE PARK
VILLAGE 4 (ALDEN BRIDGE)	TRADE CENTER
VILLAGE 5	OPEN SPACE
VILLAGE 6 (INDIAN SPRINGS)	

GENERAL PLAN

Figure 4.1

The Woodlands

The Woodlands Corporation, Montgomery County, Texas

North

Miles 0 1/8 1/2 1.0

4/15/93

Revised 7/12/93

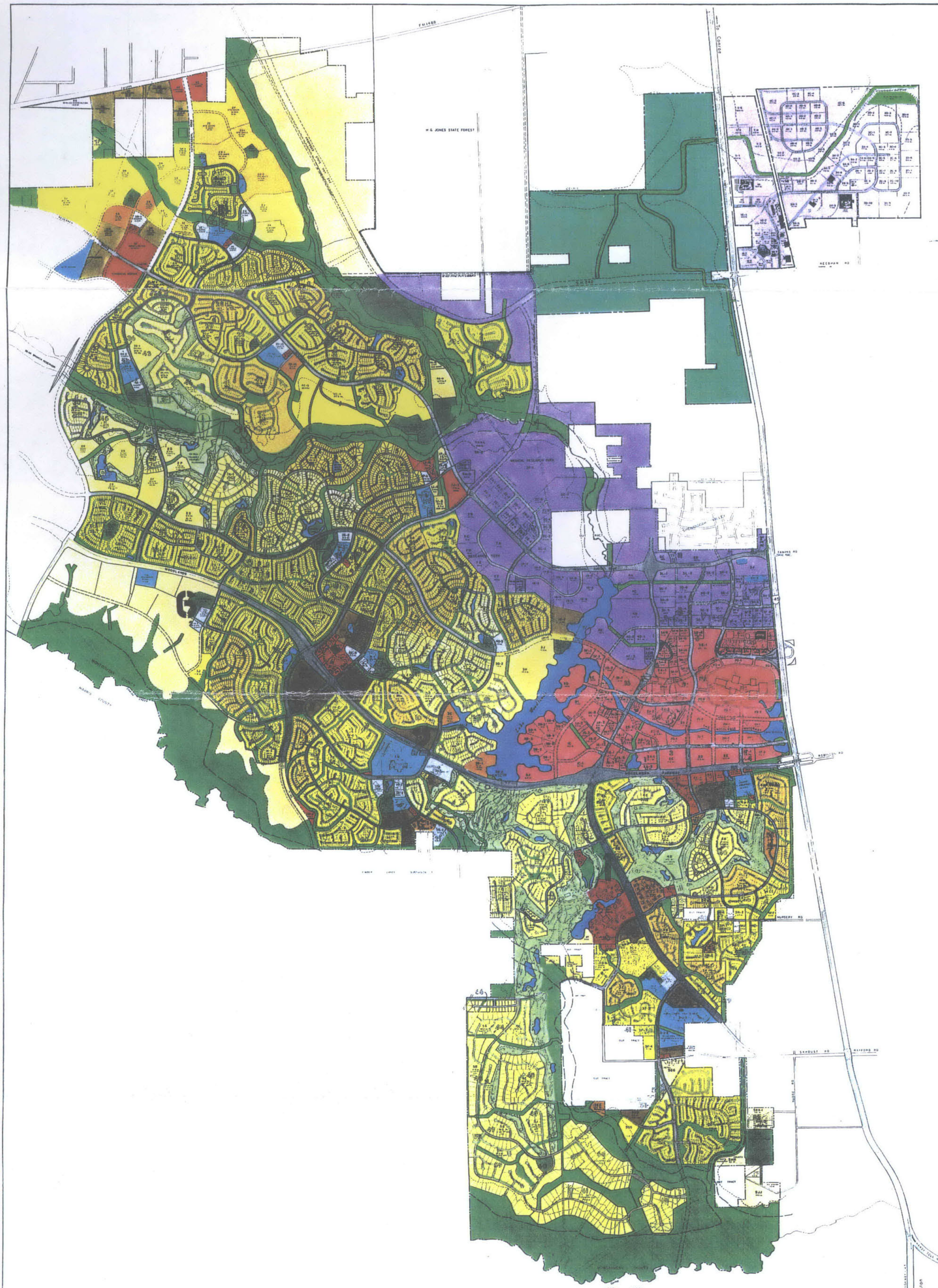


Figure 4.2

The Woodlands **Stage One and Two**

VILLAGE 1 - VILLAGE OF GROGANS MILL (VOGM)
VILLAGE 2 - VILLAGE OF PANTHER CREEK (VOPC)
VILLAGE 3 - VILLAGE OF COCHRANS CROSSING (VOCC)
VILLAGE 4 - VILLAGE OF ALDEN BRIDGE (VOAB)
VILLAGE 6 - VILLAGE OF INDIAN SPRINGS (VOIS)

Table 4.1

Changes Made to the Ecological Plan During Implementation by The Woodlands Corporation

Abandonment of ecological planning at the site scale
Abandonment of natural drainage and balanced hydrological budget
Diminution of natural open space
Relaxed development standards
Excavation of Waller Ponds for use as stormwater retention ponds
Abandonment of innovative construction techniques
Reduced development density

4.1 Abandonment of Ecological Planning at the Site Scale

Natural drainage, soil and vegetation were intended to be the primary determinants of development at all scales in The Woodlands. Soil and vegetation were to be used to determine where and at what density development could occur and were the absolute determinants of development at the house-lot scale.

Robert Heineman, Vice President of Planning for The Woodlands Corporation (1993) maintains that early on-ground attempts to interpret the vegetation and soil maps prepared by WMRT proved very frustrating. On site planning staff were apparently unable to differentiate between the various soil and vegetation types delineated by WMRT.[44] Heineman's view is that the

[44] Heineman describes difficulties in distinguishing between vegetation categories on the basis of differences in the proportional representation of pines versus hsrdwoods. He also cites an instance where field staff were unable to locate a stand of hardwoods indicated by WMRT interpretation of air photos to be prime vegetation.

differences between the various soil and vegetation categories were not as significant as WMRT had stated. He added that part of the problem with the vegetation typing lay in WMRT having depended too much on air photo interpretation without ground truthing. Since vegetation boundaries had a margin of error of 13 meters, Heineman has a valid argument.

On the basis of these in-field difficulties, the use of vegetation types and soil types as the criteria for determining land use was abandoned very early on in The Woodlands history - circa 1974-75 (Heineman 1993). Since this means of land use determination was one of the key elements of the WMRT approach, its early dismissal was very significant. Following its abandonment, decision making about where to develop on individual building sites became an ad hoc process, based on experience in the field (Heineman 1993). The primary planning goal evolved into protecting vegetation regardless of the categories employed by WMRT (Heineman 1993). Heineman felt that McHarg's hardwood favoritism was a "value judgment" in any case and therefore not a justifiable rationale for choosing between one tree and another at the site planning scale. Soil types were disregarded altogether at the lot scale (Heineman 1993, Wendt 1994).

Heineman (1993) specifies four main reasons to support The Woodlands departure from the use of soils to determine hydrologically appropriate land use intensities at the lot or street scale.

1. The difference in permeability amongst most of the soil types did not justify their having such a substantive influence on site design as was

recommended in the WMRT reports. This interpretation is supported by Bill Kendrick (1994).[45]

2. The most permeable soils are almost entirely found within the floodplains. Planning to protect numerous small pockets of permeable soils that would contribute relatively little to overall recharge was considered unjustifiable at a macro planning scale. Kendrick (1994) also supports this assessment.

3. On site interpretation of WMRT soil maps proved too difficult.

4. When new hydrological studies indicated that stormwater control could be more effectively achieved by the construction of a reservoir on Bear Branch, the need to consider soil at the individual lot scale became unnecessary This is discussed in more detail in the next section on natural drainage.[46]

Jim Wendt (1994) supports Heineman's views, stating that the McHarg approach was too "fine-grained" to permit practical planning. He states that they were quickly forced to back up a level to enable cohesive planning at the neighborhood and village scales. Though he added that McHarg's principles are still applied at the village level. Wendt (1994) contends that soils are still important at this scale, as are site features, wetlands, and irregularities in the landscape. He also emphasized that The Woodlands is still as adamant about vegetation protection as WMRT had intended.

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[45]Kendrick undertook the original soil survey work employed by WMRT in its planning process

[46] Interestingly, the 1980 Environmental Data Base Update prepared by Greiner Engineering Services Inc. (GESI) infers that the 1973 Residential Development Standards - which had emphasized aligning land use with soil types - were still in use at the time their report was done.

4.2 Abandonment of Natural Drainage and a Balanced Hydrological Budget

Natural Drainage

Heineman (1993, 1994) refers to subsequent engineering studies on the site's hydrology that TWC interpreted as discrediting many of the assumptions and determinations supporting the WMRT natural drainage scheme. These studies, which were commissioned by TWC, were undertaken by Farner and Winslow, Inc. of Houston between 1972 and 1979.[47] This suggests that reevaluation of The Woodlands drainage requirements was undertaken very early in the development's history. Greiner Engineering Sciences Inc. (GESI) used these studies in their 1980 Environmental Data Base Update, together with other information to suggest a number of changes to the hydrological (natural drainage) plan developed by WMRT.

GESI state that the more detailed hydrologic studies undertaken by Farner and Winslow demonstrated substantial differences between the area of land determined by WMRT to lie within the 100 year floodplain and that determined by GESI. In effect, GESI calculated there to be an additional 570 ha (1420 acres) (net) within the floodplain. On the basis of information conveyed to me during interviews and documentation on The Woodlands, it seems probable that this discrepancy and the 5,000 acre increase in the site area since 1973 were the main factors that supported a reevaluation of the land use plan and floodplain management plan. On this same basis, it seems likely that the

[47] At least 13 reports were prepared by Farner and Winslow, or Winslow and other associates during this period (GESI 1980). GESI (p. 43) state that these provided the technical basis for their 1980 study.

difficulties that had been experienced in implementing natural drainage at a fine-grained scale were also important.

GESI's interpretation of Farner and Winslow work suggested that stormwater control could be achieved far more effectively with a reservoir on Bear Branch than with WMRT's fine-grained approach to detention and recharge.[48] Their alternative approach recommended construction of additional stormwater detention ponds including a major retention impoundment on Bear Branch in the upstream part of the development, and straightening of a section of Bear Branch (GESI 1980). This approach was purported to offer several significant benefits over the WMRT approach.

1. It guaranteed greater protection for downstream property.
2. It alleviated the need for detention storage in a substantial proportion of the site (see Figure 4.3)
3. It required less land to achieve the same storage capability as detention within each village as advocated by WMRT.
4. It lowered the floodplain downstream of the Bear Branch reservoir, therein removing an additional 160 ha (405 acres) from the downstream floodplain.
5. It provided additional "meadowlike" open space from the straightening of Bear Branch.

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[48] Detention of stormwater on Bear Branch would require less land than a village by village detention approach.

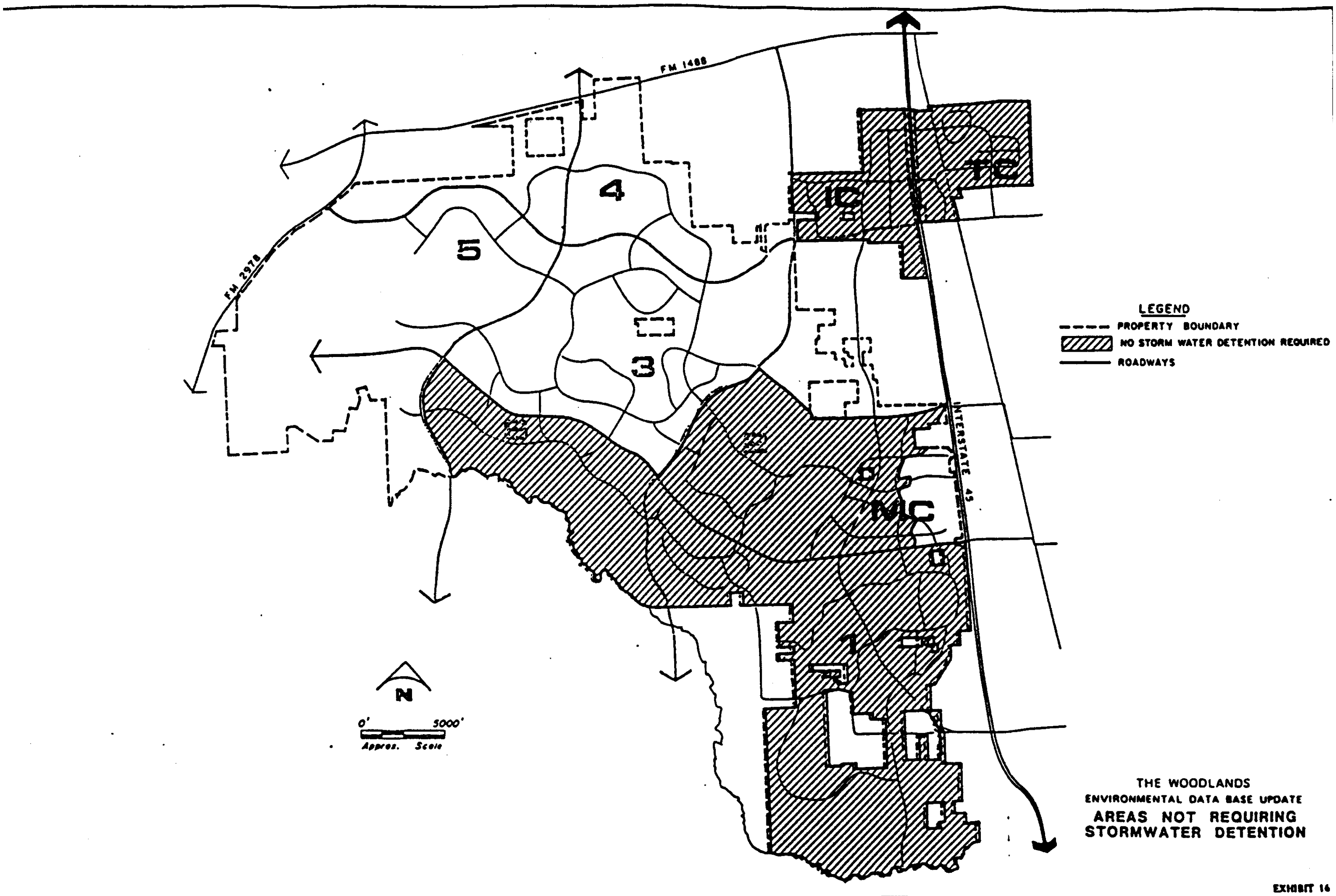

Figure 4.3 Changes in Areas Requiring Stormwater Detention as Result of Bear Branch Reservoir Construction

Source: The Woodlands: Environmental Data Base Update. Greiner Engineering Sciences, Inc., 1980.

