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Investigating Habitat Value in Support of Remedial Decisions: A Case Study of Six Sites at the East Tennessee Technology Park

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Prepared by
Oak Ridge National Laboratory
Environmental Sciences Division:

Rebecca A. Efroymson
Mark J. Peterson
Neil R. Giffen
Michael G. Ryon
John G. Smith
W. Kelly Roy
Christopher J. Welsh
Daniel L. Druckenbrod
William W. Hargrove
Harry D. Quarles

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ACRONYMS

BJC	Bechtel Jacobs Company LLC
BMAP	Biological Monitoring and Abatement Program
BSR	biological significance ranking
CrEAM	Critical Ecosystem Assessment Model
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
EPT	Ephemeroptera, Plecoptera, and Trichoptera
ETTP	East Tennessee Technology Park
GIS	geographic information system
HEA	Habitat Equivalency Analysis
HEP	Habitat Evaluation Procedures
ORR	Oak Ridge Reservation
PATH	Pathway Analysis Through Habitat
PEM1	palustrine emergent persistent
PFO1	forested broad-leaved deciduous
RBP	Rapid Bioassessment Protocols
SEF	Southeastern Ecological Framework
TDEC	Tennessee Department of Environment and Conservation
TVA	Tennessee Valley Authority
USFWS	U.S. Fish and Wildlife Service

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1. INTRODUCTION

The value of ecological resources may be determined from at least two perspectives: the value to humans and the value to ecological entities. The value of existing ecological resources to humans is often expressed as ecological or ecosystem services (Daily 1997). These include ecological functions such as water purification, air purification, pollination, carbon sequestration, and primary production, as well as other services like recreation and aesthetic value. These ecosystem services have monetary value that is usually determined mostly from market factors. Alternatively, land areas and water bodies may be valued based on the services that they provide to other ecological entities, such as wildlife and vegetation. These habitat services include food, shelter, breeding areas, and migratory pathways and other movement corridors. The value of habitat is generally expressed in descriptive rather than monetary terms. Habitat valuation processes are most often used to inform decisions about which lands to conserve (Rossi and Kuitenen 1996). In this study, the intent of habitat valuation is to support decisions about remediation of chemical contaminants on specific lands and surface waters.

The goals of this study are to summarize dimensions of habitat value in sufficient detail to support remedial decisions for six representative contaminated sites at the East Tennessee Technology Park (ETTP) on the Oak Ridge Reservation (ORR): K-25 Site Contractor's Spoil Area, K-901-A North Disposal Area, K-770 Scrap Metal Yard, K-1007-P1 Holding Pond, K-901-A Holding Pond, and Mitchell Branch (Fig. 1). Terrestrial and aquatic habitats for vertebrates, terrestrial habitat for plants, and aquatic habitat for benthic invertebrates are considered. Although this study is focused on specific sites, the habitat value results for terrestrial sites might be similar to those found at other frequently mowed, fescue-covered waste disposal areas (K-25 Site Contractor's Spoil Area), less frequently mowed waste disposal areas in powerline rights-of-way (K-901-A North Disposal Area), and highly industrialized areas (K-770 Scrap Metal Yard). The focus of this habitat valuation is on the current state of the environment, as well as a reasonable, no-action, future scenario about 5 decades in the future, if significantly different from current conditions. This study does not consider the extent to which habitat or its measures are affected by contamination; that is covered in the baseline ecological risk assessment. Although this habitat valuation relies on some of the same evidence as the ecological risk assessment, this study (1) does not rely on toxicity information, (2) is more field-based than the ecological risk assessment, and (3) is not intended to determine causality, as the risk assessment is.

Additional considerations related to habitat value and remediation are beyond the scope of this study. These include (1) the duration and intensity of potential harm that may occur during a remedial action (Efroymson et al. 2004) and (2) the desirable end state following remediation.

1.1 DEFINITIONS

We use the following definitions throughout this report:

- **habitat**—location where an organism obtains food, water and shelter; reproduces; and/or moves;
- **habitat valuation**—general process to attribute value to a particular land area or surface water body, based on use as habitat and rarity;
- **habitat evaluation**—a specific U.S. Fish and Wildlife Service (USFWS) method, Habitat Evaluation Procedures (HEP), used to document the quality and quantity of available habitat for selected wildlife species;

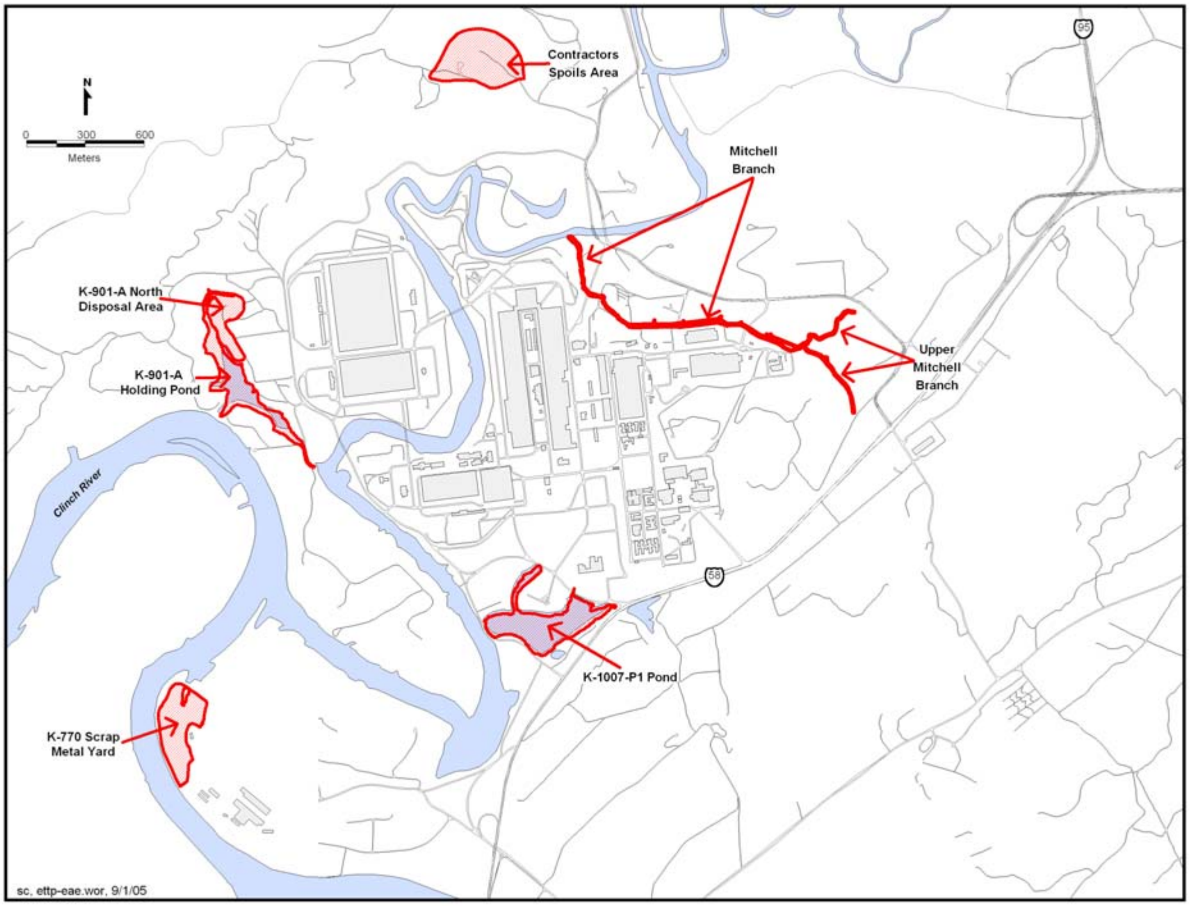


Fig. 1. Focal sites of the habitat valuation.

- **habitat suitability**—relative species-specific quality designation for a land area, usually referring to the Habitat Suitability Index, one of the results of the implementation of USFWS HEP;

- **Measures or metrics of habitat value**—quantities that are related to habitat use value or rarity value; and

- **habitat value criteria**—rules for deciding among high, medium, and low scores for particular metrics of habitat value.

1.2 EXISTING METHODOLOGIES FOR HABITAT VALUATION

Numerous methodologies and metrics related to measuring ecological condition or valuing habitat are available for use. USFWS HEP use habitat suitability factors to derive numerical indices of habitat suitability on a scale of 0.0 to 1.0 based on the assumption that key environmental variables are related to habitat carrying capacity (USFWS 1981). Some of the variables that determine wildlife habitat include soil characteristics (particle size, moisture content, pH, nutrient content, etc.), topography (slope, aspect), temperature, precipitation, vegetation characteristics (type, height, basal area, cover), distance to a specified land feature, and edge length per unit area (Hays et al. 1981). While contamination is not typically one of the variables, it may be added to the list. HEP is generally used to compare the relative value of two sites at the same point in time or one site at two different points in time (USFWS 1981). Our intent is to conduct a general evaluation of habitat values rather than to focus on particular species or representatives of particular groups of species. Therefore, in this study we opt not to perform species-specific evaluations.

Various methods have been developed to prioritize land areas for conservation. Margules and Usher (1981) found that five metrics were used in the majority of studies that they reviewed in 1981: diversity, rarity, naturalness, area, and threat of human interference. Early assessments did not include notions of connectivity and fragmentation from landscape ecology. More recently, Rossi and Kuitunen (1996) defined a habitat value index based on species present, their threat (rarity) categories, and the likelihood of occurrence in specific land cover areas.

The Nature Conservancy is currently working with the Tennessee Wildlife Resources Agency to coordinate development of the Tennessee Comprehensive Wildlife Conservation Strategy (Kirk and Bullington 2005). Conservation priorities will include areas with "high biological value [high species diversity areas and high quality habitats], imperilment, and strategic opportunity," and methods of habitat valuation will reflect these factors.

Several monitoring methodologies have been developed to characterize the status and trends of aspects of the environment. These include the U.S. Environmental Protection Agency's (EPA's) Rapid Bioassessment Protocols (RBPs) (Barbour et al. 1999) and its Environmental Monitoring and Assessment Program (USEPA 2002). Indicators within these protocols may be useful measures of habitat value; for example, physicochemical parameters for habitat assessment in RBPs may be used to estimate habitat complexity and to indicate species richness.

The Critical Ecosystem Assessment Model (CrEAM) is an EPA Region 5 geographic information system (GIS)-based method of determining "ecosystem ecological significance" based on ecological diversity, ecological sustainability, and rare species and land cover. Like the goals of this project, the emphasis is on ecological conditions rather than societal values such as flood damage mitigation or recreational value (White and Maurice, unpublished manuscript). Field measurements are not part of this methodology. Measures of ecological diversity include patch size of undeveloped land, land cover diversity, temperature and precipitation maxima, and temporal continuity of land cover type. Sustainability metrics are based on landscape fragmentation (e.g., perimeter-to-area analysis, waterway impoundment) and stressor presence (e.g., Superfund site, air quality summary). Included among rarity metrics are land cover rarity, species rarity, rare species abundance, and rare species taxa abundance (White and Maurice, unpublished manuscript).

EPA Region 7 also has developed tools for identifying critical aquatic (Nigh and Sowa 2004) and terrestrial (Missouri Resource Assessment Partnership 2004) ecosystems. Critical aquatic ecological systems are selected based on species richness, low number or intensity of stressors, high percentage of public ownership, and connectivity among "valley segment types" (Nigh and Sowa 2004). Ecological significance of land areas is determined based on patch areas that have vegetation similar to modeled historical vegetation, as well as areas with opportunity for conservation (Missouri Resource Assessment Partnership 2004). Ecological threat, another component of critical ecosystem assessment, is based on land demand, agriculture, and toxic releases. Ecological risk is based on the integration of significance and threat. The third component score for determining critical terrestrial ecosystems is the ranking for "irreplaceability," which indicates the uniqueness of a given site for achieving specified conservation goals and includes landscape-scale factors and species richness (Missouri Resource Assessment Partnership 2004).

Habitat Equivalency Analysis (HEA) is a method used to determine equivalent ecological service areas for use in Natural Resource Damage Assessments or other ecological restoration analyses. Habitat services are measured by a metric of a single factor or a metric that integrates multiple factors (Dunford et al. 2004). Resource Equivalency Analysis is a more specific type of HEA in which the number of organisms lost can be estimated in damaged habitat areas and equated to an area of replacement habitat (Allen et al. 2005).

These and other habitat valuation methods have differences in terms of data requirements, time requirements, and management goals. Habitat-specific methodologies tend to be species-specific. Methodologies intended to measure the status and trend of ecological condition may not provide criteria for distinguishing between levels of good or poor habitat value.

1.2.1 Previous Habitat Valuations of Land Areas and Water Bodies on the Oak Ridge Reservation

In 1995, the Nature Conservancy identified sites on the ORR with clusters of important species or communities, placing special emphasis on species and elements designated as globally imperiled, rare, or uncommon in the Nature Conservancy and Natural Heritage Network ranking system (TNC 1995). These sites also include the landscape features and ecological processes that were deemed important habitat for these species and communities. A biological significance ranking (BSR) was assigned to each site based on its conservation significance. Sites on the ORR were rated BSR-2 (very high significance), BSR-3 (high significance), and BSR-4 (moderate significance). The BSR-5 category (of general biodiversity interest) was not used in TNC (1995), although the authors noted that "forested land on ORR would fit in this or [a higher] category" (ORNL 2002) (Fig. 2). Sites on the ORR were evaluated primarily based on existing data; therefore, unsurveyed sites were not evaluated.

A Blackoak Ridge valuation study was performed in support of the transfer of the Blackoak Ridge conservation easement from management by the U.S. Department of Energy (DOE) to the Tennessee Wildlife Resources Agency, but this was primarily an economic valuation of ecological services to humans.

The large-scale connectivity provided by the ORR has been examined using Pathway Analysis Through Habitat (PATH), an analytical tool that can, for any land cover map, predict the location of corridors of movement between patches of habitat (Hargrove et al, in press). The algorithm works by launching virtual entities called "walkers" from each patch of habitat in the map, simulating their travel as they journey through land-cover types in the intervening matrix, and finally arriving at a different habitat "island." Each walker is imbued with a set of user-specified habitat preferences that make its walking behavior resemble a particular animal species. Because the tool operates in parallel on a supercomputer, very large numbers of walkers can be efficiently simulated. Only walkers that successfully disperse (i.e., that actually reach another patch of habitat) are retained. After walkers have been launched from all habitat patches, the collected footprints of all successfully dispersing walkers are summed together, and their combined tracks show the most heavily used pathways of movement across the map.

Figure 3 shows habitat "hubs," including the ORR, as identified in the EPA-sponsored Southeastern Ecological Framework (SEF) (http://www.geoplan.ufl.edu/epa/), in black. Although not specifically identified as such, the SEF hubs are primarily deciduous and coniferous forests, especially riparian forests (Hoctor et al. 2000). Rivers and lakes are part of some hubs, ostensibly because of their riparian forests.

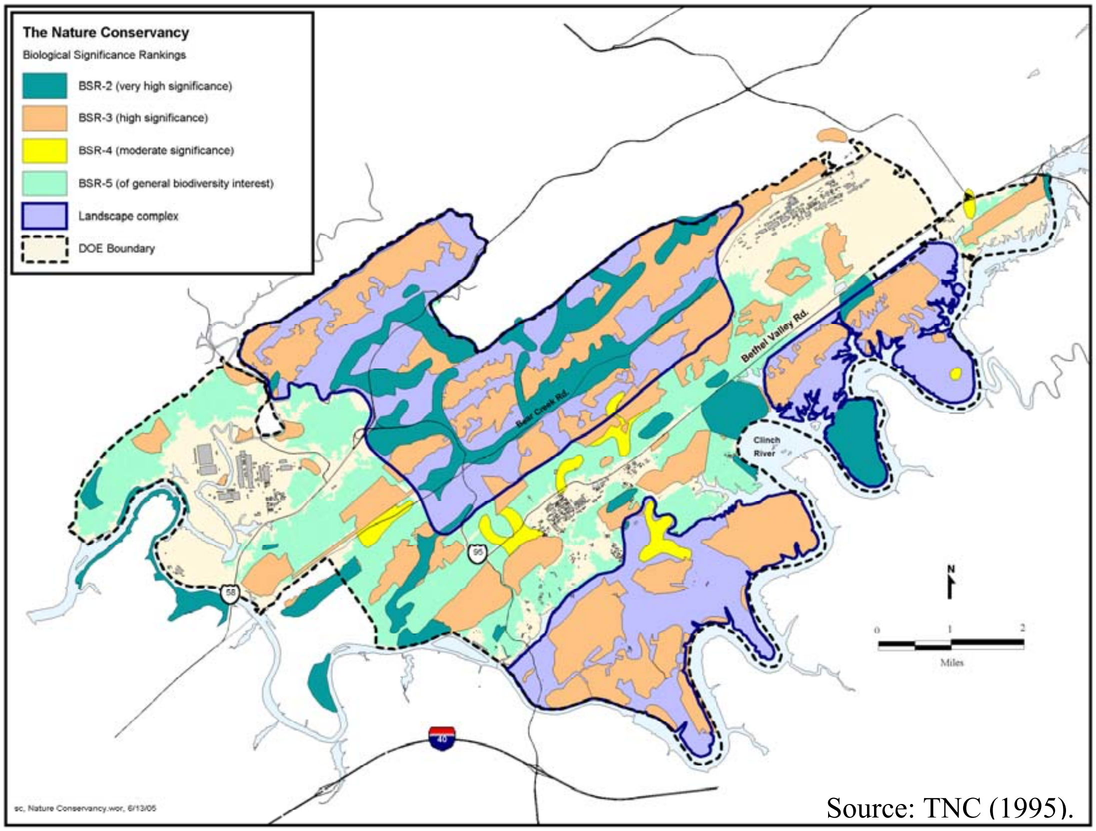


Fig. 2. Biological significance rankings for the Oak Ridge Reservation.

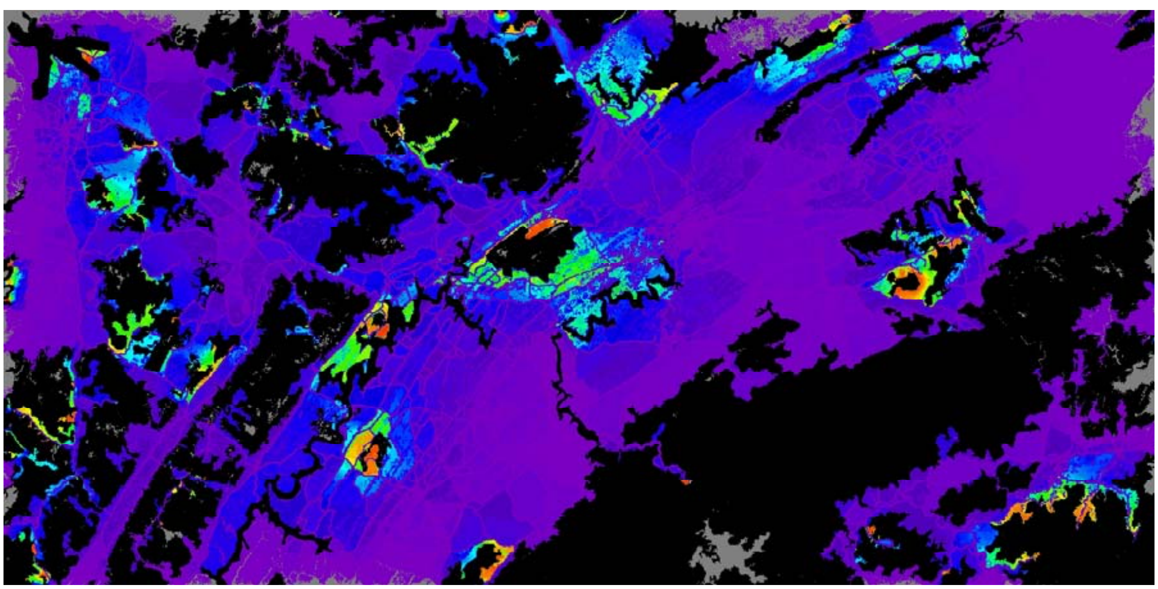


Fig. 3. Ecological corridors identified using the PATH tool.

[Based on forest hubs and waterbody boundaries from the Southeastern Ecological Framework. Hotter colors in the matrix between black hubs indicate increased density of trackways used by successful dispersers (i.e., better corridors). The ORR is shown to be of principal importance in connecting hubs within the Cumberland Mountains with large habitat hubs in the Appalachians through highly fragmented habitat.]

Intervening areas between hubs are specified by the SEF at one of 21 levels of habitat usability. The rank order of relative preference of each of these 21 habitat levels established in the SEF was retained for this analysis. While the SEF and PATH analyses are theoretical, these habitat designations and preferences might be appropriate for a generalist woodland species like the black bear, *Ursus americanus*, or the raccoon, *Procyon lotor*.

The ORR-to-Ft. Loudon Lake-to-Tellico Lake route is the best connection between the Cumberland Mountains and the Appalachians. Cherokee Lake/Panther Creek-to-Douglas Lake is an important northern pathway, but it appears to be weaker than the ORR-mediated route. A secondary route to the south, via the Hiwassee Wilderness area, also appears weaker than the route via the ORR. Areas just outside the ORR boundary, immediately northwest of sites evaluated in this report, are shown in Fig. 3 to be among the most important corridors into and out of the ORR, presumably as a part of this important larger connection between the Cumberland Plateau and the Appalachians.

