A HABITAT EVALUATION AND MANAGEMENT PLAN FOR A RIPARIAN ECOSYSTEM

THESIS

Presented to the Graduate Council of the
North Texas State University in Partial
Fulfillment of the Requirements

For the Degree of

MASTER OF SCIENCE

By

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Denton, Texas
May, 1988

KLD

Wilkinson, Robert N., *A Habitat Evaluation and Management Plan for a Riparian Ecosystem*. Master of Science (Interdisciplinary Studies - Land and Water Resource Assessment and Management), May, 1988, 101 pp., 6 tables, 4 illustrations, bibliography, 56 titles.

Ecological research involving habitat studies was conducted on the Elm Fork of the Trinity River in Denton County, Texas, from spring 1985 to spring 1986. Habitat Evaluation Procedures and Habitat Suitability Index Models developed by the United States Fish and Wildlife Service were applied to a 1419 hectares study area to determine the quality of habitat for four species: beaver, *Castor canadensis*, wood duck, *Aix sponsa*, pileated woodpecker, *Dryocopus pileatus*, and white crappie, *Poxomis annularis*. Population estimates were generated. A wildlife management plan was developed for the study area. Habitat Suitability Index Models were found to be overly conservative, underestimating the quality of habitat in areas of ecological transition.

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CHAPTER I

INTRODUCTION

Research for this thesis was stimulated by a desire to combine water resource management with wildlife conservation. An opportunity arose to study a riparian ecosystem in conjunction with a conservation/recreation plan for developing a greenbelt on the Elm Fork of the Trinity River proposed by the Fort Worth District of the United States Army Corps of Engineers (USACOE 1983a). Justification for this research is based on the following premises. Water in Texas is scarce where needed most. Water quality can be maintained (thus controlling treatment costs) by limiting inputs into rivers and lakes. Preservation of riparian ecosystems is an effective means of limiting nonpoint source pollution of rivers in addition to promoting wildlife conservation. This research seeks to identify current environmental conditions, evaluate habitat, model future conditions, and provide a management plan for wildlife habitat enhancement.

Water is limited in much of Texas due to climate and demand. Water for Texas depicts current use in North Texas, and presents an optimistic view of future supply and demand (TDWR 1984). More than 80% of potable water in Texas comes from reservoirs. Reservoirs receive their water from streams and rivers. Chances of increasing water supply are limited, since few suitable locations for additional reservoirs remain. By the year 2030, demand is projected to exceed supply in all areas of North Texas (TDWR 1984). Efficient use and conjunctive management of all phases of the hydraulic cycle are necessary in order to conserve our limited supplies of fresh water (Templer 1980).

Protection and management of the riparian ecosystem (the stream and its adjacent terrestrial biotic community, soils, and bedrock) is essential to ensure that water of the highest quality attainable flows into the reservoirs. Soil and plants next to streams act as a "living filter," removing many natural and man-made compounds and preventing them from reaching the water supply reservoirs (Kardos 1967). Sediment erosion and runoff can be decreased by proper management of riparian ecosystems, such as preserving vegetative cover. In addition to preventing water quality deterioration, the riparian ecosystem provides habitat for more plant and animal species than any other type of ecosystem (Brinson et al. 1981). The key role played by riparian environments in sustaining the ecological well being of the region cannot be over emphasized.

Conservation of land, water and wildlife are the topics addressed in this thesis. Research is interdisciplinary, drawing on the academic provinces of biology, ecology and geography for its theoretical underpinnings, techniques for data gathering, analyses and interpretations. Habitat Evaluation Procedures (HEP) developed by the United States Fish and Wildlife Service are employed to study the Elm Fork of the Trinity River and its environs in North Central Texas (USFWS 1980). Research produces a baseline habitat evaluation for selected species. As part of this study, vegetative cover types are identified and measured. A 100-Year Model based on vegetative succession is produced to predict expected changes in available habitat. Modeling is based upon Soil Survey data on native vegetation. Population estimates of index species are attempted where data permit. A wildlife management plan is developed from the HEP analysis and recommendations found in wildlife literature.

Description of the Study Area

Located in Denton County, Texas, the study area bounds the Elm Fork of the Trinity River and associated terrestrial habitats. Positioned between 33°15' - 33°22'30'' north latitude and 97°00' - 97°7'30'' west longitude, the study area is contained within the Green Valley 7.5' topographic map (USGS 1968). North to south the area is 21 km in river length (10 km straight line). East to west the width is 0.8 km, for a total area of 1419 hectares The south end of the study area above Lewisville Lake is Federal property and may be as wide as 4 km in places. Figure 1 indicates the location of the study area.

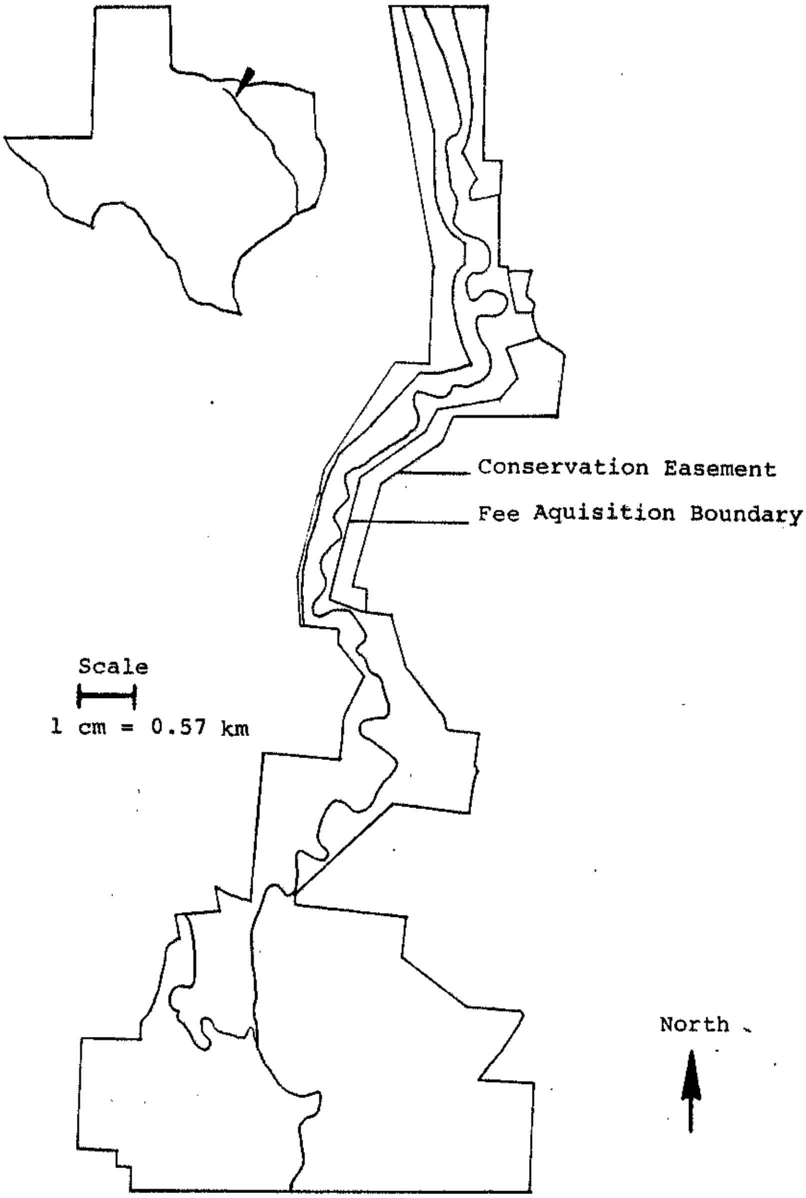

Figure 1: Study Area Denton County, Texas

The study area corresponds largely to what has been proposed as a greenbelt for conservation and recreational purposes by the United States Army Corps of Engineers (USACOE 1983a). Within the study area the Elm Fork is confined between two reservoirs. Lewisville Lake lies to the south; Lake Ray Roberts bounds the area to the north. The riparian ecosystem between these two reservoirs represents a diminishing resource. Many river valleys in this region have been lost to inundation stemming from reservoir construction as well as floodplain channelization and development. If a greenbelt is created on the Elm Fork, the ability to protect water quality and conserve wildlife habitat will be improved. Additionally, the greenbelt will provide many recreational opportunities not readily available within the region.

Physiography and Soils

Two major structural facies exist near the study area, influencing the physiography, soils and vegetation. To the west the Trinity flows through the Grand Prairie, which is underlain by calcareous deposits of Grayson Marl (UT 1972). On the east, the Trinity River abuts the Woodbine formation composed of sandstones, interbedded with layers of clay, marl and conglomerates. Between the calcareous deposits on the west and sandstones on the east lies a third zone, the terraces and floodplain of the Trinity River, composed of quaternary alluvia. Surface geology is dominated by these three facies, which influence the types of soils and associated plant and animal communities found in the study area. The variety of life found here can be attributed to this geologic diversity as well as to the presence of a permanent stream.

Most soils within the study area are formed on quaternary alluvia deposited in the form of overbank flood sediments. These vertisols and mollisols are generally deep, dark, high in organic matter and composed of silts and clays. Bottom land soils form some of the most productive agricultural land in the county.

Upland soils comprise a small but important part of the study area. These alfisols are subsumed under the Birome Rayex and Aubrey Complex of soils formed on the Woodbine Formation (USDA 1980). Blond to red in color, these upland soils are less fertile and contain less organic material than the dark bottom land clay soils. Yet these upland soils support a unique vegetation community the Eastern Crosstimbers, an oak woodland.

Climate

Climate is defined as the average amount of rainfall and available solar energy. Climate and soil directly control the types of vegetation found in a region (Strahler and Strahler 1976). Here the climate is transitional from the warm humid climates of the southeastern United States to the warm dry climates of the Plains. Climate is determined by a number of factors such as latitude, distance from the ocean, prevailing winds and reservoirs.

The climate for North Central Texas is a CFd type, or mesothermal with some dry years (Russell 1945). Soil Conservation Service researchers classify the climate as humid subtropical with hot summers (USDA 1980). Rainfall ranges between 81 cm and 91 cm per year (Jordan et al. 1984). Maximum rainfall usually occurs during April, May, June and September (Kingston 1983). Temperatures are variable but generally mild. Record temperatures have produced highs of 45°C and lows of -19°C. Maximum mean temperatures for July average to 35.5°C; minimum mean temperatures for January are 1°C. The length of the growing season on average is 226 days with the first frost occurring about November 8 and the last frost around March 27 (Kingston 1983).

Vegetation

Plant life reflects the transitional aspects of the geology and climate of the region. The Texan Province may be characterized as a "...broad ecotone between the forests of the Austroriparian and Carolinian provinces of eastern Texas and Oklahoma and the grasslands of the western parts of these states" (Blair 1950, p. 100). The Texan Province has a large number of plant species contributed from adjacent biomes. The transitional character of this province, while providing an abundance of species, precludes any from being endemic to the area (Blair 1950).

Grasslands are found to the west of the study area in what is known as the Grand or Fort Worth Prairie. Dominants of these mid-grass prairies are Western Wheatgrass, Agropyron smithii, Silver Bluestem, Bothriochloa saccaroides, Little Bluestem, Schizachyrium scoparium, Texas Wintergrass, Stipa leucotricha and Hairy Tridens, Tridens pilosus (Tharp 1926). Much of this original prairie vegetation has been destroyed due to agriculture and grazing, as well as through urban growth. Relic stands of the prairies are rare.

The Eastern Crosstimbers, an edaphic climax community bounds the study area on the east. The sandy soils formed in part from the underlying Woodbine sandstone provide the substrate for this Temperate Woodland biome (Whittaker 1975:139). Post oak, Quercus stellata, is the dominant species in this woodland (Tharp 1926).

The Eastern Crosstimbers has been greatly diminished by human activities. Initially the land was cleared for agriculture and firewood. As other fuels have become available there has been a return in some areas to oak woodland. In addition, reservoir construction and urbanization have claimed large areas of the Crosstimbers.