Other hydrological adjustments advocated by GESI included watercourse improvements along Panther Creek and the West Fork of the San Jacinto River, and the use of materials excavated from Lake Woodlands to fill adjacent floodplain areas.[49] The net gain in buildable land obtained from these adjustments was 260 ha (650 acres), including 110 ha (275 acres) of premium value property adjacent to Lake Woodlands.

To accommodate the drainage network which was to accomplish the proposed concentration of stormwater detention, GESI recommended a new drainage plan consisting of a hybrid system of open and closed drainage. Major drainage channels would now be open, grass-lined earthen swales. "Roadside drainage would be accomplished by a combination of closed and open systems."

Importantly, from a marketing viewpoint, the move away from a fine-grained natural drainage system allowed curb and channeling to be introduced. This policy appears to have been introduced almost as soon as the GESI recommendations favoring the Bear Branch reservoir were known.[50] Heineman (1993) states that the natural drainage approach was not practical in Single Family Housing neighborhoods, from the viewpoint of maintenance and visual considerations. The Woodlands Corporation (TWC) had been under considerable pressure from builders, some residents, and potential home-buyers to change their natural drainage approach at the lot scale because of the aesthetic preference for curb and channeling.

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[49] Using the fill on site as opposed to taking it off site is estimated to have saved $4.5 million in dumping and transport costs (GESI 1980).

[50] Exact dates could not be obtained for this transition.

Girling (1994) believes that competition with the Kingswood master planned community to the north-east of Houston also played an important role in convincing The Woodlands to adopt a more conventional development style. Girling contends that builders had been pressuring The Woodlands corporation for several years to adopt curb and channeling. Builders had been arguing that home buyers wanted curb and channeling and that Kingswood had a strong competitive edge over The Woodlands in this regard. Girling concludes that The Woodlands acted out of concern that their best builders would take their business elsewhere. Bill Kendrick, Director of Grounds Maintenance for TWC (1994) also points out the dissatisfaction of builders and adds that home-buyers were turned off by the deep ditches in Panther Creek. He believes that it was a combination of pressures from depressed home sales, and dissatisfied residents and builders that forced the change to curb and channeling, not whether the system worked or not.[51]

Spatially, the adoption of the revised drainage plan is said to have occurred about half way through the development of Panther Creek (Wendt 1994, Vague and Kremer 1994). The move to curb and channeling is considered by some long time residents to have had a dramatic impact on the look and feel of The Woodlands (Vague and Kremer 1994).

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[51]TWC staff refer to the large, open,' grassed channels that now prevail on site as natrual drainage, but these are not what WMRT proposed. The WMRT concept was centered on naturally vegetated swales and drainage courses, not constructed channels. These grassed channels differ very little in their function from concrete drains. They may be slightly more aesthetic, but probably have minimal effect in impeding stormwater flow, which was the underlying concept of the WMRT approach.

Hydrological Budget

Groundwater is still the only source of drinking water for The Woodlands. Average annual use is around 7-8 mgd.[52] Fred LeBlanc, Environmental Manager for TWC (1994) claims that existing use is considerably higher than the Houston average because of the penchant for new residents to over water when establishing new lawns. According to Bill More of the San Jacinto River Authority (SJRA)[53], water consumption in The Woodlands has been down-drawing its source aquifer by approximately 2 meters (7 feet) per annum for the last 10-15 years. More (1994) also states that current studies of recharge rates indicate that recharge may be negligible or at least very slow. The Woodlands will reach its maximum recommended withdrawal rate in 1996, after which time The Woodlands will need to call on a supplementary water supply.[54]

The San Jacinto River Authority is presently considering options for water supply throughout East Texas. More (1994) suggests that it is probable that The Woodlands will eventually be supplied by Lake Conroe about 15 km to the north, this is unlikely to happen until water is diverted from the Sabine Reservoir to Houston (which currently draws the Lake Conroe supply). This is not expected to happen for at least another 25 years (More 1994).

Because of these water supply problems, The Woodlands Corporation has acquired additional lands south of Spring Creek with the view to creating a reservoir on Spring Creek. Because TWC is willing to provide this land to the

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52 Millions of gallons per day

53 SJRA is responsible for monitoring water quality and water usage rates within the San Jacinto River basin. This includes all of the Woodlands site. SJRA also has responsibility for ensuring adequate water supply to the population within its jurisdiction.

54 At the maximum recommended withdrawal rate of 38,000 acre feet per annum, groundwater supplies will last another 100 years (More 1994).

San Jacinto River Authority for nothing (leaving it to acquire only an additional 40 ha (100 acres) of privately-owned property), the reservoir is favored by the SJRA. This reservoir would flood approximately 440 ha (1,100 acres) of bottomland hardwood forest within the Spring Creek floodplain (SJRA 1992).

4.3 Diminution of Open Space

The original open space system in WMRT's Ecological Plan included 44% of the site (Smith 1993). Approximately 30% was to remain in its natural state. According to promotional materials (TWC 1993 a,b,c) the current open space projections are around 25%. Heineman (1993) contends that it had always been TWC's intention to retain about 25% of the site as open space. Wendt (1994) states that approximately half of this may be natural open space, making the total proportion of natural areas on site now around 12-13%. Wendt's assessment includes roadside greenways and median strips, so a significant proportion of this 12-13% will have a very linear form. A comparison of Figure 3.7 with Figure's 4.1 and 4.2 illustrates the magnitude of the decrease in open space.

4.4 Development Standards and Design Guidelines

The original Development Standards prepared for The Woodlands in November, 1973 were essentially identical to the guidelines prepared by WMRT. The 1993 Woodlands Corporation Site Management, Vegetation Protection and Landscape Design Requirements (SMVPLDR) contain only a cursory treatment of the ecological aspects of design included in the original. There is no mention of soils or vegetation type as a determinant of land use. Wildlife is not mentioned as a goal in itself but as a spin-off benefit from vegetation protection. Specifically, the document (p.1) states "that preservation of the forest can provide habitat for species not normally expected in conventionally planned developments". Natural drainage is still mentioned in a description of development philosophy, but more for its value in reducing the nuisance value of flooding. Within the actual guidelines, promotion of natural drainage is suggested, but is not mandatory. The values of natural drainage are now restricted to one sentence as opposed to the original standards where they underpinned the whole document.

The SMVPLDR are administered by TWC, and control site development and vegetation protection during construction, up to the point when the home-owner moves in. After this point, The Woodlands Community Association (WCA) has responsibility for maintaining residential standards.[55] The WCA administers its functions through The Woodlands Residential Development Standards (TWRDS), which were developed in September, 1993. This document employs the same wording as that in the SMVPLDR in referring to natural drainage, soil, vegetation types, and wildlife.

The SMVPLDR are comprehensive in their attention to permissible construction practices, with vegetation protection the central theme of the

[55]Responsibility for the enforcement of property standards, including vegetation protection, was only ceded to the WCA in 1992. At this time it was considered that the population in the areas of Grogans Mill, Panther Creek, Cochran's Crossing, and the developed portion of Indian Springs had increased to the point where the developer's involvement needed to take a secondary role. TWC remains on the governing board for this area, but residential representatives are now in the majority. Newly developing areas in Indian Springs and Alden Bridge, as well as commercial areas remain under the control of TWC.

document. Their attention to vegetation protection is significantly greater than that pursued by other Master Planned communities in the Houston area (for example, Kingswood, First Colony, Clear Lake). The most salient environmental provisions of the SMVPLDR are included in Table 4.2

Table 4.2
Environmentally Focused Restrictions in "The Woodlands Site Management, Vegetation Protection and Landscape Design Requirements"

Site clearance limited to a 1.5 meter (5 foot) limit beyond the building pad site and 60 cm (2 feet) beyond driveways and patios
Site inspections and approval required prior to initial clearing and site work
Erection of fencing (and signage concerning the purpose of the fencing) required during construction work to prevent incursions on retained vegetation
Hand clearing of small trees and shrubs recommended within defined clearing limits
Retention of a minimum 40% non-grass in front yards required, in addition to restrictions on topping and trimming, and requirements for the retention of natural forest leaf litter
Reforestation with approved species required where the 40% requirement is not attained
Understory thinning restricted to 50% of retained vegetation and only to the lower half of each plant
Ingress to the building pad allowed only along the driveway clearing
Routing of utility lines through protected vegetation areas not permitted
Erosion control and the maintenance of the site free of litter and debris required (guidelines not provided)
Advice provided on the avoidance of tree root damage from compaction (though without specifying appropriate buffer zones)

To ensure compliance, "substantial fines" can be levied for non compliance with the 40% minimum non-grassed area requirement.[56] Several inspections are undertaken through the course of site planning and clearing. A final inspection is necessary before approval for construction can be issued (Easton 1994).

There are no restrictions on the amount of lawn permissible in backyards. Canopy trees with a caliper diameter of 15 cm (six inches), measured 60 cm (2 feet) from the ground must be retained and can only be removed with a Clearing Permit.[57]

Permissible lot coverage (developed portion) and set-back vary throughout the development. Average lot coverage in the mid 1970s was approximately 35% (Vague and Kremer 1994). Today, Vague and Kremer estimate average lot coverage to be around 55%.

As discussed previously, the extent of vegetation clearance was originally determined by soil and vegetation type. In general, builders were supposed to aim for the absolute minimum disturbance by clearing only the platform and a 1.5 meter (five foot) construction buffer surrounding the house, the basic concept for house construction being to build houses directly in the forest (see photos). The relaxation of these standards to require the retention of only 40% non-grass in the front yard and only trees over 15 cm dbh[58] in the back yard,

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[56]Penalties range from $50.00 upwards. There seems to be no set scale for violations.
[57] Permits are obtainable from the Residential Design Review Committee (RDRC), a resident elected body.
[58]Diameter at breast height.

combined with an average reduced set-back, reduced lot size, and greater permissible building coverage has substantially reduced the extent of canopy and understory retained on house lots constructed since the 1980s. Though no quantitative data is available, the chronological sequence of development indicates a gradually diminishing vegetation cover. It was obvious from my field observations that the proportion of vegetation being retained on house lots being constructed now (January 1994) is substantially less than that retained on lots constructed early in The Woodlands history.

In addition to the relaxation of builder's standards for vegetation protection, TWC appears to have also relaxed its standards in the development of infrastructure. The most noticeable relaxation has been in the attention paid to vegetation protection in median strip. Both the width and quality of vegetation in these strips has declined markedly between the Grogan's Mill area and the new suburbs (see Appendix).

Resident and builder education regarding The Woodlands Philosophy

The first residents of The Woodlands were given tours to orient them with The Woodlands philosophy and development approach and to ensure their understanding of the forest's function and landscaping goals (Kendrick 1994). This approach has now been replaced by a video show and educational pamphlets.[59] Kendrick (1994) states that this is because of the impracticality of the original approach with the much higher number of residents moving to The Woodlands each year.[60]

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[59] "A residents' guide to landscaping in The Woodlands," and " Stop before you chop."
[60] 62 dwellings were constructed in 1974 (Morgan and King 1987 p.83), 287 in 1975 (Morgan and King 1987 p.101), with recent housing starts averaging around 900 for the last 4 years (Mitchell Energy and Development Corporation 1993).

Builders are given regular educational shows to illustrate any changes in development standards and to indicate where they are performing well and where improvement is suggested.

4.5 Treatment of Waller Ponds

LeBlanc (1994) states that it has been the policy of The Woodlands Corporation "to create lakes out of wetlands." TWC categorizes the excavation of Waller Ponds as "enhancement" because of the increased area of open water created. GESI (1980) emphasize what they perceive to be the negative qualities of Waller Ponds as justification for modifying them to serve as stormwater detention ponds.[61] They also suggest filling part of the ponds to provide for recreation or building pads, suggesting that only those ponds adjacent to medium-high density development would be affected. Since 22 to 23 out of an estimated 30 Waller ponds on site fit this category (GESI 1980 p.54), it suggests that most of the Waller ponds on site will be developed.

Waller ponds are excavated to maximize stormwater holding capacity, so there is no shallow edge created. Only one (Shadowlake Marsh) of 8 ponds observed by the author appears to have been constructed in accordance with the guidelines contained within the WMRT reports. Shadowlake Marsh is comprised of remnant Waller Pond interfused with partial excavation. There may be other ponds that have been constructed in this way, but these were not amongst those I observed. Those I observed were open water ponds with little

[61] These include their low aesthetic value, the presence of snakes and mosquitoes, their ephemeral nature, shallow water and moving water's edge.

to no emergent aquatic vegetation, and no obvious wildlife habitat (see Appendix). Several of these appeared eutrophic.[62] The most common waterbirds I observed were introduced muscovy ducks.[63]. LeBlanc advised that water quality in these ponds is monitored, and that they meet required standards.