1.2.2 Multimetric Indices

Multimetric indices such as the Index of Biotic Integrity (Karr 1981) are used as general estimates of biotic integrity or ecosystem health for use in comparing ecosystems and in estimating status and trends of ecosystems. Multimetric indices have gained acceptance, particularly among aquatic toxicologists and aquatic ecologists, and are widely used in environmental monitoring and regulation (Bruins and Heberling 2005). Clean Water Act language referring to "biological integrity" promotes the use of the indices. Indices often reflect managers' bias toward a reductionist approach to habitat evaluations with simple results (Diaz et al. 2004). The growth of the use of indices is reflected in Diaz et al. (2004), who summarize 64 benthic habitat quality indices.

Habitat value is not easily expressed as a single, useful number for comparing relatively similar habitat areas (Bond et al. 1999) or, in this case, very disparate lands and surface waters. Indices have several disadvantages for broadly valuing land areas or water bodies as habitat. Most importantly, users of this valuation analysis will probably have different weightings that they would like to apply to the various scores to support their needs for decision-making. Also, in this analysis many habitat value criteria are developed with respect to different spatial scales, depending on data availability and information from the literature. Some of Suter's (1993) criticisms of ecosystem health indices would also apply to any attempt to attribute a single number to the habitat value of each of the six sites at ETTP. His arguments against indices include the following:

- ambiguity—if an index is low, one cannot tell if it is because two components were very low or several components were somewhat low;
- arbitrariness of combining functions—an index may be very sensitive to the multiplicative, additive, or other process used to calculate it;
- arbitrariness of variance—the variance of an index does not have a clear relationship to any biological response;
- unreality—indices are not measures of real-world properties; and
- disconnection from testing—indices cannot be tested in the laboratory or verified in the field.

For these reasons, we do not combine values for the various habitat measures in this study. However, we use indices as measures of habitat use in particular ecosystems.

2. APPROACH

2.1 REGULATORY AGENCY PARTICIPATION

Representatives of EPA, USFWS, and the Tennessee Department of Environment and Conservation (TDEC) participated in discussions about the scope of this study and candidate metrics for valuation of habitat. Members of the first two agencies participated in a visit to the six sites.

2.2 REQUIREMENTS FOR METRICS AND SCORING CRITERIA

In conducting this study, we sought to develop general valuation metrics and scoring criteria that would be useful for supporting remedial decisions. Although we recognize that habitat is a species-specific concept (Hall et al. 1997), we consider the broad range of taxa in a general way, rather than focusing on a few species. We recognize that a habitat suitability index that would be conducted with respect to one species or genus would be quite different from those pertaining to broader taxa (Rossi and Kuitunen 1996). The following were our requirements for candidate habitat valuation metrics and scoring criteria:

- preference for semi-quantitative metrics, not just descriptive criteria;
- emphasis on communities or broad taxa rather than numerous habitat suitability index assessments at the species or guild level;
- applicability to terrestrial and aquatic environments;
- well-defined relationship between metrics and use value or rarity value;
- ability to put some of the metrics in the spatial context of habitat value at the ORR or regional reference sites;
- ability to accomplish valuation study by making thorough use of existing information; and
- ability to transfer and implement the methodology at sites other than the focal sites of this study.

2.3 GENERAL VALUATION METRICS

Several categories of metrics were selected from the literature on habitat valuation, habitat evaluation, habitat suitability assessment, and conservation prioritization. These metrics were integrated in a general framework for habitat valuation. We assume the following:

- that supply and demand guide the selection of habitat by organisms, just as they guide human economic behavior;
- that use of an area by a species for any purpose indicates demand for that type of environment and represents habitat value;
- that a rare vegetation community or rare aquatic landscape feature is in low supply and indicates high habitat value for species that require it;

- that area and time are dimensions of habitat value; and
- that spatial context of a site can provide added habitat value to the site.

The general metrics for scoring habitat value are presented in Table 1. The core determinant of habitat value is use (for food and water, reproduction, and migration or other movement). Use is a multidimensional quantity that should include intensity, spatial extent, and temporal duration. Area is an important dimension of use value; in our approach, we include total site areas (and proportion of sites taken up by different habitat types, where known) in the site descriptions. For two similar areas, a larger habitat patch is generally more valuable as habitat than a smaller one, although edge distance is also an important habitat value factor for taxa such as birds (see below). Similarly, a patch that will become a residential development in 10 years is less valuable than one that will be conserved. Therefore, we think of habitat use value as the product of use, area, and time. This product is consistent with calculations in HEA, whose output is typically service-acre-years. However, the semiquantitative measures of use, the inexact areas, and the highly uncertain durations of habitat value prohibit us from performing this calculation. We do not attempt to establish habitat value equivalencies between site areas.

Table 1. Metrics for valuing habitat at six contaminated sites

Type of value	Metric	Explanation
		Value from site alone
Use	Taxa richness	Taxa richness or biodiversity is a direct measure of the number of species that inhabit an area.
	Number of sensitive species	Sensitive species are a subset of diversity and the number of species that use an area. Their absence provides an indication of the level of degradation of an area.
	Complexity of habitat structure	Complex habitat structure is an indirect measure of the potential number of species that may use an area.
	Presence of special wildlife habitat services	The presence of bird rookeries, bat maternity roosts, male display areas, vernal pools, or other wildlife breeding areas indicates greater use and importance compared to similar areas without these features.
	Habitat suitability relationship for broad taxa	These relationships provide information on whether particular vegetation associations or other environmental quality variables are highly suitable or not suitable for particular broad taxa.
	Number of invasive or nonnative species	Nonnative species decrease use by native species. Invasive species also decrease use by native species, and their footprint increases with time, if unchecked (therefore, the area-weighted use value for native species will decrease with time).
	Land cover designation	If the majority of a land area is paved or covered with buildings, the habitat value is low because of lack of vegetation, minimal habitat structure, and fragmentation.
	Land use designation	If land use is designated as an industrial area, the habitat use value may not continue for as long as it would if the area were conserved.

Table 1. Metrics for valuing habitat at six contaminated sites (continued)

Type of value	Metric	Explanation
		Offsite value added
Rarity	Presence of rare species	The current value of habitat is high if rare species use it. State- and federal-listed and candidate species are considered rare for this study.
	Presence of rare community with respect to the Oak Ridge Reservation, the region, the Ridge and Valley ecoregion, or the Southern Appalachians	A rare community implies little redundancy or substitutability for habitat services, and potentially a high demand for this site.
Use from spatial context	Presence of similar, adjacent habitat patch	The use value of a habitat patch increases with area, because some species need minimal patch areas for home ranges, territories, or viable populations. In addition, the size of a habitat patch is correlated with diversity.
	Presence of ecological corridor	The presence of migration and other movement corridors indicates that the community of the site in question adds use value to surrounding habitat and that the surrounding communities add use value to habitat on the site.
	Adjacency to complementary land or water	The arrangement of communities can add value to organisms that enjoy services of each (e.g., terrestrial zones around wetlands and riparian habitats).
	Adjacency to conservation land use area	The habitat value of a site that is adjacent to a reserve would probably persist longer than the habitat value of other sites.

A direct measure of use of a site by various populations is species diversity or taxa richness (Table 1). Moreover, properties of ecosystems are partly determined by biodiversity (i.e., the functional characteristics of species as well as the distribution and abundance of organisms through space and time) (Hooper et al. 2005). An increasing number of ecologists view biodiversity as an insurance policy or buffer against major ecosystem functional change (Doherty et al. 2000). However, it is notable that species richness scales with area (Storch et al. 2005). Additionally, the presence of vertebrate breeding areas is a direct measure of the use of a site. Some individuals or species may be transient, and although we recognize that species that may be foraging or using an area for reproduction are more closely linked to an area, we do not attempt to distinguish resident from transient species. Nonnative species are included in species richness measures; their negative contribution to habitat value is considered in a separate category.

Indirect measures of use by a large number of species are the presence of sensitive species, the presence of complex habitat structure, and broad habitat suitability relationships (Table 1). The presence of sensitive (sometimes called “intolerant”) species may imply that physical, chemical, and biological disturbances are not very intensive or extensive, that a sensitive group of taxa are present, and that species richness in general is probably high. (However, “intolerant” species have been observed in areas with significant disturbance, such as Upper East Fork Poplar Creek.) A commonly used method for assessing stream quality is the measurement of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa, that is, Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). Scoring criteria for sensitive plants are not developed because there are no broad taxa that are comparable to EPT taxa for showing sensitivity to physical disturbance and soil quality. An exception might be spring ephemeral wildflowers in forests, but even these are often observed adjacent to roads.

Biodiversity has been closely associated with habitat structural complexity by many researchers (Crowder and Cooper 1982, Downes et al. 1998, Benton et al. 2003, Johnson et al. 2003). For example, the diversity of prey of bluegill sunfish (*Lepomis macrochirus*) was lower at low macrophyte density than at intermediate or high macrophyte density (Crowder and Cooper 1982), though very high macrophyte density can lead to hypoxia (Miranda and Hodges 2000). Some researchers argue that few empirical studies show associations between habitat conditions and biodiversity (Doherty et al. 2000), and quantitative methods for assessing habitat structural complexity are much more common in streams (Barbour et al. 1999) than in terrestrial systems (Newsome and Catling 1979) or ponds.

Additional chemical parameters (nutrient levels, pH, organic carbon) in water, soil, or sediment are metrics of ecological condition (Young and Sanzone 2002) and may be measures of habitat use value. One clear example is dissolved oxygen concentration, which is related to abundance and production of fish and invertebrates and is presumably related to diversity.

For some bird species, the length of a forest edge is thought to be more closely related to species richness than the area of forest or adjacent land cover. However, Imbeau et al. (2003) argue that species that prefer edge habitats at agriculture-forest junctures are actually species that prefer early-successional habitats wherever they are available. The territory of some waterfowl may be more accurately represented by shore length than by water or land area.

It is assumed that nonnative species take niches that would be occupied by native species, and therefore the diversity of nonnatives is an indicator of reduced use value by native species (Table 1). The susceptibility to invasion by exotic species is strongly influenced by species composition and disturbance regime. Roads and powerline rights-of-way are viewed as corridors for exotic species. As stated above, we evaluate nonnative species in an independent metric rather than assessing native species diversity explicitly. Invasive plant species are assumed to indicate lower habitat quality than just nonnatives, because invasive species have the potential to increase their abundances so rapidly that they can dominate the landscape. In contrast, it is more difficult to identify invasive fish species as a subset of nonnative fish species; nonnative fish can rarely increase their populations to dominate a system, unless the system is severely impacted or artificially constrained (e.g., the ORR swan pond in which grass carp, goldfish, and fathead minnow dominate partially because of the intentional exclusion of other species). However, grass carp exert a large effect on habitat structure and composition without becoming the dominant species.

Another determinant of habitat value is rarity, or the lack of substitutes (Table 1). A rare vegetation association is arguably more valuable than an association with more substitutes, especially if organisms are closely adapted to that vegetation association. It may be argued that the presence of rare species also makes a biotic community more unique and valuable. “Occupation by rare species . . . is generally accepted as indicating that a habitat has high biological value” (Rossi and Kuitunen 1996). Rare plant or bird species are often indicative of rare vegetation associations (SAMAB 1996b). An important dimension of rarity is the region or land area—i.e., rare with respect to what particular spatial area? Our analysis focuses on uniqueness with respect to the ORR and uniqueness with respect to broader areas for which we have information. These may include (1) the region around the ORR defined by areas that have been sampled previously as reference areas, (2) Roane County (the county in which the ETTP portion of the ORR is located), (3) the Ridge and Valley physiographic province or ecoregion, or (4) the Southern Appalachian region that is the subject of the Southern Appalachian Man and the Biosphere Program (SAMAB 2005). The Southern Appalachian Man and the Biosphere assessment area includes the Northern Piedmont, Southeastern Plains, Blue Ridge, Ridge and Valley, Southwestern Appalachians (including Cumberland Plateau), Central Appalachians, and Interior Plateau (SAMAB 1996a, b, Omernik 1995). This region includes parts of West Virginia, Virginia, Kentucky, Tennessee, North Carolina, Alabama, Georgia, and South Carolina.

In general, older successional communities are rarer than early successional ones, especially within forest cover zones. The presence of legacy trees can be associated with high wildlife diversity (Mazurek and Zielinski 2004).

Wetland communities generally have high value because of their decline nationally. Between 1986 and 1997, forested wetlands displayed the greatest areal decline of all wetland types, with a loss of 1.2 million acres, a 2.4% change. Freshwater emergent wetlands experienced a greater percentage decline, a 4.6% change, or 1 million acres, during the 11-year period (Dahl 2000).

It is notable if the occurrence of landscape features (such as stream density or water cover) is much higher than a regional average. Then the density of that land cover type may be viewed as rare. This type of measure is particularly important in the context of remedial actions that can alter the ratio of water body area to land area.

In addition to habitat use value that is easily measured, additional use value of a site may result from its spatial context (Table 1). Ponds and streams may serve as sources of drinking water for terrestrial organisms. Semlitsch and Bodie (2003) note that "biological interdependence between aquatic and terrestrial habitats is essential for the persistence of populations." Wetlands may remove toxicants entering aquatic ecosystems, reduce sediment loads, transform nutrients, and serve as aquatic habitat (e.g., breeding habitat for amphibians) (King et al. 2000, Rosensteel and Awl 1995). Forests and grasslands may serve as habitat for amphibians and reptiles that reproduce in wetlands or ditches (Semlitsch and Bodie 2003). Forests may provide maternity roost sites for bats that forage above ponds.

The connectivity of habitat is often as important as soil or vegetation type in determining if habitat for a particular species is adequate (Turner et al. 2001). For example, the presence of a vegetation association on a particular land area or pond may create habitat corridors that improve the habitat quality or suitability of adjacent land areas or water bodies (Rosenberg et al. 1997, Hargrove et al., in press). Similarly, vegetated areas that provide cover for mammals and birds traveling through industrial land use areas would have high habitat value. The absence of the same communities might be a measure of fragmentation of habitat (i.e., loss of area of the original habitat, reduction in habitat patch size, and increasing isolation of habitat patches). Typically, fragmentation results in a decline of those species that avoid or will not move across unsuitable habitats, though species that thrive in ecotones (e.g., forest edges) may become more abundant (Andren 1994). Fish require a waterway, flooded weir, or fish ladder to move. Aquatic ecosystems are at least partially fragmented if weirs are present.

Adjacency to a conservation land use area implies that habitat value will endure or may improve to the level of habitat quality in the conserved area (Table 1). For example, Ostendorp (2004) includes the proportion of strictly enforced, conservation shore areas as part of his Quality Elements of an Integrated Lakeshore Quality Assessment.

As stated above, habitat valuation is most often conducted in the context of prioritizing conservation actions. However, a few measures of habitat value often associated with this goal are inappropriate here. For example, representativeness is often viewed as a criterion for reserve selection (Margules and Usher 1981), which means that (1) lands representing communities that are more common often get conserved first and (2) examples of all communities should eventually get conserved. In this study, rarity is viewed as a major component of value, which contrasts with the first meaning of representativeness described above. Similarly, conservation assessments often consider the risk of development among their habitat valuation metrics (Rossi and Kuitunen 1996, Tans 1974), because lands that are not threatened by development will retain their habitat value without formal conservation. In this study, land use and the associated management practices are indicators of the duration of existing habitat value and provide information about the limits of succession (e.g., mowed areas in industrial parks or along powerline rights-of-way), but risk of development is not used as a measure of habitat value. Moreover, ecological fragility is sometimes considered a criterion for conserving land (Margules and Usher 1981), but we do not believe that fragility indicates habitat value unless it is related to rarity, and measures of rarity are already included in the analysis.

Several additional characteristics were considered but not selected as measures of habitat value. These include abundance, disturbance, replaceability, and area. Abundance could be used as a measure of habitat value but would have to be implemented carefully and perhaps arbitrarily. Many generalist species such as white-tailed deer, Canada geese, and raccoons are overabundant (Borenstein 2005), and their numbers do not correlate well with habitat suitability for a variety of species. McDonough and Hickman (1999) assert that the dominance of the fish community by one species is indicative of disturbance or degraded conditions. In addition, relative abundance of a species does not always correlate with ecosystem importance of a species, because rare species such as keystone predators can significantly influence energy and material flows (Hooper et al. 2005). Taxa richness metrics for benthic invertebrates on the ORR tend to be more consistent than indices that combine richness and abundance. On the other hand, poor fish habitats may be characterized by moderate diversity, and low abundance (sometimes one fish per taxa) is a better indicator that recovery is not complete. The only habitat value measure that factors in abundance in this study is the abundance of rare fish. This is consistent with EPA Region 5's CrEAM methodology, in which rare species abundance is a measure of ecological significance (White and Maurice, unpublished manuscript).

The importance of various physical disturbances and to what extent the term "disturbance" represents physical or biological exposure versus biological effect are uncertain. Although we did not opt to use disturbance as an independent measure for valuing habitat, we decided to include descriptions of actual disturbances or management practices as part of the site descriptions: presence of weir, absence of riparian zone, presence of concrete liner, substantial nutrient influx, presence of chemical contamination, pine beetle damage, erosion, plantation land cover, presence of burial ground, mowing, presence of roads, presence of buildings, and presence of scrap metal. Some of these disturbances are included in the analysis of habitat complexity, land cover, and ecological corridors. In addition, we include the presence of invasive biota as a metric of habitat value in our analysis.

We also considered replaceability as a metric for the habitat valuation. Examples of communities that cannot easily be replaced or reproduced are scored more highly than others in many valuation criteria supporting conservation decisions (Margules and Usher 1981). We hope to capture the fact that a mowed lawn or a concrete-lined stream may have substitutes elsewhere. However, replaceability is really a combination of disturbance, which has the problems described above, and rarity, which is the basis for multiple metrics of habitat value (Table 1). Moreover, Margules and Usher (1981) argue that the value of communities developed on artificial sites can be determined only if the course of ecological succession is accurately predicted. Karr et al. (1986) have asserted that the presence of altered habitat structure is one of the major stressors of aquatic systems, but we believe that this is accounted for directly in the habitat complexity measure and spatial context measures of use value, such as the presence or strength of ecological corridors and land cover adjacency, and indirectly in measures of diversity.

Clearly, area would be a pertinent measure of habitat value for sites within a single ecosystem. A larger, contiguous habitat patch is generally more valuable to any species than a smaller one (see discussion of spatial context above). For example, rates of species loss are dependent on land or water body area (Margules and Usher 1981). However, such a comparison cannot be made across ecosystem types. A small, ephemeral ditch may be highly valuable for amphibians for example. This category is not conducive to a valuation of high, medium, or low unless it is linked to particular species and critical patch sizes for individuals (e.g., territory or home range size) or viable populations (Carlsen et al. 2004). For example, many species at higher trophic levels require large habitat areas.

2.4 CRITERIA FOR SCORING

Measures of habitat value (specified below) are scored according to three levels of habitat quality: high, medium. and low. Most supporting datasets allow us to develop definitions of three categories of value, but we do not believe that more categories are justified. As Margules and Usher (1981) note, "Arbitrary definitions and value judgments do not lend themselves to quantification, yet quantification is essential for true comparisons to be made." Therefore, we choose as few categories as we believe will be useful for decision-makers. When scores are highly uncertain, we provide a range of two levels (e.g., medium to high). Total habitat value indices are not calculated for each site for the reasons stated above.

It would not be unusual for sites to receive apparently conflicting scores for different metrics. For example, early successional areas would receive a low score for successional age (an indicator of rarity of vegetation community) but might earn a high score for bird diversity.

For future scenarios, we do not have the data to support particular scores for various metrics. Recovery of ecosystem diversity, for example, does not automatically result in recovery of rare, native fauna (Stewart et al. 2005). Therefore, results of the habitat valuation for future scenarios are presented in a qualitative manner.

2.5 SPECIFICATION OF MEASURES OF HABITAT VALUE FOR VARIOUS ECOSYSTEMS

The development of measures of habitat value for various ecosystems has been guided by (1) data availability and (2) ease of development of criteria for high, medium, and low habitat value, based on descriptions or statistics from the literature or other reasonable definitions. If regional reference data were available for rather undisturbed ecosystems, we chose 25th and 75th percentiles as thresholds for high and medium and medium and low habitat value designations. Other metrics and scoring criteria were borrowed from existing biotic indices. Many measures were developed much more arbitrarily, with qualitative characteristics assigned to the high, medium, and low categories based on the possible range of land cover types of the mean of land cover occurrence data from the Southern Appalachian Man in the Biosphere program. Specific criteria for scoring streams (Table 2), ponds (Table 3), and terrestrial lands (Table 4) are developed from the broad metrics in Table 1. No metrics are available for habitat value for mammals because of lack of data and the fact that most mammals on the ORR are generalists.