The third and largest vegetational zone represented is bottom land forest. Quaternary alluvia form the parent material for soils of this zone which is limited to the floodplain and first river terrace. Bottom land vegetation is the most complex cover type in the study area. Dense stands of bottom land hardwoods with a diverse understory form an area of great importance as wildlife habitat. Appendix A lists the tree and shrub species found within the study area. Bottom land vegetation is important in controlling runoff and soil erosion, as well as preventing chemicals used in agriculture from reaching the river and downstream water supply reservoirs.

Fauna

Fauna within the region reflect similar diversity as found in the vegetation. Large amounts of ecological edge created by the interdigitation of geologic substrates, soils, and vegetation provide habitat for many species. The 49 mammalian species, 2 species of terrapene, 16 species of lizards, 39 species of snakes, 5 species of urodols, and 18 species of amphibians, are not native to the Texan Province (Blair 1950). Only one vertebrate species, Pseuda steckeri, the tree frog, may be endemic (Blair 1950, p. 102). Avian fauna are represented by 82 species of which 36 are permanent residents of the study area and 46 are migratory (USACOE 1974). Between 21 and 28 species of fish are native upper Trinity River drainage basin (USFWS 1984). These fish are hardy and adapted to major fluctuations in water levels, flows and temperature which characterize the rivers of North Central Texas. Insects, microbes and other invertebrates are of tremendous ecological importance in terms of tropic interactions and nutrient cycling. It is not the realm of this thesis to address their roles aside from recognizing their importance and contributions to the overall community structure and function of the ecosystem.

CHAPTER II

OVERVIEW OF ENVIRONMENTAL EVALUATION TECHNIQUES

The National Environmental Policy Act of 1969 (NEPA) is largely responsible for the development and refinement of environmental evaluations. NEPA promulgated, as national policy, that an assessment of the impact on the environment be conducted prior to initiation of any Federally funded or licensed project (NEPA 1969).

Since NEPA's inception many types of environmental evaluations have been employed. Environmental evaluations may be classified in terms of the subject being such as social, cultural, economic, and biological impacts. Methods used to assess impacts vary according to the type of impact and project goals.

Early approaches to environmental impact assessment were primarily descriptive and qualitative. Descriptive EIA's are employed by urban planners, foresters, and soil scientists to identify gross characteristics of an area. Soils are classified in terms of crop production, suitability for building, and native plant composition (USDA 1980). Forests are categorized in terms of species composition and economic value (Avery 1978). Urban planners employ a Standard Industrial Classification to identify various urban land use types (USOMB 1972). In biological assessments this descriptive approach is termed ad hoc and includes an inventory of species present, identification of rare or endangered species, and general discussions of expected land use changes (Atkinson 1985). The ad hoc approach is limited since the methodology is specific to a particular locale and no attempt to quantify change is made. Furthermore, information from different projects cannot be systematically compared. Techniques for evaluating the environment have been greatly improved since the first endeavors. These new techniques possess a number of assumptions which warrant discussion.

Assumptions of Environmental Evaluation Techniques

There are a number of implied and expressed assumptions in the various habitat evaluation techniques. In general, these assumptions are concerned with ecological concepts such as habitat quality, secondary succession, carrying capacity, species diversity, and indicators of diversity.

Habitat quality is somewhat of a nebulous concept subject to individual judgement. It is concerned with which species are supported by a habitat and assumes that the presence of select species indicates a high quality habitat. Vegetative structure is a critical component of habitat quality and may be used to identify the habitat requirements of a particular species. Consequently, vegetative analyses are believed to be sufficient to identify the more important (limiting) habitat components. Most evaluations assume that the reproductive and breeding habits of wildlife are sufficiently documented to allow analysis.

Vegetational succession is a critical assumption, especially when attempting to predict future habitat changes. Habitat evaluations generally assume that a specific seral stage will be reached during the process of secondary succession.

Carrying capacity deals with the ability of a particular habitat to support a given number of individuals of a species. Biological evaluations assume that higher ranked habitats possess the greatest potential carrying capacity. Closely related to the concept of carrying capacity is species diversity. More vegetationally diverse habitats are assumed to be capable of supporting equally diverse wildlife populations. Furthermore, the greater the amount of edge or interspersion of habitats, the greater the diversity of wildlife.

Assumptions underlying the various habitat evaluation methodologies are believed to be sound and correct in most instances. The remaining question is the assumption that deals with succession. Once interrupted by human activities, vegetational succession may never return to the original native plant community. This makes projections of changes in habitat based on secondary succession suspect. Close monitoring of habitats believed to be returning to native communities should reduce this speculative aspect of habitat evaluations.

Types of Evaluation Techniques

A key element in assessing biological impacts is the effect of habitat modifications on wildlife populations. Numerous methods exist to determine the relationship between wildlife abundance and land use. These methods are classified here in terms of the approach used to evaluate wildlife habitat.

One group of evaluation methods focuses on general attributes of habitats measured by specific parameters. A parameter is a characteristic such as percent vegetative cover or dissolved oxygen content which can be used to evaluate environmental conditions. In contrast to the second group, these general procedures do not evaluate habitat in terms of a particular species (Erickson 1980).

A second group is composed of those methods of habitat evaluation possessing the following characteristics. Habitats are evaluated for numerous species and land use types. Techniques for inventorying key habitat factors are specified. Habitat quality and quantity are integrated into ranked values (Erickson 1980). Methods of this group are among those commonly employed in EIA and include the methodology utilized in this thesis.

Generalized Habitat Evaluations

Generalized habitat evaluations measure environmental factors without regard to any particular species. Texas Parks and Wildlife (TPW) developed the Wildlife Habitat Appraisal Procedure (WHAP) (Frye 1984). WHAP seeks to identify, evaluate, and quantify cover types using a set of specified parameters. WHAP assumes that vegetative structure is adequate to evaluate habitat suitability, that vegetative diversity indicates wildlife diversity, and that vegetative composition and primary production control wildlife population density (Frye 1984). WHAP is designed to establish baseline data, estimate impacts, and evaluate land in terms of its potential for wildlife management.

The United States Army Corps of Engineers (USACOE) Habitat Evaluation System (HES) classifies habitats and evaluates them by specified weighted parameters to produce a relative index of habitat quality (USACOE 1979). Habitat types include stream, lake, river, swamp, bottom land forest, upland forest, and open land. The size and composition of the habitat are included in the assessment.

Fresh water wetlands are of tremendous ecological importance. A hierarchical system for modeling and evaluating these habitats was developed in Massachusetts (Larson 1976). Eleven attributes critical to wildlife habitat are rated and multiplied by a significance value to determine the quality of the wetland. Wetlands possessing all eleven attributes are considered worthy of conservation and preservation.

The Soil Conservation Service (SCS) has produced a wildlife evaluation technique based on the premise that optimum habitats are those producing the greatest species diversity (USDA 1977). Habitats are classified into four types: woody, herbaceous, grain and seed crops, and water. Habitat types are evaluated for their diversity. Baseline habitat quality can then be compared to what is expected if the habitat is managed for wildlife.

Demand for quantitative methods of environmental assessments resulted in techniques such as the Environmental Evaluation System (EES) developed by Battelle Columbus (Cantor 1977, 1979). This methodology utilizes a weighted scale checklist approach to generate ranked values for a number of environmental parameters. EES organizes the environment hierarchally into 4 main categories, 18 components, and 78 parameters. Parameters are measured and ranked relative to optimum habitat conditions. Baseline analysis of parameters of interest is conducted and compared to estimates of the parameters after project completion. Net losses or gains in the parameters indicate adverse or positive impacts of the project. Information gained from the EES is applied to management decisions such as project alternatives, mitigation of adverse impacts, and compensation for losses. In Texas a modified EES was employed in assessing the impacts on a number of parameters affected by the construction of Lake Ray Roberts (Fitzpatrick 1972).

Species-Based Habitat Evaluations

Species-based habitat evaluations measure environmental factors in terms of suitability for a particular species. Wildlife management in the Blue Mountains of Oregon and Washington is addressed by Thomas (1979). Research is oriented towards habitat improvement, impact assessment, and land use planning. Vertebrates are classified into 16 life forms based on breeding and feeding habits. Plant communities and successional stages are examined in terms of how they are used by animals for feeding and breeding. Vulnerability of species to alterations of their feeding and reproductive requirements is assessed and ranked numerically. Optimum conditions can be identified and models developed to assist managers increase wildlife abundance.

Habitat Evaluation Procedures (HEP's) developed by the United States Fish and Wildlife Service (USFWS) represent the methodology used in this thesis (USFWS 1980). HEP's were designed to identify the amount and quality of various habitats. Cover types (habitats) are defined and quantified. Index species (those to be studied) are selected by organizing species into guilds based on reproductive and feeding requirements. Specified parameters are quantified to evaluate the habitat's suitability for an index species in terms of available acreage. Additionally, HEP's are used to project changes in habitat and for compensation analysis.

HEP's were selected for use in this thesis for the following reasons. To use HEP the physical and biotic characteristics of the study area must be identified and understood. HEP's are the most intensive and thorough of the various techniques available. By evaluating habitat for the needs of particular species HEP can be useful as a wildlife management tool. Finally, if HEP is mastered the other methods of evaluation can be readily utilized. The following section of this thesis will detail the use of HEP.

CHAPTER III

METHODOLOGY

Habitat Evaluation Procedures (HEP's) are the analytic techniques employed in this thesis. HEP's were applied to the study area to estimate its suitability as habitat for selected index (indicator) species. To conduct HEP's the following sequence of tasks was performed. 1. The study area was defined. 2. Vegetative cover types were identified and measured. 3. Index species were selected. 4. A Habitat Suitability Index (HSI) was determined for each index species. 5. The amount and quality of suitable habitat for each index species was determined. Information gained from these steps produced base line data on habitat suitability and availability. Identification of the major vegetational components present was the purpose of cover type analysis. Vegetative data were used to model future conditions on the basis of cover and soil types. Types of cover governed the selection of terrestrial index species, since species found in an area are controlled by the type of vegetation. Furthermore, cover type identification enables extrapolation of information on habitat from sampled to unsampled areas.

Cover Type Determination

Cover types were defined in terms of vegetative community or land use and quantified by total area encompassed. Seven cover types were identified within the study area. Temperate woodlands (the Eastern Crosstimbers) and bottom land forest are habitats defined on the basis of native vegetation. Agricultural (land currently in production), pasture, old fields (land once in production and now undergoing the process of secondary succession) and man made (the lacustrine plain of old Lake Dallas) are cover types defined in terms of land use. Aquatic cover is that area occupied by the river.

Identification of cover types was based on sample transects and photo interpretation. Cover types were mapped by overlaying a 7.5' base map with remote sensing data. Slide copies of false color aerial infrared photographs were projected on to a 7.5' topographic map. Cover types were identified and then traced on the base map.

Cover type was quantified by the cut and weight technique (Lind 1979). Once the vegetational map was completed a copy was made and the different cover types were cut out, sorted, and weighed on an analytical balance. The mass/area relationship was used to determine the area of land occupied by each cover type. On a copy of the 7.5' base map one square centimeter weighed 0.01 gram and equaled an area of 6.25 hectares.

In order to model the overall environmental conditions from the base line data to the 100-year target date it was necessary to estimate temporal changes in cover type. Expected changes in habitat were based upon the native plant community occupying a particular soil type. The assumption is that soil type determines the type of native vegetation. The model of expected native vegetation is based on interpretation of data contained in the Soil Survey of Denton County (USDA 1980). The 100-Year Model used in this thesis was based on the premise that in the study area 100 years is adequate time for bottom land forests to establish (Wilson 1986).

Index Species

Selection of the species to be studied is critical to producing a meaningful habitat evaluation. Index species should have a low threshold to changes in the environment (i.e., they should be sensitive to changes in their habitat). Species exhibiting a wide range of tolerances and habitat utilization make poor indicator organisms (USFWS 1980). Species possessing economic and/or environmental importance make desirable index species (USFWS 1980).