4.6 Innovative construction

None of the WMRT suggestions for innovative housing prototypes have been implemented.

4.7 Development densities

WMRT projected a population in The Woodlands of 150,000 on 6,800 ha (17,000 acres), with 44% open space. With 10,000 ha (25,000 acres), and 25% open space, the projected population is now only 120,000 (Wendt 1994). This equates to a change from 22 people per hectare (16 people per acre) to 12 people per hectare (6.4 people per acre) - 40% of the original proposed density.

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[62] Mystic Lake, in particular, had a noticeably greenish hue.

[63] These are resident on all ponds in the Woodlands. Egrets were also present, and a colony of cormorants is resident on Lake Harrison. Cicero (1989) contends that ponds located in small parks without an adequate buffer will probably not support a varied avifauna because of constant disturbance.

CHAPTER 5

A CRITIQUE OF THE WOODLANDS ECOLOGICAL PLAN AND ITS IMPLEMENTATION

5.1 Chapter Outline

1. Critique of the ecological planning process and derived ecological goals in light of present knowledge;
2. Critique of implementation in relation to original goals;
3. Discussion of how well The Woodlands of today addresses contemporary conservation concerns, i.e. how good a model is it for modern ecological planners and advocates of sustainability in suburban design and development?

5.2 Ecological Plan Critique

This chapter draws on the discussion of landscape ecological principles and studies presented in Chapter 2 to critically examine the principles that guided the ecological planning process discussed in Chapter 3. The purpose of this critique is to determine the relevance of those principles to contemporary conservation issues, and so to evaluate whether the landscape that derived from this planning process would have met the goals of contemporary environmental planners. All four WMRT reports are examined. For the most part though, the critique is focused on assessing the durability of WMRT's definitive report (the Ecological Plan) in the face of rapid advances in the theory and practice of planning for ecological protection at the landscape scale. The examination of the WMRT ecological planning process also provides a baseline from which to predict the ecological impact of changes made to the plan during its implementation by TWC.

Because current conservation goals are primarily focused on the protection of biodiversity, the following critique is targeted at examining the capacity of the ecological planning process employed by WMRT to meet those goals. The development of The Woodlands by TWC is critiqued on this same basis.

Table 5.1 lists those elements of the Ecological Plan and its implementation that are most important for assessing the success of ecological planning at The Woodlands relevant to current conservation concerns.

Table 5.1
Criteria Evaluated to Assess the Success of Ecological Planning in The Woodlands

Scale considerations
Natural drainage and hydrological budget
Wildlife habitat preservation
Vegetation preservation
Waller Pond preservation and aquatic ecology
Monitoring and evaluation

5.3 Implementation of the Ecological Plan

The story of development of The Woodlands is one of sometimes incremental, sometimes dramatic changes in direction from its original principles. These changes apparently began even before WMRT's involvement ended, as the principle architects of the ecological planning process (the visionaries) were replaced by others with more conventional ideas (Spirn 1993). Spirn (1993) also attributes further erosion to the involvement of Land Design Research in land use planning for the revised General Plan.

My principle environmental criticisms of The Woodlands current development approach, and its implementation of the Ecological Plan are summarized in Table 5.2. These criticisms are directed at substantial impacts on the ecological integrity of The Woodlands.[64] These are discussed in the context of the headings listed in Table 5.1.

Table 5.2

Criticisms of The Ecological Plan's Implementation

Abandonment of natural drainage
Abandonment of the use of soil and vegetation as determinants of site clearance and development density
Diminution of natural open space
Inattention to wildlife protection needs
Waller pond excavation and poorly designed pond and lake development
Weakened vegetation retention standards and enforcement
Inattention to protection of high quality natural sites
Absence of ecological performance monitoring and evaluation
Absence of natural areas management program
Unsustainable water usage
Reduced water quality in site watercourses and ponds
Abandonment of innovative construction techniques
Reduced resident education emphasis

[64]Other environmental impacts such as the use of fertilizers and pesticides on lawns and golf courses are not discussed because these are unrelated to landscape ecological principles.

5.4 Scale Considerations

There were several major flaws in the ecological planning methodology employed by WMRT. However, the two most significant oversights affecting the plan's ability to succeed were WMRT's inadequate considerations of scale, and the use of natural drainage as the cornerstone of the ecological plan.

The Ecological Plan was meant to apply at all scales of design and development. In fact it was dependent on the interconnectivity of each scale of planning. The master plan for the site determined planning at the village scale, which in turn dictated what could occur at the neighborhood scale, and subsequently the site scale. But because the plan was based on development constraints and opportunities dictated by the pattern of soils, drainage, and vegetation (which were inventoried at the micro scale), events at the site scale also determined what happened in the other direction. The interconnectivity of the plan made holistic sense, but also exposed it to greater risk from unforeseen weak links.

WMRT's differentiation of developable areas and open space at the scale of the whole property, the village scale and the neighborhood scale is fundamentally sound - based on data derived from their inventory and analysis process.[65] It is at the site scale, that the plan falters. At this point the plan becomes less specific, providing only guidelines to assist the developer and builder in designing each individual lot to achieve planning objectives at the larger scales of planning.

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[65]Note that the data used has substantial problems which are laid out during this chapter. Also, it is important to recognize that the pursuit of contemporary conservation goals would likely create a much different plan to WMRT's plan.

The problem with this approach is that builders work at the lot or street level, and it is precisely at this point that they need detail in order to implement the goals of the broader scale planners. Essentially, the plan expected that builders would be able to interpret maps describing vegetation, soils and drainage at broader scales and apply them to each lot. Chapter 3 pointed out that there were 11 types of vegetation described in the reports (for Phase 1), with a mapping margin of error of about 13 meters (40 feet). There were also 4 main soil types (with sub categories), with no specified margin of error.

The botanist employed by WMRT expressed his difficulty with differentiating between most of the vegetation types. Yet the untrained person on site was expected to use these maps to differentiate between vegetation types and often marginal differences in soil permeability in order to develop the site in accordance with larger scale goals. This was a highly unrealistic assumption, which, as was discussed in Chapter 4, led to the almost immediate demise of site level ecological planning. It is possible that this discrediting of site level planning also weakened the credibility of using soil and vegetation as spatial and density determinants of development at larger scales. It also affected the credibility of the natural drainage system which was dependent on the protection of permeable soils.

Planning at the micro scale may not have been possible for WMRT to undertake because of the scope of their consultancy. Nevertheless, there is an obvious lesson that failure to consider the operating scale of those executing the plan will severely limit the plan's capacity for implementation. This is especially so in instances where those implementing the plan are not comfortable with its basic precepts. For it to have been applicable, WMRT should have ensured that suitably trained personnel were permanently employed by the developer to both apply the plan at the site level and to train builders in its instigation.[66]

The other major flaw in WMRT's scale considerations occurs at the other end of the spectrum, at the regional scale. WMRT essentially treats The Woodlands as an island, taking no account of ecological processes that transcend The Woodlands property boundaries. Neither the effects of The Woodlands development on regional ecological functions, or the potential ecological impacts of regional development on The Woodlands are considered. This neglect may have been due to the scope of their consultancy, but is no less significant in its impact on the validity of the ecological planning undertaken. As Chapter 2 discusses, planning at the landscape scale is the only effective means of achieving contemporary conservation objectives. Faunal populations that rely on habitat within and without The Woodlands for maintaining a viable population are especially affected by incremental approaches to regional development and ecological degradation.[67]

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[66]It is possible that this might have also facilitated dispersal of this planning methodology beyond The Woodlands.

[67]The viability of many species or communities is not usually endangered by any one development, but by cumulative effects. The literature supports the view that incremental ecological impacts have been the main impetus for the general nation-wide degradation of ecosystems, and the population decline of all U.S fauna and flora that does not directly benefit from human activities. The sanctity of private property rights and cultural non-alignment with the concepts of common pool resources constitutes a substantial barrier to effective multi-property conservation efforts. The Endangered Species Act, and similarly directed Federal, State and local legislation are attempts to correct these externalities, but are invariably reactive in their design and so are applied only when the situation has reached crisis proportions.

5.5 Natural Drainage and Hydrological Budget

The success or failure of the Ecological Plan rested on the success of natural drainage .

Natural Drainage

Although the natural drainage system's credibility was weakened by the abandonment of site level ecological planning, it still underpinned development through the 1970s. Its ability to meet drainage goals was apparently never seriously questioned. Early tests of the natural drainage system by heavy storm rains had demonstrated its effectiveness (Spirn 1984, Kendrick 1994)[68]. Nevertheless, natural drainage was abandoned in the early 1980s.

WMRT had accorded natural drainage a cornerstone role in the Ecological Plan, linking its implementation with the achievement of other fundamental ecological goals such as the protection of wildlife habitat, high quality vegetation stands, and water quality. For example, the bulk of the wildlife habitat on The Woodlands was contained in the natural drainage system. Likewise, maintaining water quality could not have been achieved without natural drainage. The natural drainage system was presented by WMRT as the only solution to the site's drainage difficulties, and was designed with no flexibility.

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[68]Spirn (1984) cites evidence that at least up to the time it was abandoned, the natural drainage system had been working very well. She attests to the superior quality of urban runoff from Grogans Mill compared to that from other Houston residential areas. She also reports that a record storm which hit the area in April, 1979, in which nine inches of rain fell in five hours, caused major flooding in neighboring subdivisions without flooding a single house in the Woodlands.

When natural drainage was abandoned, this catalyzed the disintegration of these other goals. From interviews with TWC staff, it seems likely that a lack of individual commitment by TWC to these other goals was also important in their abandonment. Nevertheless, WMRT's placement of all their ecological eggs in the one basket (natural drainage) was a serious tactical planning error. This is not to suggest that these goals should not have been linked. Their interconnectedness is a reflection of ecosystems, and was critical to achieving the Plan's vision. But greater emphasis of each element's stand-alone values might have prevented or mitigated their individual abandonment.

The Woodlands Corporation (TWC) abandoned natural drainage because new hydrological studies indicated the Bear Creek reservoir required less land for stormwater retention than that required by an incremental approach; avoided the need to consider recharge soils at a fine-grained scale; and made more floodplain land available for development. Heineman (1993) attests to the effectiveness of the post-WMRT drainage system in handling several low frequency storm events. The new studies, however, neglected WMRT's considerations of environmental benefits, such as water table recharge, runoff quality, and additional wildlife habitat. Like traditional planning approaches, these became environmental externalities. Because these were essential elements of the Ecological Plan, their abandonment with natural drainage basically crippled the Plan's environmental vision.

Vegetation retention within the developed areas is now the only objective pursued by TWC, and as is discussed in Section 5.5, their approach in this regard also has limited ecological value.

Hydrological Budget

WMRT's estimates of recharge rates, pathways and sustainable groundwater withdrawal rates have proven to be inaccurate (More 1994). Groundwater is essentially being mined, due in part to WMRT's under-estimates of the rate of recharge of the supply aquifers north of the site, and of the rate of flow through the aquifer beneath The Woodlands. WMRT were also incorrect in their assumption that surface recharge on The Woodlands site would eventually percolate through surface aquifers to replenish the deeper aquifers from which The Woodlands' water supply was being withdrawn. Apparently, there is no downward flow, because of impermeable layers of hardpan (Greiner Engineering Services Inc. 1980). WMRT's aquifer recharge plan also relied on artificial recharge of tertiary treated waste water through deep dry wells. This practice was never implemented.

In retrospect, information on recharge rates and groundwater behavior at the time WMRT was preparing the Ecological Plan was inadequate for the detail of the recommendations made by WMRT. The behavior of the surface water table has not been measured, but according to Kendrick (1994), there have been no noticeable signs of water stress on the hardwoods.[69] His view is that the water table has been little affected by development. Sauer (1993) believes that lowering of the water table by development on The Woodlands led to increased hardwood mortality on adjoining subdivisions.

TWC's proposed solution to its impending groundwater shortages - the creation of a new reservoir on Spring Creek - will mean the loss of the most valuable

[69]Hardwoods are more susceptible to lowering of the water table than pines.

natural habitat remaining on The Woodlands. The bottomland forest on this site is apparently in very good condition, exhibiting few signs of previous human disturbance (Roach 1994, San Jacinto River Authority 1992). Scientists with the U.S. Fish and Wildlife Service (USFW) in Houston contend that this type of habitat has been severely depleted in the Gulf Coastal Plain over the last few decades. With a resurgence of logging in the southern forests, this habitat type will be further degraded, resulting in significant regional ecological impacts. USFW (Houston) believe there is no necessity for this reservoir and that alternative water supplies could be obtained from existing reservoirs. They are concerned that if the project is approved by the U.S. Army Corps of Engineers (COE) required mitigation will be unsuccessful. Their view is that mitigated restoration of bottomland hardwood forests is virtually impossible, and has been universally unsuccessful in Texas, a view supported by the National Research Council (1992 p.18).

The Woodlands current proposal for mitigation is to protect other forest along Spring Creek. Since The Woodlands intended to retain this forest in any case, being within the floodplain, this proposal equates to "double-dipping". This double-dipping approach has also been used for other required wetland mitigation efforts undertaken by The Woodlands. LeBlanc (1994) cites an example where TWC were required to mitigate for 15 cumulative acres of small scattered wetlands outside of the floodplain in Cochran's Crossing. Their approach was to create 3 acres of open water pond and set aside an additional 68 acres within the floodplain that had already been designated for protection in The Woodlands General Plan (LeBlanc 1994). This double dipping approach completely defeats the purpose of mitigation.