Table 2. Habitat value metrics and scoring criteria for stream

Metric	Criterion	Criterion	Criterion
Taxa richness—fish	Based on distributional and habitat use information in Etnier and Starnes (1993)—75% value of possible species occurrences (>15 species)	Based on distributional and habitat use information in Etnier and Starnes (1993)—(15-6 species)	Based on distributional and habitat use information in Etnier and Starnes (1993)—25% value of possible species occurrences (<6 species)
Taxa richness—benthic invertebrates	Mean taxa richness equivalent to that found at reference streams around and within the ORR[1] (Smith et al. 2005), i.e., ≥25th percentile of reference distribution (Gerritsen 1995) = 28	Mean taxa richness 12.5 to 24th percentile of the reference distribution for streams around and within the ORR (Smith et al. 2005) = 23 to 27	Mean taxa richness of <12.5 percentile of the reference distribution of streams around and within the ORR (Smith et al. 2005) ≤ 22
Taxa richness—waterfowl[2]	>11 of 15 (>75%) water bird species observed at ETTP during 10 months of waterfowl surveys in 2004	4 to 11 (25% to 75%) of 15 bird species observed at ETTP during 10 months of waterfowl surveys in 2004	<4 of 15 (<25%) water bird species observed at ETTP during 10 months of waterfowl surveys in 2004
Number of sensitive fish species	>1 sensitive species present (northern hogsucker, banded sculpin, logperch, stripetail darter, snubnose darter)	1 sensitive species present	No sensitive fish species present
Number of sensitive benthic invertebrate species	Mean EPT taxa richness equivalent to that found at reference streams around and within the ORR (Smith et al. 2005), i.e., > 25th percentile of the reference distribution = ≥ 11	Mean EPT taxa richness of 12.5 to 24th percentile of the reference distribution for streams around and within the ORR (Smith et al. 2005) = 9 to 10	Mean EPT taxa richness of < 12.5 percentile of the reference distribution of streams around and within the ORR (Smith et al. 2005) = ≤ 8
Presence of shallow, slow-flowing areas for amphibian reproduction	Extensive shallow areas present	Few shallow areas present	Shallow areas absent
Presence of waterbird rookery	Rookery present	Rookery absent	
Presence of nonnative or invasive species[3]	Nonnative species absent	Nonnative, noninvasive species present	Invasive species present

Table 2. Habitat value metrics and scoring criteria for streams (continued)

Metric	Criterion	Criterion	Criterion
Complexity of habitat structure	Score of >131 (minimum score for protection of stream habitat based on habitat assessments for several reference streams in Tennessee ecoregion 67f - Southern Limestone/Dolomite Valleys and Low Rolling Hills region (Arnwine and Denton 2001) for 10 physical and vegetation habitat parameters in EPA Rapid Bioassessment Protocols (Barbour et al. 1999)	Score of 33–131 for ten physical and vegetation habitat parameters in EPA Rapid Bioassessment Protocols (Barbour et al. 1999)	Score of <33 for physical and vegetation ten habitat parameters in EPA Rapid Bioassessment Protocols (Barbour et al. 1999)
Abundance of rare species—fish	More than 1 individual (flame chub, spotfin chub, Tennessee dace)	1 individual	No individuals
Presence of rare species—benthic invertebrates	Rare mussels present (applicable to large streams only)	Rare mussels absent (applicable to large streams only)	
Presence of rare community—wetlands	Presence of floodplain pool, boggy forested wetlands, or streamhead seepage swamps [rare communities according to TNC (1995)]	NA	Absence of floodplain pool, boggy forested wetlands, or streamhead seepage swamps [rare communities according to (TNC 1995)]
Presence of movement corridor—fish	Easily accessible to upstream and downstream sources of fish for colonization. A wide range of taxa that include species that are not strong swimmers indicates that weirs are at least easily accessible at high flows and high water levels	Easily accessible to upstream or downstream sources of fish for colonization	Not easily accessible to upstream and downstream sources of fish for colonization
Presence of movement corridor—benthic invertebrates	Upstream, downstream, and nearby stream sources of invertebrates for colonization; if weir is present, it is sometimes crossed	One or two sources of invertebrates for colonization from upstream, downstream, or adjacent stream sources	Poor upstream or downstream sources of invertebrates for colonization; weir is seldom crossed; no stream nearby
Presence of movement corridor—avian piscivores	Additional water bodies within territory of herons, kingfishers, and ospreys and rookeries or nests near those water bodies.	NA	No additional water bodies within territory of herons, kingfishers, osprey, etc.

Table 2. Habitat value metrics and scoring criteria for streams (continued)

Metric	Criterion	Criterion	Criterion
Stream density relative to Roane County, Lower Clinch River, and Southern Appalachian regional averages	Stream density above 15 ft per acre. [The mean density of stream and river channels is 12 ft per acre in the Southern Appalachians, 11.02 ft per acre in Roane County, and 15 ft per acre in the Lower Clinch River watershed (SAMAB 1996a)].	Stream density between 10 ft and 15 ft per acre. [The mean density of stream and river channels is 12 ft per acre in the Southern Appalachians, 11.02 ft per acre in Roane County, and 15 ft per acre in the Lower Clinch River watershed (SAMAB 1996a)]	Stream density below 10 ft per acre. [The mean density of stream and river channels is 12 ft per acre in the Southern Appalachians, 11.02 ft per acre in Roane County, and 15 ft per acre in the Lower Clinch River watershed (SAMAB 1996a)]
Riparian wetland coverage, relative to Southern Appalachian regional average	>2% of stream riparian zone is wetlands [Riparian zone wetlands average 0.7% of total riparian area for Southern Appalachian Assessment area (SAMAB 1996a)]	0.5-2%[2] of stream riparian zone is wetlands [Riparian zone wetlands average 0.7% of total riparian area for Southern Appalachian Assessment area (SAMAB 1996a)]	<0.5% of stream riparian zone is wetlands [Riparian zone wetlands average 0.7% of total riparian area for Southern Appalachian Assessment area (SAMAB 1996a)]
Forested riparian coverage, relative to Southern Appalachian regional coverage	>80% of stream riparian zone is forested [69.9% of the Southern Appalachian riparian zone is forested (SAMAB 1996a)]	60-80% of stream riparian zone is forested [69.9% of the Southern Appalachian riparian zone is forested (SAMAB 1996a)]	<60% of stream riparian zone is forested [69.9% of the Southern Appalachian riparian zone is forested (SAMAB 1996a)]
Forested riparian coverage, relative to Ridge and Valley regional coverage	>40% of stream riparian zone is forested [Less than 40% of the Ridge and Valley riparian zone is forested (SAMAB 1996a)]	30-40% of stream riparian zone is forested [Less than 40% of the Ridge and Valley riparian zone is forested (SAMAB 1996a)]	<30% of stream riparian zone is forested [Less than 40% of the Ridge and Valley riparian zone is forested (SAMAB 1996a)]
Adjacent amphibian habitat	Amphibian foraging, refuge, or overwintering habitat zone consisting of leaf litter, coarse woody debris, boulders, small mammal burrows, cracks in rocks, spring seeps and rocky pools to a distance of at least 159-290 m (Semlitsch and Bodie 2003) surrounding >75% of wetland area at site	Amphibian foraging, refuge, or overwintering habitat zone consisting of leaf litter, coarse woody debris, boulders, small mammal burrows, cracks in rocks, spring seeps and rocky pools to a distance of at least 159-290 m (Semlitsch and Bodie 2003) surrounding 25%-75% of wetland areas at site or to a distance of at least 80 m surrounding at least 75% of wetland areas at site	Amphibian foraging, refuge, or overwintering habitat zone consisting of leaf litter, coarse woody debris, boulders, small mammal burrows, cracks in rocks, spring seeps and rocky pools to a distance of at least 159-290 m (Semlitsch and Bodie 2003) surrounding <25% of wetland area at site or to a distance of less than 80 m surrounding <50% of wetland area at site

Table 2. Habitat value metrics and scoring criteria for streams (continued)

Metric	Criterion	Criterion	Criterion
Adjacent reptile habitat[5]	Reptile upland habitat zone for nesting, aestivating, feeding, hibernating, and basking to a distance of at least 127–289 m (Semlitsch and Bodie 2003) surrounding >75% of wetland area at site	Reptile upland habitat zone for nesting, aestivating, feeding, hibernating, and basking to a distance of at least 127–289 m (Semlitsch and Bodie 2003) surrounding 25%-75% of wetland areas at site or to a distance of at least 80 m surrounding at least 75% of wetland areas at site	Reptile upland habitat zone for nesting, aestivating, feeding, hibernating, and basking to a distance of at least 127–289 m (Semlitsch and Bodie 2003) surrounding <25% of wetland area at site or to a distance of less than 80 m surrounding <50% of wetland area at site

[1] Reference streams include Pinhook Branch, Gum Hollow Branch (two locations), Mill Branch, First Creek, Fifth Creek, White Oak Creek headwaters, University of Tennessee Farm Creek, and Mitchell Branch headwaters. Eight of the reference sites were located in second growth forests that have been minimally disturbed for about 50 years.

[2] We have no regional reference, ecoregional, or Appalachian data for waterfowl. Also, waterfowl surveys are less quantitative than other types of surveys because different ecosystem types have different visibility. Clearly, expected diversity at streams should be different from that at ponds, but we have no means to determine how, nor can we relate expected diversity to shore length.

[3] Nonnative species of fish cannot be determined, because North American nonnatives are uncertain, and the stream is too small for Asian nonnatives such as common carp and grass carp. The stream is also too small for nonnative mussels.

[4] Because this average is based on a 30-m buffer, our range has a higher midpoint, allowing for smaller wetlands at lower resolution.

[5] The only reptile sampling that we know of is sampling of northern water snakes from the upper reach of East Fork Poplar Creek inside Y-12, during the summer of 2002 by Kym R. Campbell of Biological Research Associates, Tampa, FL. Five papers related to this study are currently in press.

EPA = U.S. Environmental Protection Agency
EPT = Ephemeroptera, Plecoptera, and Trichoptera
ETTP = East Tennessee Technology Park
NA = not applicable
ORR = Oak Ridge Reservation

Table 3. Habitat value metrics and scoring criteria for ponds

Metrics	High habitat value	Medium habitat value	Low habitat value
Taxa richness—fish	Based on distributional and habitat use information in Etnier and Starnes (1993) — 75% value of possible species occurrences (>27 species)	Based on distributional and habitat use information in Etnier and Starnes (1993) — (26-10 species)	Based on distributional and habitat use information in Etnier and Starnes (1993) — 25% value of possible species occurrences (<10 species)
Taxa richness—Lepomid sunfish species, indicator of high quality littoral zone[1]	Equivalent to high (5) score for forebay sections of reservoirs in the Ridge and Valley ecoregion of the Tennessee River Valley in a Reservoir Fish Assemblage Index, namely >3 species (McDonough and Hickman 1999)	Equivalent to medium (3) score for forebay sections of reservoirs in the Ridge and Valley ecoregion of the Tennessee River Valley in a Reservoir Fish Assemblage Index, namely 2–3 species (McDonough and Hickman 1999)	Equivalent to low (1) score for forebay sections of reservoirs in the Ridge and Valley ecoregion of the Tennessee River Valley in a Reservoir Fish Assemblage Index, namely <2 species
Taxa richness—waterfowl[2]	>11 of 15 (>75%) water bird species observed at ETTP during 10 months of waterfowl surveys in 2004	4 to 11 (25% to 75%) of 15 bird species observed at ETTP during 10 months of waterfowl surveys in 2004	<4 of 15 (<25%) water bird species observed at ETTP during 10 months of waterfowl surveys in 2004
Number of sensitive fish species	> 1 sensitive species present (brook silverside, logperch, spotted sucker, greenside darter, snubnose darter)	1 sensitive species present	No sensitive fish species present
Ambient dissolved oxygen concentration—fish[3]	30-day mean above 5.5 mg/L and minimum measurement above 3.0 mg/L, indicating no impairment of production of warm water fish (USEPA 1986)	30-day mean between 3.5 mg/L, indicating severe impairment of production of warm water fish, and 5.5 mg/L, indicating slight impairment of production of warm water fish (USEPA 1986)	30-day mean at or below 3.5 mg/L, indicating moderate impairment of warm water fish (USEPA 1986)
Ambient dissolved oxygen concentration—invertebrates[3]	30-day mean above 5 mg/L, indicating no impairment of production of warm water fish (USEPA 1986)	30-day mean between 4 mg/L and 5 mg/L, indicating some impairment of production of warm water fish (USEPA 1986)	30-day mean below 4 mg/L, indicating acute mortality (USEPA 1986)
Presence of shallow areas for amphibian reproduction	Extensive shallow areas present	Few shallow areas present	Shallow areas absent
Presence of waterbird rookery	Rookery present	Rookery absent	

Table 3. Habitat value metrics and scoring criteria for ponds (continued)

Metrics	High habitat value	Medium habitat value	Low habitat value
Number of nonnative or invasive species—fish[4]	Non-North American native species absent (common carp, grass carp, goldfish)	Non-North American native species present	>1 Non-North American native species present (or grass carp[5] present)
Presence of nonnative or invasive species—shellfish	Nonnative species absent	Nonnative species present	Invasive species present (e.g., Asiatic clam, *Corbicula fluminea*; zebra mussel, *Dreissena polymorpha*)
Complexity of habitat structure	>8 of the following ecosystem structural elements: woody debris, root wads, undercut banks, boulders, cobble, gravel, sand, aquatic vegetation, emergent vegetation, shallows (<0.3 m depth), deep areas (>3 m depth), overhanging vegetation	8-4 types	<4 types
Abundance of rare species—fish[6]	More than 1 individual (flame chub, spotfin chub, Tennessee dace)	1 individual	No individuals
Presence of rare species—bats	T&E bats present	Presence of regionally rare bats	Rare bats absent
Presence of rare community—wetlands	Presence of floodplain pool, boggy forested wetlands, or streamhead seepage swamps [rare communities according to TNC (1995)]	NA	Absence of floodplain pool, boggy forested wetlands, or streamhead seepage swamps [rare communities according to TNC (1995)]
Presence of movement corridor—fish	Easily accessible to upstream and downstream sources of fish for colonization. A wide range of taxa that include species that are not strong swimmers indicates that weirs are at least easily accessible at high flows and high water levels	Easily accessible to upstream or downstream sources of fish for colonization	Not easily accessible to upstream and downstream sources of fish for colonization
Presence of movement corridor—avian piscivores	Additional water bodies within territory of herons, kingfishers, osprey	Not applicable	No additional water bodies within territory of herons, kingfishers, osprey, etc.

Table 3. Habitat value metrics and scoring criteria for ponds (continued)

Metrics	High habitat value	Medium habitat value	Low habitat value
Area of water coverage relative to Southern Appalachian regional average	>2% of local area covered by water bodies	1–2% of local area covered by water bodies. [Flooded river and lake surface is about 1.5% of the total Southern Appalachian Assessment area (SAMAB 1996a)]	<1% of local area covered by water bodies.
Riparian wetland coverage, relative to Southern Appalachian regional average	>2% of pond riparian zone is wetlands [Riparian zone wetlands average 0.7% of total riparian area for Southern Appalachian Assessment area (SAMAB 1996a)]	0.5-2%[7] of pond riparian zone is wetlands [Riparian zone wetlands average 0.7% of total riparian area for Southern Appalachian Assessment area (SAMAB 1996a)]	<0.5% of pond riparian zone is wetlands [Riparian zone wetlands average 0.7% of total riparian area for Southern Appalachian Assessment area (SAMAB 1996a)]
Forested riparian coverage, relative to Southern Appalachian regional coverage	>80% of pond riparian zone is forested [69.9% of the Southern Appalachian riparian zone is forested (SAMAB 1996a)]	60-80% of pond riparian zone is forested [69.9% of the Southern Appalachian riparian zone is forested (SAMAB 1996a)]	<60% of pond riparian zone is forested [69.9% of the Southern Appalachian riparian zone is forested (SAMAB 1996a)]
Forested riparian coverage, relative to Ridge and Valley regional coverage	>40% of pond riparian zone is forested [Less than 40% of the Ridge and Valley riparian zone is forested (SAMAB 1996a)]	30–40% of pond riparian zone is forested [Less than 40% of the Ridge and Valley riparian zone is forested (SAMAB 1996a)]	<30% of pond riparian zone is forested [Less than 40% of the Ridge and Valley riparian zone is forested (SAMAB 1996a)]
Adjacent amphibian habitat	Amphibian foraging, refuge, or overwintering habitat zone consisting of leaf litter, coarse woody debris, boulders, small mammal burrows, cracks in rocks, spring seeps and rocky pools to a distance of at least 159–290 m (Semlitsch and Bodie 2003) surrounding >75% of wetland area at site	Amphibian foraging, refuge, or overwintering habitat zone consisting of leaf litter, coarse woody debris, boulders, small mammal burrows, cracks in rocks, spring seeps and rocky pools to a distance of at least 159–290 m (Semlitsch and Bodie 2003) surrounding 25%–75% of wetland areas at site or to a distance of at least 80 m surrounding at least 75% of wetland areas at site	Amphibian foraging, refuge, or overwintering habitat zone consisting of leaf litter, coarse woody debris, boulders, small mammal burrows, cracks in rocks, spring seeps and rocky pools to a distance of at least 159–290 m (Semlitsch and Bodie 2003) surrounding <25% of wetland area at site or to a distance of less than 80 m surrounding <50% of wetland area at site

Table 3. Habitat value metrics and scoring criteria for ponds (continued)

Metrics	High habitat value	Medium habitat value	Low habitat value
Adjacent reptile habitat[8]	Reptile upland habitat zone for nesting, aestivating, feeding, hibernating, and basking to a distance of at least 127–289 m (Semlitsch and Bodie 2003) surrounding >75% of wetland area at site	Reptile upland habitat zone for nesting, aestivating, feeding, hibernating, and basking to a distance of at least 127–289 m (Semlitsch and Bodie 2003) surrounding 25%-75% of wetland areas at site or to a distance of at least 80 m surrounding at least 75% of wetland areas at site	Reptile upland habitat zone for nesting, aestivating, feeding, hibernating, and basking to a distance of at least 127–289 m (Semlitsch and Bodie 2003) surrounding <25% of wetland area at site or to a distance of less than 80 m surrounding <50% of wetland area at site

[1] Average reservoir size may be larger than the K-901-A and K-1007-P1 Holding Ponds.

[2] We have no regional reference, ecoregional, or Appalachian data for waterfowl. Also, waterfowl surveys are less quantitative than other types of surveys because different ecosystem types have different visibility.

[3] It is assumed that dissolved oxygen concentrations are measures of diversity as well as abundance.

[4] There is quite a bit of uncertainty regarding where some North American natives (e.g., fathead minnow and redbreast sunfish) formerly occurred and where they were introduced). Therefore, we focus on nonnative species from Asia in this analysis.

[5] Grass carp exert a large effect on habitat structure of ponds.

[6] T&E species have rare and spotty distributions in the region, and we believe that abundance of these individuals is a better measure of rarity than number of rare species.

[7] Because this average is based on a 30-m buffer, our range has a higher midpoint, allowing for smaller wetlands at lower resolution.

[8] The only reptile sampling that we know of is sampling of northern water snakes from the upper reach of East Fork Poplar Creek inside Y-12, during the summer of 2002 by Kym R. Campbell of Biological Research Associates, Tampa, FL. Five papers related to this study are currently in press.

ETTP = East Tennessee Technology Park
NA = not applicable
T&E = threatened and endangered

Table 4. Habitat value metrics and scoring criteria for terrestrial land areas

Metric	High habitat value	Medium habitat value	Low habitat value
Major vegetation cover[1]	Forest and native herbaceous cover such as barrens and marshes	Managed or recently disturbed systems such as mowed grass, roller-chopped areas, herbicide-treated areas, shrub/scrub cover, and pine plantations.	Mowed areas, industrial infrastructure, paved areas, gravel areas.
Percent impervious surface or bare ground	Less than 10%	10% to 50%	Over 50%
Taxa richness, breeding birds, forest species	>75% of highest bird richness observed in a single day at East Fork Ridge Road/McNew Hollow Road area of the ORR (21), i.e., >15 species	Between 25% and 75% of highest bird richness observed in a single day at East Fork Ridge Road/McNew Hollow Road area of the ORR (21), i.e., 6 to 15 species	<25% of highest bird richness observed in a single day at East Fork Ridge Road/McNew Hollow Road area of the ORR (21), i.e., <6 species
Taxa richness, breeding birds, edge or early successional species	>75% of highest bird richness observed in a single day at Freels Bend area of the ORR (25), i.e., >18 species	Between 25% and 75% of highest bird richness observed in a single day at Freels Bend area of the ORR (25), i.e., 7 to 18 species	<25% of highest bird richness observed in a single day at Freels Bend area of the ORR (25), i.e., <7 species
Habitat suitability relationship—reptiles	Grass for most turtles and lizards; all successional stages for most snakes [Wilson (1995) and Trani (2002)]	Sapling, poletimber, and sawtimber successional stages for most turtles and lizards [Wilson (1995) and Trani (2002)]. It is also assumed that mowed grass has medium suitability for reptiles.	Little or no vegetation associated with industrial infrastructure, paved areas, gravel areas
Presence of nonnative or invasive species—plants	Native species present over greater than 90% of the canopy, shrub, and herbaceous layer of each plant community.	Native species dominant (>50%) in the majority of plant communities at a site	Invasive or nonnative species dominant (>50%) in the majority of the communities found at a site
Complexity of vertical habitat structure	Having at least 4 of 5 characteristics from the following list: >50% canopy cover; >50% shrub cover; >50% ground vegetation cover above 0.5 m; significant litter, fallen logs and/or rocks, and high moisture [modified from Newsome and Catling (1979)]	Having 2 or 3 characteristics from the following list: >50% canopy cover; >50% shrub cover; >50% ground vegetation cover above 0.5 m; significant litter, fallen logs and/or rocks, and high moisture [modified from Newsome and Catling (1979)]	Having fewer than 2 characteristics from the following list: >50% canopy cover; >50% shrub cover; >50% ground vegetation cover above 0.5 m; significant litter, fallen logs and/or rocks, and high moisture [modified from Newsome and Catling (1979)]

Table 4. Habitat value metrics and scoring criteria for terrestrial land areas (continued)

Metric	High habitat value	Medium habitat value	Low habitat value
Length of edge between patches	Extensive edge between at least three patches of vegetation	Two habitat patches with an edge between them	No edge between vegetation associations
Presence of rare species—plants	T&E or other rare species present	T&E species absent	
Age of vegetation[2]	Mid-successional [41–80 years, value for mixed mesophytic hardwood forests (SAMAB 1996b)]	Saplings and poletimber [11-40 years, value for mixed mesophytic hardwood forests (SAMAB 1996b)]	Grass, shrubs and seedlings [0-10 years, value for mixed mesophytic hardwood forests (SAMAB 1996b)]
Presence of special wildlife breeding areas	Special breeding areas present	Special breeding areas absent	
Presence of rare species—birds	T&E birds present	Presence of regionally rare birds	Rare birds absent
Presence of rare terrestrial vegetation community	Presence of one of seven rare vegetation communities on the Oak Ridge Reservation: northern white-cedar woodland, oak-hickory-ash limestone woodland, limestone cliff, limestone sinkhole, limestone barren (annual grass-dominated), limestone barren (perennial grass-dominated), ridge and valley calcareous mixed mesophytic forest (TNC 1995)	Absence of the seven rare vegetation communities listed in TNC (1995)	
Designation of land as a preliminary conservation site on the ORR based on Biological Significance Rankings of the Nature Conservancy (TNC 1995)	Biological Significance Ranking of BSR 1 (outstanding significance), BSR 2 (very high significance), or BSR 3 (high significance) based on clusters of T&E species, significant communities, or other important landscape features (TNC 1995)	Biological significance ranking of BSR 4 (Moderate significance) or BSR 5 (of general biodiversity interest) (TNC 1995)	Surveyed but not designated as BSR 1-5

Table 4. Habitat value metrics and scoring criteria for terrestrial land areas (continued)

Metric	High habitat value	Medium habitat value	Low habitat value
Part of ecological corridor linking deciduous forests from Cumberland Plateau to Great Smoky Mountains	Presence of deciduous forest or land cover in primary ecological corridor connecting forest patches of forest-loving species (Hargrove and Hoffman, unpublished, based on SEF hubs, Fig. 3)	NA	Absence of deciduous forest or land cover in primary ecological corridor connecting forest patches of forest-loving species (Hargrove and Hoffman, unpublished, based on SEF hubs, Fig. 3)
Adjacency to conservation area	Adjacent to or part of Blackoak Ridge conservation easement (Fig. 4)	Adjacent to conservation easement, but land use prevents area from merging with conserved habitat patch (i.e., becoming deciduous forest)	Not adjacent to or part of Blackoak Ridge conservation easement

[1] More direct measurements of plant species richness are not available.
[2] It is assumed that older vegetation is rarer, and these vegetation associations would take longer to recover/replicate. One type of estimate of the minimum time to recovery could be provided by the average age of the lost vegetation (Vasek et al. 1975).