The first step in selecting an index species was to develop a species inventory for the study area. Secondly, the species were categorized into feeding and reproductive guilds based on their behavior and the geographic locations where these activities occur. After these organizational tasks were completed those species best meeting the requirements of HEP were selected as index species.

Numerous publications exist listing species found within the study area and region. The species lists in this thesis are composites derived from reports and personal observation (Fitzpatrick 1972, USACOE 1974, USFWS 1984). Appendices B through F list the species found in the region. Feeding and reproductive guilds of commonly occurring mammals and migratory birds were omitted since they either lacked the environmental sensitivity for selection, or their life requisites were not met in the study area. Appendices G and H represent the feeding and reproductive guilds developed for the study area. Species are classified as to their reproductive behavior and where they obtain the bulk of their diet.

Four animals were selected as index (indicator) species for evaluating the environment: beaver, Castor canadensis, wood duck, Aix sponsa, pileated woodpecker, Dryocopus pileatus, and white crappie, Poxomis annularis. Beaver was selected because the study area is on the western edge of its eastern range, and little is known of their habits in the region. Wood duck and pileated woodpecker are rare in the study area and believed to be sensitive to changes in habitat quality (USACOE 1974, personal observation). White crappie is a popular sport fish and fits the economic requirements for an index species.

Habitat Suitability Models

Once the index species were selected, a model of their individual life requisites was needed to evaluate the habitat. There are a number of Habitat Suitability Index Models available from the USFWS. Models for wood duck (Sousa and Farmer 1983), white crappie (Edwards et al. 1982), pileated woodpecker (Schroeder 1983), and beaver (Allen 1982) were employed in this thesis. The requirements of these models guided field data collection.

Measured parameters were converted into ranked values by applying Suitability Indices (SI) to every parameter for each index species. Then the HSI for each species and cover type was determined using the formulae contained in the habitat models. HSI's offer a crude attempt to quantification of the ecological carrying capacity of a particular study site. After establishing the HSI for each species, the values were used to estimate the total amount of optimum habitat expressed in terms of Habitat Units (HU's).

Habitat Units form the basis of HEP and represent the quality and quantity of all cover types utilized by a particular index species. HU's were calculated by adding the total area of all cover types used by an index species and multiplying by the appropriate HSI value for each species. The following sections discuss habitat models, data collection, and how data are used in the analysis.

Wood Duck Habitat Suitability Model

Three key variables were used to characterize a habitat's suitability for wood duck: the density of potential nesting trees, the percent of water surface occupied by brood cover, and the percent of water surface occupied by winter cover (Sousa and Farmer 1983). Appendix I indicates the relationship of the variables to the HSI for wood duck.

Nesting potential is determined by the number of trees with a mean diameter at breast height (dbh) greater than 28 cm. The mean dbh was determined by direct measurement of trees in quadrants along transects both perpendicular and parallel to the Elm Fork. The estimated number of acceptable sized trees is then placed in the following equation. No. of trees x 0.18 x 0.52 = No. of potential nest sites, where 0.18 is the utilization rate of suitable nesting trees, and 0.52 is the percent of successful nestings (USFWS 1983a). The percent of brood and winter cover is estimated by visual inspection. Additional variables affecting wood duck populations are the distance of nest trees to water, sheltered slow moving water from 7.5 - 45 cm in depth, and the presence of artificial nest boxes. Since trees of suitable size are all within 0.4 km of the river, distance is not a limiting factor. Much of the length of river also fits the optimum flow and depth criteria posing no limitations on wood duck. No nest boxes are presently located in the study area, thus they were not considered in the evaluation of current conditions.

Pileated Woodpecker Habitat Suitability Model

Seven variables were measured in evaluating the study area for pileated woodpeckers. These variables are (v1) the percent of canopy closure, (v2) the number of trees greater than 51 mc dbh, (v3) the number of logs and stumps greater than 18 cm in diameter, (v4) the number of snags greater than 38 cm dbh, (v5) the mean dbh of snags greater than 38 cm dbh, (v6) the number of snags greater than 51 cm dbh, and (v7) the mean dbh of snags greater than 51 cm (Schoreder 1983). These variables are designed to evaluate habitat in terms of the feeding and reproductive requirements of the woodpecker. Appendix J indicates the relationship of the variables to the HSI for pileated woodpecker.

Techniques for obtaining data were the same as those used for the wood duck. Transects were placed in areas representative of bottom land forest. The number and diameter of trees, stumps, and snags were taken by direct measurement. Percent cover (canopy closure) was determined by visual estimation of the percent of light penetrating the tree canopy in summer. The HSI was calculated using one of the following equations: (v1 x v2 x v3)1/2, or (v4 x v5)1/2. The lowest HSI was applied to the habitat evaluation (USFWS 1983b).

White Crappie Habitat Suitability Model

Twelve parameters were measured to evaluate the Elm Fork riverine habitat for white crappie. The parameters were gradient in m/km (v1, percent cover (v2), percent pools in summer (v3), pH (v5), temperature for adults (v6), temperature for fry (v7), and temperature for embryos (v8), dissolved oxygen in mg/l in summer (v9) and for spawning (v10), turbidity in Jackson Candle Turbidity Units (JTU) (v11), velocity in cm/sec. (v12), and maximum conductivity (v13). The percent littoral area (v4) was not employed in the study since it does not apply to a riverine environment. However, the variable enumeration sequence was retained in order to correspond to the habitat model. These parameters characterize the feeding and reproductive requirements of the white crappie (Edwards et al. 1982). Appendix K presents the relationship of variables to the HSI for white crappie.

Measurements of the water quality parameters were made in triplicate. Field work was conducted during the summer of 1985 to measure the worst case situation in terms of water quality. Dissolved oxygen was measured with a YSI 51B Oxygen Meter as was temperature. Conductivity was determined using a YSI Model 33 S-C-T Meter. Turbidity was measured using the Hach Model 2100A Turbidimeter. Turbidity was taken in nephelometer turbidity units (NTU) and converted to Jackson Candle Turbidity Units (JTU) by dividing the NTU reading by two (Lind 1978). Velocity was measured with a General Oceanics Model 2030 Flowmeter which was specially converted to measure low flow streams. Measurement of pH was taken with a Protomatic 175 pH Meter. All water quality parameters were measured in the field except turbidity, which was conducted in the laboratory.

Gradient of the Elm Fork was measured directly from the Green Valley topographic map (USGS 1968). Vertical distance between the highest and lowest parts of the river channel was determined by counting contour lines. Distance between the high and low points was measured using a cartometer. Gradient was calculated by dividing the difference in high and low elevation by the distance between these points.

Percent pools was calculated using a cartometer. The total length of meanders was divided by the length of the Elm Fork in the study area.

Percent cover was determined by visual inspection of the amount of light passing through the stream side vegetation, brush, and dead wood. A canoe was used as transportation to survey the amount of cover along the Elm Fork. Cover was characterized as 0 - 25%, 25%- 50%, 50% - 75% and 75 - 100%.

Beaver Habitat Suitability Model

Water and winter food are the primary considerations in the habitat evaluation for beaver (Allen 1982). The following eight variables were used in the evaluation: percent tree closure (v1), percent trees between 2.5 - 15.2 cm dbh (v2), percent shrub crown cover (v3), mean height of shrub canopy (v4), species composition (v5), percent steam gradient (v7), annual water fluctuation (v8), and shoreline development (v9). Variable six of the model deals with water lilies and does not apply in this situation. Enumeration of the variables was kept the same as in the model to avoid confusion.

Vegetation variables were sampled on transects placed parallel to the river. Percent tree cover (v1) was determined by visual estimation. The percent of trees with a dbh between 2.5 - 15.2 cm was directly measured. Crown cover percent (v3) was estimated by visual inspection and defined in terms of 0 - 25%, 25% -50%, 50% -75% and 75% - 100%. Mean height of the shrub canopy (v4) was directly measured. Species composition (v5) was determined by quadrant sampling with identification done in the field or lab as necessary. Stream gradient (v6) was determined by direct measurement off the Green Valley map (USGS 1968). Annual water fluctuations (v7) were determined from geological information (USGS 1983) and personal observation. Shoreline development was measured on the Green Valley map

(USGS 1968) using a cartometer, and calculated by the formula contained in Lind (1979).

CHAPTER IV

ANALYSIS AND DISCUSSION

Vegetational (Cover Type) Analysis

Seven cover (habitat) types were identified in the study area. Habitat types include bottom land forest, temperate woodlands, aquatic, agricultural, pasture, old field, and man-made. Table I shows the amount of land occupied by each habitat. In varying degrees all these habitats have been affected or created by man's activities, particularly timber cutting, ranching, farming, urbanization, and reservoir construction.

TABLE 1

Cover (Habitat) Types in the Study Area

Cover Type	Area (Hectares)	Percent Total
Bottom Land Forest	412	29
Temperate Woodlands	69	5
Aquatic	50	3
Pasture	38	3
Agricultural	394	28
Old Field	112	8
Man-Made	334	24
TOTAL	1419	100

Three habitat types comprise 81% of the total area in roughly equal proportions: bottom land forest, agricultural, and man-made (the lacustrine plain of old Lake Dallas). Bottom land forest is the most important since it supplies habitat for all the index species except white crappie. Agricultural land and pasture are pertinent to the evaluation because of their potential to support other cover types, particularly bottom land forest. The man-made lake bottom is not considered in the habitat evaluation or the 100-Year Model since much of it will be inundated when the level of Lewisville Lake is raised. Furthermore, the man-made habitat has not established the bottom land forest expected for this soil type in the 30 years since Lake Dallas was drained, and it is not expected to do so in the future, because the area will be innundated (USDA 1980). Figure 2 illustrates the distribution of cover types.