According to LeBlanc (1994), current water use in The Woodlands is very high, a trend he attributes to the establishment of new lawns. The Woodlands could alleviate the impending urgency attached to finding an alternative water supply if water use was restricted, but he says TWC is reluctant to impose restrictions on water use, because residents are already subject to so many other restrictions.[70]

5.6 Wildlife and Habitat Preservation

WMRT's consideration of wildlife is cursory, and for the most part ecologically incorrect. Their less than thorough treatment of wildlife is a significant weakness in what WMRT portrays as a comprehensive ecological planning process. The major faults with their approach and The Woodlands Corporation's wildlife considerations are discussed in light of achieving current conservation goals.

Scope of Inventories

WMRT's inventory methodologies were not thorough. Poche's surveys were carried out from roads, creating a natural bias towards edge and generalist species. Maestro's methodology is unknown, though it would appear to have been significantly less thorough than Poche's. More representative transects may have uncovered additional interior species. Schmidley (1994) states that the approach and recommendations of both were considered satisfactory by standards at the time, but are problematical by today's standards.

[70]Most of these are contained in the Residential Development Standards (TWC 1993c).

Species lists were not comprehensive, but were rather intended to be representative of the species present. Relative abundances are noted for birds by Poche (WMRT 1973b), and mammals and some birds by Maestro (WMRT 1974a).[71] Interestingly, the species lists in Poche's thesis (Poche 1973) are much more comprehensive than those contained in the WMRT reports. For example, he lists 99 species of birds in his thesis, but only 55 species are listed under his name in the WMRT report, Phase 1: Land Planning and Design Principles (WMRT 1973b Appendix).

The failure to consider aquatic species has already been discussed. Invertebrates and micro-organisms (mostly resident in soil) are other major omissions. Poche (1973 p.87) recognized the need to consider these, but not WMRT. As modern ecologists focus increasingly on biodiversity issues, failure to consider invertebrates and even smaller organisms equates to leaving out the bulk of The Woodlands biodiversity. Importantly, many higher vertebrates, including many songbirds depend on a diverse native insect population for food, and the functioning of the whole system is dependent on the mineral-fixing and decompositional functions of micro-organisms. Considering only the larger fauna is akin to constructing a high rise building but forgetting the foundations. It is recognized that comprehensive surveys of invertebrates and micro-organisms would be cost-prohibitive, but alternative cost-effective methods of representative analysis are now available in the form of gap analysis (Scott et al. 1993), hot spot determination (Prendergast et al. 1993), and sensitive species determination (Noss and Harris 1986, Soule 1986).

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[71]The assessments of Maestro may be suspect considering the generally poor quality of his report.

Consideration of fragmentation effects

Maestro (WMRT 1974a) grossly overstates the benefits deriving from forest fragmentation, while simultaneously understating the adverse effects. Maestro strongly suggests that development is extremely beneficial for most wildlife.[72] Only two cursory and generally non-informative paragraphs are given over to discussion of adverse impacts (WMRT 1974a p.60). Poche (1973 p. 75) states that "Even though natural areas and wide corridors are retained the effects of land clearing on the majority of wildlife populations will remain *catastrophic*" (author's emphasis).

Focus on game species

WMRT's attention is focused almost solely on the promotion of game species, due largely to the bias of Maestro (WMRT 1974a). For the most part, the game species advocated by Maestro are edge or generalist species, which, as Chapter 2 illustrates, do not require special protective attention. It could be argued that it is unfair to level criticism at WMRT for this error, because they were only responding to what was then considered standard wildlife survey practice. However, in his Masters dissertation, Poche (1973) cautions against favoring game species, calling for more emphasis on non-game avian fauna, and more sensitive species. He also states that "it is virtually impossible to maintain substantial numbers of game numbers within the confines of a city." WMRT either did not have access to this viewpoint when the reports were written, or chose to ignore it in favor of Maestro's recommendations.

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[72]In my view, Maestro seems to have either been extremely naive in his understanding of wildlife ecology, or was attempting to report what he thought the Woodlands wanted to hear.

As Chapter 2 shows, the emphasis on game species would now be detrimental to goals of maximising overall species richness and regional biodiversity. Protection of sensitive interior and rare species is a major contemporary focus of ecological planning.

Species behavior patterns and sensitivity to suburban development

Chapter 2 points out that understanding the behavior patterns of interior and rare species is an essential step in planning for their protection. Unfortunately, the WMRT reports only considered the habitat requirements of game species, which consequently severely limited the ecological value of their planning process. In his Masters dissertation, Poche (1973) considers the sensitivity to disturbance of 58 species or groupings of species. This was not included in the WMRT reports.[73] Poche also emphasizes understanding the habitat requirements of all species before delineating protected habitat. In contrast, Maestro attempts to categorize species according to sensitivity to development, but he describes very few species, most of which are game species (see Table 3.3). His breakdown does not address biological diversity as an ecological concept.

One of Maestro's major conceptual failings occurs when he groups all songbirds and assigns them a collective sensitivity assessment of "least sensitive." As ecologists know now, and which some ecologists may have recognized in the early 1970s, the individual behavior patterns of songbirds cover the spectrum of sensitivity, from the ubiquitous cardinal (which would

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73 Possibly, this information became available after the WMRT reports were completed. More recent empirical data on species sensitivity to fragmentation and human disturbance may demonstrate that some of Poche's sensitivity determinations are inaccurate.

fit Maestro's assessment) to the extremely sensitive Bachmans sparrow which may now be extinct in its Gulf Coast range (Terborgh 1992).[74]

WMRT failed to consider the dispersive capabilities of wildlife, i.e. their capacity to move between habitat patches in order to contend with the fragmentation effects occasioned by development. As noted in Chapter 2, landscape flows are influenced by spatial structure, notably the suburban mosaic.

The failure of the WMRT planning process to consider interior species behavior patterns, and especially their sensitivity to development severely limited their capacity to design open space retention to effect the greatest benefit for wildlife. Essentially, WMRT were required to take a shotgun approach to wildlife conservation. Their view was that if deer could be retained, this would also protect almost all the other species present, with the exception of only the most sensitive species.[75] Present evaluation of the success rates of interior species under this approach is difficult, given the limitations of the original species lists, and the lack of quantitative data on species abundance at the time of the original survey. The subsequent development of several major upland corridors by TWC has also complicated this analysis.[76] Therefore only a qualitative prediction of the impacts of development on wildlife is possible.

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[74]The Bachmans sparrow is a neotropical migrant that winters in Cuba (Terborgh 1992).
[75]These sensitive species were not identified by WMRT.
[76]It is possible that the additional habitat provided by these corridors may have been enough to retain some species that could now be in difficulty as a result of the increased level of development that has occurred. The corridors now developed include those proposed to link with Jones State Forest, and the major link between Bear Branch south to Spring Creek (see Figure 3.7).

Habitat form - patch size, shape, quality

Most habitat recommended for retention falls within the natural drainage system or upland corridors. Recommendations are also made in WMRT (1973b p.34) for the designation of "several large open space preserves" as wildlife refuges. Wildlife and vegetation surveys in the WMRT reports also recommend the protection of several smaller patches of habitat considered to have exceptional botanical and/or wildlife value. Except for corridors, no spatial dimensions are given to guide the allocation of land for protection. When WMRT was involved in The Woodlands the concept of maximizing interior habitat for species richness had not been developed. Similarly the importance of patch size and shape had also not been considered. This lack of awareness of spatial issues that are now fundamental to contemporary ecological planning partly explains why no attention was given to specifying patch sizes. Part of it also may have been because WMRT only developed guidelines, leaving The Woodlands Corporation to work out the details of reserve size and location.

Though a circular form is recommended for small patches which would be retained in suburban developments, no such recommendation is made for the shape of larger patches.

Habitat quality (vegetation condition and structural diversity) was recognized by WMRT's biological consultants but was considered independent of patch size. In effect, the sites recommended for protection were seen as analogous to museum pieces. The scalar and contextual issues associated with maintaining those conservation values were not considered.

TWC has paid no attention to habitat form during development. Attention is focused on the built environment. As a result, most of the extant natural habitat in the developed areas is extremely linear.

Diminution of natural open space

Heineman (1993) contends that it was always The Woodlands intention to retain between 25-30% of the site as open space, and that the 44% suggested by WMRT was never seriously considered as a viable option. LeBlanc (1994) states that the reduced apportionment of open space in the development (from 44% to around 25%) is a reflection of economic realities. LeBlanc contends that the original open space provisions would have made it impossible to spread infrastructure costs sufficiently over the developed area to remain market competitive.

Perhaps the real pressure on the open space though, has not derived from the need to concentrate infrastructure costs, but from unwillingness of TWC to develop at the densities proposed by WMRT, and the unwillingness of home buyers to live at these densities. Probably the latter has had the greatest influence. As Chapter 4, section 4.7 demonstrates, present residential densities are only 40% of those proposed by WMRT.

Promotion of Edge Conditions

The development of edge conditions is strongly advocated in WMRT's Ecological Plan as a way of increasing the abundance of desired species (game species). Maestro (WMRT 1974a p.61) basically says that opening up the forest by development is the best thing one could do to benefit wildlife. Maestro (WMRT 1974a p.60) further exacerbates the flaw in his reasoning by asserting that the pine-hardwood forest type found on the site "provides a small range of ecological niches and therefore the diversity of habitat is narrow." This contrasts with the plant ecologist's report (McCloud in WMRT 1974a p.37) that asserts that this is a "reasonably complex" forest.

Increasing the abundance of edge and generalist species was the standard view of wildlife biologists at this time.[77] Attitudes to wildlife were more utilitarian then and have in practice only evolved into a more holistic ecosystem approach in the period since The Woodlands was designed. Most of the literature that addresses wildlife for reasons other than game management is less than 20 years old. As Chapter 2 indicates, there is substantial evidence supporting the view that edge effects are detrimental to species diversity at the landscape scale. WMRT's emphasis on edge effects is a major flaw in their recommendations and prototype design guidelines, but is due primarily to the state of wildlife science at that time, compounded by the exceptionally poor quality of their primary wildlife assessment.

Corridor preservation

Deer were used to determined corridor widths because they were considered by both Maestro and Poche (WMRT 1973b) to be about the most sensitive species capable of being retained in an economically viable development. As demonstrated in Chapter 2, empirical evidence for optimal corridor widths for most species is extremely limited, with most researchers opting for a "wider the better" strategy.

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[77]Much of the emphasis on the perceived positive effects of edge can be traced to Aldo Leopold's book "Game Management," published in 1933.

According to Heineman (1994), the decision to delete upland corridors was founded on advice received from Texas A&M University subsequent to the Ecological Plan. This advice suggested that deer would be unlikely to use the corridors to move between The Woodlands and Jones State Forest, because their home range was only "2-3 miles." This argument is flawed for three reasons. First, the corridors were to protect not just deer, but also the "vast majority of species presently on site" (WMRT 1974a p.63). Second, based on Short's work in 1986, the corridors would likely still have constituted habitat for deer, although their linear movement may have been limited.[78] Third, corridors function not only by the physical translocation of individual animals, but just as importantly through exchange of genetic material, as demonstrated by Bennett (1990).

The intended purpose of these corridors was to link with Jones State Forest to the north. Apparently, there was no intention to provide connections elsewhere, though one logical connection would have been to the habitat abutting Spring Creek. Since these corridors and the floodplain forest would have comprised most of the habitat area actually preserved on The Woodlands site, it is prudent to look at their value for habitat. This can be done by looking at patch size and shape, in conjunction with edge effects.

Studies of edge effect suggest that negative edge impacts extend at least 200 meters and as much as 500 meters into forest before they level off (Catteral et al. 1991, Wilcove 1985, Andren and Angelstam 1988). To be effective for protecting interior bird species, especially neotropical migrants, corridors

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[78]Short (1986 p.10) states that habitat patches should be ≥ 40 ha. Deer are also a very adaptive species (Short 1986), as is witnessed in the northeast and many other parts of the country where deer populations in suburban situations are extremely high.

would need to be at least 600 meters wide, based on a conservative estimate of edge impacts extending 200 meters from either side, and leaving 200 meters of interior habitat that is reasonably free of edge effects. This estimate strongly suggests that the 200 meter corridors proposed by WMRT would have been inadequate as habitat and significantly deficient for use as corridors by species susceptible to edge effects.[79] Suburban adjacency effects and frequent connectivity breaks would have further degraded their efficacy as corridors.

Despite their probable inadequacies in width, the upland corridors constituted the only upland habitat designated for preservation on The Woodlands. Their subsequent development for housing implies that any possibility of preserving upland interior species (for example, foraging RCWs from Jones State Forest) has most likely been lost.

Riparian habitat areas

Preservation of undeveloped floodplains has obvious hydrological benefits which are detailed at length in the WMRT reports. Furthermore, Harris and Gallagher (1989 p. 20) state that "even if rivers and woods and riparian woods had no fisheries value, no recreation value, and no hydro-period regulation, water recharge, or cleansing value, we would still choose them as priority wildlife conservation areas." Harris and Gallagher (1989 p. 20) add that "riparian woods represent our single best hope for creating a system of interconnecting corridors," for wildlife movement.

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[79] It needs to be stressed that this estimate is based on limited empirical evidence from similar situations elsewhere, and that on-site studies are required to gauge its validity.

Excluding the linear strips of vegetation along roadways, almost 100% of the remaining natural open space in the developed portions of The Woodlands lies within the floodplains of Spring, Bear Branch, and Panther Creeks.