BSR = biological significance ranking
NA = not applicable
ORR = Oak Ridge Reservation
SEF = Southeastern Ecological Framework
T&E = threatened and endangered

2.6 DATA AVAILABILITY

The habitat valuation was conducted using existing information, although this information was supplemented by additional statistical analyses, summaries of observations from notebooks that had not previously been summarized on a site basis, and bird counts at two of the sites. Data from 2004 were used for most aquatic endpoints because of positive trends in some of the case study ecosystems. However, a range of benthic invertebrate data from 1998–2004 were used for Mitchell Branch because of high interannual variability, and unpublished 2005 data were used if there was an obvious change (e.g., the collection of grass carp from the K-1007-P1 Holding Pond in 2005). Data from reference locations were sometimes summarized for a period of several years. In studies of the ORR, regional reference ponds and streams were selected that did not include the major disturbances present from DOE industrial facilities (runoff, chemical contamination), but were sometimes found in areas supporting low to moderate agricultural development. These reference water bodies provide a regional context for this study.

Major sources of local information included the following:

- a recent bird count for the K-25 Site Contractor's Spoil Area and K-901-A North Disposal Area (Appendix A);
- fish community (spring), invertebrate community (spring), and waterfowl surveys (monthly) conducted within the Biological Monitoring and Abatement Program (BMAP) (Peterson et al. 2005a), including reference streams (Smith et al. 2005) and waterfowl surveys by site (Appendix B);

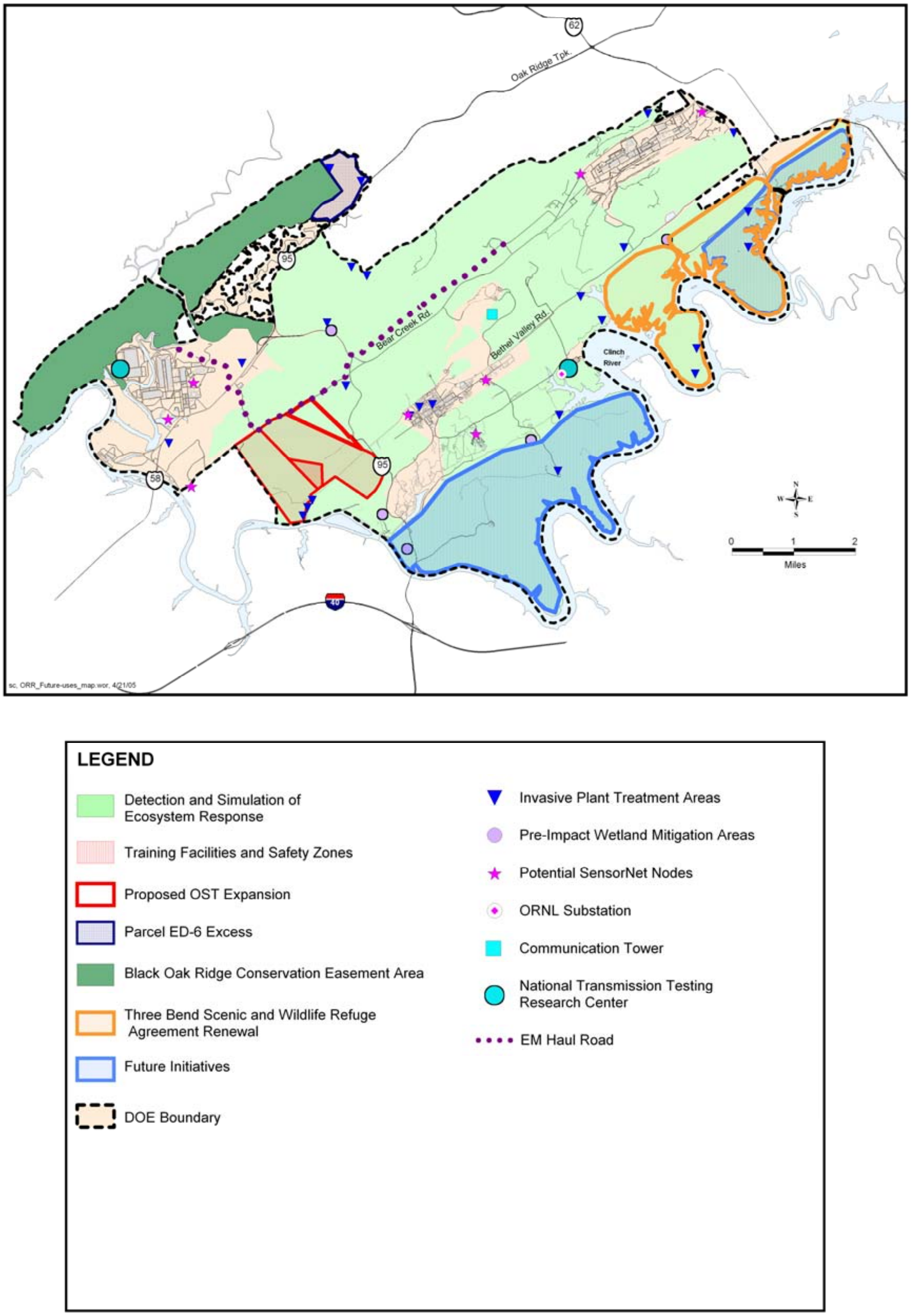


Fig. 4. Future land uses on the ORR.

- fish community and pond vegetation surveys performed in support of the ETTP sitewide remedial investigation (Peterson et al. 2005b);

- a report summarizing a bat survey conducted at the K-1007-P1 Holding Pond in 2003, as well as past studies and observations of bats on the ORR (Harvey and Britzke 2004, summarized in Appendix C);

- a report describing a wetland survey of ETTP (Rosensteel and Awl 1995);

- results of wetland surveys conducted by Mark Peterson over the 1998–2004 time period at ETTP (Tetratech Map, 2005; Personal field notes) (Figs. 5, 6, and 7);

- invasive species surveys at select locations along roads at ETTP;

- a site description of the K-25 Site Contractor's Spoil Area, entitled "Appendix A—Checklist for Ecological Assessments/Sampling, K-25 Site Contractor's Spoil Area," February 2004;

- surveys of rare vegetation and rare vegetation communities on the ORR by Larry Pounds and others and summarized in maps and BSRs by the Nature Conservancy (TNC 1995);

- past observations and photographs; and

- a map of future land use at the ORR (Fig. 4).

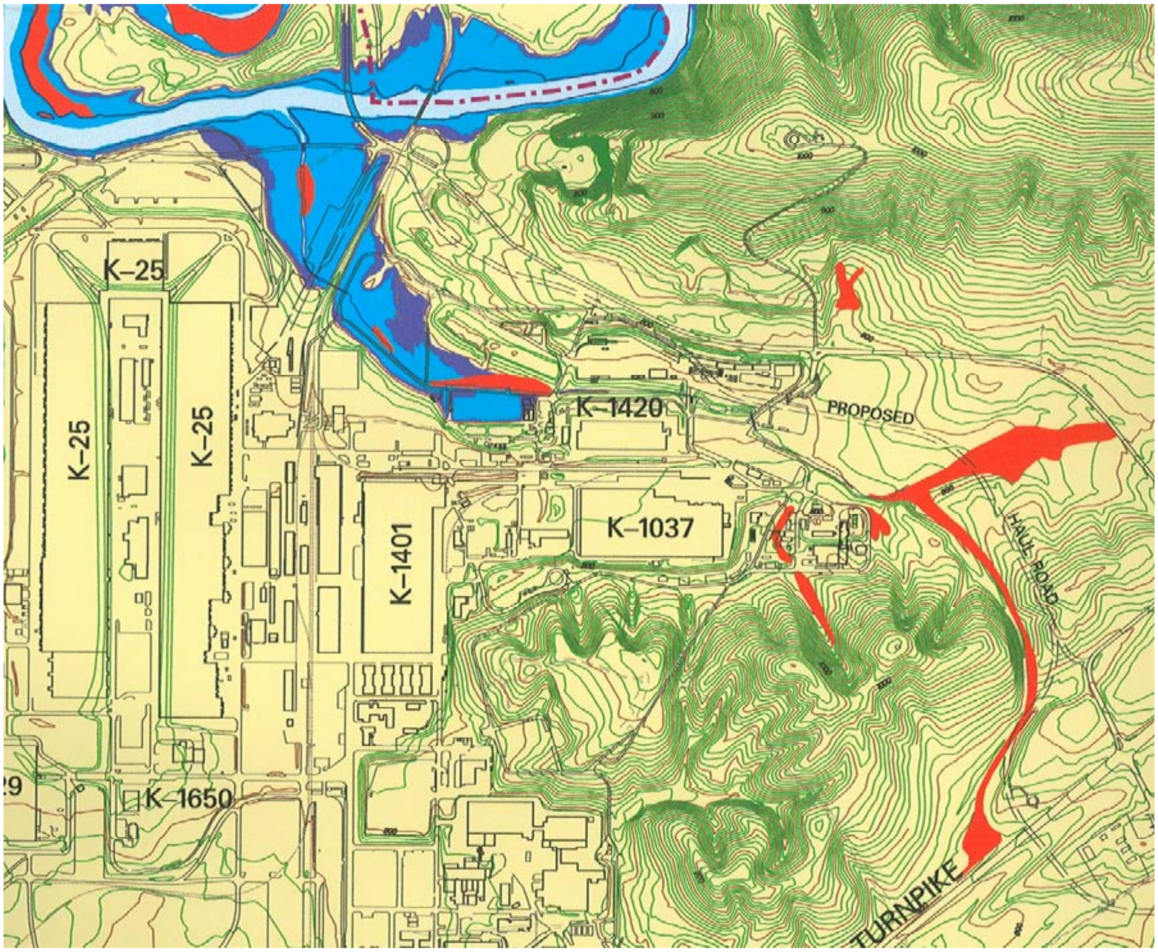
We did not have survey information for mammals or birds at the three terrestrial sites. Because the mammals on the ORR are primarily habitat generalists (and therefore will probably not affect remedial decisions based in part on habitat value) and because trapping is a much more time-consuming and rigorous exercise, we focused the only new sampling of this study on birds (Appendix A). A complete bird list for the ORR is included as Appendix D, and a complete list of mammals, amphibians, and reptiles is in Appendix E.

3. SITE DESCRIPTIONS

The boundaries of the six sites are depicted in Fig. 1. These areas cover known disposal or contamination areas plus any adjacent land (for terrestrial sites) that have had soils collected for contaminant measurements.

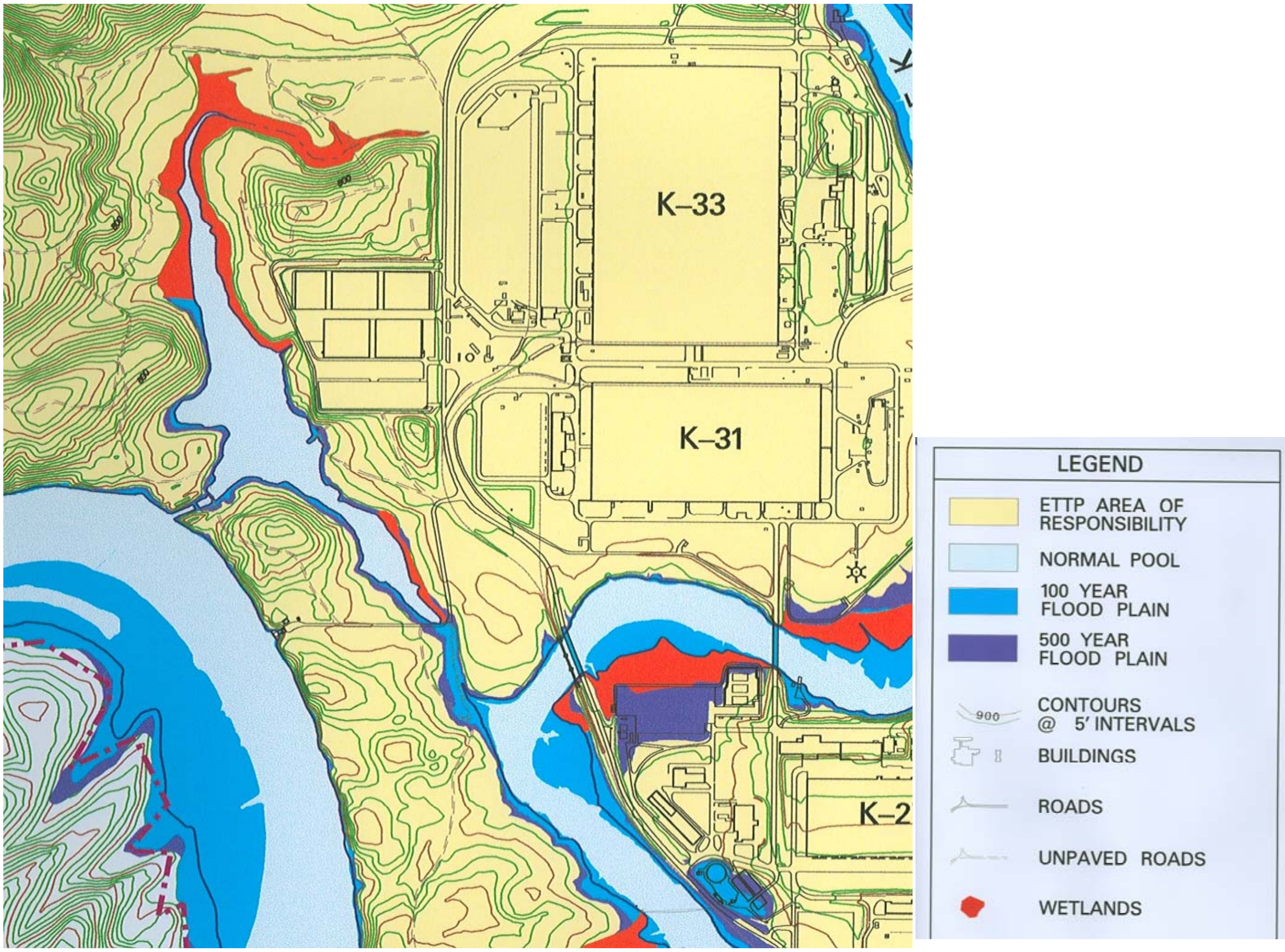
3.1 MITCHELL BRANCH

Mitchell Branch is a second order stream, approximately 1900 m long, that enters ETTP from an area that is replete with seeps and springs, has diverse vegetation (including a mature forested floodplain) and may be habitat for rare plants. The creek then runs between the former K-1407-B and K-1407-C Holding Ponds, continues on the north side of the main ETTP plant area, and flows across a weir to Poplar Creek (Fig. 1). The weir serves as a compliance sampling point rather than to regulate flow. The weir is only effective at regulating very low flows, though it may have been constructed for that purpose. The intake of a drainage pipe that runs under the weir is covered with silt (T. Poole and C.L. Dan, personal communication, May 20, 2005). This formerly natural stream has been channelized and rerouted to its current position. The area adjacent to Mitchell Branch within the ETTP security fence is highly industrialized. Flooding to the level of an adjacent road sometimes occurs during storm events.



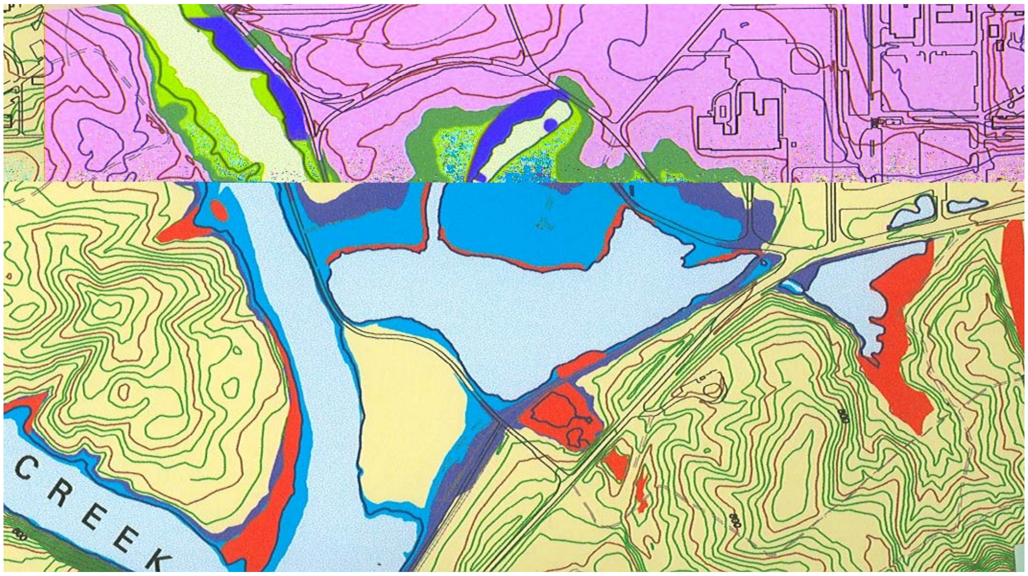
Source: ETTP Wetlands Map 2005 Update, Revision 2, May 25, 2005.

Fig. 5. Wetlands at Mitchell Branch.



Source: ETTP Wetlands Map 2005 Update, Revision 2, May 25, 2005.

Fig. 6. Wetlands at the K-901-A Holding Pond.



Source: ETTP Wetlands Map 2005 Update, Revision 2, May 25, 2005.

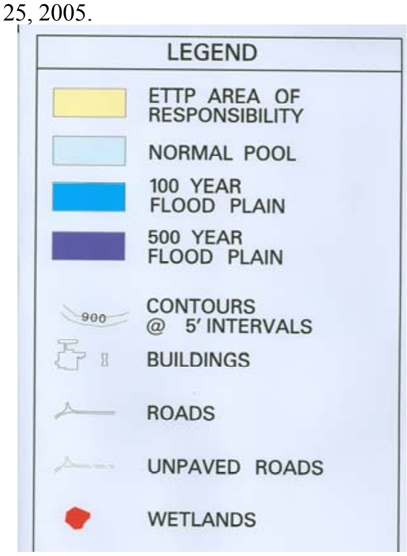


Fig. 7. Wetlands at the K-1007-P1 Holding Pond.

In 1997–98 an interceptor trench was constructed to collect and treat contaminated groundwater alongside Mitchell Branch. This removal action entailed the construction of a liner and a new interlocking (tri-lock) concrete substratum between storm drains SD-170 and SD-180. (Prior to the removal action, the stream bottom consisted of fine gravel, silt, and clay through the stream reach.) The tri-lock bottom does not entirely discourage root growth; for example, black willows have been observed to grow through the tri-lock material. Although the trilock prevents the stream from undercutting its banks, the root development provides a partial substitute for this microhabitat. Also, the tri-lock material has spaces between blocks that can collect sediment and organisms. Pools and riffles have begun to develop from gravel inputs following extreme storm events. This structure is not that different from the bedrock that characterizes many headwater streams. Benthic and fish communities were initially severely impacted by the lining of Mitchell Branch but have improved substantially since the removal action (BMAP studies).