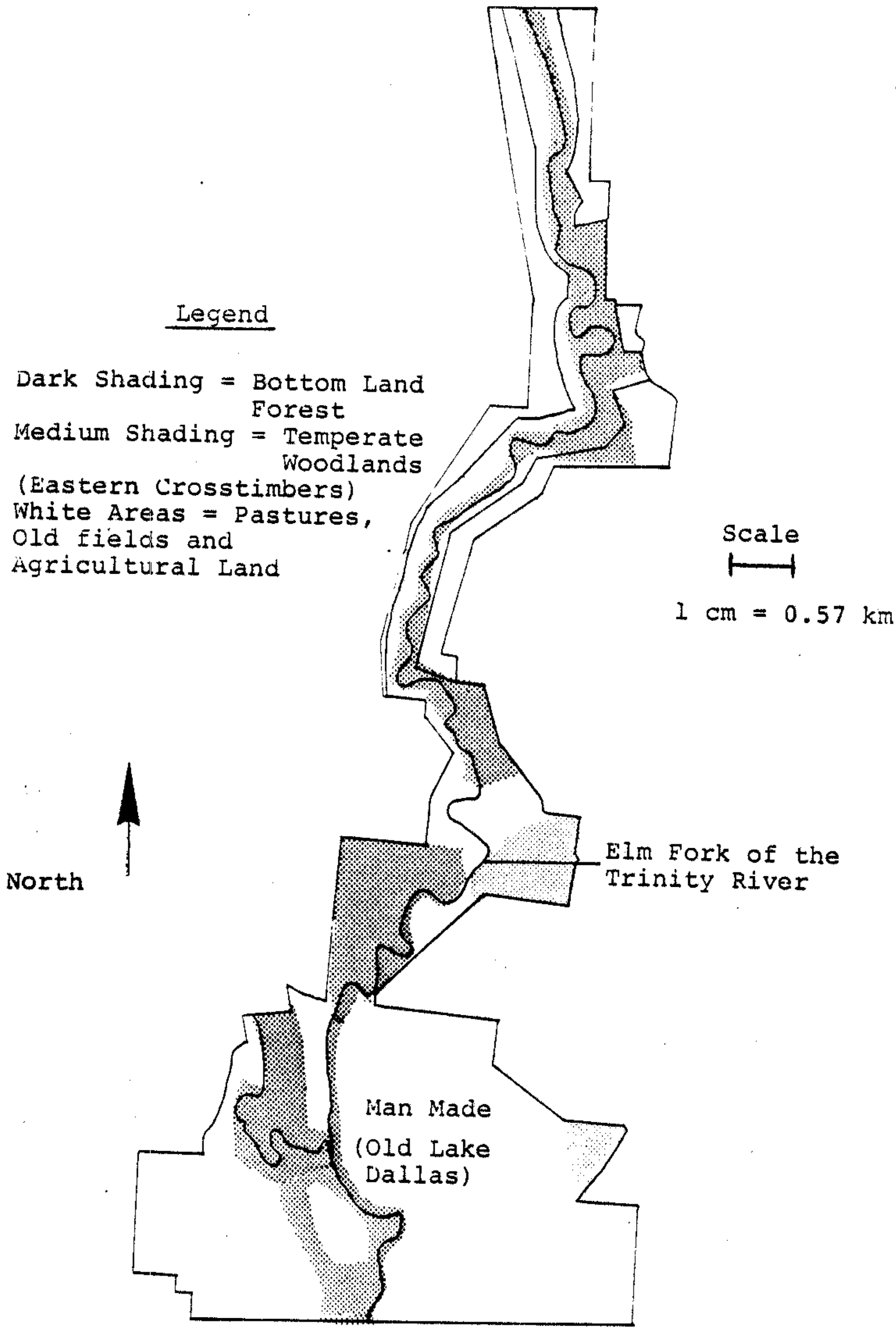

Figure 2: Simplified Cover Type Location Map

In North Central Texas bottom land forest is the only habitat where large stands of trees are naturally occuring (aside from diminishing areas of Eastern Crosstimbers). Presently, bottom land forest is the only habitat suitable for all the terrestrial index species within the study area, except for the 69 hectares of temperate woodlands marginally useful to the pileated woodpecker.

Aquatic habitat of 50 hectares is of much greater importance than its small area would indicate. The Elm Fork provides one or more of the life requisites upon which all the index species depend. White crappie, wood duck, beaver, and pileated woodpecker depend upon the river for survival.

Temperate woodland (Eastern Crosstimbers) is important in terms of its potential for wildlife. At present the 69 hectares occupied by the Eastern Crosstimbers are in secondary succession, dominated by immature stands of post and blackjack oaks. Personal observation indicates these areas will return to a post oak dominated woodlands characteristic of the Crosstimbers. The addition of mature stands of Eastern Crosstimbers to the area should increase the amount of edge and habitat for numerous species. Such an increase in a small but valuable cover type should raise the overall quality of the area for wildlife.

Baseline Habitat Evaluations

Habitat Suitability Models for wood duck, pileated woodpecker, white crappie and beaver were employed to evaluate the study area for each species (Sousa and Farmer 1983, Schroeder 1983, Edwards et al. 1982 and Allen 1982). Quality of habitat is determined from data applied to the models to establish a Habitat Suitability Index (HSI) for each species. The product of applying the HSI to the study area is a baseline habitat evaluation of its suitability to wildlife.

Wood Duck Habitat Evaluation

Wood ducks nest near water in cavities of trees greater than 28 cm in diameter. Flooded vegetation, shallow water, and mast crops provide food. Cover adjacent to water, such as shrubs, emergent vegetation, and downed trees, is critical for over wintering and as brood protection (Sousa and Farmer 1983). The habitat suitability model measures five variables to quantify the life requisites. Table 2 indicates the variables measured, actual values, and values as converted to ranked Suitability Indices (SI).

TABLE 2

Variables and Values for Wood Duck HSI

Variable Definition		Actual Value	Suitability Index
V1.	Number of Tree Cavities/ha. for nesting (dbh >28 cm)	0.5 trees/ha. (412 ha. X 0.5 =206 potential nest sites)	N/A
V2.	Number of potentially successful nests	(206 X 0.18 X 0.52 =18.54)	N/A
V3.	Density of Potential Nests / acre	(18.54 / 412 = 0.045 nests/ha.)	0.01
V4.	Percent of Water Surface Occupied by Brood Cover	10%	0.2
V5.	Percent of Water Surface Occupied by Winter Cover	10%	0.2

The highest value is used for wood duck HSI (Sousa and and Farmer 1983). Thus the HSI is 0.2.

The Suitability Indices rank the variables in ascending order of habitat suitability from 0 - 1.0. Data indicate that presently the study area is only marginally valuable as wood duck habitat. The overall HSI for wood duck is 0.20, indicating that only 10% of the water surface is occupied by usable winter and brood cover.

The estimated number of potential nest sites within the study is 19. Assuming 2 adults per nest, the maximum number of mature wood duck currently occupying the study area is 38. Since the area contains 1419 hectares the population density of wood duck is one nesting pair per 75 hectares. Optimum wood duck habitat contains about 12.35 nests per hectare (Sousa and Farmer 1983). The difference between optimum habitat population density and that of the study area is an indication of a species living on the edge of its range in a marginal environment.

Piliated Woodpecker Habitat Evaluation

Pileated woodpeckers are one of the largest varieties found in North America. Denton County is on the western edge of the species' range (Peterson 1960). Nests are in cavities excavated into large mature or dead trees usually greater than 51 cm dbh. Habitat is dense woods with a large number of snags. Carpenter ants are the prefered food (Schroeder 1983). A pileated woodpecker was sighted in the study area on April 11, 1985 near the Green Valley Bridge. Seven parameters were measured to assess the study area habitat for pileated woodpecker. Table 3 shows the variables, actual values, and SI conversions for baseline habitat assessment. Variables were measured by quadrant sampling and direct observation.

TABLE 3

Variables and Values for Pileated Woodpecker HSI

Variable Definition		Actual Value	Suitability Index
V1.	Percent Tree Canopy Closure	50% - 75%	0.8
V2.	Number of Trees > 51 cm dbh	2/ha.	0.03
V3.	Number of Logs and Stumps > 18 cm diameter	5/ha.	0.6
V4.	Number of Snags > 38 cm dbh	10/ha.	0.6
V5.	Mean dbh of Snags >38 cm	40 cm	0.25
V6.	Number of Snags >51 cm dbh	2.47/ha.	0.05
V7.	Mean dbh of Snags >51 cm	53 cm	0.25

Habitat suitability is determined by the following equations: (V1 XV2 X V3) 1/2 or (V4 X V5) 1/2 the equation producing the lowest value is used for the HSI.

So (0.8 X 0.03 X 0.6) 1/2 produces an HSI of 0.12.

The Elm Fork provides only marginal habitat for the pileated woodpecker. Stands of bottom land forest and temperate woodlands were cut, and only a few locations provide trees of appropriate size for nesting. Since the study area is on the edge of the species' range one expects low population densities. Multiplying the HSI of 0.12 by the amount of habitat potentially useful to the species 481 hectares (bottom land forest and temperate woodland) produces a value of 57.72 hectares habitat units. Thus, according to the model there is not sufficient habitat to support the species. Yet, pileated woodpeckers are present in the study area. As was the case for wood duck, the Elm Fork provides suitable habitat for pileated woodpecker, but the models used were developed from data derived from optimal habitats. It is apparent that models for avian fauna need modification for habitats on the edge of species ranges. I suggest that in the study area the unique character of the Elm Fork habitat, combined with the large amount of edge, mitigate to increase the value of what superficially appears to be unsuitable habitat.

An estimate of pileated woodpecker population density is based on the assumption that about 70 hectares of habitat are needed to support a nesting pair (Schroeder 1983). Currently there are 481 hectares of bottom land forest and temperate woodland habitat. Thus, there is habitat for around 7 pairs of nesting adults within the study area.

White Crappie Habitat Evaluation

White Crappie, Poxomis annularis, is a spiny rayed fish native to streams and lakes from the Great Plains eastward throughout the United States. Adults feed on forage fish (Miller and Robinson 1973). Spawning is from March through July. Nests are built on a variety of substraits at depths varying with water clarity. Spawning begins when water temperature reaches 13°C and can continue to 26°C (Edwards et al. 1982). In rivers white crappie prefer low gradient streams. Generally the species is tolerant of warm slow moving streams with moderate turbidity such as the Elm Fork within the study area. Table 4 indicates the parameters that were measured to assess the Elm Fork habitat for white crappie.

TABLE 4

Variable Values and SI for White Crappie

Variable Definition	Actual Value	Suitability Index
1. Percent Stream Gradient	0.043%	1.0
2. Percent Cover	37.5%	1.0
3. Percent Pools in Summer	32%	0.6
4. Percent Littoral Area	NA	NA
5. Yearly pH Range	6.5-8.5	1.0
6. Average Water Temperature July - August	29.6°C	1.0
7. Average Pool Temperature July - August	29.6°C	1.0
8. Average Water Temperature March - July	23.6°C	0.2
9. Dissolved Oxygen Summer>5 mg/l	>5 mg/l	1.0
10. Dissolved Oxygen Backwaters	>5 mg/l	1.0

The ranked SI variables were input into the equations presented in Appendix L.

Calculations resulted in a HSI for white crappie of 0.6638 in the Elm Fork.

Overall the Elm Fork provides a suboptimum but good quality habitat for white crappie. The main limiting factor is the high water temperatures during the spawning season. The model may be overly conservative since spawning season may begin earlier than March and end before July. If this is the case the HSI for the Elm Fork should approach optimum conditions.

Beaver Habitat Evaluation

Beaver, *Castor canadensis* is North America's largest rodent with weights reaching 30 kg (Caras 1967). Aquatic herbivores, beavers live in small ponds and low gradient streams. Prefered foods are willow, cottonwood, alder, and herbaceous vegetation (Caras 1967, Allen 1982). Beaver live in colonies of 6 - 7 individuals composed of adults, subadults, and juveniles (Davis 1974). Historically beaver have been prized for their pelts and their numbers greatly diminished by 1900 due to trapping (Davis 1974). In the study area beaver dig burrows into the stream banks rather than build dams. Prior to this research the presence of beaver was not documented in recent scientific literature pertaining to the study area.

Parameters measured to evaluate the Elm Fork habitat for beaver are designed to estimate water and winter food life requisites. Cover and reproductive needs of beaver are assumed to be the same as water life requisites (USFWS 1983b). Table 5 gives parameter ranges, mean values, and SI ranks for beaver habitat evaluation.

TABLE 5

Beaver Habitat Variables

Variable Definition	Range	Mean Value	SI
1. Percent Tree Cover	50%-75%	63%	0.9
2. Percent Trees 2.5cm-15cm dbh	66%-90%	74%	0.8
3. Percent Shrub Crown Cover	50%-75%	63%	1.0
4. Mean Height Shrub Canopy	2.5m-4m	2.9 m	1.0
5. Species Composition	Woody Vegetation Not Dominated By Willow or Cottonwood		0.6
6. Percent Lacustrine Dominated By Water Lily		N/A	
7. Percent Stream Gradient	0.043%		1.0
8. Annual Water Fluctuations		Moderate	0.5
9. Shoreline Development	SLD=13		1.0

Data were input into the equations shown in Appendix M. An overall HSI of the study area for beaver was determined to be 0.5.

Presently the Elm Fork provides a moderately suitable habitat for beaver. The main limiting factor is the annual fluctuations of water levels in the river.

Field survey documented 12 beaver colonies. Colonies were separated by approximately 1 km from each other. Figuring 6 individuals per colony, the population in the study area is estimated at 72 beaver. Beaver colonies on the Elm Fork are associated with fine grained sediments (silt and clay), seep springs flowing on top of Grayson marl, and sedges Carex spp. growing above the seep. It appears that the fine sediments produce burrows with more stable walls than would coarser sand sized particles. Sedges associated with the seep springs are believed to provide a food source. Figure 3 shows the location of beaver colonies within the study area.