Floodplain habitat has been considerably reduced in extent by the revised drainage system and the encroachment of golf courses.[80] GESI (1980 p.50) states that the 100 year floodplain in some parts of Cochran's Crossing would be reduced to the natural 3 year floodplain. The most substantive reductions have occurred downstream of the reservoir on Bear Branch; in the corridor now dominated by Lake Woodlands; and adjacent to Spring Creek, especially the area in the southern portion of Grogan's Mill. Prior to revision of the natural drainage system, the Cochran's Crossing section of the Bear Branch floodplain averaged 1300 meters (4,000 feet) in width (Greiner Engineering Services Inc. 1980a p.14). Before its development for one acre estate housing, the wide floodplain area in Grogan's Mill was the most consolidated (least linear) habitat on The Woodlands. The dimensions of this area within The Woodlands measured approximately 2 km from north to south, and 4 km east to west. The area's habitat value would have been further enhanced by its east-west connectivity with the wide Spring Creek floodplain both within The Woodlands, and on the southern side of the Creek. On the basis of estimated edge effects in the preceding section on corridors, it seems probable that both the areas on Bear Branch and Spring Creek, especially the latter, would have been able to sustain a significant area of interior habitat.

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[80]The Ecological Plan (WMRT 1974d p.37) states that golf courses were supposed to complement but not infringe upon natural open space. With 6 golf courses projected by the time the Woodlands is completed, the land demand of golf courses would have placed an extreme demand on developable upland sites. Financially, therefore, this encroachment is understandable from LeBlanc's arguments about spreading infrastructure costs.

According to LeBlanc (1994), present floodplain corridor width along Bear Branch and Panther Branch ranges on average between 130-200 meters (400-600 feet), and up to 260 meters (800 feet) in places. Based on the estimates of minimum corridor width requirements described in the preceding section on corridor viability (600 meters), present corridor widths are probably not sufficient to sustain much, if any, interior habitat.[81] The frequent breaks in connectivity that result from roads would also limit their effectiveness as corridors and habitat. Sensitive species such as the timber rattlesnake, which prefers floodplain habitat, would be unlikely to persist along Bear Branch and Panther Branch. Craig Rudolph[82] estimates that enabling persistence of the Timber rattlesnake would require continuous habitat 10 km (7 miles) long and approximately 1.6 km (1 mile) wide, with no disruption by roads. The habitat along the Grogan's Mill section of Spring Creek is still 600-800 meters wide. If combined with vegetation on the Creeks southern side, this area may continue to support some interior species if managed appropriately.

Other than reducing corridor widths, and developing some corridors for residential use, TWC has had one other major impact on the corridor network proposed by WMRT. This has been on connectivity. The northern link to Jones State Forest and the link between Bear Branch and Spring Creek have been developed for residential use; Lake Woodlands has severed Panther Branch from Spring Creek; and the Bear Branch reservoir has severed the east to west connection in the central part of the development. Bear and Panther

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[81]Further research would be needed to assess the extent of the edge effect in this habitat type, as well as the area requirements of interior species.
[82] Research Ecologist, Southern Forest Experiment Station, USDA Forest Service, Nacogdoches, Texas.

Branches are severed by several existing and proposed roads, and golf course fairways. Spring Creek remains the most continuos corridor, but its security is threatened by the proposed reservoir. Habitat adjoining The Woodlands is not protected. Based on regional growth trends, it seems likely that many areas adjoining The Woodlands will eventually be developed to capitalize on The Woodlands facilities and reputation.[83] In effect, remaining corridors can only be characterized as linear patches of habitat that do not connect to any substantive areas of interior habitat.

Minimum viable population size

This concept was not established in ecological thinking at the time WMRT was involved at The Woodlands. If The Woodlands development process were to be repeated today, consideration of minimum viable populations (in conjunction with species behavior patterns) would be essential for determining which sensitive species would be most likely to be threatened by development. With this information, it would be possible to develop strategies aimed at assisting the persistence of interior species on site, or at a larger spatial scale.

Focus on hardwood preservation

WMRT's focus on hardwood preservation is mostly aesthetically driven, and only ecologically motivated in the sense that the mast from hardwoods is considered an important food source for desired game species (See Chapter 3). This approach is problematical ecologically, especially since the only confirmed terrestrial federally Endangered Species on site, the Red-cockaded woodpecker (RCW), is dependent on mature pine forest. In addition, McFarlane

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[83]The area between The Woodlands and south to Houston's territorial boundary is rapidly being infilled by urban development. The town of Conroe, to the north of The Woodlands has also grown substantially in recent years (Conroe Chamber of Commerce 1994).

contends that the pre-colonial condition of the forest in this area was most likely a mature park-like pine forest, and that hardwoods are a more recent successional stage induced by suppression of the natural fire regime. WMRT's emphasis on hardwoods favors a different assemblage of species than historically occurred in the area.

TWC maintain an emphasis on hardwoods, but not to the extent proposed by WMRT. Vegetation is now protected more on the basis of coverage, than type.

Endangered species

Poche (WMRT 1973b p.35) states that tracts of pines in refuge areas "must be set aside to serve as breeding and nesting areas for this species (RCW)." These recommendations were made without consideration of minimum viable populations, the dispersing capability of the bird, and the need for conservation strategies to address larger scales than The Woodlands site. However, the need for protective measures was at least recognized by WMRT.

The Woodlands Corporation has not acted on WMRT's recommendations, failing to protect any area of mature or potentially mature pine forest. McFarlane (1994) points out that RCWs have been found to forage (but not nest) in fragmented pine forest in golf courses in South Carolina. Conceivably, RCWs nesting in Jones State Forest could be encouraged to forage in The Woodlands if preservation of pines were favored instead of hardwoods within their normal foraging range. To this end, the corridors linking to Jones State Forest could have served a more ecologically significant function by accomodating foraging RCWs rather than deer, and could have been managed for this purpose.

Wildlife habitat management

Post-development habitat management is recommended by Maestro in WMRT (1974a), but is focused almost solely on manipulation of habitat to promote game species. His management suggestions (for example, continued logging and introduction of non-native cover plants for quail) are contrary to contemporary ecological management principles. No consideration is given to ecological management along the lines of that practiced in national parks, where the focus is on maintaining natural ecological disturbance and regeneration processes as free as possible from human-created detrimental impacts. In The Woodlands, this could mean controlling exotic invasive plants, feral animals, and the negative impacts of edge species (cowbirds, for example).

Ideally, management should also involve the continuation or emulation of natural disturbance regimes. The exclusion of fire has significantly changed the botanical and structural composition of The Woodlands. WMRT should have decided whether this condition was an acceptable human-induced change or whether intervention was required to maintain the pre-colonial condition. This question is significant in terms of maintaining viable populations of the RCW and other sensitive species. To their credit, WMRT do recognize the need to restrict human access to prevent disturbance resulting from human recreation (see Chapter 3).

The Woodlands Corporation has not implemented any of the WMRT recommendations for wildlife management. This approach has had some benefits because most of WMRT's recommendations (such as the promotion of edge and game species) would have been detrimental to the achievement of current conservation concerns. TWC has also prohibited public access to undeveloped areas. LeBlanc (1994) states that access is restricted for liability reasons.

The official policy of TWC towards the management of natural areas is a "hands off" approach (Kendrick 1994).[84] Despite the benefits derived from failing to implement WMRT's recommendations, the landscape ecological literature suggests that continued failure to manage preserved natural areas is likely to result in their gradual degradation as a result of edge effects, adjacency impacts, and altered natural disturbance regimes.

No quantitative data exists on changes in the abundance and diversity of wildlife populations since fragmentation. Based on the literature, it is probably safe to assume that all area sensitive mammal species have disappeared from the developed portion of The Woodlands, or will over the next few decades. LeBlanc (1994) maintains that he has not noticed any significant increase in cowbirds and states that there are no foreseeable plans to manage these. In contrast, Lorna Felton of the Piney Woods Wildlife Society.[85] (1994) has observed a noticeable increase, as well as increases in blue jays, grackles and crows - all of which impact on nesting songbirds (see Chapter 2).

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[84]Only linear vegetation along roads and easements is managed, and this is only to remove dead trees. Felton (1994) believes this has had a significant detrimental impact on species reliant on these trees for foraging and nests, for example woodpeckers.

[85]I decided that Xmas bird counts (administered by the Audubon Society) would not be useful for evaluating the impact of development on bird populations in The Woodlands, because the Xmas census area covers 4 times the area of The Woodlands and it would be impossible to differentiate where species were recorded. In addition, Xmas bird counts are conducted from roads, and so are less useful for determining impacts on interior species.

Mrs. Felton is one of the first residents of The Woodlands, and lives in one of the first display homes constructed in The Woodlands.[86] Mrs. Felton has monitored birds in her yard and throughout The Woodlands since she first moved to The Woodlands. During this period, she has noted a marked decline in 35 of the 73 plus species she has recorded in The Woodlands. Several of these she notes have disappeared altogether. Several other species have increased in abundance, notably ubiquitous edge species and common water birds that have taken advantage of the increased areas of open water. Very few species populations appear to remained unchanged as a result of development. Comparison with Poche's (1973) early species lists reveals the modern absence of several interior species, including Kentucky warblers, myrtle warblers, and Louisiana waterthrush.[87]

Though qualitative, these trends indicate substantive changes in the composition and abundance of bird species in The Woodlands, with population declines apparent for several interior species. This result is to be expected based on the literature, but is a very different result from that forecast by WMRT, and promoted by TWC. In the absence of quantitative wildlife monitoring, it is not possible to determine if the correlation between the increase in generalist species and the decline in songbirds is statistically significant.

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[86]These houses were built in the forest, with no lawn.

[87]These species may or may not still be present within the developed portion of The Woodlands. Their absence is suggested only by qualitative observations, and research would be required to determine their presence and viability in The Woodlands.

5.7 Vegetation Preservation

Vegetation preservation was essential to the effectiveness of the natural drainage system, for wildlife habitat, and for creating the defining forested character of The Woodlands.

WMRT's vegetation analysis

WMRT's vegetation analysis is more complete than their wildlife analysis, but is still inadequate in several respects.

Foremost among its problems is the emphasis on categorizing vegetation types according to their individual species and habitat values, without recognizing their role in creating the spatial structure of the forest system as a whole. Small locales considered to have exceptional value are singled out for protection. However, maintenance of the high values of particular sites is dependent on continuing biological interactions with the adjoining forest. At the very least, adjoining forest serves a critical buffering role. From a holistic ecological perspective, segmenting the forest into high and low value areas is a nonsensical approach because it allows developers to feel as though their destruction of vegetative communities 'perceived to have lesser value' has less impact on the forest ecosystem than it actually does.

The other major flaw of the WMRT vegetation analysis is the failure of the principle vegetation consultant, Dr. Claude McCloud[88] to consider how the forest might function in a fragmented state. Nothing is said about possible

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[88]Dr. McCloud was Assistant Professor of Biology at Sam Houston University when engaged by WMRT.

weed impacts as the forest is opened up. Also little is said about potential nutrient impacts from stormwater runoff, or the effects of altering the water table. Nothing is said about what impact elimination of natural disturbance regimes (fire for example) will have on the long term structure and composition of the forest elements remaining.

Other aspects of McCloud's work that are not supported by contemporary ecological standards are his suggestions that "wet weather swales would offer interesting aesthetic and wildlife possibilities" if excavated to create permanent ponds (WMRT 1974a p. 46); that open areas on the floodplains be enhanced to promote wildlife (pp. 45-6); that part of Bear Branch be channelized to facilitate movement of water during heavy rain (p. 46); that (for aesthetic reasons) "certain species of orchids and pitcher plants" (p. 47) be introduced into Waller Pond areas; and that cattle grazing is probably beneficial to vegetation structure (p. 48). (WMRT 1974a)

WMRT's application of McCloud's work to determinations of permissible clearance ratios is ecologically misguided in its emphasis on hardwoods (see discussion in Chapter 3). The principle of clearing according to selective habitat potentials is an attractive idea, but one which is not supported by the landscape ecological literature without a discussion of spatial distribution. From work by Goldstein et al. (1986) it seems that overall natural vegetation mass and structure, rather than the favoring of one natural vegetation type over another, may be more important as a determinant of suburban bird densities and diversity. The other problem with WMRT's proposed clearance guidelines is that the highest rates of clearance were specified for stands of pure pine. This may have been targeted at young dense pine regrowth but could have equally affected mature pine stands - the favored habitat of Red-cockaded woodpeckers.

Vegetation protection in residential areas

Abandonment of the use of soil and vegetation as determinants of site clearance and development density essentially removed any design constraint on individual lots. The first residents of The Woodlands embraced the vegetation protection concepts of the Ecological Plan, preserving 100% of the natural vegetation in their yards (Vague 1994). But it seems this market niche was limited, and in response to builders and the market, the standards for vegetation retention were increasingly relaxed.[89] Residents of the most recently developed areas in The Woodlands, especially in Cochran's Crossing and Alden Bridge, may be more typical suburban residents with a preference for lawn and the use of flowers and exotic shrubs for yard "enhancement."

Based on interviews with Kendrick (1994), Vague and Kremer (1994), and Girling (1994), it would appear that this trend in relaxed standards was probably unavoidable for The Woodlands. Faced with heavy competition from other developments, it would have been financially reckless for them to have maintained standards so strict that they forced home buyers elsewhere. Many residents obviously support strict vegetation standards, perhaps even stricter (Vague and Kremer, 1994). But surveys undertaken by Bohlke & Associates Market Research (1992) suggest that the majority prefer more latitude. Only 29% of residents cited trees as their most important reason for moving to The

[89] In a survey of Houston area residents, Bohlke & Associates Market Research (1993) found that only 5% cited environs/natural beauty, 3% cited trees and 0.2% greenbelts when asked what was their most important criteria for selecting a community to live in if they were in the market for a home. In contrast, 37% (first and other choices combined) said that good schools was their most important criteria, and 33% cited security.

Woodlands. The same percentage of residents said that trees were what they liked most about living in The Woodlands, after having lived in The Woodlands. This implies that 70% value other aspects of The Woodlands more highly than its environmental qualities and suggests that The Woodlands may have difficulty in achieving much greater vegetation protection than they presently are.