On the north side of the creek in the vicinity of SD-170 are organic soils and seeps that support a variety of wetland plant species, including black willow, cattails, bulrush and soft rush, as well as potential amphibian habitat (Fig. 5). Nonnative plants such as Fescue and honeysuckle are common to abundant, but the area is not dominated by invasives. Kingfishers and great blue herons were observed at the site during the site visit by regulatory agencies. At SD-190, the creek has a more natural structure, with pools and riffles including 25-cm-diam holes. Vegetation succession along the creek banks is more advanced than in the tri-lock area. Just uphill of SD-190 on the north side of the stream, vegetation has been cleared at the K-1300 Clean Fill Area, which is used as an accumulation area for excess ETTP excavated fill material (dirt, rubble, etc.). The weir below SD-190 serves as a barrier to fish movement at low flow but allows enough fish passage for new species to colonize the stream at higher flows.

Wetlands are present in the headwater areas north and east of Blair Road (Fig. 5). Palustrine forested broad-leaved deciduous (PFO1) wetlands extend downstream to a utility right-of-way, where they meet palustrine emergent persistent (PEM1) wetlands (Rosensteel and Awl 1995). As of 1995, the dominant species in the PFO1 wetlands were red maple, sycamore, green ash, tulip poplar, alder, silky dogwood, poison ivy, microstegium, leafy bulrush, and fowl manna grass (Rosensteel and Awl 1995). In the PEM1 wetlands (and portions of the PFO1 wetlands) are black willow, buttonbush, seedbox, soft rush, sallow sedge, monkeyflower, bulrush, false nettle, bugleweed, fox sedge, grass-leaf rush, American potato-bean, and arrowleaf tearthumb (Rosensteel and Awl 1995).

As of 1995, five wetland areas were present in the developed portions of the ETTP site (Rosensteel and Awl 1995). The first two are upstream of SD-190: a palustrine scrub-shrub, broad-leaved, deciduous (PSS1) wetland in a forested area adjacent to the Toxic Substances Control Act of 1976 Incinerator and a PEM1 wetland near SD-150. Another PEM1 wetland is located at a spring (first observed in 1993) between Mitchell Branch and the K-1407 ponds. As of 1995, the area supported hydrophytic species including black willow, bulrush, jewelweed, cattail, horsetail, ironweed, fox sedge, soft rush, and peppermint (Rosensteel and Awl 1995). Downslope of SD-190 is another PSS1 wetland originating from groundwater seeps. As of 1995, vegetation present included black willow, green ash, silky dogwood, rice cutgrass, and smartweeds. Finally, a PSS1 wetland is located between the Portal 5 access road and the weir in a narrow area between the bottom of the steep sideslopes and the stream channel (Rosensteel and Awl 1995, Peterson, unpublished report). Wetland trees and shrubs such as black willow, green ash, sycamore, box elder, buttonbush, and silky dogwood dominate the narrow riparian zone. Herbaceous wetland vegetation included species such as soft rush, bulrush, and lurid sedge.

3.1.1 Future No-Action Scenario

In general, the no-action future scenario is assumed to have habitat characteristics close to the current environment, with gradual succession of the riparian zone during the next several decades. It is possible that the liner will fail in the future, and failure would increase the substrate complexity, possibly increasing diversity of the invertebrate community because of increased riffle structure and stimulating growth and succession of riparian vegetation and associated wildlife. The liner probably does not need be removed to improve habitat quality, because species richness would not be likely to improve from a return to a silty clay bottom, unless, after a long period of time, the stream developed meanders.

3.2 K-901-A HOLDING POND

The pond is located west of the main ETTP facility and has about a 17-acre surface, including extensive wetlands, with maximum depth of about 10 ft (Fig. 1). In 1965–66, a weir was constructed between the wetland and the Clinch River to create a holding pond, which received chemicals and sludges from recirculating cooling water blowdown and served as a disposal ground for contents of select cylinders, including uranium hexafluoride. The pond also received oil through the storm drain system from spills west of the K-31/K-33 building. In a 1997 removal action, the pond was completely drained to remove cylinders and other debris from the bottom of the pond. The fish in the pond were also removed during the action. After the removal action, the pond was allowed to refill with water, and during a major high water event, fish from the Clinch River crossed the weir to the pond (and have subsequently reproduced). The pond is much shallower than a few meters for most of its area, and these extreme shallow zones cannot support pelagic fish such as shad. Because of the removal action, the fish species richness is thought to represent the diversity of fish that crossed the weir in 1998. The sediments probably do not support a very diverse benthic invertebrate community, but the community has not been sampled. A large abundance of frogs has been observed in the shallow areas of the pond, with few fish. A very large snapping turtle has been found in the pond. Ospreys (that nest on Poplar Creek) have been observed to feed in the K-901-A Holding Pond.

Just north of the pond is a large, 2.5–5 acre PSS1 wetland (Fig. 6), which is somewhat rare on the ORR, because most wetlands on the ORR are small, relatively narrow, and associated with seeps. The wetland is dominated by willow and buttonbush (Rosensteel and Awl 1995). The wetland supports *Juncus* (soft rush) but no cattails. No complete floristic survey has been performed. Many dead black willow trees are present, perhaps because of utility right-of-way management activities, though we could find no experts who believed that herbicides were used in this area. The area surrounding the pond to the south has both open water and emergent wetland areas. Beaver are active in this area as well as near the outlet of the K-901-A Holding Pond. As of 1995, the southern area supported red maple, sweetgum, ironwood, elm, *Microstegium*, and sedges. The K-901-A Holding Pond has more wetland development in its bays (Fig. 6) compared to the K-1007-P1 Holding Pond (Fig. 7), which has steeper and more abrupt banks. Riparian areas of the pond include hibiscus and buttonbush. No mowed areas border the pond, but the gravel laydown area where the removal action was conducted in 1998 remains. The sloped, upland habitat adjacent to the pond and its margins is approximately 50% mature forest, approximately 40% old field to early successional forest, and 10% mowed and managed areas below powerlines.

3.2.1 Future No-Action Scenario

In the no-action, future scenario, the K-901-A Holding Pond is assumed to have habitat characteristics close to the current environment (i.e., forested riparian zone predominating with continued management of vegetation below powerlines). Therefore, an explicit habitat valuation for the no-action scenario is not described.

3.3 K-1007-P1 HOLDING POND

This approximately 22-acre pond is located next to the main plant area of the ETTP site in a rounded triangle of land formed by State Highway 58, Contractors Road, and Perimeter Road (Rosensteel and Awl 1995) (Fig. 1). The pond has received storm drainage and wastes from the K-1004 Area Lab Drain (SD-100) from the 1950s to the present. The pond currently functions as a retention basin for stormwater. The primary contaminant of concern is polychlorinated biphenyls. Outflow to Poplar Creek has been permitted by the National Pollutant Discharge Elimination System from 1974 to 1992. Outflow has continued to be monitored by the K-25 Site Environmental Management Division since 1992.

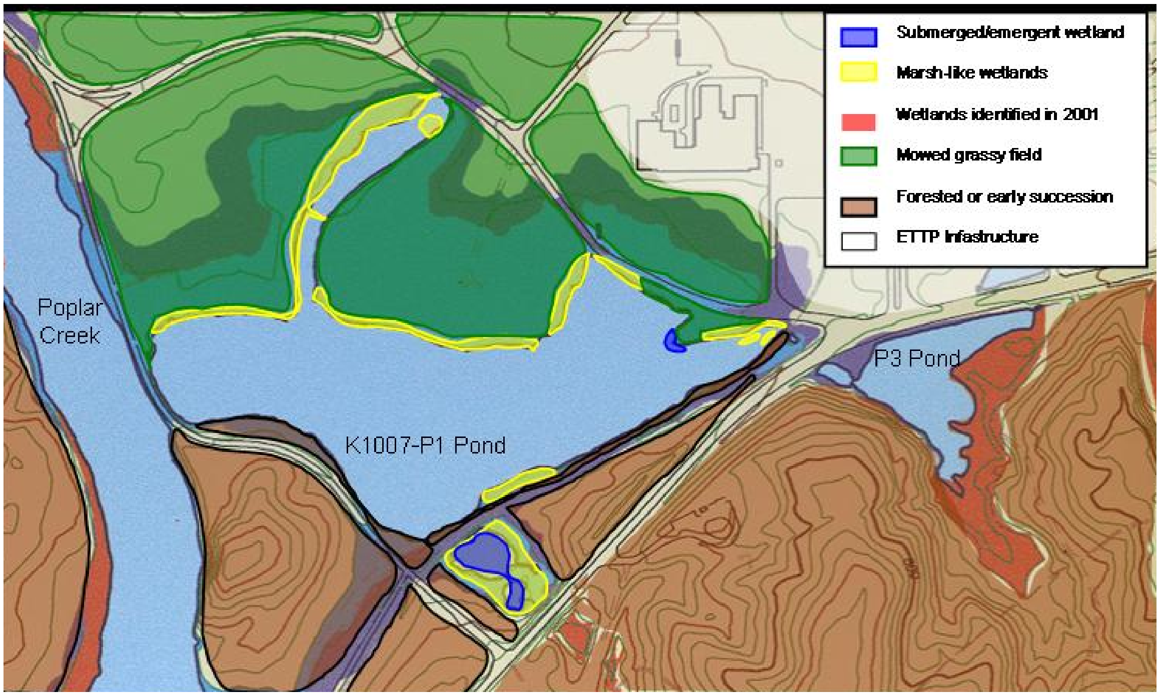
The pond is bordered by State Highway 58 to the southeast, a large mowed grassy (*Lespedeza* and grasses) and often saturated field to the north, a weir to Poplar Creek and Perimeter Road to the west, and railroad tracks to the southwest. The banks of the pond are generally steep (except for the northeastern border), with the water level several meters below the banks (Rosensteel and Awl 1995). Various species that are tolerant of saturated soils grow on the banks, including bald cypress, black willow, and false indigobush. The pond receives high nutrient inputs from geese that graze on the mowed lawn. Powerlines cut across the area.

In a 2004 survey of vegetation around the pond (Peterson et al 2005b), only one small area in the K-1007-P1 Holding Pond along a point on the east end of the pond contained submerged, rooted vegetation. Two species were present: *Chara sp*. (an alga) and species of Potamogeton. Between bank rocks in other areas of the pond, a couple small individual plants of watercress were also present. The absence of emergent vegetation in the pond is undoubtedly due to the presence of grass carp. Emergent plants were prevalent in the waterways entering the K-1007-P1 Holding Pond, both at the K-1007-P3 Holding Pond, where there is extensive aquatic vegetation, and at a small ponded area to the southwest. This southwest ponded area is fed by a clear stream flowing from the upland areas south of State Highway 58 and contains an extensive area of natural wetlands. Cattails, bulrush, water plantain, and soft rush are common in this shallow, ponded area.

Narrow fringe wetlands are evident around the K-1007-P1 Holding Pond, especially toward the east and north end, but these areas are tightly encroached upon by mowed areas and nonnative plant species. In many areas, especially along the east end, the grasses are mowed to the pond shore. Figure 8 shows the major plant community types surrounding the K-1007-P1 Holding Pond.

3.3.1 Future No-Action Scenario

In the no-action, future scenario, the K-1007-P1 Holding Pond would probably have habitat characteristics close to the current environment (i.e., mostly mowed riparian zone). However, it is possible that management practices could change so that the mowed area slowly succeeds to deciduous forest. The lack of mowing would discourage geese, decreasing the nutrient inputs to the pond, although some increased nutrient inputs would originate from leafy and woody material.



Source: Peterson et al. 2005b.

Fig. 8. Vegetation surrounding the K-1007-P1 Holding Pond.

3.4 K-25 SITE CONTRACTOR'S SPOIL AREA

The area was opened in 1974 as a borrow pit by the Tennessee Valley Authority (TVA) for construction of the Roane electric substation on Blair Road. During the late 1970s, the area was designated as a construction spoils and non-contaminated disposal area for ETTP, including a fly ash pile, a disposal area for spent, pressurized canisters, and a borrow pit. In 1982–1983, approximately 13,750 gal of oil was land-farmed on the roads and through the area to suppress dust. The site was capped with clay and topsoil (2 ft cover) and seeded with fescue in 1985. Closure of the area was approved by TDEC in 1987. The facility is still used for burning scrap lumber. A small fraction of the area is cut by a powerline right-of-way. The area is drained by several riprapped ditches in the open grassy area and at the west boundary. Water moves to Blair Road and Poplar Creek.

The fill area portion of this site is 7.5 to 8 acres. The open field portion of the site (including uncontaminated old field) is approximately 15 acres. The mowed area is still predominantly fescue. The surrounding upland, over 20% of the site, is a deciduous forested area that abuts Blackoak Ridge. The spoil area is within the Blackoak Ridge conservation easement land use zone (Fig. 4). The forest north of the disposal area includes an intermittent drainageway that in its lower sections turns into an emphemeral creek. This intermittent stream has substrate consisting of silt, clay, debris, and detritus. Aquatic vegetation is not present, and no observations were made of organisms in the creek. On the north boundary, several large red maples and southern red oaks were observed during a walkdown in December 2003, along with blackjack oak, sweetgum, black cherry, red cedar, Virginia pine, and white pine. Along the west boundary were Virginia pine and hickories in a mixed deciduous forest community. An old field plant community is in the northwest section of the site.

3.4.1 Future, No-Action Scenario

After several decades of not maintaining the cap, it is assumed that tree roots would be able to break through the ground, and the mowed and old field areas will undergo succession toward the forest communities represented on the adjacent land. In any case, most of the roots would appear near the soil surface. For example, 70% of tree root endings for northern hardwood, cove hardwood, and oak-hickory forest associations in West Virginia are in the top 0.5 m of soil (Kochenderfer 1973).

3.5 K-901-A NORTH DISPOSAL AREA

This 6- to 8-acre disposal area of unknown depth operated from the late 1940s to mid-1970s. The area received waste from on-site contractors and maintenance activities. Currently, the waste disposal area is covered with fescue, and four areas of radiological surface contamination are enclosed in fencing. The 9-acre site (ecological evaluation area) is approximately 5–10% forested and 25–30% shrub/scrub, and the remainder is maintained in an early successional state, with some portions mowed (Fig. 1). The vast majority of the area is covered by powerlines (Fig. 9), and most of these rights-of-way are mowed once a year, with TVA lines mowed every other year (D. Sanford, OMI Inc., personal communication, June 1, 2005).

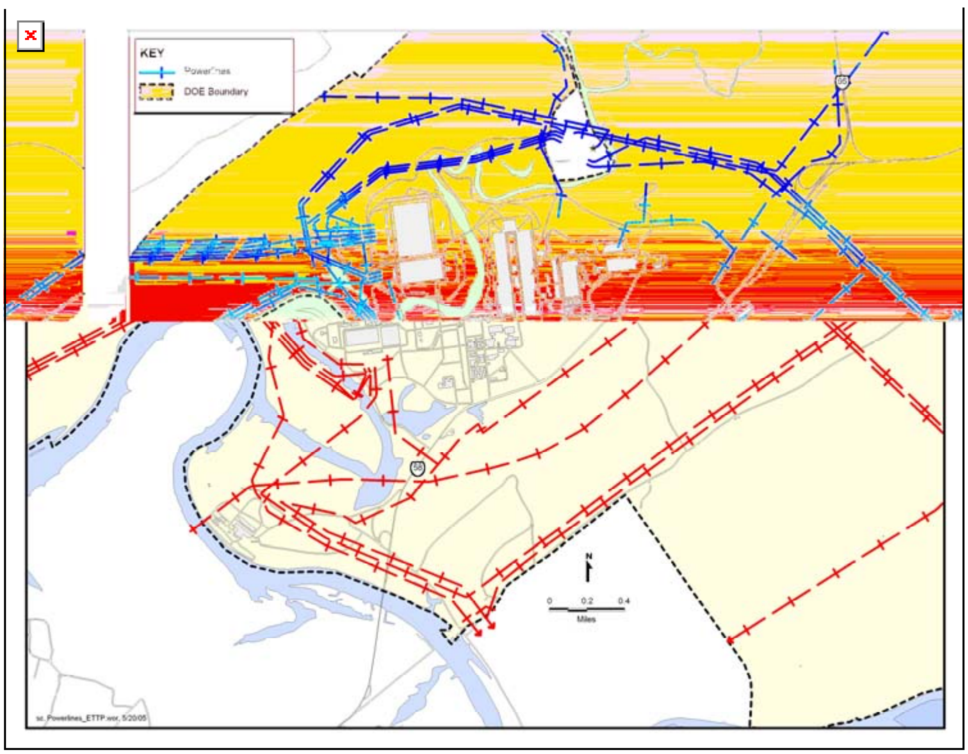


Fig. 9. Powerlines at ETTP.

As of 1993, about 1.5% of the total U.S. land area was taken up by unpaved rights-of-way (highways, power lines, gas lines and railroads), and Stephenson et al. (1993) assumed that a similar percentage existed in the Appalachian Forest Region. Powerlines are much more extensive at ETTP, and the powerline right-of-way on the K-901-A North Disposal Area is probably 50 times that proportion (75%).

Much of the K-901-A North Disposal Area is on sloping upland topography, with dry soils and plant species adapted to disturbance. Most of the vegetative community was dominated by nonnative or disturbance adapted weeds. Plant species dominating in this section were upland grasses such as fescue, numerous composites [e.g., common and giant ragweed, goldenrods, sneezeweeds, Japanese honeysuckle, and various disturbance adapted species in the pea family (clovers, vetches, and lespedezas)]. At the edges of the power lines, roads, and fence lines, as well as near and below the metal powerline supports or other areas less mowed, were a greater percentage of small trees, shrubs, and woody vines. Small trees and shrubs associated with these early successional areas included sumac (smooth and winged), tulip poplar, redbud, autumn olive, red cedar, and sweet gum. Woody vines included two species of raspberries, grapes, and poison ivy.

3.5.1 Future, No-Action Scenario

It is expected that this site would remain in its current land cover state because of maintenance requirements for mowing under powerline rights-of-ways.

3.6 K-770 SCRAP METAL YARD

This 7.1-km site in the Powerhouse area (Fig. 1) has had tens of thousands of tons of metal stored in piles, with extensive gravel roads developed for moving scrap to and from the site. The area operated during the 1940s as an oil storage area and has operated from the 1960s to the present as a scrap yard (including asbestos-contaminated pipe), although it is currently inactive. The scrap piles are in the process of being removed, along with some topsoil. Large gravel pads have been found under vegetation during scrap removal. A separate area is used by the Waste Management Division for radiologically contaminated scrap metal.

The extensive and frequent disturbance of soils from roads and their construction, bulldozed areas, and scrap piles has resulted in a plant community highly adapted to disturbance. In the most recently impacted areas are various vines, such as Japanese honeysuckle, raspberries, grapes, and poison ivy. The vines often extend over the metal buildings, paved areas, scrap metals, and fence lines. Areas near the Clinch River, if not paved or graveled, include shrubs and small trees, many of which are nonnative and invasive. Shrubs and small tree species at the site include privet, autumn olive, sumac, redbud, and red cedar. Some tree and shrub species characteristic of bottomland communities that were identified in this area in 1998 in an early successional stage include tulip poplar, white ash, red maple, and shrubs such as alder. Graminoid species at the site include nonnative fescues, plantago, and microstegium. No jurisdictional wetlands are known to be present within the scrapyard, though wetlands are located immediately to the north.

3.6.1 Future, No-Action Scenario

Gravel driveways and other bare ground would remain for several years under the no-action scenario, but vegetation cover would be expected to increase. Exotics such as privet could become established and dominate parts of the site. However, young forest cover would be likely to dominate after

50 years. Species such as sycamore, tulip poplar, white ash, red maple, and shrubs such as alder and spice bush, (all native) would probably dominate in this bottomland community. These species were identified along the east bank of the Clinch River at ETTP in surveys done in October of 1998.

4. RESULTS OF HABITAT VALUATION

4.1 CURRENT HABITAT VALUE

Mitchell Branch tends to have medium habitat value in terms of taxa richness for fish, benthic invertebrates, and waterfowl (Table 5). The stream has no rare fish species. Biota in the stream are recovering, and the stream channelization is not the dominant habitat complexity indicator of species richness. The stream has high-value amphibian habitat in adjacent wetlands, but with little buffer by upland habitats suitable for amphibians or reptiles. The riparian zone is developing but is constrained by roads and other management activities. Stream density at ETTP is low relative to Roane County, Lower Clinch River, and Southern Appalachian regional averages. Forested riparian coverage at Mitchell Branch is well below Ridge and Valley and Southern Appalachian averages.