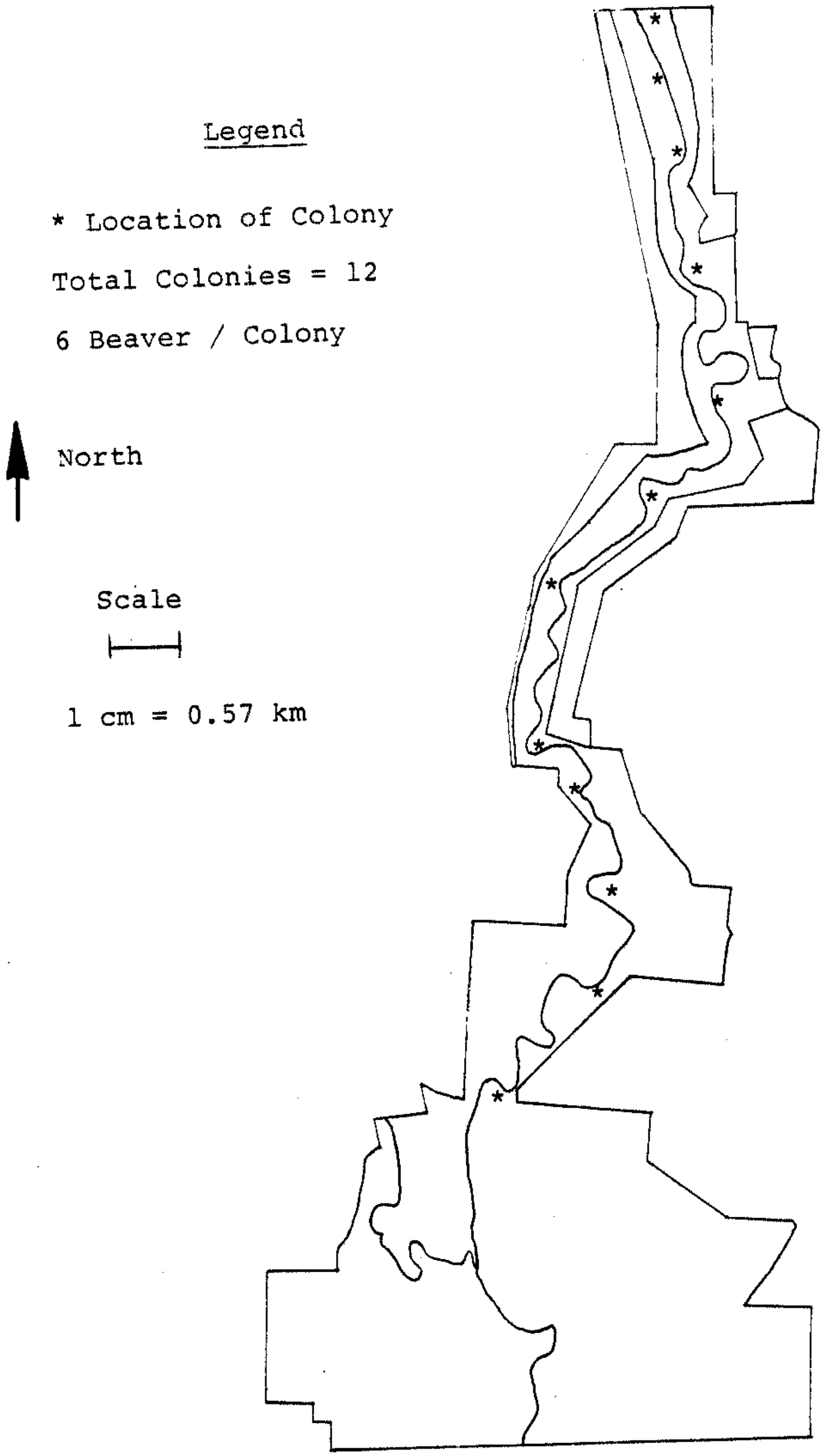

Figure 3: Map of Beaver Colony Locations

The 100-Year Model

In order to assist wildlife and recreational planning a 100-Year Model for changes in cover (habitat) type is presented. The model was developed from information contained in the Soil Survey of Denton County, Texas (USDA 1980). The main assumptions of the model are that a greenelt will be created preserving the area and allowing secondary succession to produce habitat types that are predictable, that the area will be managed in a way to allow natural succession to proceed, and that 100 years is sufficient time for native vegetation to reestablish.

A base map of the study area was overlain with a soil map. The area occupied by each soil type was quantified using the cut and weight method. Vegetation expected in the area was derived from descriptions of the native vegetation for each soil type found in the soil survey manual. Table 6 shows the area covered by each soil type and the cover type expected to occur in the area.

TABLE 6

Soils, Area Covered and Expected Vegetation

Soil Name	#	Family	Area Ha.	Vegetation
Altoga	2	Inceptisol	28	Prairie
Altoga	3	"	13	"
Arents	7	Arents	9	N/A
Bastrop	9	Alfisol	6	Temperate Woodland
Birome	12	"	6	" "
Birome	13	"	78	" "
Bunyan	20	Entisol	38	Bottom Land Forest
Burleson	21	Vertisol	6	Prairie
Callisburg	23	Alfisol	3	Temperate Woodland
Ferris	32	Vertisol	3	Prairie
Frio	33	Mollisol	13	Bottom Land Forest
Frio	34	"	134	" " "
Gasil	35	Alfisol	15	Temperate Woodland
Kaufman	49	Vertisol	125	Bottom Land Forest
Ovan	64	"	806	" " "
Trinity	78	"	6	" " "
Trinity	79	"	6	" " "
Wilson	84(1)	Alfisol	22	Prairie
Wilson	84(2)	"	13	"

Cover Type	100-Year Model Area Covered Ha.
Bottom Land Forest	794
Temperate Woodland	121
Prairie	85
Man-Made + Arents	353
Aquatic	50
Total	1403

Large scale changes are expected in vegetative cover in the 100-Year Model. Bottom land forest nearly doubles in size from 412 hectares to 794 hectares. Temperate woodlands show a sizable gain from 69 to 121 hectares. Prairie increases from 0 to 85 hectares. There is no expected increase in the area covered by man-made and aquatic cover types. Pasture, agricultural, and old field classifications fall out in the 100-Year Model; they are subsumed by the increases in bottom land forest, temperate woodland, and the new classification of prairie.

Soil type is the controlling factor in the type of vegetation expected. Bottom land forest is expected on the Bunyan Entisol, Frio Mollisol, and the Kaufman, Ovan, and Trinity Vertisols. Temperate woodlands will occur on the Bastrop, Birome, Callisburg, and Gasil Alfisols. Prairie is expected on the Burleson and Ferris Vertisols, Wilson Alfisols and Altoga Inceptisols. Generally the distribution of future habitats in the 100-Year Model is what is expected. Deep dark bottom land soils support dense stands of hardwoods. Sandy upland soils of the Woodbine formation produce the Eastern Crosstimbers. Dark soils formed on limestone and some vertisols and alfisols should produce prairie vegetation. Changes in the distribution and area of habitats have implications for the biota dependent upon them. Figure 4 shows the expected distribution of habitats in 100 years.

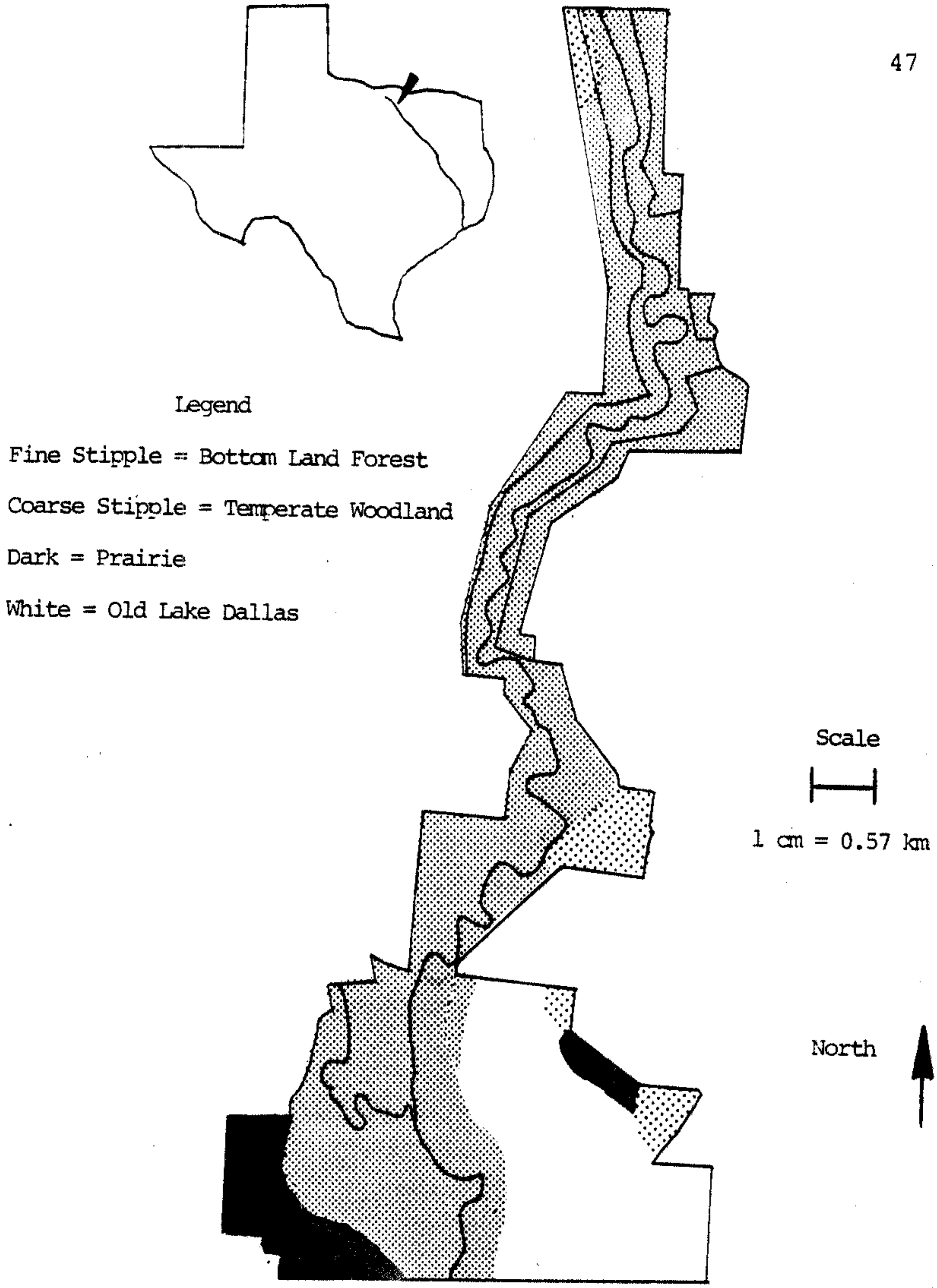

Figure 4: Expected Distribution of Vegetation in 100 Years

<u>Habitat Changes and Index Species</u>

As the area of available habitat increases one expects a corresponding increase in the abundance of wildlife. Appendix N is a computer print out of HEP applying the incremental increase in habitat and corresponding changes in HSI's to the study area. The management plan associated with the model allows for natural succession to proceed in the study area. The alternative plan is that development will occur and the land will be lost as wildlife habitat.

Form B in Appendix N is the baseline habitat assessment. Shown are the areas of habitat utilized by the index species, HSI's, and the amount of optimal habitat shown as Habitat Units (HU's). These data were derived from the habitat evaluations previously discussed.

Form C in Appendix N are data showing the Average Annual Habitat Units (AAHU's) reflecting the incremental increase in available habitat and expected changes in HSI's for each index species in 25 year intervals. For beaver and white crappie the area of habitat remains the same since their reproduction and feeding is confined to the river or its immediate surroundings.

In the case of beaver it is believed that increases in bottom land forest will be in areas further from the Elm Fork than the species would normally forage. Thus, the area of available habitat remains constant at 412 hectares. There is a slight increase in the HSI from 0.50 to 0.60

based on the assumption that fluctuations in flow will decrease with a constant minimum outflow from Ray Roberts Dam. Thus the quality of habitat is expected to increase while the total area will remain stable. An increase in the quality of habitat over 100 years should enable some increase in beaver population beyond the present estimate of 72 individuals.