The amount of natural vegetation retained in residential areas within The Woodlands has declined significantly between the time construction began at Grogan's Mill and the present. This has been caused by the combined effects of:

- reduced lot size combined with increased permissible building coverage,
- increased permissible lawn coverage (60%) in front yards and no restrictions on the removal of the understory in back yards,
- incremental thinning of remnant vegetation, and replacement of natural vegetation with exotic species by home-owners, and
- inadequate enforcement of codes to protect vegetation during and post construction.

Though restrictions on vegetation clearance on private lots are stricter than other developments in the Houston area, these have nevertheless fallen considerably short of implementing the vision of the Ecological Plan. From interviews and personal observations, I believe these restrictions have proven inadequate for protecting vegetation - both before and after the home-owner moves in. A back-of-the-envelope estimate reveals that many yards will retain no more than 10% of their original understory and, at most, 30% of the original canopy.[90]

Based on interviews with Easton (1994), LeBlanc (1994), Kendrick (1994), Vague and Kremer (1994) and the surveys of Bohlke and Associates (1992, 1993), it seems highly likely that the strong market demand for lawns has played a substantial role in eroding vegetation preservation standards. A qualitative assessment by the author of residential areas in The Woodlands suggests that very few residents are interested in maintaining completely naturally vegetated yards, and most seem to have extended the percentage of lawn beyond the mandated 60% maximum allowed in front yards. There is also no restriction on the use of non-native plants in landscaping other than in required restoration. This loophole has been liberally utilized by residents to replace native shrubs with non-endemic spp (see Appendix). Understory clearing has also been exacerbated by resident paranoia about snakes (Vague and Kremer 1994). Furthermore, Vague and Kremer[91] point out that a much higher proportion of residents in the villages constructed since Grogan's Mill have young families, which may be another important factor favoring lawns.

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[90]Understory retention is based on 55% of the lot being developed. This leaves a potential 45% in natural vegetation, but there is no onus on protection of backyard understory and only a 40% requirement on the front yard. I saw little evidence to suggest that many backyards retain their understory. By my qualitative assessment, probably less than 10% of new dwellings do. If one assumes that undeveloped space is equally divided between front and back yards, i.e. 22.5% in each (probably a generous estimate for the front yard), then the maximum understory that would be retained is 40% of 22.5%, or roughly 10%. Similarly, for canopy cover, this is comprised of the same 10% in the front yard plus the 22.5% in the back yard - approximately 30%. This is not accounting for side yards, which usually contain no vegetation on the smaller lots, and pools, tennis courts and other yard improvements.

[91]Diane Vague and Margaret Kremer are respectively Manager of the Residential Design Review Committee and the Development Standards Committee. Both committees are resident within the Woodlands Community Association, the organization responsible for enforcing vegetation retention standards after the home-owner has moved in.

In contrast, Grogan's Mill has higher numbers of retirees and renters, to whom a lawn is not as important (Vague and Kremer 1994).

Vague and Kremer (1994) state that it is difficult to enforce covenant restrictions relating to maintenance of landscaping post construction, because this requires taking violators to court, an action they are concerned would be viewed as draconian by many residents.[92] Also, they doubt the courts would be very supportive because of the relative pettiness of most offenses, especially understory removal. The WCA have denied permit applications for mature tree removal, but nevertheless find this hard to justify in many cases. A large number of pool applications also result in extensive vegetation clearance.[93] The WCA's approach to achieving the vegetation protection objectives of the Residential Development Standards is to focus on education and the promotion of peer pressure, though Vague and Kremer (1994) suggest this approach has limited effectiveness.

Vague's and Kremer's impression of most new residents is that their first priority after moving in is the removal of understory plants and trees under 15 cm (6 inches) dbh.[94] This impression was also held by Kendrick (1994) and Easton (1994). Easton expressed his frustration at this trend, because of the effort TWC makes to retain vegetation during the construction phase. He contends that it is the builders and residents who are most at fault for undermining the success of TWC's efforts to retain vegetation. Getting home-

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[92]All home-owners in the Woodlands have covenants attached to their property deeds that restrict their ability to modify natural vegetation retained on the property during the construction phase.

[93]Vague and Kremer (1994) advise that on average, 250 private swimming pools are constructed annually in the Woodlands. This equates to around 28% of annual new home construction.

[94]Trees under 6 inches dbh do not require a permit for removal.

owners to buy into The Woodlands philosophy is critical but very difficult (Easton 1994).

Builders are very reluctant to make the extra effort required to construct without damaging vegetation (Kendrick 1994, Easton 1994). Kendrick (1994) points out that on the whole, it has been very difficult to get builders enthused about The Woodlands vision, though custom builders are apparently more compliant than the production builders.[95] Kendrick adds that it is the installation of utilities that frequently leads to the greatest site disturbance. My on-site observations suggest that general builder site sensitivity is poor. Violations of site standards were noted on numerous sites. Some of the most frequent violations noted involved the dumping of soil and debris within fenced protected vegetation areas, and the absence of sediment controls. Soil accumulation in the street adjacent to many sites under construction was considerable. Attention to the protection of tree root zones was universally ignored. Root protection was heavily emphasized in the WMRT reports, and is included in TWC Site Management, Vegetation Protection and Landscape Design Requirements, yet is seemingly not enforced. Easton (1994) noted root damage was responsible for the deaths of one to two mature trees on a third of new allotments in some areas.[96]

The number of violations observed by the author suggests that enforcement is inadequate for ensuring builder compliance,[97] and that the penalties for non-

[95]Custom builders have more interaction with what happens on site. Production builders operate largely through contractors and are often unaware of what happens on the building site.

[96]Easton also noted that tree death varied according to soil type, soil moisture and other variables, and that stressed trees are more susceptible to pine beetle attack.

[97]My impression from talking to TWC staff is that there are not enough enforcement staff. Rick Easton, who handles all TWC site inspections to ensure compliance with the

compliance are not sufficient to constitute a deterrent to builders. Easton (1994) stated that TWC has recently introduced requirements for builders to submit a landscape plan before they are permitted to remove protective fencing. The purpose of this plan is to ensure that preserved vegetation is integrated into the landscape plan. Though an admirable step, it seems improbable that this will make much difference on the smaller lots, based on the permitted lot coverage and permitted clearance standards. Based on present resident attitudes to vegetation preservation, it also seems unlikely that it will be adhered to by residents after they have moved in.

Several TWC staff suggested that given time, the newer, sparsely vegetated areas will more closely resemble Grogan's Mill. The relaxed requirements for vegetation protection, and the influx of a different type of resident in the newer areas suggests this revegetation will not eventuate. These areas have potential to become more vegetated, but could not reach the same density as older areas, simply because of the smaller lot sizes, reduced setbacks, and the strong resident desire for lawns. Based on the poor level of existing resident attention to the preservation of natural vegetation, it seems improbable that lawns and gardens will be allowed to revert to natural vegetation.

Attention to vegetation retention has also been declining at the village and city scales. In contrast to the vigorous vegetation occupying the median strips and road sides in the earlier development, that in the newer areas is much sparser and less robust. Residents are no longer effectively screened from

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Woodlands Site Management, Vegetation Protection, and Landscape Design Requirements is now dealing with over 900 new homes annually. Considering the complexity of the inspection and permitting process, this seems too much for one person to be able to supervise adequately.

roads as they are in Grogan's Mill. There is little feel of the development being within the forest as is experienced in Grogan's Mill, the Town Center and other older areas, and as is proclaimed in numerous TWC promotional materials.

The other significant difference between road side and median vegetation in the new areas is that these are not used for natural drainage as in the older areas. Runoff from roads is directed to storm drains, which together with curbing means that the newer roadside vegetation strips receive significantly less water than their counterparts in the older developed areas. Restricted drainage also restricts vegetation vigor. The understory has also been removed in many of the new median strips (see Appendix). New road construction seems to have little regard for the protection of median strips. In addition to effects on vegetation, water quality and stream dynamics have been impacted by increased runoff and sedimentation. This could have been largely avoided by applying inexpensive best management practices for erosion and sediment control.

Many forest systems which become fragmented or disturbed by human activities are quickly degraded by invasive exotics (weeds), Kendrick (1994) has not noticed any significant influx of weeds in remnant forest patches in The Woodlands. He suggests that weed growth is enhanced following disturbance but that these are quickly replaced by succession of natural vegetation. Kendrick attributes this succession to The Woodlands emphasis on understory retention. Professor Paul Harcomb, Chairman of the Department of Ecology and Evolutionary Biology at Rice University confirmed Kendrick's opinion of the weak weed response in fragmented pineywood forests. In his view, this forest type appears to be substantively resistant to weeds, and that there are only a few relatively innocuous invasives. This assessment was further supported by Craig Rudolph of the Southern Forest Experiment Station in Nacogdoches (Rudolph 1994). Since many forest systems are much more susceptible to invasion by exotic invasives, The Woodlands "hands-off" approach could not be generally applied to other developments.

The use of fire in management of protected natural areas has not been considered, nor has there been any recognition of the need to maintain other natural disturbance regimes.

Inattention to protection of high quality natural sites

Bedias Lake is secure in the short term, but is threatened by the proposed reservoir on Spring Creek (LeBlanc 1994a). Mooney Pond has been altered for stormwater detention purposes (LeBlanc 1994a).[98] Neither LeBlanc (1994) or Heineman (1994) were aware of the location of the other high value sites recommended for protection by WMRT, nor whether these still existed. These sites were considered the biological highlights of the site by WMRT biological consultants (WMRT 1974a). Without an adequate buffer zone (which was not recommended by WMRT), the protection of these areas may not have been important at the landscape scale. Nevertheless, their protection would have provided baseline examples of the original system, which is important for evaluating the impacts of development.

[98]In its natural state, Mooney Pond was a shallow pond, with emergent grasses. It has since been excavated to an average depths of 3 meters.

Reduced emphasis on new homeowner orientation to environmental vision

The impacts of the reduced educational efforts of The Woodlands are difficult to quantify. The booklets and brochures that have replaced personal tours are well written and informative. Nevertheless, they do not convey the message of conviction that derives from a personal touch. If The Woodlands philosophy is as important as purported, it seems the minimal additional cost associated with running orientation tours would be insignificant relative to the sense of philosophical conviction these would portray. The Woodlands Corporation would also need to more rigorously enforce breaches of development standards.

5.8 Waller Pond Preservation and Aquatic Ecology

Waller Ponds and the construction of artificial impoundments

The ecological value of the Waller ponds was emphasized by all WMRT consultant biologists. Yet, from early on in the development phase, these areas have been systematically excavated for use as stormwater detention ponds to support the modified drainage system, and for aesthetic and recreational purposes. This excavation is viewed by The Woodlands as environmental enhancement (LeBlanc 1994). However, excavation has not followed any of the guidelines contained in the WMRT reports, most of the ponds being constructed with steep sides and providing little opportunity for establishment of aquatic plants. USFW inspections of The Woodlands expressed the view that "enhancement" techniques were creating poor quality habitat.

Up until very recently, excavation was not regulated, and occurred without any oversight from Federal agencies (LeBlanc 1994). The Army Corps of

Engineers (COE) were the only active agency controlling wetlands modification up until the late 1980s, when the U.S. Fish and Wildlife Service (USFW) also became active in pursuing their regulatory obligations under various Federal acts. According to LeBlanc, the COE apparently agrees with The Woodlands assessment that Waller pond excavation constitutes enhancement.

More recent interpretations of Section 404 of the Clean Water Act (1972) now consider excavation as a form of fill, so further Waller pond excavations will require COE permits (LeBlanc 1994). LeBlanc sees no problem with this, but believes future excavation design will have to be more environmentally responsive, by developing greater pond heterogeneity (shallow areas with emergent macrophytes for example).

LeBlanc (1994) stated that he recognized inadequacies in pond construction methods and had begun limited enhancement of one pond by transplanting emergent vegetation. Corporate funds however, had not been allocated to any formal enhancement program (as would be needed to re-contour pond edges), and the use of volunteers was not considered an option because of liability risks.

At present, there is no monitoring of biota, and no evaluation of changes in biota from pre-enhancement to post enhancement has been conducted (LeBlanc 1994). Poche (1973 p.102) had noted a rich diversity of frogs and other amphibians dependent on Waller Ponds and it must be assumed that these and most other formerly extant fauna (and certainly flora) no longer exist on "enhanced" Waller ponds. Most enhanced pond surrounds are mown grass. In some cases, housing is very close to the ponds. This construction approach to these ponds contravenes every condition considered by Cicero (1989) to be important for enriching bird communities associated with urban ponds (see discussion in Chapter 2).

Evergreen Park exemplifies The Woodlands Corporation's lack of attention to Waller Pond protection (see Appendix). Evergreen Park was not converted to a detention pond, but has nevertheless been modified to a picnic area. The former Waller pond on which the picnic site is located is bisected by a road, which in my view could easily have averted the pond, since there is no adjoining development, and the pond is only about an acre in size. The invasion of trees in the area north of the road suggests that the road has had a serious impact on the site's hydrology. The picnic area south of the road is a verdant green, suggesting that there is a risk of fertilizer leaching into the adjoining remnant vegetation.[99] Grass clippings from the picnic ground are dumped in the remaining Waller area. My impression was that everything was being done to degrade, rather than protect what WMRT considered an important ecological feature of The Woodlands.

Bulkheading along the entire perimeter of Lake Woodlands has removed the transition zone between aquatic and terrestrial ecosystems, and has substantially destroyed the considerable ecological value of the interface. This bulkhead excludes fauna reliant on the interface zone, and significantly inhibits the movement of species that interact between habitats. The populations of most amphibians, turtles, waterfowl, and fauna dependent on

[99]Waller ponds are characterized by naturally very low fertility soils.

the interface vegetation must be severely restricted by this action. Felton (1994) states that there is very little birdlife on the lake.