Table 5. Habitat valuation results for Mitchell Branch

Metric	Score	Explanation
Taxa richness—fish	Medium	A total of 8 taxa of fish were present in samples from two sites (Mitchell Branch kilometers 0.45 and 0.71) taken in spring 2004.
Taxa richness—benthic invertebrates	Medium	Lower Mitchell Branch was still recovering in 2004, and remains unstable as the recovery process continues. Since 1998, mean taxonomic richness has fluctuated between medium and high quality at MIK 0.78, and between low and medium quality at MIKs 0.71 and 0.45.
Taxa richness—waterfowl	Medium	4 of 15 waterbird species observed during surveys at ETTP in 2004 were observed at Mitchell Branch (Appendix B).
Number of sensitive fish species	Medium	A total of 1 sensitive species was present in samples from two sites (Mitchell Branch kilometer 0.45 and 0.71) taken in spring 2004.
Number of sensitive benthic invertebrate species	Medium	Lower Mitchell Branch was still recovering in 2004, and remains unstable as the recovery process continues. Since 1998, mean EPT taxonomic richness has fluctuated between low and high quality in lower Mitchell Branch. (There are some locations where EPT taxa are naturally low, but results for upper Mitchell Branch and other reference locations on the ORR suggest that lower Mitchell Branch is not among these.)
Presence of shallow, slow-flowing areas for amphibian reproduction	High	In addition to areas at the headwaters and near the weir, shallow wetland areas are present on the north side of the stream between SD170 and SD180 for amphibian reproduction.
Presence of waterbird rookery	Low-medium	No rookery present.
Presence of nonnative or invasive species—fish and benthic invertebrates	Uncertain	Nonnative fish species cannot be determined, because North American nonnatives are uncertain, and the stream is too small for Asian nonnatives such as common carp and grass carp and nonnative mussels.

Table 5. Habitat valuation results for Mitchell Branch (continued)

Metric	Score	Explanation
Presence of nonnative or invasive species—benthic invertebrates	Medium	The Asiatic clam, *Corbicula fluminea*, is present in lower Mitchell Branch. The zebra mussel, *Dreissena polymorpha,* is present in Watts Bar Reservoir, but its presence in Mitchell Branch has not been recorded.
Complexity of habitat structure	Medium	At Mitchell Branch kilometers 0.78 and 0.71 (remediated zone), the RBP score was 99 (below the threshold of 131 for high value), with most parameters in the middle range, but with a low score for channelization of the stream and a high score for bank stability (low erosion). At Mitchell Branch kilometer 0.45 (downstream from remediated zone), the RBP score was 108 (below the threshold of 131 for high value), with most parameters in the middle range, but with a high score for bank stability (low erosion).
Abundance of rare species—fish	Low	No rare fish were found in samples from two sites (Mitchell Branch kilometer 0.45 and 0.71) taken in spring 2004.
Presence of rare species—benthic invertebrates	Uncertain	Little is known about rare aquatic insect species worldwide, and virtually none is known about them in Tennessee. Possible rare or T&E species of mollusks on the ORR inhabit bodies of water that are larger than Mitchell Branch. The Spiny River Snail, *Io fluvialis*, and Anthony's River snail, *Athearnia anthonyi*, historically existed in the lower Clinch River but not likely Mitchell Branch.
Presence of rare community—wetlands	High	In addition to the headwaters, a stream seepage swamp is present on the north side of the stream between SD-170 and SD-180.
Presence of movement corridor—fish	Medium	Fish in the reaches of the ETTP plant are easily accessible by downstream fish.
Presence of movement corridor—benthic invertebrates	Medium	Upstream areas of Mitchell Branch are only slightly impacted, especially the extreme headwaters upstream of Blair Road. Unimpacted tributaries are not present, and proximity to unimpacted streams is limited, so only the most mobile insects will likely colonize.
Presence of movement corridor—avian piscivores	High	ETTP has the largest abundance and diversity of avian piscivores on the Oak Ridge Reservation and the highest density of water bodies, including Mitchell Branch, the K-901-A Holding Pond, the K-1007-P1 Holding Pond, Poplar Creek, and the Clinch River. A heron rookery is located on Poplar Creek.
Stream density relative to Roane County, Lower Clinch River, and Southern Appalachian regional averages	Low	The stream density at ETTP is probably significantly less than values for Roane County, Lower Clinch River, and Southern Appalachian regional averages because of the extensive development at the site, the flat topography of much of the site, and its history of having extensive floodplain and wetland areas and (later) reservoirs. Steve Goodpasture, a historian at ETTP, has noted that ETTP had many more small streams and wet backwater bays before the facility was built, that were filled in and built over.
Riparian wetland coverage, relative to Southern Appalachian regional average	High	The riparian wetland coverage for Mitchell Branch is greater than 2%, even in the industrialized reach. This coverage is similar to or greater than lengths of relatively unimpacted riparian wetlands along streams nearby in Bear Creek Valley.

Table 5. Habitat valuation results for Mitchell Branch (continued)

Metric	Score	Explanation
Forested riparian coverage, relative to Southern Appalachian regional coverage	Low	Although some young trees line the portion of Mitchell Branch that is within the ETTP plant, the riparian zones are not very wide (far less than the 18-m recommended in Barbour et al. (1999), which is probably consistent with the threshold for designating a 30-m GIS pixel as forest in SAMAB (1996a), the southern riparian zone width is limited by a road, and the length of the riparian zone is far less than 60% of the length of the stream on each side.
Forested riparian coverage, relative to Ridge and Valley regional coverage	Low	Although some young trees line the portion of Mitchell Branch that is within the ETTP plant, the riparian zones are not very wide (far less than the 18-m recommended in Barbour et al. 1999, which is probably consistent with the threshold for designating a 30-m GIS pixel as forest in SAMAB (1996a), the southern riparian zone width is limited by a road, and the length of the riparian zone is less than 30% of the length of the stream on each side.
Adjacent amphibian habitat	Low	Wetlands in the developed part of Mitchell Branch do not have a buffer of good amphibian habitat surrounding them.
Adjacent reptile habitat	Low	Wetlands in the developed part of Mitchell Branch do not have a buffer of good reptile habitat surrounding them.

ETTP = East Tennessee Technology Park
EPT = Ephemeroptera, Plecoptera, and Trichoptera
ORR = Oak Ridge Reservation
RBP = Rapid Bioassessment Protocols
GIS = geographic information system

The K-901-A Holding Pond has medium habitat value for waterfowl and fish, with a high quality littoral habitat zone (Table 6). However, the number of sensitive fish species is low. The habitat corridor for waterfowl at ETTP appears strong, and the coverage of ETTP by water bodies in general is higher than the Southern Appalachian regional average. The pond has high-value amphibian habitat in adjacent wetlands, with medium-value buffer by upland habitats suitable for amphibians or reptiles. No rare fish have been observed in the past year. One Asian fish species has been observed. Riparian cover is high relative to ETTP and the Ridge and Valley province, but low or medium with respect to the Southern Appalachian region. Wetlands are extensive, but plant species richness is probably not high.

Table 6. Habitat valuation results for the K-901-A Holding Pond

Metric	Score	Explanation
Taxa richness—fish	Medium	12 species were observed in samples made in August 2004.
Taxa richness—Lepomid sunfish species	High	4 of these species were observed in samples made in August 2004, indicating a high quality littoral zone.
Taxa richness—waterfowl	Medium	6 of 15 waterbird species observed during surveys at ETTP in 2004 were observed at the K-901-A Holding Pond (Appendix B).
Number of sensitive fish species	Low	No sensitive species were observed in samples taken in August 2004.
Presence of shallow areas for amphibian reproduction	High	The embayments of the K-901-A Holding Pond are shallow.
Presence of waterbird rookery	Low-medium	A waterfowl rookery is not present at the K-901-A Holding Pond.

Table 6. Habitat valuation results for the K-901-A Holding Pond (continued)

Metric	Score	Explanation
Presence of nonnative or invasive species—fish	Medium	One non-North American species, common carp, was observed in samples taken in August 2004.
Number of nonnative or invasive species—shellfish	Uncertain	Nonnative species have not been surveyed in the K-901-A Holding Pond, but Asiatic clam is probably present, and zebra mussel may be present.
Complexity of habitat structure	Medium	This pond has woody debris, root wads, gravel, emergent vegetation, overhanging vegetation, and shallows (<0.3 m depth), but not undercut banks, boulders, cobble, sand, aquatic vegetation, and deep areas (>3 m depth). Therefore the score is 6 of 12 characteristics.
Abundance of rare species—fish	Low	No rare species were observed in samples taken in August 2004.
Presence of rare species—bats	Uncertain	Bats were not surveyed at K-901-A Holding Pond.
Presence of rare community—wetlands	High	Extensive wetlands border the northern areas of the pond.
Presence of movement corridor—fish	Medium	The pond is accessible by downstream fish, as evidenced by the diversity of fish sampled following the removal of fish during the 1998 pond removal action. Routine movement is unlikely, however.
Presence of movement corridor—avian piscivores	High	ETTP has the largest abundance and diversity of avian piscivores on the ORR and the highest density of water bodies, including Mitchell Branch, the K-901-A Holding Pond, the K-1007-P1 Holding Pond, Poplar Creek, and the Clinch River. A heron rookery is located on Poplar Creek.
Area of water coverage relative to Southern Appalachian regional average	High	The evaluation of this metric requires an arbitrary definition of "local area." However, because the Clinch River and Poplar Creek are so close, it is clear that over 2% of ETTP (if the Clinch River is included) is covered by water bodies.
Riparian wetland coverage, relative to Southern Appalachian regional average	High	The wetlands at the north and south ends of the pond comprise greater than 2% of the riparian zone of the pond.
Forested riparian coverage, relative to Southern Appalachian regional coverage	Low-medium	We estimate that about 60% of the pond riparian zone is forested, but the uncertainty could place the actual proportion of riparian forest in the low or medium categories.
Forested riparian coverage, relative to Ridge and Valley physiographic regional coverage	High	We estimate that about 60% of the pond riparian zone is forested, i.e., above the 40% threshold for a high proportion of forested riparian coverage.
Adjacent amphibian habitat	Medium	The forested area around at least 25% of the wetlands should provide these habitat services.
Adjacent reptile habitat	Medium	The forested area around at least 25% of the wetlands, as well as the steeper shoreline to the K-901-A North Disposal Area, should provide these habitat services.

ETTP = East Tennessee Technology Park
ORR = Oak Ridge Reservation

The most notable result for the K-1007-P1 Holding Pond is the observation of gray bats, along with three more common bat species (Table 7). This pond has medium habitat value for fish generally and high habitat value for Lepomid sunfish, an indicator of a high quality littoral zone, and waterfowl. No rare fish species have been observed. The pond has limited areas of high-value amphibian habitat in adjacent wetlands, with little buffer by upland habitats suitable for amphibians or reptiles. However, the wetland coverage is much higher than the Southern Appalachian regional average. Forested riparian coverage is low, compared to Ridge and Valley ecoregion and Southern Appalachian averages (Table 7). It is unknown to what extent the nutrient influx from Canada geese affects the habitat value for aquatic organisms.

Table 7. Habitat valuation results for the K-1007-P1 Holding Pond

Metric	Score	Explanation
Taxa richness—fish	Medium	17 species were observed in samples made in August 2004.
Taxa richness—Lepomid sunfish species	High	4 of these species were observed in samples made in August 2004, indicating a high quality littoral zone.
Taxa richness—waterfowl	High	12 of 15 waterbird species observed during surveys at ETTP in 2004 were observed at the pond (Appendix B).
Number of sensitive fish species	Medium	One sensitive species, spotted sucker, was observed in samples taken in August 2004.
Ambient dissolved oxygen concentrations—fish	Medium-high	On one of two sample dates in September 2004, dissolved oxygen concentrations in the water column were below 5.5 mg/L (4.8 mg/L) at the K-1007-P1 Holding Pond dam, and it is possible that concentrations are below the water quality criterion for long periods during the summer.
Ambient dissolved oxygen concentrations—benthic invertebrates	Medium but uncertain	On one of two sample dates in September 2004, dissolved oxygen concentrations in the water column were below 5.0 mg/L (4.8 mg/L) at the K-1007-P1 Holding Pond dam, and it is likely that concentrations are below the invertebrate threshold for slight impairment for long periods during the summer, especially close to the sediments.
Presence of shallow areas for amphibian reproduction	Low to medium	In general, the pond has few shallow zones that cannot be accessed by fish. However, there are a few floodplain pools at the north and southwest end of the pond.
Presence of waterbird rookery	Low to medium	A waterfowl rookery was not present.
Number of nonnative or invasive species—fish	Low	One non-North American species, common carp, was observed in samples taken in August 2004. Common carp and grass carp were collected in BMAP sampling efforts in 2005.
Presence of nonnative or invasive species—shellfish	Low	The pond has not been surveyed for shellfish. However, Asiatic clams have been observed, and zebra mussels could be present.
Complexity of habitat structure	High	This pond has woody debris, root wads, undercut banks, boulders, gravel, emergent vegetation, overhanging vegetation, shallows (<0.3 m depth), and deep areas (>3 m depth), but not cobble, sand, or aquatic vegetation. Therefore, the score is 9 of 12 characteristics.
Abundance of rare species—fish	Low	No rare fish species are present.
Presence of rare species—bats	High	Gray bats (as well as 3 more common species) observed in Anabat survey conducted in August 2004 (Appendix C).

Table 7. Habitat valuation results for the K-1007-P1 Holding Pond (continued)

Metric	Score	Explanation
Presence of rare community—wetlands	High	A forested wetland seep is located at the southwest side of the pond. Floodplain pools are also found along the north end of the pond.
Presence of movement corridor—fish	Medium	The pond is accessible by downstream fish.
Presence of movement corridor—avian piscivores	High	The ETTP site has the largest abundance and diversity of avian piscivores on the ORR and the highest density of water bodies, including Mitchell Branch, the K-901-A Holding Pond, the K-1007-P1 Holding Pond, Poplar Creek, and the Clinch River. A heron rookery is located on Poplar Creek.
Area of water coverage relative to Southern Appalachian regional average	High	The evaluation of this metric requires an arbitrary definition of "local area." However, because the Clinch River and Poplar Creek are so close, it is clear that over 2% of the ETTP site (if the Clinch River is included) or of a smaller area is covered by water bodies.
Riparian wetland coverage, relative to Southern Appalachian regional average	High	Riparian wetland coverage is much greater than 2% (Fig. 6).
Forested riparian coverage, relative to Southern Appalachian regional coverage	Low	Very little of the pond riparian zone is forested, certainly less than 60%.
Forested riparian coverage, relative to Ridge and Valley regional coverage	Low	Very little of the pond riparian zone is forested, certainly less than 30%.
Adjacent amphibian habitat	Low to medium	With the exception of small areas to the southwest and north, the combination of mowing and roads surrounding the wetlands and pond provides very little buffer area for amphibians.
Adjacent reptile habitat	Low to medium	With the exception of small areas to the southwest and north, the combination of mowing and roads surrounding the wetlands and pond provides very little buffer area for amphibians.

ETTP = East Tennessee Technology Park
BMAP = Biological Monitoring and Abatement Program

The K-25 Site Contractor's Spoil Area encompasses low-value mowed grass, mostly fescue, high-value deciduous forest, and a small fraction of medium- or high-value old field vegetation (Table 8). Thus, the average value of many habitat value measures is medium. Habitat value for forest and edge bird species averages medium across the area, although the wildlife biologist who surveyed the area indicated that without the forest edge, the mowed area would have low-value habitat for birds. The grass is probably suitable for reptiles, but less so because it is a mowed monoculture. The ephemeral stream supports forest and disturbed vegetation. The entire area lies within the Blackoak Ridge conservation easement, which increases the likely duration of its habitat use, particularly the forest, and the value added based on spatial context. The habitat value for the fescue-covered area is probably more important, as remedial decisions will affect primarily this area. This subset of the site currently has low value in terms of plant diversity, especially native species, and bird diversity, but high potential for future value because of its location and lack of paved areas.

Table 8. Habitat valuation results for the K-25 Site Contractor's Spoil Area

Metric	Score	Explanation
Major vegetation cover	Medium	2/3 of the area is low-value mowed grass, and 1/3 is high-value deciduous forest.
Percent impervious surface or bare ground	Medium-high	This site appears to have very little impervious surface or bare ground. However, the cap over the spoils area may be somewhat impervious to tree roots, at least for a few decades.
Taxa richness—forest breeding birds	Medium	13 species were recorded, which is 62% of 21 species, the largest number that have been recorded during any one survey at the East Fork Ridge Road/McNew Hollow Road area of the ORR, which contains similar forested habitat to this site (Appendix A).
Taxa richness—early successional or edge breeding birds	Medium	17 species were recorded, which is 68% of 25 species, the largest number that have been recorded during any one at The Freels Bend Area of the Three Bend Scenic and Wildlife Management Refuge Area. The fescue field that encompasses the majority of the site provides little habitat value (Appendix A).
Habitat suitability relationship—reptiles	Medium	Grass is available for turtles, lizards, and snakes, but it is mowed.
Presence of nonnative or invasive species—plants	Low	Over 50% of the area is covered by fescue. Invasive plant surveys at ETTP have not included this site (Fig. 10).
Complexity of vertical habitat structure	Low-medium	Mowed grass has low habitat-value structure, and adjacent deciduous forest has medium habitat-value structure.
Length of edge between patches	Medium	Only 2 patches are present: forest and mowed grass.
Presence of special wildlife breeding areas	Low-medium	Special wildlife breeding areas are absent.
Presence of rare species—plants	Low-medium	Most of this area was surveyed by Larry Pounds (personal communication, June 13, 2005), and no rare species were found.
Age of vegetation	Medium	High value for forest; low value for mowed grass.
Presence of rare species—birds	Low	Rare birds absent.
Presence of rare terrestrial vegetation community	Low-medium	Most of this area was surveyed by Larry Pounds (personal communication, June 13, 2005), and no rare communities were found. Also, the area is not designated as a rare community in Fig. 11.
Designation of land as a preliminary conservation site on the ORR based on Biological Significance Rankings of the Nature Conservancy (TNC 1995)	Medium	This area was designated as BSR-5 (of general biodiversity interest) (Fig. 2).
Part of ecological corridor linking deciduous forests from Cumberland Plateau to Great Smoky Mountains	High	The deciduous forest is part of the ecological corridor identified by the Southeastern Ecological Framework and Hargrove and Hoffman. The spoil area probably receives high vertebrate traffic because of its adjacency to forest, but this is somewhat uncertain at the resolution of the Southeastern Ecological Framework and analysis by Hargrove and Hoffman (unpublished, Fig. 3). (Areas north of Blackoak Ridge have very high corridor value on Fig. 3).
Adjacency to conservation area	High	The site is part of the Blackoak Ridge conservation easement (Fig. 4).

BSR = biological significance ranking
ETTP = East Tennessee Technology Park
ORR = Oak Ridge Reservation

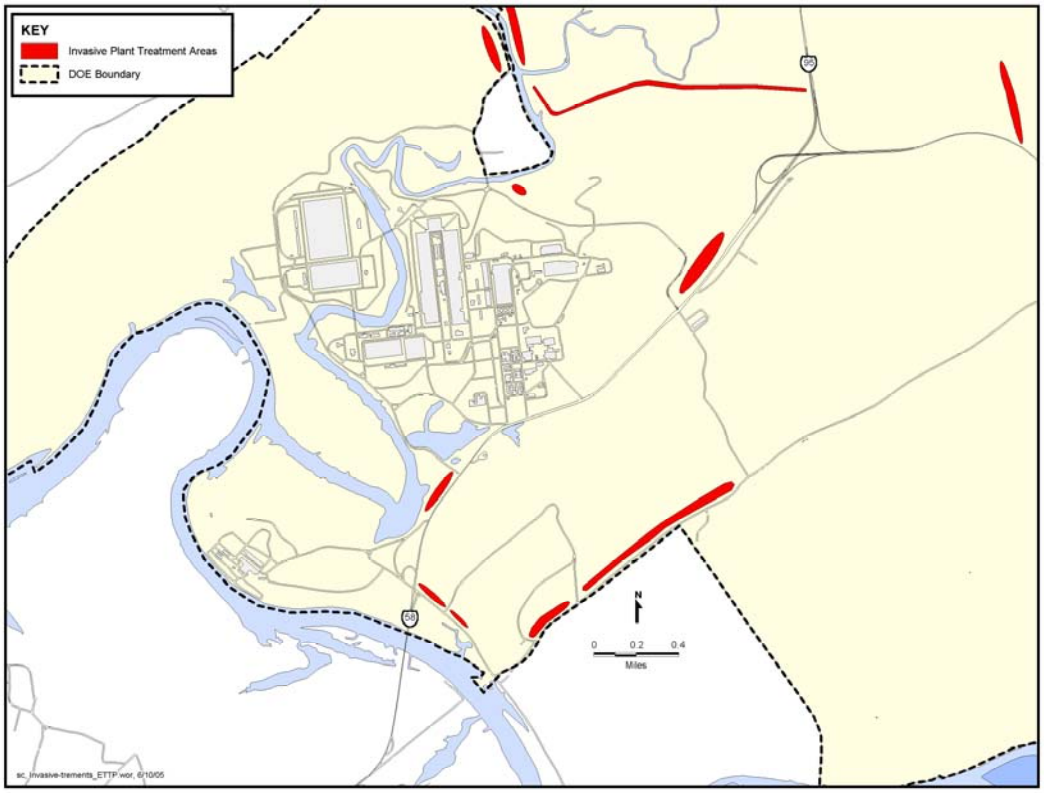


Fig. 10. Invasive plants surveyed for treatment at ETTP.