Riverine habitat of the Elm Fork will remain unchanged in terms of suitability for white crappie. Turbidity is expected to remain stable. Breeding season temperatures should drop due to continuous minimum out flow from Ray Roberts Dam, thus raising the HSI. This rise is offset by a decrease of pools in summer, attributed to minimum discharges from the Dam. Changes associated with the variables should balance each other, producing no net change in area or suitability of white crappie habitat.

Dramatic changes in quantity and quality of habitat are expected for the pileated woodpecker. Changes are associated with increases in the size of trees and area of land covered by bottom land forest and temperate woodland. As the area increases and trees grow in size, the number of trees greater than 51 cm dbh should increase, providing more nesting sites. If the current population of pileated woodpecker is 6 - 7 pair, the 12 fold increase in Habitat Units (HU's) from 57.72 to 732 suggest that as many as 84 nesting pair may be supported in 100 years.

Wood duck habitat is expected to increase four fold from 82.4 to 317.6 HU's in the next 100 years. Growth is due to increases in the number and size of trees greater than 28 cm dbh needed for nesting. Winter and brood cover are not expected to change. If the current estimate of 19 nesting pair is correct a total of 76 pair can be expected in 100 years.

Overall, the 100-Year Model predicts relative constant population levels for white crappie and beaver and large increases in wood duck and pileated woodpecker due to growth in the size and number of trees.

The Management Plan

The study area corresponds generally to what has been proposed as a greenbelt for recreation and conservation purposes (USACOE 1983a). Presented in this thesis is a plan designed to manage the area to improve its quality as wildlife habitat. This plan is intended to accomplish one stated goal for the greenbelt, to preserve the natural resource base of the Trinity (USACOE 1983a).

A greenbelt on the Elm Fork of the Trinity between lakes Ray Roberts and Lewisville offers an opportunity to encourage wildlife in a region of increasing urbanization. Linking lakes Lewisville and Ray Roberts with an undeveloped corridor of riparian habitat, coupled with the rural character of the land north of Ray Roberts, presents the chance to create a wildlife refuge extending from near the Red River to the Dallas - Fort Worth area. This wildlife corridor would allow unmolested migration of terrestrial species from the Red River to the south. For example, white tailed deer, Odocoleus virginianus, rare in Denton County, could reestablish small populations if migratory corridors existed.

Land Management Policies

Development of the flood plain between the lakes should be strictly limited. A simple solution to impinging development would be to prohibit the issuing of flood insurance. Financial incentives for development would be curtailed if flood insurance were unavailable. If this proposal proves unfeasible, strict and updated regulations on septic systems and zoning classifications would be reasonable alternatives to outright prohibition of development.

Incentives for land owners to participate in wildlife management need to be developed and encouraged. Tax deductions for donations of land for conservation easements should be high enough to offset any financial losses from land taken out of production. Incentives currently available through the Agricultural Stabilization Service are the Agricultural Conservation Program (ACP) and the Conservation Reserve Program (CRP). The CRP is primarily concerned with soil erosion. Eroded land is planted in grass cover and left undisturbed for 10 years, with the Federal Government paying the owner a fixed rate per acre to participate. The ACP is designed to provide food and cover for wildlife; wild food crops, shrubs and small trees are planted with the land owner receiving a per acre subsidy from the government (Smith 1986).

Policies and programs such as the ACP and CRP could greatly enhance the greenbelt in its ability to support wildlife. Upstream from Lake Ray Roberts the programs of the Agricultural Stabilization Service would aid in development of a wildlife corridor from the Red River. Furthermore, development of programs such as those mentioned will improve the wildlife value of the greenbelt by providing additional habitat.

Land Management Practices

Land management practices designed to reduce erosion, nonpoint source pollution, and preserve the natural channel of the river can improve the quality of wildlife habitat within the greenbelt. Channelization, putting the river in culvert and other large scale earth moving operations should be avoided. Emphasis should be placed on controlling stream bank erosion and sheet erosion from over land flow in plowed fields. Vegetative cover on banks should be left undisturbed. Planting of sedges, willows, cottonwoods, or canary grass will increase bank stability as well as providing food for beaver and other species (KSU 1984).

A major point of erosion is located just south of the Green Valley Bridge on the west side of the river. Here, plowing too close to a meander has resulted in field erosion, and an extensive gully exists. At this location revegetation, gabions, rip rap, and erosion control matting are conservation approaches that can be used to limit the severe erosion problem. If erosion continues, current deflectors or wing dams may provide a solution. Deflectors should be placed on alternate banks below high water levels (KSU 1984). In addition to reducing erosion, the current deflectors will provide habitat for white crappie and other fish species. Elsewhere, small gullies should be filled and check dams used to control larger gullies (KSU 1984).

Fields adjacent to the river are a major contributor of nonpoint source pollution in the form of sediment and agricultural chemicals which needs to be controlled in order to preserve riparian habitat and maintain water quality. Small drainages in fields should not be plowed, but planted in permanent grass cover to reduce sheet wash erosion (KSU 1984). Grass planted drainages also provide cover for wildlife. Additionally, planting native grasses in buffer strips 8 to 16 meters wide at the edge of fields will reduce erosion and provide nesting, roosting, and cover for some bird and small mammal species (KSU 1984). Control of erosion and nonpoint source pollution should enhance the habitat of both beaver and white crappie.

Cattle grazing is a source of erosion and fecal contamination that needs to be controlled in riparian habits. Grazing should be prohibited in the greenbelt and discouraged in conservation easements. However, some winter grazing may be desirable to prevent certain areas from becoming choked with vegetation (KSU 1984). Salt licks for stock should be placed in areas outside the riparian zone. Alternative watering holes such as stock tanks can be developed. Shade shelters can be built as an alternative to bottom land forest to provide a respite for cattle from heat and flies. The entire greenbelt should be fenced with a deer fence to keep cattle out and allow deer access. Four wires spaced bottom to top 16", 8", 8" and 10" enable deer to cross without catching their hind legs (KSU 1984). Since the study area is small in terms of a wildlife refuge, with high levels of recreational use expected, hunting should be discouraged. These practices will improve the greenbelt's ability to function as a wildlife refuge.

Plant Management

The vegetational component of the greenbelt determines the kinds of habitat present. Diversity of habitats is widely recognized as a critical element in producing optimum conditions for wildlife (Frye 1984 and Erickson et al.

1980). Plans for managing the greenbelt for optimum wildlife habitat include two goals: to allow native vegetation to reestablish through succession, and to maximize the amount of edge present.

As discussed in the 100-Year Model it is assumed that, in time, bottom land forest will occupy much of the study area. Expected increases in the number and size of trees will benefit avian index species, such as the pileated woodpecker and wood duck, as well as other wildlife. Quality of habitat can be improved by employing proven timber management practices.

Thinning trees every 5 to 8 years will improve growth and habitat. Species diversity should be encouraged during thinning (KSU 1984). During revegetation, plant less common tree and shrub species. Leave vines and standing dead timber in place. Edges of woodlands can be cut back 7 to 10 meters to encourage shrub species growth, creating greater diversity of habitat (KSU 1984). Cull trees should be girdled and left standing. Thinnings of brush and small trees should be placed in piles at the edge of the woods to provide cover and habitat. Stumps should not be chemically treated so they can resprout, creating browse (KSU 1984). Soils naturally dominated by grasses should be replanted in native grasses to increase the amount of edge and habitat diversity. Areas dominated by the Eastern Crosstimbers and bottom land forest should be thinned to promote growth of large sized trees and rapid renewal of the biome. Overall, the vegetation management practices should produce greater habitat diversity than would naturally occur, resulting in an improved wildlife habitat, particularly for wood duck and pileated woodpecker.

Reiteration and Conclusions

Important findings and observations of this thesis research warrant summation. A greenbelt along the Elm Fork of the Trinity River between lakes Lewisville and Ray Roberts should be established and managed in part as a wildlife refuge. Otherwise urban growth and development will have a severe adverse impact on this important ecosystem. Reaches of natural rivers need preservation for wildlife, recreation, water conservation, and aesthetic purposes.

Undisturbed prairies are rare in Texas. Soils in the study area that are capable of supporting prairie vegetation should be replanted in native species. Revegetation will increase the area of prairie biome and provide habitat for animals of the grasslands.

The Eastern Crosstimbers is in need of immediate conservation efforts. North Texas' sandstone hills, once covered with oak woodlands, are rapidly being cut over for urban and commercial development. Large expanses of the Crosstimbers have been lost due to reservoir construction.

The Eastern Crosstimbers should be considered an endangered habitat. Ordinances and zoning regulations need to be adopted and enforced to preserve what remains of these upland forests.

HEP's and HSI models used in the application of HEP's are useful tools but possess distinct limitations. No attempt is made to obtain actual numbers of a species' population or the carrying capacity of a particular site. Some of the ranked Suitability Indices are entirely too general and vague to provide trustworthy information. Habitat models are not readily applicable to regions of ecological transition, such as the study area. Edges are important to wildlife; one expects greater species diversity where ecotones are present. Presently there is no way to input edge effect in HEP's.

One distinct limitation of HEP's is its reliance on index species. Realistically, managing land for species is difficult due to factors beyond the control of wildlife management personnel, such as hunting and pesticide use on adjacent properties. Secondly, wild animals may or may not be amenable to management strategies. However, land can be managed to encourage, create, or preserve habitat. Since species survival is often controlled by availability of habitat, the chances of promoting certain species are improved by increasing the areas of critical habitat. Therefore, HSI models based on species life requisites may not be the best way to evaluate land for wildlife. It is suggested that HEP's should be reoriented to appraise land for the quality of habitat types and move away from species based indices.

Computerized HEP's upon which the changes in habitat are tracked over time (Appendix N) also have some distinct short comings. The largest problem is that total acres of a study are employed to track changes in quantity and quality of habitat, not cover types. All habitat types are lumped together as acres in the study area, ignoring areas of the most critical habitats. In this research the problem was not insurmountable since the water and bottom land hardwoods were the critical habitats, and their acreages were the ones used in the model. However, in terms of compensation or trade off analysis between two study sites, lumping habitats (total study acres) and multiplying by a single HSI value could produce misleading and erroneous results.

Population estimates are presented in this thesis as a tool to assess the reliability of Habitat Suitability Models and as a means of evaluating the success of wildlife management endeavors. No change in the population of white crappie is predicted since the quality and area of habitat remain constant in the 100-Year Model.

Wood duck population is estimated at 19 pairs nesting in 412 hectares of bottom land forest. As the quality and area of habitat increases to 794 hectares in accordance with the

100-Year Model wood duck population is expected to reach 76 nesting pairs.

Currently the population of pileated woodpeckers is estimated to be 7 pairs nesting in 481 hectares of bottom land forest and temperate woodland. The 100-Year Model expects 915 hectares of habitat capable of sustaining approximately 84 nesting pairs of pileated woodpecker.

Beaver population is estimated at 72 individuals dispersed between 12 colonies. Since beaver are restricted to the river and immediate environs no large changes are expected in their numbers.