WMRT 's considerations of aquatic ecology

Maestro, in An Ecological Inventory (WMRT 1974a)[100] dismisses extant aquatic ecosystems as having any ecological value. The "intermittent nature of the streams inhibit (the) presence of game and fish and most other "typical" stream wildlife" (WMRT 1974a p.60). This assessment directly conflicted with the concurrent work of Poche (1973 p.72) who stated that "several lakes, Spring Creek, and Panther Creek are rich in fish." Poche (1973) listed 40 species of fish resident in waterways and ponds within The Woodlands site. Beaver, nutria, and an alligator, all large permanent water dependent species were also recorded on site by Poche (1973).

Contrary to Maestro's dismissal of its value, the site clearly contained a diverse aquatic wildlife. This aquatic species richness was almost entirely ignored by WMRT. Extant fish were not incorporated in the Ecological Plan, and reptiles and amphibians - other water associated species - were only listed in an Appendix (WMRT 1974a), and not otherwise addressed in discussions on wildlife. Since Poche was funded by The Woodlands Corporation, it seems unlikely that WMRT did not have access to this information.

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[100]Robert Maestro was a consultant wildlife biologist. His work is the dominant influence on WMRT's considerations of wildlife in the ecological planning process. Though the WMRT reports refer to work done by Richard Poche, the other wildlife analyst, it seems obvious that WMRT did not have access to his Masters thesis (1973) when they developed their reports. The views of Poche are often in direct contrast to those of Maestro, with Poche being much closer in his thinking to contemporary ecologists.

Despite this omission and the lack of information on aquatic ecosystems and their biota, artificial impoundments are enthusiastically espoused because they would benefit aquatic species (WMRT 1974a pp. 61, 63, 64). The introduction of game fish is also advocated, but with no consideration given to potential impacts on extant biota through competition and predation. Though simplistic, WMRT's guidelines for pond and lake construction are comparable to approaches recommended in today's limnological literature (National Research Council 1992).

WMRT did recommend a long term limnological study be undertaken of Panther Creek and lakes on the site.[101] However, this survey was never undertaken, therein excluding a major component of The Woodlands ecosystem from the planning process. Since much of the planning for The Woodlands has entailed modifications to aquatic systems, this omission has significantly limited opportunities to assess the level of impact of subsequent development.

Water quality in site watercourses and ponds

Wastewater was originally intended to be treated to tertiary standards. This has been lowered to advanced secondary,[102] which is the standard required by the San Jacinto River Authority (SJRA). SJRA are responsible for monitoring and maintaining the quality of water entering Lake Houston, which is a major drinking water source for Houston.[103] Bill More (1994) of SJRA states that it is difficult to justify treating beyond this standard for cost reasons. He says

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[101]Their suggested methodology was comprehensive and included analysis of biological, physical, bacteriological and chemical parameters. The biological analysis would have covered aquatic invertebrates, fish, aquatic plants, and other organisms in the benthos and water column.

[102]This entails an additional filtration beyond secondary treatment. It does not remove nutrients and heavy metals.

[103]SJRA measures BOD, dissolved oxygen, ammonia, and suspended solids.

water quality standards are being maintained in Spring Creek, downstream from the point where wastewater is discharged from The Woodlands, except in storm events. More (1994) adds though that he "would hesitate to say we don't have problems (with the quality of water within and discharged from The Woodlands)."

More says that water levels and water quality have so far been maintained in Lake Woodlands, but adds that he is concerned the lake may be susceptible to stagnation if there is a prolonged dry period.[104]

5.9 Monitoring and Evaluation

Temporally, WMRT's ecological planning process for The Woodlands stands out very much as a one shot deal. In reading the Ecological Plan (WMRT 1974d), the impression is gained that the design was meant to be appropriate over the life of the development. Little avenue was provided for evolution towards more effective ecological protection, as new information came to hand. But considerable opportunity existed for devolution. For example, note previous discussion of the problems associated with attaching linchpin status to the natural drainage system.

Despite their failure to recognize the necessity for flexibility in their plan, WMRT does recognize the need for monitoring. This, they view as important for evaluating the ecological and social performance of design concepts

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[104]WMRT's original proposal was to employ groundwater to maintain water levels and quality in the lake (on the incorrect premise that yield was sustained). Lake Woodlands is now maintained solely by runoff. Most of the lake's inflow still derives from relatively undeveloped portions of the site. As these develop, water quality may degrade.

(WMRT 1974d pp. 75-76). WMRT viewed the site as an ideal laboratory for a unique experiment in ecological planning, stressing that their comprehensive ecological baseline would enable detailed measurement of bio-physical changes resulting from development.[105] WMRT recognized that measuring performance of The Woodlands was crucial for understanding the limitations and opportunities of the ecological design process, and for enabling its development as an accepted urban design technique. However, as has been discussed previously, their ecological baseline was inadequate in many respects, and would therefore have been of limited value in evaluating the "performance" of the ecological planning approach. In addition, WMRT provided no framework to enable The Woodlands Corporation to follow up on their suggestions for monitoring and performance evaluation, or to effect changes to the plan.

For their part, TWC failed to pursue WMRT's recommendations for additional, more comprehensive biological surveys.[106] If undertaken, these may have provided the baseline required for meaningful evaluation of the ecological planning process, and changes in The Woodlands ecosystem.

TWC also seems to have ignored the work of Poche (1973). The main purpose of Poche's wildlife work in The Woodlands was to develop a monitoring system to enable evaluation of the effects of development on wildlife. Poche (1973 p.87) stated that yearly or seasonal monitoring "may be of considerable aid in evaluating a system for maintaining wildlife in an urban environment." He

[105] WMRT assumed that development would proceed as outlined in the Ecological Plan, an event that did not transpire.
[106] More detailed inventories were recommended for vegetation and wildlife, including micro-organisms, invertebrates, and aquatic biota.

also contends that progressive monitoring would permit mid-course corrections to enable the implementation of protective measures to aid species found to be especially sensitive to development (Poche 1973 p.92). Poche's work was funded by TWC, so it seems highly improbable that they did not have access to his completed thesis. Yet there has been no monitoring of any kind conducted in The Woodlands since the initial wildlife surveys were undertaken.

Without an adequate ecological baseline, or data from subsequent monitoring of ecological changes, evaluation of The Woodlands ecological success is necessarily restricted to mostly qualitative assessment.[107] This makes it difficult to specify modifications to particular ecological planning techniques employed by WMRT to enable their more effective application in contemporary planning situations.

5.10 Implications for Future Planning

Overall, WMRT's ecological planning approach was significantly limited by lack of a landscape ecological framework. Their approach was further inhibited by inadequacies in their baseline data. This data was inadequate for supporting several of their key recommendations. These recommendations consequently failed to adequately mitigate the negative effects of habitat fragmentation. Weak baseline data also prevented meaningful evaluation of the ecological changes induced by development.

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[107] Quantitative assessment of existing patch size, and corridor width and connectivity may be possible from air photos.

Nevertheless, despite fundamental flaws in their analysis, the revised general plan that resulted from WMRT's integrated approach would still have protected 44% of the site as open space (see Figure 3.7).[108] Because of the presence of several larger habitat patch and a high degree of connectivity, this plan - had it been implemented - would have resulted in a significantly better ecological performance than a conventionally engineered approach to development. In the final plan, just over 30% of the site was slated for protection as natural habitat. In addition, the intended suburban environment would have contained a large amount of remnant natural vegetation. This might have supported a higher abundance and diversity of moderately sensitive species than in a conventional development (Goldstein et al. 1986).[109]

WMRT's ecological planning approach was considered exceptionally innovative for its time. It attempted to be holistic in its scope, and importantly, emphasized the interconnectedness of landscape elements and the constraints these imposed on development. Their approach in scope and thoroughness was flawed by contemporary ecological planning standards, and failed to address many current conservation concerns. Nevertheless, compared to present development practice, The Woodlands "innovative" label is still applicable, especially in relation to hydrological design and pursuing general principles of built form following natural function.

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[108]This plan includes a number of compromises that came from the incorporation of other development goals, primarily financial.
[109]Includes those capable of tolerating human presence if vegetation conditions are suitable.

There are four main reasons why subsequent approaches to urban development have failed to improve on the central elements of The Woodlands original design.

1. Unlike George Mitchell, few developers have had the capital and temporal flexibility to invest in a development on the scale of The Woodlands. Increased property prices, and an erratic housing market (and economy) are added disincentives.

2. There is no longer federal support available to initiatives on the scale of The Woodlands. This follows the general failure of the "New Towns" initiative, HUD's incompetence in managing federal grants and loans (Morgan and King 1987), and Executive reorientation of HUD's priorities away from funding for private town development. The financial responsibility for large scale developments now rests solely with the developer.

3. Since the early 1970s, numerous local, state, and federal regulations have been introduced to govern development procedures. These have controlled some ecologically negative practices, but their "command and control" approach has also hindered design innovation. Most regulations are very narrowly focused and unable to facilitate a planning approach that applies a landscape ecological framework. For example, the Endangered Species Act (1973) has a single species focus that limits consideration of a whole ecosystem approach. This contributes to declines in the populations of presently non-threatened species through incremental loss and fragmentation of habitat.

4. The lack of monitoring and evaluation of ecological performance during the development of The Woodlands, as well as other attempts at sustainable

development, provides no learning capacity for the development industry or its critics. Each new attempt at ecological planning must start from scratch, there being no information available from previous attempts about what worked or didn't work to achieve ecological goals. As with any project requiring implementation over extended time frames, the failure to install feedback mechanisms to facilitate mid-course corrections can significantly weaken a project's durability. This omission undoubtedly contributed to the failure of ecological planning at The Woodlands and should provide lessons for future ecological planning efforts.

CHAPTER 6

CONCLUSION

As stated in the Introduction, I have had two principle objectives in critiquing the use of ecological planning in The Woodlands. The first of these has been to see how successful ecological planning has been in The Woodlands relative to original goals and contemporary conservation concerns. Second, I have sought to determine the worth of ecological planning for achieving ecological protection in contemporary suburban developments, i.e. to determine what level of ecological integrity can realistically be preserved.

The first part of Chapter 6 deals with the first of the objectives stated above. The second part attempts to address issues related to the future of ecological planning based on lessons learnt from The Woodlands case study.

Because of the absence of quantitative data on the performance of key elements of the Ecological Plan, it is not possible to pinpoint precise ecological impacts resulting from The Woodlands development. Nevertheless, using landscape ecological theory and studies conducted elsewhere on similar disturbance events, it is possible to project the likely impacts.

6.1 The Woodlands

Ecological Planning Phase

The Ecological Plan developed by WMRT was a well intentioned and moderately well considered plan for its time, taking into account the considerable limitations in available ecological knowledge in the early 1970s. Had it been implemented as intended, the ecology of The Woodlands would most likely have a higher integrity than that which exists today. This view is based on the fact that the original plan would have preserved at least three times as much natural open space, including areas of interior habitat. These areas would have also possessed a greater degree of connectivity. Waller ponds would have been protected and water quality would have been improved by natural drainage. It is also possible that the increased attention to vegetation preservation envisaged for the developed areas may have supported increased numbers of moderately sensitive species in the suburbs.

Importantly, for contemporary planning, The Woodlands may have provided a useful laboratory for analyzing some aspects of the ecological planning process. For example, it might have been possible to assess the effectiveness of natural drainage as an alternative system for managing stormwater, and maintaining water quality in recipient streams and waterbodies. Had natural drainage been proven effective at each stage of The Woodlands' development, this assessment could have made a substantial contribution to urban drainage design. As another important example, determining changes in the use of corridors and habitat patches by wildlife would have made a major contribution to present scientific understanding of ecosystem responses to development. Today, there still exists no comprehensive long term assessment of changes in species abundance and diversity in response to residential development.

Despite these possible benefits, WMRT's Ecological Plan was nevertheless seriously flawed in several respects. Based on the landscape ecological literature, these flaws probably would have significantly limited the plan's ecological success relative to contemporary conservation goals of maintaining maximum biodiversity. The plan's flaws are of two types, those that inhibited the plan's implementation, and those that would have inhibited the plan's ecological success had they been implemented. In pointing out these flaws, it is recognized that several of these failings may have resulted partially from limitations in the scope of WMRT's consultancy.

Planning flaws inhibiting implementation of the Ecological Plan

Emphasizing natural drainage as the cornerstone of the Ecological Plan
Though the promotion of a holistic approach to planning is commendable, WMRT erred in not sufficiently emphasizing the value of each contributing element to The Ecological Plan. The plan's success was pinned to natural drainage. When natural drainage was discarded for reasons not foreseen by WMRT, the impetus to pursue interconnected ecological goals, for example habitat protection and water quality, dissipated.

Inadequate consideration of scale
Implementation of the Ecological Plan at the site and neighborhood scales depended on the developer and builders being able to interpret WMRT's guidelines at a very fine grain. When the plan's executors were unable to do this because of inadequacies in WMRT's ecological data maps and inadequate training in interpreting the plan, fine-grained ecological planning was quickly abandoned. WMRT's failure to adequately anticipate and plan for these difficulties was a major oversight on their part. These early difficulties may have weakened the credibility of other elements of the plan.

Plan inflexibility

The utility of the Ecological Plan over time was severely limited by its inflexibility and a lack of contingency provisions to enable adjustment to changes in market demand, fluctuations in the economy, supplemental land acquisitions, and advances in ecological knowledge. With no guidelines provided by WMRT and no-one on The Woodlands Corporation staff capable of restructuring the plan to adapt to these changes, the plans applicability was progressively diminished.

Ecological failings of the Ecological Plan

The most significant ecological failings of the Ecological Plan are as follows

Failure to consider regional scale effects

WMRT's failure to consider The Woodlands regional ecological context is a significant failing of their planning process. As Chapter 2 demonstrated, many current conservation concerns, especially in relation to the maintenance of biodiversity, are frequently best addressed at the regional scale.