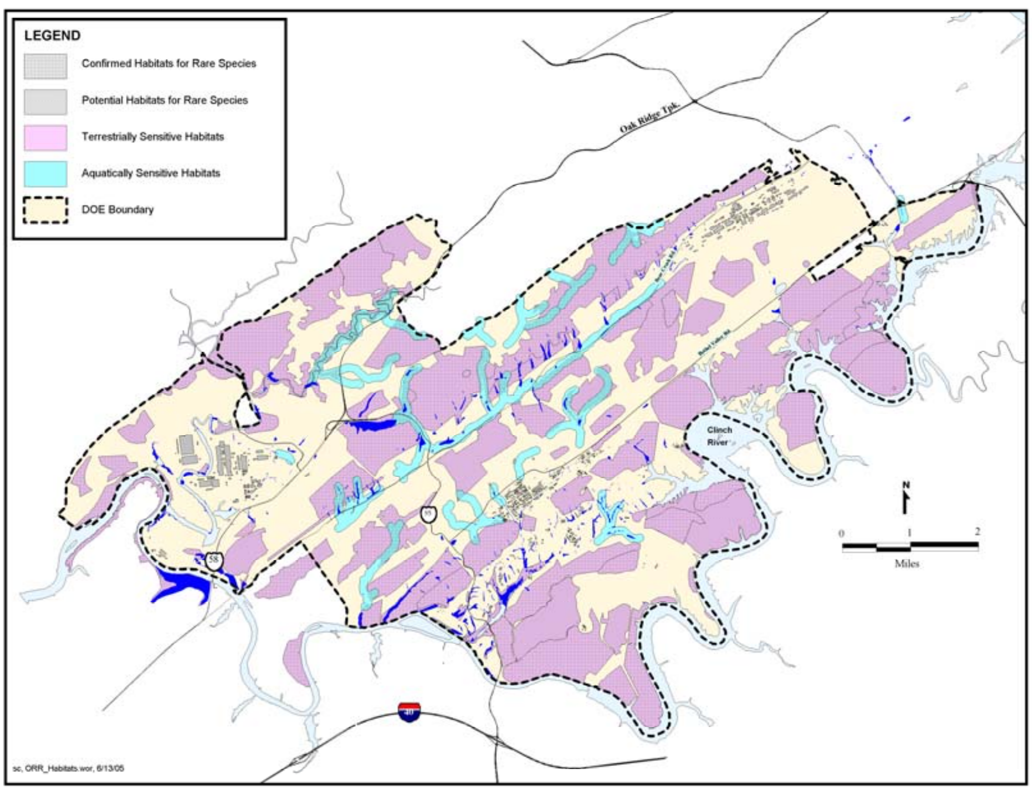


Fig. 11. Areas with high habitat suitability for rare species.

The majority of the K-901-A North Disposal Area lies in a powerline right-of-way and, as such, is characterized by annually mowed grass, biennially mowed grass, and shrubland with a small fraction of forest (Table 9). Although plants have not been formally surveyed at this site, plant species richness, especially of native species, apparently varies across the site, with fescue and other mowed areas having low species diversity, scrub-shrub areas having medium or high species richness, and forest probably having high species richness. The bird species richness is consistent with medium habitat value, with substantial edge perimeter between grass patches, shrub/scrub patches, and forest patches to support even more early successional bird species. Habitat value for reptiles appears high. Plants have not been surveyed for rarity. The entire area lies within the Black Oak Ridge conservation easement; therefore its habitat use value is expected to endure (though management of the powerline right-of-way will continue).

Table 9. Habitat valuation results for the K-901-A North Disposal Area

Metric	Score	Explanation
Major vegetation cover	Medium	The major vegetation cover is low-value mowed grasses and old field vine and shrub communities (medium value), with 5–10% high value forest.
Percent impervious surface or bare ground	High	The site has very little impervious surface or bare ground.
Taxa richness—early successional or edge breeding birds	Medium	18 species were recorded, which is 72% of 25 species, the largest number that have been recorded during any one at The Freels Bend Area of the Three Bend Scenic and Wildlife Management Refuge Area (Appendix A).
Habitat suitability relationship—reptiles	High	Grass available for turtles, lizards, and snakes.
Presence of nonnative or invasive species	Low to medium	Autumn olive, fescue, and Japanese honeysuckle are dominant in many areas of the site. However, many of the early successional areas have native species such as tulip poplar and sumac. The small area of forest is predominantly native.
Complexity of vertical habitat structure	Medium	The area has over 50% ground cover and 50% shrub cover (two of the elements of good vertical habitat structure).
Length of edge between patches	High	Numerous patches of shrub/scrub are present.
Presence of rare species—plants	Uncertain	This area was never surveyed by Larry Pounds (personal communication, June 13, 2005).
Age of vegetation	Low	Vegetation is young, including mowed grass, old field, and shrub/scrub.
Presence of rare species—birds	Low	Rare birds absent.
Presence of rare terrestrial vegetation community	Low-medium	The area is not designated as a rare community in Fig. 11 and was never surveyed by Larry Pounds (personal communication, June 13, 2005), but it is unlikely that we would have missed a rare community in our site visits.

Table 9. Habitat valuation results for the K-901-A North Disposal Area (continued)

Metric	Score	Explanation
Designation of land as a preliminary conservation site on the ORR based on Biological Significance Rankings of the Nature Conservancy (TNC 1995)	Low	This area was not designated as a conservation site, and vegetation was not surveyed at this site in support of this study. However, the management of the site within a powerline right-of-way suggests that this would not be a biologically significant site.
Part of ecological corridor linking deciduous forests from Cumberland Plateau to Great Smoky Mountains	Medium-high	At high spatial resolution, this site is part of the ecological corridor identified by the Southeastern Ecological Framework and Hargrove and Hoffman (Fig. 3), which includes all of the ORR except for the plant areas. However, because it is not adjacent to a large tract of forest, the highest-use corridor may not include this site.
Adjacency to conservation area	High	The site is part of the Blackoak Ridge conservation easement (Fig. 4).

ORR = Oak Ridge Reservation

We did not have access to many areas within the K-770 Scrap Metal Yard, so there is some uncertainty about values of habitat for different groups of species (Table 10). Areas visible from the road appear to have low vegetation cover, with substantial gravel road cover and bare ground. These areas are clearly of low habitat value for most plant or animal species. In contrast, localized areas of shrub/scrub and early successional forest, especially along the Clinch River, have medium habitat-use value for plants. It is likely that nonnative plant species are present.

Table 10. Habitat valuation results for the K-770 Scrap Metal Yard

Metric	Score	Explanation
Major vegetation cover	Low to medium	Much of site is road and scrap infrastructure, and mowed or vine-covered areas. Also, areas of scrub/shrub and early successional forest are present.
Percent impervious surface or bare ground	Low	Up to 50% of the visible area is covered by gravel or scrap.
Taxa richness, breeding birds—edge species	Low-medium	Information is not available, but given the sparse and managed vegetation cover and human presence, it is unlikely that the bird diversity is high.
Taxa richness—waterfowl	Low-medium	No information is available concerning the waterfowl along the Clinch River at the K-770 Scrap Metal Yard, but given the sparse and managed vegetation cover, human presence, and absence of shallow water areas and an accessible riparian slope, it is unlikely that the bird diversity is high.
Habitat suitability relationship—reptiles	Medium	The site has grass to support turtles, lizards, and snakes, including gravel for snakes to bask. However, the current disturbance of the area during removal of scrap will likely keep some reptiles away.
Presence of nonnative or invasive species	Low	Abundant to dominant zones of privet, autumn olive, Nepal grass, and Japanese honeysuckle. Invasive species surveys at ETTP have not included this site (Fig. 10).
Complexity of vertical habitat structure	Low	Large areas of the site are covered by road or scap with no vertical habitat. Vegetated zones, which are largely ground and/or shrub cover, are unlikely to exceed 50% (two of the elements of good vertical habitat structure).

Table 10. Habitat valuation results for the K-770 Scrap Metal Yard (continued)

Metric	Score	Explanation
Length of edge between patches	Low-medium	The edge of vegetation patches is low in the gravel-covered areas where vegetation cover is low. Closer to the Clinch River, there may be more habitat patches present, with corresponding medium or high edge between them (if cover is like the K-901-A North Disposal Area).
Presence of rare species—plants	Low-medium	This area was never surveyed by Larry Pounds (personal communication, June 13, 2005). Rare plants are not expected in the gravel-covered areas but could be present along the Clinch River.
Age of vegetation	Low	The vegetation cover is primarily grasses, vines, and shrubs.
Presence of rare species—birds	Low-medium	This area has never been surveyed for rare birds, and they are not expected.
Presence of rare terrestrial vegetation community	Low but uncertain	This area was not surveyed by Larry Pounds (personal communication, June 13, 2005) and is not designated as a rare community in Fig. 11.
Designation of land as a preliminary conservation site on the ORR based on Biological Significance Rankings of the Nature Conservancy (TNC 1995)	Low	This area was not designated as a conservation site, and vegetation was not surveyed at this site in support of this study. However, the extensive coverage of the site by scrap and gravel suggests that this would not be a biologically significant site.
Part of ecological corridor linking deciduous forests from Cumberland Plateau to Great Smoky Mountains	Medium	At high spatial resolution, this site is part of the ecological corridor identified by the Southeastern Ecological Framework and Hargrove and Hoffman (Fig. 3), which includes all of the ORR except for the plant areas. Also, there is a narrow band of small trees along the riverbank that connects forest to the immediate north and south of the site. However, because it is fenced, highly disturbed, and not adjacent to a large tract of forest, the highest-use corridor probably does not include this site.
Adjacency to conservation area	Low	This site is not adjacent to a conservation area (Fig. 4).

Note: We have very little information about this site, and we were unable to visit this site because of construction activities occurring there. However, we were able to see a small fraction of the site through the fence.

ETTP = East Tennessee Technology Park
ORR = Oak Ridge Reservation

4.2 FUTURE HABITAT VALUE UNDER THE NO-ACTION ALTERNATIVE

Four examples of ecological change under the no-action remedial alternative are discussed here:

- a scenario whereby an unmaintained liner in Mitchell Branch fails or is removed;
- a possible, but perhaps unlikely, scenario whereby mowing on the north and southeast sides of the K-1007-P1 Holding Pond ceases and the riparian zone succeeds to bottomland deciduous forest;
- lack of maintenance of the cap at the K-25 Site Contractor's Spoil Area, leading to succession of that area to forest; and
- succession of vegetation to forest at the K-770 Scrap Metal Yard along the Clinch River.

Habitat value is described for conditions about 50 years from now, but there is a high degree of uncertainty associated with these estimates. As stated above, recovery of rare, native fauna based on recovery of ecosystem diversity is not always predictable (Stewart et al. 2005). Therefore, this discussion is based on habitat use value rather than rarity.

4.2.1 Failure of Mitchell Branch Liner

Removal of the liner would cause short-term decreases in fish and invertebrate diversity; gradual failure would not. Also, in the short term, species richness would not be likely to improve from a return to a silty clay bottom, because the stream would still have a channelized structure with few cobbles. After fifty years, one might expect increasing habitat use value as exemplified by species richness of benthic invertebrate and fish because of increased riffle structure, undercut banks, meanders, and aged riparian vegetation. Still, these might not yet have "high" scores, especially if the stream boundaries and riparian zone are still constrained by roads and other management activities. In summary, after 50 years, succession of riparian vegetation would improve plant species diversity and that of associated wildlife.

4.2.2 Succession of Riparian Zone at the K-1007-P1 Holding Pond to Deciduous Forest

Under this scenario, riparian zone vegetation and songbird diversity would be expected to increase. Waterfowl diversity would probably also increase to an even higher level, based on the fact that White Oak Lake has higher waterfowl diversity and is a forested site. (Also, anecdotal evidence suggests that the abundance of waterbirds is higher when Canada geese are not present.) Wood ducks, hooded mergansers, herons, egrets, and probably bufflehead and ring-necked ducks would benefit from the forest growth. A forested riparian zone is likely to be unfavorable toward shorebirds such as greater and lesser yellowlegs, killdeer, other sandpipers and plovers, etc. The K-1007-P1 Holding Pond is probably large enough that open-water species such as loons, grebes, and canvasbacks would not be significantly deterred by a forested riparian zone, and osprey should be unaffected. The riparian zone would provide improved habitat for amphibians and reptiles, especially near wetlands in the north slough area. It is unknown how the removal of nutrient input from goose excrement and the addition of new, forested riparian cover would affect fish and benthic invertebrate diversity. It is not known if wooded riparian areas would positively or negatively affect the likelihood of the gray bat foraging at the pond or waterfowl using the pond. In summary, after 50 years, succession of riparian vegetation would be expected to improve plant species diversity and that of most waterbirds, amphibians, and reptiles.

4.2.3 Succession of K-25 Site Contractor's Spoil Area to Deciduous Forest

After 50 years, tree roots would be expected to penetrate the cap, and, eventually, the current fescue-covered portion of this site would become deciduous forest with species similar to those on adjacent Blackoak Ridge. Clearly, the species richness of vegetation would increase dramatically. The species richness of forest interior birds would increase on the site, and that for edge species could increase or decrease, depending on the quality of edge habitat. Reptile diversity could also increase or decrease. The site would become part of the deciduous corridor connecting the Cumberland Plateau to the Great Smoky Mountains. In summary, after 50 years, the habitat use value for vegetation and birds would be expected to increase substantially.

4.2.4 Succession of K-770 Scrap Metal Yard Area to Deciduous Forest

After 50 years, tree roots would be expected to penetrate the gravel roads and pads, and eventually (but perhaps in a longer timeframe than 50 years), the current grassy and shrub/scrub portions of this site would become bottomland deciduous forest. The species richness of vegetation would probably increase dramatically, and the percent forested riparian zone would be more comparable to regional averages or might exceed them. The species richness of forest birds would increase on the site, and that for edge species would probably also increase, because many of them are probably absent due to noise and other human disturbance. Reptile diversity could increase or decrease. The site would become part of the deciduous corridor connecting the Cumberland Plateau to the Great Smoky Mountains. In summary, after 50 years, the habitat use value for vegetation and birds would be expected to increase.

5. DISCUSSION

The ORR, a National Environmental Research Park, has high habitat value as a rather contiguous tract of vegetated land in the context of increasing development in East Tennessee (Dale and Parr 1998). The natural vegetation of the ORR is the most significant area of preserved natural vegetation in the Ridge and Valley physiographic province in Tennessee (Mann et al. 1996). The ORR supports 1100 species of vascular plants, 21 of which are rare (Parr 2000). A complete bird list for the ORR is presented in Appendix D, and a list of other vertebrates is in Appendix E. A large tract of land across Blackoak Ridge has been designated as a conservation easement (Fig. 4). Based on clusters of rare plants and vegetation communities, 81 sites were ranked by The Nature Conservancy as having very high or high significance nationally for conservation (TNC 1995, Parr 2000). A primary question in this study was the importance of the habitat use value and species and community rarity of the six study sites compared to the ORR and the region generally. Four of these sites are within the industrial-use area of ETTP, and two, the K-25 Site Contractor's Spoil Area and the K-901-A North Disposal Area, are in the Blackoak Ridge conservation easement.

Metrics of habitat value in this study were not evaluated with respect to a consistent spatial scale. Often, more information was available about local regional reference habitat value or landscape statistics for the Ridge and Valley Physiographic Province or the Southern Appalachian region than for the ORR. Rarity was determined based on federal or state listing status. Thus, habitat values were evaluated rather inconsistently at variable spatial scales.

As expected, there is significant variation in habitat value among the six sites, among measures for different taxa at a single site, between measures of use and rarity at a single site, and among measures for particular taxa at a single site with respect to different spatial scales. Most sites had aspects of low, medium, and high habitat value. Few high scores for current use value were given. These include the following: wetland plant communities at all aquatic sites, Lepomid sunfish (littoral zone) and waterbirds at the K-1007-P1 Holding Pond, and Lepomid sunfish and amphibians at the K-901-A Holding Pond. The habitat complexity was high at the K-1007-P1 Holding Pond, which might be an indicator of high value habitat for benthic invertebrates, but many of the measures are bank measures rather than bottom measures. In addition, all aquatic sites (plus the Clinch River and Poplar Creek) create a high-value ecological corridor for waterfowl, and the K-25 Site Contractor's Spoil Area and possibly the K-901-A North Disposal Area have areas that are probably part of a strong terrestrial ecological corridor. The only example of recent observations of rare species at these sites is the gray bat observed at the K-1007-P1 Holding Pond.

Some aspects of habitat value are expected to improve under at least a few no-action scenarios: if mowing near the K-1007-P1 Holding Pond ceases and the riparian zone succeeds to bottomland deciduous forest; if the cap is not maintained at the K-25 Site Contractor's Spoil Area, leading to succession of that area to forest; if vegetation at the K-770 Scrap Metal Yard along the Clinch River is allowed to succeed to forest; and possibly if an unmaintained liner in Mitchell Branch fails or is removed. Any of these scenarios and associated habitat values may change if land or water areas are managed differently from the assumptions described above. Mowing of the K-901 powerline right-of-way will continue, but plant and bird species richness would probably increase if mowing were carried out less frequently or avoided during the bird breeding season. The planting of native grasses in early successional areas such as the K-25 Site Contractor's Spoil Area, the K-901-A North Disposal Area, and the shoreline of the K-1007-P1 Holding Pond would increase vegetation and bird diversity and possibly increase the rate of succession to forest. Powerline rights-of-way are corridors for the spread of invasive plants, and native grasses could serve as a buffer against exotic spread at sites like the K-901-A North Disposal Area. Similarly, nonnative or invasive species could move into the shoreline if mowing ceases near the K-1007-P1 Holding Pond, so the planting of willows, silky dogwoods, and similar species might bring substantial ecological benefits. Whether or not the Mitchell Branch liner fails or is removed, species richness of fish and benthic invertebrates would be likely to return to reference conditions if minor restoration actions occurred, such as pool creation, a little armoring, vegetation planting, and/or other structural additions such as the addition of boulders. Removal of grass carp from the K-1007-P1 Holding Pond would allow vegetation to grow, increasing the diversity of fish and waterfowl.

A question that has arisen during this study is the importance of constrained plant succession (e.g., under powerline rights-of-way) in determining habitat value. Except for one measure of rarity (age of vegetation), this analysis does not address this comparative question. Part of the answer depends on whether it is better to have forest birds or early successional birds, a subjective preference. Other methodologies do not address the value of succession. For example, in CrEAM, the category "Temporal continuity of land cover type" could reflect succession, but the developers of this methodology believe that changes from one land cover type to another over time typically reflect human management activities rather than ecological succession (M. White, EPA, personal communication, June 2005).

In this study, the measures of the spatial context of the six sites have been important measures of habitat value. Early investigations of habitat value did not consider principles of landscape ecology, such as connectivity, adjacency, and fragmentation of lands and waters (Margules and Usher 1981). We do not use some of the GIS-based measures of habitat value that are components of GIS-based methodologies such as CrEAM, and remotely sensed measures would probably improve our understanding of habitat value for inaccessible sites like the K-770 Scrap Metal Yard. Moreover, distance-based measures of habitat suitability (distance to roads, distance to streams, distance to weirs) that can relate to species richness and abundance (Conner et al. 2003) are not used here. However, the corridor and adjacency measures of habitat value illustrate the importance of considering spatial context.

Given that indices are not used to score measures of habitat value in this study, the question arises concerning how all of these metrics may be evaluated together. Weight-of-evidence guidance for ecological risk assessment may be useful here. Evidence is judged based on relevance, quantity, quality, and uncertainty of data, among other criteria (Suter et al. 2002). Relevance comprises factors such as direct versus indirect measures and appropriate spatial scale. For example, we suggest relying on more direct measures of use (species richness) than less direct (complexity of habitat) if the scores are in conflict. However, even direct measures of use (species richness) should be accompanied by the consideration of the presence of invasive or other nonnative species. For some habitat value parameters (use by vegetation), the use of multiple indirect measures is recommended, because direct measures (species richness) are not available. Moreover, we recommend that the spatial scales be adjusted to the needs of risk managers. If only a fraction of a site (e.g., Mitchell Branch, K-25 Site Contractor's Spoil Area, K-770 Scrap Metal Yard) is under consideration for remediation, then the user of this analysis can sometimes extract habitat value information for just that fraction (e.g., the industrialized portion of Mitchell Branch, the fescue-covered disposal area of the K-25 Site Contractor's Spoil Area, or the gravel-covered areas of the scrapyard). Some habitat value information may be ignored; habitat suitabilities for most mammals at these sites are not very important, because the mammals on the ORR (other than bats) are generalists. In this study, the precision of scoring criteria is also an important determinant of the reliability and uncertainty of habitat value judgments. For example, data for waterfowl species richness at reference sites were not available, so the scoring criteria have been set arbitrarily. Also, we have not adjusted expected species richness values for pond areas, though larger ponds would be expected to host more species.

Habitat valuations of other contaminated sites at ETTP may benefit from the results of this study. Although, for example, we cannot directly transfer the valuation results from the six study sites to other candidates for remediation, we can offer guidance for doing rapid valuation studies. All terrestrial areas covered by mowed fescue or impermeable or barren ground would be expected to have low habitat-use value for plants and vertebrates. Forested and early successional areas could have medium or high value for plants and vertebrates. The reason that the valuation at these sites has not been so straightforward is the presence of multiple highly disturbed and less-disturbed habitat patches within a site and (in the case of the K-770 Scrap Metal Yard) lack of access to the site. An important question is whether the habitat value results would have been the same in the absence of direct measures of habitat use (species richness). The answer is "no." The estimate of habitat value based on habitat complexity alone was often not the same as that based on fish, Lepomid sunfish, benthic invertebrate, or waterfowl species richness. One might have guessed that the bird taxa richness in the forest at the K-25 Site Contractor's Spoil Area would have medium value, but by our measure it had high value. Similarly, the only way to get to the observation of gray bats at the K-1007-P1 Holding Pond was through direct surveys.