APPENDIX A

TREES, SHRUBS AND VINES IN THE STUDY AREA

Species

Common Name	Scientific Name
Maple	Aceraceae
Boxelder	*Acer Negundo*
Sumac	Anacardiaceae
Smooth sumac, Scarlet sumac	*Rhus glabra*
Poison ivy	*Rhus toxicodendron*
Flame leaf sumac	*Rhus copallina*
Polecat bush	*Rhus aromatica*
Holly	Aquifoliaceae
Possum-haw holly	*Ilex decidua*
Honeysuckle	Caprifoliaceae
Rusty blackhaw viburnum	*Viburnum rifidulum*
Coral berry	*Symphoricarpus orbiculatus*
Dogwood	Cornaceae
Red dogwood	*Cornusstolonifera*
Rough-leaf dogwood	*Cornus drummondii*
Cypress	Cupressaceae
Eastern red cedar	*Juniperus virginiana*
Beech	Fagaceae
Bur oak	*Quercus macrocarpa*
Shumard oak	*Quercus Shumardii*
Blackjack oak	*Quercus marilandica*

Post oak	*Quercus stellata*
Legume	Leguminosae
Common honeylocust	*Gleditsia triacanthos*
Texas sophora	*Sophora affinis*
Eastern redbud	*Cercis canadensis*
Honey mesquite	*Prosopsis glandulosa*
Lily	Liliaceae
Cat brier	*Smilax bona-nox*
Moonseed	Menispermiceae
Red-berried moonseed	*Cocculus carolinus*
Mulberry	Moraceae
Red mulberry	*Morus rubra*
Osage-orange	*Maclura pomifera*
Walnut	Myricaceae
Pecan	*Carya illinoinensis*
Black Hickory	*Carya texana*
Ash	Oleaceae
Green ash	*Fraxinus pensylvanica*
Sycamore	Platanaceae
Sycamore	*Plantanus occidentalis*
Rose	Rosaceae
Green hawthorn	*Crataegus viridis*
One-flowered hawthorn	*Crataegus uniflora*
Downy hawthorn	*Crataegus mollis*
Southern dewberry	*Rubus trivialis*
White prairie rose	*Rosa foliolosa*

Chickasaw plum	*Prunus angustifolia*
Citrus	Rutaceae
Pepperbark	*Zanthoxylum Clava-Herculis*
Willow	Salicaceae
Black willow	*Salix nigra*
Eastern cottonwood	*Populus deltoides*
Soapberry	Sapindaceae
Soapberry	*Sapindus Saponaria*
Sapodilla	Sapotaceae
Wooly bucket bumelia, Wooly buckthorn	*Bumelia lanuginosa*
Elm	Ulmaceae
Sugar hackberry	*Celtis laevigata*
Netleaf hackberry	*Celtis reticulata*
Cedar elm	*Ulmus crassifolia*
American elm	*Ulmus americana*
Winged elm	*Ulmus alata*
Slippery elm	*Ulmus rubra*
Grape	Vitaceae
Virginia creeper	*Parthenocissus quinquefolia*
Mustang grape	*Vitis mustangensis*
Possum grape	*Cissus incisa*

Source (IES 1972)

APPENDIX B

MAMMALS IN THE STUDY AREA

Species	
Common Name	Scientific Name
Opossum	*Didelphis marsupialis*
Armadillo	*Dasypus novemcinctus*
Red Bat	*Lasiurus borealis*
Raccoon	*Procyon lotor*
Ringtail	*Bassariscus astutus*
Spotted Skunk	*Spilogale putorius*
Striped Skunk	*Mephitis mephitis*
Gray Fox	*Urocyon cinereoargenteus*
Coyote	*Canis latrans*
Fox Squirrel	*Sciurus niger*
Pocket Gopher	*Geomys bursarius*
Hispid Pocket Mouse	*Perognathus hispidus*
Long-tailed Harvest Mouse	*Reithrondontomys fulvescens*
Gray Harvest Mouse	*Reithrondontomys montanus*
Deer Mouse	*Peromyscus maniculatus*
White-footed Mouse	*Peromyscus leucopus*
Cotton Rat	*Sigmondon hispidus*
Eastern Wood Rat	*Neotoma floridana*
Muskrat	*Onadatra zibethicus*
Nutria	*Myocastor coypus*
Housemouse	*Mus musculus*

Jack Rabbit	Lepus californicus
Swamp Rabbit	Sylvilagus aquaticus
Cottontail	Sylvilagus floridanus
White-tailed Deer	Odocoileus virginianus
*Beaver	Castor canadensis

* personal observation

Source (USACOE 1974)

APPENDIX C

BIRDS IN THE STUDY AREA

Common Name	Scientific Name	Resident	Migratory
Great Blue Heron	*Ardea herodias*		X
Green Heron	*Butorides virescens*		X
Little Blue Heron	*Florida caerulea*		X
Common Egret	*Casmerodius albus*		X
Gadwall	*Anas strepera*		X
Pintail	*Anas acuta*		X
Green-Winged Teal	*Anas carolinensis*		X
Blue-Winged Teal	*Anas discors*	X	
American Widgeon	*Mareca americana*		X
Shoveler	*Spatula clypeata*		X
Redhead Duck	*Aythya americana*		X
Turkey Vulture	*Cathartes aura*	X	
Black Vulture	*Coragyps atratus*	X	
Cooper's Hawk	*Accipiter cooperii*	X	
Red-Tailed Hawk	*Buteo jamaicensis*	X	
Swainson's Hawk	*Buteo swainsoni*		X
Marsh Hawk	*Circus cyaneus*	X	
Sparrow Hawk	*Falco sparveius*	X	
Bobwhite	*Colinus virginianus*	X	
American Coot	*Fulica americana*	X	
Killdeer	*Charadrius vociferus*	X	
Upland Plover	*Bartramia longicauda*		X

Spotted Sandpiper	Actitis macularia		X
Mourning Dove	Zenaidura macroura	X	
Screech Owl	Otus asio	X	
Great Horned Owl	Bubo virginianus	X	
Chuck-Wills-Widow	Caprimulgus carolinensis		X
Common Nighthawk	Chordeiles minor		X
Chimney Swift	Chaetura pelagica		X
Ruby Throated Hummingbird	Archilochus colubris		X
Black Chinned Hummingbird	Archilochus alexandri		X
Belted Kingfisher	Megaceryle alcyon	X	
Yellow Shafted Flicker	Colaptes auratus		X
Red Bellied Woodpecker	Centurus carolinus	X	
Donny Woodpecker	Dendrocopos pubescens	X	
Eastern Kingbird	Tyrannus tyrannus		X
Scissor-Tailed Flycatcher	Muscivora forficata	X	
Great-Crested Flycatcher	Myiarchus crinitus		X
Eastern Wood Pewee	Contopus virens		X
Horned Lark	Eremophila alpestris	X	
Bank Swallow	Riparia riparia		X
Barn Swallow	Hirundo rustica		X
Cliff Swallow	Petrochelidon pyrrhonota		X
Bluejay	Cyanocitta cristata	X	
Crow	Corvus brachyrhynchos	X	

Carlina Chickadee	Parus carolinensis	X	
Tufted Titmouse	Parus bicolor	X	
Brown Creeper	Certhia familiaris		X
House Wren	Troglodytes aedon		X
Carolina Wren	Thryothorus ludovicianus	X	
Mockingbird	Mimus polyglottos	X	
Catbird	Dumetella carolinensis		X
Brown Thrasher	Toxostoma rufum	X	
Robin	Turdus migratorius	X	
Eastern Bluebird	Sialia sialis	X	
Cedar Waxwing	Bombycilla cedrorum		X
Loggerhead Shrike	Lanius ludovicianus	X	
Starling	Sturnus vulgaris	X	
Red-Eyed Vireo	Vireo olivaceus		X
Warblers(Bl.&Wh.)	Mniotilta varia		X
House Sparrow	Passer domesticus	X	
Eastern Meadowlark	Sturnella magna	X	
Redwing Blackbird	Agelaius phoeniceus	X	
Orchard Oriole	Icterus spurius		X
Boat-Tailed Grackle	Cassidix mexicanus	X	
Cowbird	Molothrus ater	X	
Cardinal	Richmondena cardinalis	X	
Blue Brosbeak	Buiraca caerulea		X
Indigo Bunting	Passerina cyanea		X
Painted Bunting	Passerina ciris		X
Dickcissel	Spiza americana		X

Savannah Sparrow	*Passerculus sandwichensis*		X
Vesper Sparrow	*Pooecetes gramineus*		X
Lark Sparrow	*Chondestes grammacus*		X
Goldfinch	*Spinus tristis*	X	
Slate-Colored Juneo	*Junco hyemalis*		X
Field Sparrow	*Spizella pusilla*		X
Harris Sparrow	*Zonotrichia querula*		X
White Crowned Sparrow	*Zonotrichia leucophrys*		X
White Throated Sparrow	*Zonotrichia albicollis*		X
Lincoln's Sparrow	*Melospiza lincolnii*		X
Song Sparrow	*Melospiza melodia*		
*Wood Duck	*Aix sponsa*	X	
*Pileated Wood-pecker	*Dryocopus pileatus*	X	

*Confirmed sightings but not reported.

Source (USACOE 1974)

APPENDIX D

REPTILES IN THE STUDY AREA

Species		
Common Name	Scientific Name	Abundance
Snapping turtle	Chelydra serpentina	Common
Yellow mud turtle	Kinosternon flavescens	Common
Common mud turtle	Kinosternon subrubrum	Occasional
Keel-backed Muskturtle	Sternothaerus carinatus	Occasional
Chicken turtle	Deirochelys reticularia	Occasional
Gray-false map turtle	Graptemys pseudogeographica	Rare
Pond slider	Pseudemys scripta	Common
Box turtle	Terrapene carolina	Occasional
Western box turtle	Terrapene ornata	Common
Spiny softshell	Trionyx spinifer	Common
Green anole	Anolis carolinensis	Rare
Collared lizard	Crotaphytus collaris	Rare
Texas horned lizard	Phrynosoma cornutum	Occasional
Texas spiny lizard	Sceloporus olivaceus	Common
Eastern fence lizard	Sceloporus undulatus	Occasional
Slender grass lizard	Ophisaurus attenuatus	Occasional
Six-lined racerunner	Cnemidophorus seclineatus	Rare
Five-lined skink	Eumeces fasciatus	Rare
Ground skink	Lygosoma laterale	Common
Racer	Coluber constrictor	Occasional
Eastern ringneck snake	Diadophis punctatus	Occasional

Rat snake	*Elaphe obsolete*	Occasional
Rough earth snake	*Haldea striatula*	Common
Coachwhip	*Masticophis flagellum*	Common
Watersnake	*Natrix erythrogaster*	Occasional
Diamond-backed water snake	*Natrix rhombifera*	Common
Rough green snake	*Opheodrys aestivus*	Common
Bull snake	*Pituophis melanoleucus*	Occasional
Flat-headed snake	*Tantilla gracilis*	Common
Western Ribbon snake	*Thamnophis proximus*	Occasional
Copperhead	*Agkistrodon contortrix*	Occasional
Cottonmouth	*Agkistrodon piscivorus*	Common

Source (USACOE 1974)

APPENDIX E

AMPHIBIANS IN THE STUDY AREA

Species		
Common Name	Scientific Name	Abundance
Small-Mouthed Salamander	_Ambystoma texanum_	Occasional
Eastern Spadefoot	_Scaphiopus holbrooki_	Common
Green Toad	_Bufo debilis_	Common
Texas Toad	_Bufo speciosus_	Common
Woodhouse's Toad	_Bufo woodhousei_	Common
Cricket Frog	_Acris crepitans_	Common
Green Tree Frog	_Hyla cinerea_	Rare
Spotted Chorus Frog	_Pseudcris clarki_	Common
Bullfrog	_Rana catesbeiana_	Common
Leopard Frog	_Rana pipiens_	Ocassional
Western Narrow-Mouthed Toad	_Gastrophryen olivacea_	Rare

Source (USACOE 1974)

APPENDIX F

FISH SPECIES BELIEVED TO BE PRESENT IN THE STUDY AREA

Common Name	Scientific Name	Abundance
Gizzard shad	*Dorosoma cepedianum*	Common
Golden shiner	*Notemigonus crysoleueas*	Common
Red shiner	*Notropis lutrensis*	Common
Blacktail shiner	*Notropis venustus*	Common
Bluntnose minnow	*Pimephales notatus*	Common
Stoneroller	*Campostoma anomalum*	Rare
Carp	*Cyprinus carpio*	Common
Spotted sucker	*Minytrema melanops*	Common
River carpsucker	*Carpiodes carpio*	Common
Smallmouth buffalo	*Ictiobus bubalus*	Rare
Tadpole madtom	*Notarus gyrinus*	Rare
Channel catfish	*Ictalurus punctatus*	Common
Black bullhead	*Ictalurus melas*	Common
Yellow bullhead	*Ictalurus natalis*	Rare
Blackstriped topminnow	*Fundulus notatus*	Common
Mosquitofish	*Gambusia affinis*	Common
Inland silversides	*Menidia berylina*	Rare
Bluegill	*Lepomis macrochirus*	Common
Redbreast sunfish	*Lepomis auritus*	Common
Redear sunfish	*Lepomis microlophus*	Common
Longear sunfish	*Lepomis megalotis*	Common
Green sunfish	*Lepomis cyanellus*	Common
Warmouth	Lepomis gulosus	Common