Inadequate consideration of wildlife

WMRT's attention to wildlife preservation was deficient in virtually every respect. For example, their focus on promoting the conditions that support common game species contrasts directly with current conservation objectives. Overall, WMRT's wildlife analysis was totally inadequate for informing truly "ecological" planning. The failure of WMRT to recognize the poor quality of the consultant's wildlife assessment highlights the importance of cross-disciplinary awareness by planners. Planners need not know as much technical detail as consultants but they do need to be aware of what questions the consultant should be seeking to answer.

Inadequate consideration of fragmentation effects

WMRT failed to consider how fragmentation of the extant ecosystem would affect the integrity of remaining vegetation and viability of wildlife populations.

Failure to specify an adequate program for management of natural areas

Based on their wildlife analysis, this failing may have been fortuitous. Nevertheless, maintaining the integrity of natural areas in suburban mosaics is dependent on appropriate management, a fact that should have been stressed by WMRT.

Failure to specify a program for monitoring and evaluation during and post development

The value of monitoring and evaluation for building understanding of the efficacy of ecological planning is mentioned by WMRT, but no guidelines are provided as to how these should be conducted. In this and several other instances (plan inflexibility, recommendations for further studies), WMRT relied heavily on TWC adopting their vision and pursuing their generalist suggestions. This was an error in judgment about the level of expertise and commitment of the developer.

Implementation phase

The Woodlands of today bears little resemblance to that envisioned during the development of the Ecological Plan. Virtually all of the central, guiding ecological concepts which were to shape The Woodlands have been discarded in favor of a conventional development approach. Although the early construction in Grogan's Mill retains some elements of the Ecological Plan, most development during the 1980s through to the present has been little different from conventional developments. The only significant difference in the approach taken by The Woodlands is the minor attention given to the retention of natural vegetation (including understory) during construction. As discussed in Chapter 5, this attention may have resulted in slightly more vegetation being retained than conventional development processes,[110] but the degree of retention is not spatially consistent through the development and is wholly inadequate for maintaining the most important ecological features and functions of the site. By contemporary conservation standards, the ecological value of the vegetation retained is considerably less than that perceived by The Woodlands Corporation and residents.

Far from how it is portrayed by The Woodlands Corporation, The Woodlands is not a "self-sustaining development," it is not co-existing in "harmony with nature," nor can it be said that "careful attention has been paid to ecology" (TWC 1993a,b,c,e). The Woodlands is not practicing "uncompromising dedication to the protection of the native forests of The Woodlands" (TWC

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[110] This is probably open to debate, since I saw greater tree retention in the adjoining township of Shenandoah, though there was no understory retained. Shenandoah houses were also on larger lots than most of the new development in The Woodlands. Interestingly, they also employed the same lot-scale grassy swale drainage system as The Woodlands.

1993f), and far from the claims of George Mitchell (TWC 1993g p.2), The Woodlands Corporation has not "demonstrated that profitable development can meet the needs of people and be sensitive to the environment."

In summary, The Woodlands Corporation has:

- substantially reduced the extent and diversity of habitat preserved on The Woodlands, mostly as a result of abandoning natural drainage and encroachment by golf courses, residential development, and reservoirs,
- failed to protect interior habitat, necessary for the maintenance of sensitive interior species,
- destroyed many of the wetland systems (Waller Ponds) on the site, replacing them with ecologically depauperate open-water ponds,
- destroyed all corridor connectivity with residential development, roads, reservoirs, and golf courses,
- substantially weakened standards and enforcement protecting natural vegetation on individual residential lots.

Positive aspects of The Woodlands

Though The Woodlands has not lived up to its original expectations, and is far from ecologically sustainable, residents nevertheless derive significant "quality of life" benefits from the moderate attention to vegetation protection in some parts of the development. Better than average vegetation retention[111] significantly enhances the aesthetic quality of much of Grogan's Mill, the Town Center and parts of Panther Creek and Indian Springs. The microclimate in these areas is likely to be better than the newer suburbs

[111]Relative to conventional developments.

There is some possibility that a higher diversity and abundance of moderately sensitive bird species exists in these areas. Protected riparian vegetation may be maintaining some sensitive species on site in the short term, and is important in buffering the damaging impacts of runoff from developed areas on stream water quality. The general satisfaction of residents with The Woodlands all-round features should also be recognized.[112]

6.2 The Future of Ecological Planning

The overall failure of ecological planning in The Woodlands suggests that future efforts in this regard will require much more comprehensive analysis of ecological parameters both before and during development. Continual performance monitoring will be essential for ensuring that future ecologically planned developments can adapt to unforeseen negative pressures and respond to new information that can aid the planning process. Commitment by the developer, builders and homeowners to the philosophy of ecological planning will also be essential. The Woodlands suffered from not having an ecological planner permanently on staff, and this would seem to be an important requirement for ensuring long term commitment to ecological planning principles.

The Woodlands has shown that it is difficult to achieve integration of ecological protection goals with development goals. Integration requires more than consideration of the constraints and opportunities provided by the extant

[112] Residents accorded The Woodlands an 8.6 rating out of 10 as a place to live, and 8.8 for environmental quality (Bohlke and Associates Market Research 1992). It would be interesting to see how these ratings compare with The Woodlands residents ratings of other developments they have lived in.

landscape. Consideration must also be given to external economic pressures, the expertise of the developer and builders, and educating residents.

Attainment of optimal ecological protection goals, such as maintaining existing biodiversity may be close to impossible for individual developments. Yet, the landscape ecological literature also supports the view that a higher level of ecological functioning can be achieved through understanding the form and function of ecosystems, and flows within ecosystems. The ecological impacts of suburban development can be partially mitigated by understanding species behavior, protecting interior habitat, maintaining corridor connectivity, and mitigating the negative effects of the adjoining suburban matrix. Table 2.2 summarizes the main ecological principles that need to be followed when designing for ecological protection in suburban developments. Gap analysis (Scott et al. 1993), landscape resistance evaluation (Knaapen et al. 1992), hot spot identification (Prendergast et al. 1993), and analysis of rare and sensitive species behavioral patterns are amongst a growing number of other techniques available to planners to assist in minimizing the negative ecological impacts deriving from suburban development. There is also a growing wealth of "how to" literature on ecological planning approaches, for example Lahde (1982), Adams and Dove (1989), Adams and Leedy (1987).

Based on the literature, the most effective way to achieve goals of sustained biodiversity and representative protection of ecosystems in the face of suburban development needs may be to take a regional approach. A regional approach is most appropriate for directing development to where the least ecological damage is likely, and only a regional approach can avoid or mitigate the effects of incremental ecological degradation of ecosystems and their dependent biota.

At present, there is no regional plan to sustain the type of ecosystem found in The Woodlands (pineywoods forest). While the land area of The Woodlands is less than 0.1% of the total area of this system within Texas, it's development is representative of the process of incremental fragmentation and loss of interior habitat that is threatening the entire system (Stegman 1993). Were there in place a regional plan to ensure the protection of a sufficient area or areas of the pineywoods system to maintain its diverse functions and biota (allowing for catastrophic impacts), then development of The Woodlands may be of regional inconsequence. But until a regional overview is conducted, the broader ecological impact of The Woodlands development will remain unknown.

To reverse the problems of incremental ecosystem degradation, governments at all levels need to initiate and encourage private consideration of regional conservation goals.[113] Retaining existing regulations is essential for maintaining minimum standards, but additional mechanisms are also required

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113 They could do this for example, by examining ways of broadening the site specific focus of many planning and environmental regulations, and rewarding innovative planning, such as the Woodlands once was, by tax breaks or other inducements. Care would need to be taken to ensure inducements provide benefits for all sections of society, and do not contribute to the development of socially non-representative communities such as the Woodlands is evolving into.

that induce developers and landowners to go beyond compliance.[114] Improved interagency cooperation is also critical.[115]

Promoting higher living densities is one means of reducing development pressure on sensitive environments. But, this will be difficult to achieve, especially in Texas and other states where land values have traditionally been relatively low. As The Woodlands case study suggests, the market demand for single family housing is very difficult for developers to circumvent. In this respect, WMRT may have been at fault for overestimating market demand for the higher density housing they were advocating. Based on Fred LeBlanc's statements about the economic realities of spreading infrastructure costs, the greater demand for low density housing may have played a significant role in forcing The Woodlands' encroachment on the original open space allocation. Though this has not been studied, the failure of The Woodlands may in fact be not so much the fault of The Woodlands Corporation itself, but of its residents and their unwillingness to live at the higher densities advocated by WMRT, and to abide by vegetation protection requirements. To its credit, The Woodlands Corporation persists in its attempts to protect residential vegetation despite opposition and regulatory indifference on the part of builders, and the "lawn mentality" of home-owners. Notably also, there are no local conservation groups who have objected to The Woodlands Corporation's erosion of the original ecological vision for The Woodlands.

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[114]Attention needs to be directed to developing policies and procedures that provide financial recognition of private actions that provide public goods. The reverse is also true, in that private actions that detract from public goods, i.e. which create negative environmental externalities, should also be internalized into the private decision-making process.

[115]Harris (1984) and Salwasser (1991) describe the necessity of interagency management strategies in order to provide expanses of landscape sufficiently large enough to maintain viable populations and mitigate the problems of isolated parks.

Based on my observations of The Woodlands, the motivation for future attempts at ecological planning will need to come more from home-buyers and emerging communities. The Woodlands case suggests to me that successful ecological planning must be driven by demand not supply. Unless there is a much broader public mandate for increased attention to the protection of ecological values, it is my belief that ecological planning principles will not enter the planning and development mainstream to any significant degree. I must add though that this belief is based on a single case study and additional critiques of ecological planning efforts are required to confirm or disprove this belief.

It is regrettable that The Woodlands Corporation was unable to provide a laboratory for the analysis of ecological planning, as Wallace, McHarg, Roberts, and Todd had intended. But I believe understanding how it failed to do so provides valuable lessons for the planning profession, the development industry, community groups and others with an interest in ecological planning and environmentally sustainable development.

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APPENDIX

The Woodlands - Photographs

Figure 1. The Woodlands vegetation. The top photograph depicts the typical structure of the pine-hardwood forest that dominates The Woodlands. Note the dense understory, and mid story of hardwoods. In some places, hardwoods are less evident: in others, they form part of the canopy. The lower photograph depicts typical floodplain hardwood forest. Photographs were taken off Research Forest Drive and in Bear Branch respectively.

Figure 2. Early housing in The Woodlands. These photographs illustrate WMRT's concept of positioning housing within the forest. Photographs were taken in Grogan's Mill. Top photograph depicts some of the first model homes constructed in The Woodlands. Lower photograph depicts housing on small lots that retain substantial natural vegetation cover in vicinity of Red Cedar Drive.

Figure 3. Vegetation preservation in Grogan's Mill. Top photograph depicts street scene taken off South Millbend Drive. Lower photograph depicts housing on South Doe Run. Note, in the second photograph, the contrast between house set in natural vegetation and the completely grassed yard in the foreground.

Figure 4. Corporate landscaping in The Woodlands. Top photograph is of Trident Office building, taken off The Woodlands Parkway. Lower photograph depicts courtyard of office building designed and constructed by The Woodlands Corporation.

Figure 5. Drainage in The Woodlands. Top photograph is of typical grassed channel that has replaced naturally vegetated swales proposed by WMRT. Lower photograph (taken off Watertree Drive) is of grassed stormwater swale on residential lots in the estate section of Grogan's Mill. The type of drainage depicted in the lower photograph is largely restricted to Grogan's Mill.

Figure 6. Transition from preservation of natural vegetation to conventional grassed yards. Top photograph depicts housing on large lots in northern section of Grogan's Mill. Note removal of all understory. Lower photograph was taken in Panther Creek. Note reduced retention of canopy trees, reduced setbacks, and introduction of curb and channeling.

Figure 7. Recent housing in The Woodlands (constructed within last 5 years). Photographs were taken in Grogan's Mill. Note dramatic reduction in vegetation preservation compared to Figure 2.

Figure 8. Recent housing in The Woodlands. Top photograph taken in Grogan's Mill depicts transition from natural understory to exotic shrubs. Lower photograph is of typical street scene in Panther Creek.

Figure 9. Recent Housing in Cochran's Crossing. Note soil on road in top photograph.

Figure 10. Roadside vegetation in Grogan's Mill. Top photograph taken from Grogan's Mill Road. Lower photograph taken on South Millbend Drive.

Figure 11. Roadside vegetation in new suburbs. Top photograph taken from Golden Sage Drive in west Cochran's Crossing. Lower photograph taken from Cochran's Crossing Drive in north Cochran's Crossing

Figure 12. Change in median strip quality. Top photograph depicts naturally vegetated median strip on Timberloch Place. Lower photograph taken on Cochran's Crossing Drive north of Research Forest Drive.

Figure 13. Waller Pond conversions. Top photograph is of a Waller Pond in Grogan's Mill (off Vinebrook) that has been excavated for stormwater detention. Note absence of emergent vegetation, lack of buffer zone to adjacent housing, and paucity of vegetation within house yards. Lower photograph is of Evergreen Park (off Grogan's Mill Drive). This pond has been partially converted to a picnic area, and bisected by a road.

Figure 14. Converted Waller Ponds. Top photograph depicts Meadowlake Park in Panther Creek. This pond has one small patch of emergent vegetation, and is surrounded by an extensive grassed area. Note the proximity of housing. Lower photograph is of Mystic Lake in Cochran's Crossing. This pond has steep sides and supports no emergent vegetation. Note also its proximity to adjacent housing.

Figure 15. Lake Woodlands. Top photograph depicts typical housing adjoining Lake Woodlands. Note absence of buffering vegetation and bulkheading along shoreline. Lower photograph depicts housing constructed on fill adjacent to the lake.