White crappie	Pomoxis annularis	Common
Largemouth bass	Micropterus salmoides	Common
Striped bass	Morone saxatilis	Rare
Orange-throated darter	Etheostoma spectabile	Rare
Drum	Aplodinotus grunniens	Rare
White bass	Morone chrysops	Common

Source (USFWS 1984)

APPENDIX G

FEEDING GUILDS

Cover type:	Feeding Guilds			
Woodland & Bottom Land Forest	Vertebrate carnivore	General omnivore	Scavenger	Herbivore
Trees	Carolina Wren	Opossum, C. Chickadee, T. Titmouse, Br. Thrasher, Mockingbird, Robin	T. Vulture, Bl. Vulture	Fox Squirrel
Tree boles	All Woodpeckers			
Shrub layer				White-tailed Deer
Terrestrial surface	Striped & Spotted Skunks, Raccoon, Bobcat, Gray Fox, Ringtail, Armadillo	Coyote, Bobwhite, C. Chickadee, Br. Thrasher		Fox Squirrel, Cottontail, Jackrabbit, Beaver, Mourning Dove
Terrestrial subsurface	Armadillo			
Pasture	Killdeer, Marsh Hawk, Sparrow Hawk, Red-tailed Hawk, Coopers Hawk	Mockingbird, Redwinged Blackbird		Great Horned Lark, Cardinal
Water	Belted King-fisher, Great Blue Herron White Crappie	Wood Duck		Muskrat

APPENDIX H

REPRODUCTIVE GUILDS

Cover type: Temperature Woodland and Bottom Land Forest	Reproductive Guilds
Tree canopy	Fox Squirrel, Carolina Wren, Mockingbird, Boat-tailed Grackel, Cardinal
Small branches	
Large live branches	Red-tailed Hawk, Coopers Hawk, Great Horned Owl, Fox Squirrel, Boat-tailed Grackel
Large dead branches	Great Blue Herron, Wood Duck, Fox Squirrel, Raccoon, Ringtail, Opossum, Screech Owl
Tree boles Live tree cavity	Black Vulture, Turkey Vulture, Wood Duck, Raccoon, Pileated Woodpecker, Carolina Chickadee, Carolina Wren, Ringtail, Opossum, Screech Owl, Tufted tit-mouse
Dead hard cavity	See Above
Dead soft cavity	See Above
Shrub	Eastern Cottontail, Cardinal, Mourning Dove, White-tailed Deer, Mockingbird, Boat-tailed Grackel
Surface Live vegetation	Eastern Cottontail, Bobwhite Quail, Bobcat
Organic litter	Striped Spotted Skunk, Opossum
Cliff, talus, rocky terrain	Black & Turkey Vulture, Bobcat, Sparrow Hawk, Spotted & Striped Skunk, Coyote, Opossum
Bare ground	
Subsurface **Cave, crevice**	
Flat ground	Stripped & Spotted Skunk, Armadillo, Coyote
Bank	Armadillo, Gray Fox, Coyote, Muskrat, Beaver, Belted Kingfisher

APPENDIX I

HABITAT VARIABLE RELATIONSHIPS FOR WOOD DUCK

The relationship of habitat variables, life requisites, and cover types to an HSI value for the wood duck during the breeding season.

Habitat variables		Life requisites	Cover types	
Number of potentially suitable tree cavities/ 0.4 ha (1.0 acre) [cavities/0.4 ha (1.0 acre) with minimum entrance dimensions of 7.6 by 10.0 cm (3.0 by 4.0 inches); cavities may be in live trees or snags].	Density of potential nest sites/0.4 ha (1.0 acre).	Nesting	Bottom Land Forest	
Number of nest boxes/ 0.4 ha (1.0 acre) that are predator-proof and maintained.				HSI (breeding season)
Percent of the water surface covered by potential brood cover.		Brood-rearing	Bottom Land Forest	

APPENDIX J

HABITAT VARIABLE RELATIONSHIPS FOR PILEATED WOODPECKER

Relationship of habitat variables, life requisites, and cover types in the pileated woodpecker model.

Habitat variable	Life requisite	Cover types
Percent tree canopy closure		
Number of trees > 51 cm (20 inches) dbh/0.4 ha (1.0 acre)		
Number of tree stumps > 0.3 (1 ft) in height and > 18 cm (7 inches) diameter and/or logs > 18 cm (7 inches) diameter/ 0.4 ha (1.0 acre).		
Number of snags >38 cm (15 inches) dbh/0.4 ha (1.0 acre) (eastern portion of range only).	Food/Cover/ Reproduction ————	Bottom Land Forest Woodland ——HSI
Average dbh of snags >38 cm (15 inches) dbh (eastern portion of range only).		
Number of snags >51 cm (20 inches) dbh/0.4 ha (1.0 acre) (western portion of range only).		
Average dbh of snags >51 cm (20 inches) dbh (western portion of range only).		

APPENDIX K

HABITAT VARIABLE RELATIONSHIPS FOR WHITE CRAPPIE

Habitat Variables	Life Requisites	
% cover (vegetation, brush, debris, etc.) (V_2)	Food-cover (C_{F-C})	
% pools, overflow areas, or backwaters (V_3)		
Temperature (V_6, V_7)		
Dissolved oxygen (V_9)		
pH (V_5)	Water quality (C_{WQ})	
Turbidity (V_{11})		
Conductivity (V_{14})		HSI
% cover (V_2)		
% pools (V_3)	Reproduction (C_R)	
Temperature (embryo) (V_8)		
Dissolved oxygen (embryo (V_{10})		
Stream gradient (V_1)	Other (C_{OT})	
Average current velocity (V_{12})		

APPENDIX L

RIVERINE HABITAT SUITABILITY INDEX EQUATIONS

These equations utilize the life requisite approach and consist of four components: food-cover, water quality, reproduction, and other.

Food-Cover (C_{F-C}).

$$C_{F-C} = (V_2 \times V_3)^{1/2}$$

Water Quality (C_{WQ}).

$$C_{WQ} = \frac{V_5 + 2[(V_6 \times V_7)]^{1/2} + 2V_9 + V_{11}}{6}, \text{ or}$$

If $(V_6 \times V_7)^{1/2}$ or V_9 is ≤ 0.4, C_{WQ} equals the lowest of the following: $(V_6 \times V_7)^{1/2}$, V_9, or the above equation.

Note: If V_{14} (optional salinity variable) is added,

$$C_{WQ} = \frac{V_5 + 2[(V_6 \times V_7)]^{1/2} + 2V_9 + V_{11} + V_{14}}{7}$$

Reproduction (C_R).

$$C_R = (V_2 \times V_3 \times V_8{}^2 \times V_{10}{}^2)^{1/6}$$

Other (C_{OT}).

$$C_{OT} = (V_1 \times V_{12})^{1/2}$$

HSI determination.

$$HSI = (C_{FC} \times C_{WQ} \times C_R \times C_{OT})^{1/5}, \text{ or}$$

If C_{WQ} or C_R is ≤ 0.4, then the HSI equals the lowest of the following:

C_{WQ}, C_R, or the above equation

APPENDIX M

BEAVER HABITAT SUITABILITY INDEX EQUATIONS

Equations for determining life requisite values by cover type for the beaver. If equation products exceed 1.0, they should be considered equal to 1.0.

Life requisite	Cover type	Equation
Winter food	Bottom Land Forest	$\frac{a+b+c}{2.5}$
Winter food	R	$\frac{b+c}{1.5}$
		$\frac{b+c}{1.5} + V_6$

where: a = woody vegetation value within actual wetland boundary. The suggested equation is:

$$[(V_1 \times V_2)^{1/2} \times V_5]^{1/2} + [(V_3 \times V_4)^{1/2} \times V_5]^{1/2}$$

b = woody vegetation value within 100 m (328 ft) from the water's edge. The suggested equation is:

$$[(V_1 \times V_2)^{1/2} \times V_5]^{1/2} + [(V_3 \times V_4)^{1/2} \times V_5]^{1/2}$$

c = woody vegetation value within 100 m (328 ft) to 200 m (656 ft) from the water's edge. The suggested equation is:

$$0.5\ [(V_1 \times V_2)^{1/2} \times V_5]^{1/2} + [(V_3 \times V_4)^{1/2} \times V_5]^{1/2}$$

Life requisite	Cover type	Equation
Water	R	V_7 or V_8, whichever is lowest.
		V_8 or V_9, whichever is lowest, if lacustrine area ≥ 8 ha (20 acres) in surface area.
		V_8, if lacustrine area is $<$ 8 ha (20 acres) in surface area.
Water	Bottom Land Forest	V_8

HSI determination. Based on the limiting factor concept, the HSI is equal to the lowest life requisite value obtained for either food or water.

APPENDIX N

COMPUTERIZED HABITAT EVALUATION PROCEDURES

Form B: Habitat Units Date: 08/28/1986

Study Name: GREENBELT
Action: PA 1 (with project) GREENBELT
Target Year: 0

Evaluation Species ID#	Name	Area of Habitat	Habitat Suitability Index	Habitat Units
1	BEAVER	412.00	0.50	206.00
2	WOODPECKER	481.00	0.12	57.72
3	DUCK	412.00	0.20	82.40
4	FISH	50.00	0.66	33.00

Form C: Average Annual Habitat Units Date: 08/28/1986

Study Name: GREENBELT
Action: PA 1 (with project) GREENBELT
Period of Analysis: 100
Evaluation Species: 3 DUCK AAHU's: 187.05

Target Year	Area of Habitat	Habitat Suitability Index	Habitat Units
0	412.00	0.20	82.40
1	412.00	0.20	82.40
25	507.50	0.25	126.88
50	603.00	0.30	180.90
75	698.50	0.35	244.47
100	794.00	0.40	317.60

Form C: Average Annual Habitat Units Date: 08/28/1986

Study Name: GREENBELT
Action: PA 1 (with project) GREENBELT
Period of Analysis: 100
Evaluation Species: 4 FISH AAHU's: 33.00

Target Year	Area of Habitat	Habitat Suitability Index	Habitat Units
0	50.00	0.66	33.00
1	50.00	0.66	33.00
25	50.00	0.66	33.00
50	50.00	0.66	33.00
75	50.00	0.66	33.00
100	50.00	0.66	33.00

Form C: Average Annual Habitat Units

Date: 08/28/1986

Study Name: GREENBELT
Action: PA 1 (with project) GREENBELT
Period of Analysis: 100
Evaluation Species: 1 BEAVER

AAHU's: 241.84

Target Year	Area of Habitat	Habitat Suitability Index	Habitat Units
0	412.00	0.50	206.00
1	412.00	0.50	206.00
25	412.00	0.60	247.20
50	412.00	0.60	247.20
75	412.00	0.60	247.20
100	412.00	0.60	247.20

Form C: Average Annual Habitat Units

Date: 08/28/1986

Study Name: GREENBELT
Action: PA 1 (with project) GREENBELT
Period of Analysis: 100
Evaluation Species: 2 WOODPECKER

AAHU's: 381.95

Target Year	Area of Habitat	Habitat Suitability Index	Habitat Units
0	481.00	0.12	57.72
1	481.00	0.12	57.72
25	589.50	0.37	218.12
50	698.00	0.57	397.86
75	806.50	0.66	532.29
100	915.00	0.80	732.00

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