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APPENDIX A

BIRD SURVEY RESULTS
K-25 SITE CONTRACTOR'S SPOIL AREA AND K-901-A NORTH DISPOSAL AREA

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A.1 METHODS

Birds were censused using the variable circular-plot method (Reynolds et al. 1980). Grid points were established at each site approximately 100 m apart. Six grid points were established at the K-25 Site Contractor's Spoil Area. Three grid points were positioned through the center of the fescue field, and three points were positioned in the forested area of the site. Three grid points were also established through the center of the K-901-A North Disposal Area.

Each grid point was visited twice, once on June 2 and once on June 7, 2005. Censuses were conducted 3–4 h following local sunrise during favorable weather conditions (little wind and no rain). The observer remained at each point for 10 min and recorded all birds detected and their estimated distance and direction from the census point.

A.2 RESULTS

A.2.1 K-25 SITE CONTRACTOR'S SPOIL AREA

Bird species recorded at this site were mainly those associated with old field and edge habitats. The old field and edge species recorded on this site were similar to those found on other areas of the Oak Ridge Reservation (ORR) with similar habitat. The majority of old field/edge species recorded during the surveys were present along forest edges and power line rights-of-way on and adjacent to the site. The open fescue field that makes up the majority of this site was virtually devoid of birds. The only notable exception was the presence of barn and cliff swallows feeding on flying insects. The virtual absence of birds in the fescue field is not unexpected because the area provides a virtual monoculture with very little habitat structure. Field/forest edges and patches of trees along the perimeter of the site, on the other hand, provide structure with mixtures of herbaceous vegetation, shrubs, and trees.

Forest bird species were recorded on the northeast corner of the site, an area that is contiguous with a relatively large forested tract. These included typical forest species found in other similar areas on the reservation, although the diversity of species found was less than expected. An increase in the number of surveys and censuses conducted deeper into this contiguous forest tract could result in the recording of increased species numbers.

Table A.1 summarizes the bird species recorded at the K-25 Site Contractor's Spoil Area.

A.2.2 K-901-A NORTH DISPOSAL AREA

Bird species recorded at this site were mainly those associated with old field and edge habitats. The diversity of old field and edge species recorded on this site is representative of other similar areas on the ORR. This area contains mainly old field habitat with some large patches of fescue. Some edges are created by the existence of small patches of trees and shrubs. The virtual absence of birds from areas dominated by fescue is not unexpected because the area provides a virtual monoculture with very little habitat structure. Old field habitat and patches of trees and shrubs in certain areas of the site, on the other hand, provide good structure.

Table A.1. Bird species recorded at the K-25 Site Contractor's Spoil Area, June 2005

Bird species	Habitat[1]	On or off site[2]	Assumed status[3]
Wild turkey	Old field	Off	Breeding
Mourning dove	Forest/forest edge	Off	Breeding
Yellow-billed cuckoo	Forest/forest edge	On and off	Breeding
Red-bellied woodpecker	Forest/forest edge	Off	Breeding
Pileated woodpecker	Forest/forest edge	On and off	Breeding
Acadian flycatcher	Forest	On	Breeding
Great crested flycatcher	Forest	On and off	Breeding
Cliff swallow	Fescue field	On	Breeding
Barn swallow	Fescue field	On	Breeding
American crow	Forest/forest edge	Off	Breeding
Blue jay	Forest edge	Off	Breeding
Carolina chickadee	Forest	On and off	Breeding
Tufted titmouse	Forest	On	Breeding
Carolina wren	Forest edge	On	Breeding
White-eyed vireo	Edge	Off	Breeding
Red-eyed vireo	Forest	On and off	Breeding
Prairie warbler	Old field	Off	Breeding
Common yellowthroat	Old field	On	Breeding
Yellow-breasted chat	Forest edge	On and off	Breeding
Scarlet tanager	Forest	On and off	Breeding
Northern cardinal	Forest edge	On and off	Breeding
Indigo bunting	Forest edge	On	Breeding
Eastern towhee	Forest edge	Off	Breeding
Field sparrow	Forest edge/ old field	On and off	Breeding
Common grackle	Forest edge	Off	Breeding
Brown-headed Cowbird	Forest edge	On and off	Breeding
American goldfinch	Old field	On and off	Breeding

[1]Habitat observed during bird surveys.
[2]Notes whether birds observed on or off study site.
[3]Known status (breeding, non-breeding, transient, etc.) on the Oak Ridge Reservation.

The openness of the site allowed the observer to hear and see birds at long distances from the actual site boundaries.

Table A.2 summarizes the bird species recorded at the K-901-A North Disposal Area.

Table A.2. Bird species recorded at the K-901-A North Disposal Area, June 2005

Bird species	Habitat[1]	On or off site[2]	Assumed status[3]
Turkey vulture	Flyover	Off	Breeding
Osprey	Flyover	Off	Breeding
Northern bobwhite	Old field	On	Breeding
Mourning dove	Old field	On	Breeding
Yellow-billed cuckoo	Forest	Off	Breeding
Pileated woodpecker	Forest	Off	Breeding
Eastern kingbird	Old field	On	Breeding
Tree swallow	Old field	On	Breeding
Barn swallow	Old field	On	Breeding
American crow	On building	Off	Breeding
Carolina wren	Edge	On	Breeding
Northern mockingbird	Edge	On	Breeding
Red-eyed vireo	Edge	On	Breeding
Prairie warbler	Old field	On	Breeding
Common yellowthroat	Old field	On	Breeding
Yellow-breasted chat	Edge	On	Breeding
Scarlet tanager	Forest	Off	Breeding
Northern cardinal	Edge	On	Breeding
Indigo bunting	Edge	On	Breeding
Eastern towhee	Edge	On	Breeding
Field sparrow	Edge	On	Breeding
Brown-headed cowbird	Edge	On	Breeding
Orchard oriole	Edge	On	Breeding
American goldfinch	Edge/old field	On	Breeding

[1]Habitat observed during bird surveys.
[2]Notes whether birds observed on or off study site.
[3]Known status (breeding, non-breeding, transient, etc.) on the Oak Ridge Reservation.

A.2.3 CRITERIA FOR DETERMINING HABITAT QUALITY

The criteria established for assessing the habitat quality of the two sites was based on a comparison of bird species numbers recorded at the subject sites with ORR Partners In Flight (PIF) survey sites that contain similar habitat. Low, medium, and high habitat quality categories were represented as the percentage of expected bird species found on the site based on these other ORR survey sites with similar habitat. The following criteria were used:

Percentage of species	Habitat value
0-25%	Low
26-74%	Medium
75-100%	High

Bird species recorded at the K-25 Site Contractor's Spoil Area that were recorded outside the boundaries of the site, but in similar habitat to the site, were included in the calculation of habitat value. A similar criterion was used for the K-901-A North Disposal Area; however, birds recorded at far distances from the site in dissimilar habitat were not included in the calculation.

A.2.3.1 Calculated Habitat Quality for the K-25 Site Contractor's Spoil Area

There were 17 species of birds recorded during this survey that could be considered birds associated with edge and old field habitats. The Freels Bend Area of the Three Bend Scenic and Wildlife Management Refuge Area (Three Bend Area) contains similar habitat types to this site. Freels Bend is considered to provide high quality habitat for such species. PIF bird surveys conducted at Freels Bend have recorded up to 25 edge/old field species during any one survey. Using 25 as the number of expected species for this habitat type, 68% of the expected species were recorded at the K-25 Site Contractor's Spoil Area site. Based on our criteria, this site provides medium quality edge/old field habitat for birds. It should be emphasized that the fescue field that encompasses the majority of the site provides little habitat value. The medium quality habitat reading for this site is based on structurally diverse habitat on the perimeter and adjacent to the site.

There were 13 species of birds recorded during this survey that could be considered birds associated with forest habitats. The East Fork Ridge Road/McNew Hollow Road area of the ORR contains similar forested habitat to this site. The East Fork Ridge Road/McNew Hollow Road area is considered to provide high quality habitat for forest bird species. PIF bird surveys conducted in that area have recorded up to 21 forest bird species during any one survey. Using 21 as the number of expected species for this habitat type, 62% of the expected species were recorded at the K-25 Site Contractor's Spoil Area site. Based on our criteria, this site provides medium quality forest habitat for birds.

A.2.3.2 Calculated habitat quality for N-901-A North Disposal Area

There were 18 species of birds recorded during this survey that could be considered birds associated with edge and old field habitats. The Freels Bend Area of the Three Bend Area contains similar habitat types to this site. Freels Bend is considered to provide high-quality habitat for such species. PIF Bird surveys conducted at Freels Bend have recorded up to 25 edge/old field species during any one survey. Using 25 as the number of expected species for this habitat type, 72% of the expected species were recorded at the K-901-A North Disposal Area site. Based on our criteria, this site provides relatively medium quality edge/old field habitat for birds.

A.3 CONCLUSIONS

A.3.1 K-25 SITE CONTRACTOR'S SPOIL AREA

The greatest bird habitat value for this site exists around the perimeter of the site, where additional habitat structure is found with the creation of field/forest edges. Habitat structure is also increased with the presence of a powerline corridor, which provides old field and edge habitat. The forested area, which is part of a much larger tract, provides habitat for forest interior birds. The fescue field that encompasses the majority of this site provides limited habitat value for birds, due to the fact that it is a virtual monoculture with little habitat structure.

The establishment of native grasses in place of the fescue monoculture would provide greater habitat structure and be attractive to grassland bird species. This type of management has been successful at the Three Bend Area on the ORR. The presence of the grasshopper sparrow in the fields of the Three Bend Area is a prime example of the success of such a program. The establishment of native grass fields also increases the quality of field/forest edges with increases in habitat structure.

Contiguous forest areas are increasingly fragmented with the development of roads and other man-made disturbances. The fragmentation of forest habitat has great impacts on interior forest birds by establishing corridors for predators and nest parasites (i.e. the brown-headed cowbird), and by decreasing acreage to smaller patch sizes incapable of supporting viable forest bird populations. Therefore, the maintenance of contiguous forest areas such as that which exists on and adjacent to this site is extremely valuable in maintaining these forest interior bird species.

A.3.2 K-901-A NORTH DISPOSAL AREA

The greatest bird habitat value for this site exists in the areas that support old field vegetation and mixed patches of trees and shrubs. Patches of trees and shrubs in certain areas of this site provide valuable habitat for edge species. The areas of fescue present on certain areas of this site provide limited habitat value for birds, due to the fact that it is a virtual monoculture with little habitat structure.

The establishment of native grasses in place of areas dominated by a fescue monoculture would provide greater habitat structure and be attractive to grassland bird species. This type of management has been extremely successful at the Three Bend Area on the ORR. The presence of the grasshopper sparrow in the fields of the Three Bend Area is a prime example of the success of such a program. Although the small size and narrowness of the K-901-A North Disposal Area site may have an impact on the success of such a program, similar management on adjacent areas could significantly increase the viability of such a program. The establishment of native grass fields would also increase the quality of edges with increases in habitat structure.

A.4 REFERENCES

Reynolds, R. T., J. M. Scott and R. A. Nussbaum. 1980. A variable circular-plot method for estimating bird numbers. *Condor* 82:309-313.

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APPENDIX B

2004 ETTP WATERFOWL SURVEY OBSERVATIONS NEAR THREE SITES

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Table B.1. 2004 ETTP waterfowl survey observations near three sites

K-1007-P1 Holding Pond	J	F	M	A	M	J	J	A	S	O	N	D	Total
Double-crested cormorant													0
Green heron							1						1
Great egret								1					1
Great blue heron	2	1		1		2	1	1					8
Canada goose	98	22	13	12	21	34	92	56	48		7		403
Mallard													0
Gadwall		3	2										5
Wood duck				2									2
Ring-necked duck													0
Hooded merganser	11	8											19
American coot			3										3
Killdeer	1					6	10	2	5		3		27
Ring-billed gull	1												1
Sharp-shinned hawk													0
Red-shouldered hawk													0
Broad-winged hawk													0
Red-tailed hawk													0
Osprey				1	1		2	1					5
American kestrel													0
Belted kingfisher	1						1	1	1				4
K-901-A Holding Pond	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Total**
Double-crested Cormorant													0
Green heron													0
Great egret													0
Great blue heron	1				1	1	3	1					7
Canada goose					26								26
Mallard													0
Gadwall	20												20
Wood duck													0
Ring-necked duck													0
Hooded merganser													0
American coot													0
Killdeer						1							1

Table B.1. 2004 ETTP waterfowl survey observations near three sites (continued)

K-901-A Holding Pond (continued)	J	F	M	A	M	J	J	A	S	O	N	D	Total
Ring-billed gull													0
Sharp-shinned hawk													0
Red-shouldered hawk													0
Broad-winged hawk													0
Red-tailed hawk													0
Osprey					2	3	1						6
American kestrel						1	2				2		5
Belted kingfisher											1		1
Mitchell Branch	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Total**
Double-crested cormorant													0
Green heron													0
Great egret													0
Great blue heron					1								1
Canada goose	14		2			20	9						45
Mallard													0
Gadwall													0
Wood duck													0
Ring-necked duck													0
Hooded merganser													0
American coot													0
Killdeer				1									1
Ring-billed gull													0
Sharp-shinned hawk													0
Red-shouldered hawk													0
Broad-winged hawk													0
Red-tailed hawk									1				1
Osprey													0
American kestrel	1												1
Belted kingfisher	1												1

APPENDIX C

OBSERVATIONS OF BATS ON THE OAK RIDGE RESERVATION

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Appendix C. Observations of bats on the Oak Ridge Reservation

Common name	Latin name	Observations on Oak Ridge Reservation other than at K-1007-P1 Holding Pond[1]	Observations at K-1007-P1 Holding Pond
Gray bat	*Myotis grisescens*	Anabat survey summer 03[2]	Anabat survey, north and south ends of pond, 8/14/04 and 8/15/04
Eastern pipistrelle	*Pipistrellus subflavus*	Mist-netting, 5/92 Mist-netting 5/97-7/97 Mist-netting and Anabat survey summer 03	Anabat survey, north and south ends of pond, 8/14/04 and 8/15/04
Eastern red bat	*Lasiurus borealis*	Mist-netting, 5/92 Mist-netting 5/97-7/97 Mist-netting and Anabat survey summer 03	Anabat survey, north and south ends of pond, 8/14/04 and 8/15/04
Big brown bat	*Eptesicus fuscus*	Mist-netting, 5/92 Mist-netting 5/97-7/97 Mist-netting and Anabat survey summer 03	Anabat survey, south ends of pond, 8/15/04
Silver-haired bat	*Lasionycteris noctivagans*	Mist-netting, 5/92 Mist-netting 5/97-7/97	
Evening bat	*Nycticeius humeralis*	Mist-netting 5/97-7/97	
Northern long-eared bat	*Myotis septentrionalis*	Mist-netting 5/97-7/97	

Source: (Harvey and Britzke 2004)

[1]Most surveys were conducted in the area of East Fork Poplar Creek.
[2]At Freels Bend on Melton Hill Lake.

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APPENDIX D

BIRDS OF THE OAK RIDGE RESERVATION AND THEIR STATUS

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Table D.1. Birds of the Oak Ridge Reservation and their status

Species		Status
	Loons	
Common Loon	*Gavia immer*	winter
	Grebes	
Pied-billed grebe	*Podilymbus podiceps*	casual visitor
Horned grebe	*Podiceps auritus*	winter
Eared grebe	*Podiceps nigricollis*	transient
	Cormorants	
Double-crested cormorant	*Phalacrocorax auritus*	casual visitor
	Darters	
Anhinga	*Anhinga anhinga*	transient
	Bitterns and herons	
Great blue heron	*Ardea herodias*	breeder
Great egret	*Ardea alba*	casual visitor
Snowy egret	*Egretta thula*	migrant
Little blue heron	*Egretta caerulea*	casual visitor
Green heron	*Butorides virescens*	breeder
Black-crowned night-heron	*Nycticorax nycticorax*	breeder
	Swans, geese, and ducks	
Canada goose	*Anser canadensis*	breeder
Ross' goose	*Chen rossii*	migrant
Snow goose	*Chen caerulescens*	migrant
Greater white-fronted goose	*Anser albifrons*	migrant
Wood duck	*Aix sponsa*	breeder
Green-winged teal	*Anas crecca*	winter
American black duck	*Anas rubripes*	winter
Mallard	*Anas platyrhynchos*	breeder
Northern pintail	*Anas acuta*	winter
Blue-winged teal	*Anas discors*	winter
Gadwall	*Anas strepera*	winter
American wigeon	*Anas americana*	winter
Northern shoveler	*Anas clypeata*	winter
Canvasback	*Aythya valisineria*	winter
Ring-necked duck	*Aythya collaris*	winter
Greater scaup	*Aythya marila*	winter

Table D.1. Birds of the Oak Ridge Reservation and their status (continued)

Species		Status
	Swans, geese, and ducks (cont.)	
Lesser scaup	*Aythya affinis*	winter
Bufflehead	*Bucephala clangula*	winter
Hooded merganser	*Lophodytes cucullatus*	winter
Red-breasted merganser	*Mergus serrator*	winter
Common merganser	*Mergus merganser*	winter
Ruddy duck	*Oxyura jamaicensus*	winter
	Vultures	
Black vulture	*Coragyps atratus*	breeder
Turkey vulture	*Cathartes aura*	breeder
	Kites, hawks, eagles, and allies	
Osprey	*Pandion haliaetus*	breeder
Bald eagle	*Haliaeetus leucocephalus*	migrant
Northern harrier	*Circus cyaneus*	winter
Sharp-shinned hawk	*Accipiter striatus*	possible breeder
Cooper's hawk	*Accipiter cooperii*	possible breeder
Red-shouldered hawk	*Buteo lineatus*	breeder
Red-tailed hawk	*Buteo jamaicensis*	breeder
Broad-winged hawk	*Buteo platypterus*	breeder
	Falcons	
American kestrel	*Falco sparverius*	breeder
Peregrine falcon	*Falco peregrinus*	migrant
	Grouse, turkey, and quail	
Ruffed grouse	*Bonasa umbellus*	casual visitor
Wild turkey	*Meleagris gallopavo*	breeder
Northern bobwhite	*Colinus virginianus*	breeder
	Rails and coots	
Sora	*Porzana carolina*	migrant
American coot	*Fulica americana*	casual visitor
	Cranes	
Sandhill crane	*Grus canadensis*	migrant
	Plovers	
Killdeer	*Charadrius vociferus*	breeder
Semipalmated plover	*Charadrius semipalmatus*	migrant

Table D.1. Birds of the Oak Ridge Reservation and their status (continued)

Species		Status
	Sandpipers and allies	
Greater yellowlegs	*Tringa melanoleuca*	migrant
Lesser yellowlegs	*Tringa flavipes*	migrant
Solitary sandpiper	*Tringa solitaria*	migrant
Spotted sandpiper	*Actitus macularius*	casual visitor
Pectoral sandpiper	*Calidris melanotos*	migrant
White-rumped sandpiper	*Calidris fuscicollis*	migrant
Least sandpiper	*Calidris minutilla*	migrant
Wilson's snipe	*Gallinago gallinago*	winter
American woodcock	*Scolopax minor*	breeder
	Gulls and terns	
Bonaparte's gull	*Larus philadelphia*	winter
Ring-billed gull	*Larus delawarensis*	winter
Caspian tern	*Sterna caspia*	transient
Forster's tern	*Sterna forsteri*	transient
	Pigeons and doves	
Rock pigeon	*Columba livia*	breeder
Mourning dove	*Zenaida macroura*	breeder
	Cuckoos	
Yellow-billed cuckoo	*Coccyzus americanus*	breeder
	Owls	
Northern Saw-whet owl	*Aegolius acadicus*	transient
Eastern screech-owl	*Megascops asio*	breeder
Great horned owl	*Bubo virginianus*	breeder
Barred owl	*Strix varia*	breeder
Barn owl	*Tyto alba*	possible breeder
	Goatsuckers	
Common nighthawk	*Chordeiles minor*	breeder
Chuck-will's-widow	*Caprimulgus carolinensis*	breeder
Whip-poor-will	*Caprimulgus vociferus*	breeder
	Swifts	
Chimney swift	*Chaetura pelagica*	breeder
	Hummingbirds	
Ruby-throated hummingbird	*Archilochus colubris*	breeder
	Kingfishers	
Belted kingfisher	*Ceryle alcyon*	breeder

Table D.1. Birds of the Oak Ridge Reservation and their status (continued)

Species		Status
	Woodpeckers	
Red-bellied woodpecker	*Melanerpes carolinus*	breeder
Red-headed woodpecker	*Melanerpes erythrocephalus*	breeder
Yellow-bellied sapsucker	*Sphyrapicus varius*	winter
Downy woodpecker	*Picoides pubescens*	breeder
Hairy woodpecker	*Picoides vollosus*	breeder
Northern flicker	*Colaptes auratus*	breeder
Pileated woodpecker	*Dryocopus pileatus*	breeder
	Tyrant flycatchers	
Olive-sided flycatcher	*Contopus cooperi*	migrant
Eastern wood-pewee	*Contopus virens*	breeder
Acadian flycatcher	*Empidonax virescens*	breeder
Willow flycatcher	*Empidonax trailii*	breeder
Eastern phoebe	*Sayornis phoebe*	breeder
Great crested flycatcher	*Myiarchus crinitus*	breeder
Eastern kingbird	*Tyrannus tyrannus*	breeder
Western kingbird	*Tyrannus verticalis*	transient
	Larks	
Horned lark	*Eremophila alpestris*	casual visitor
	Swallows	
Purple martin	*Progne subis*	breeder
Tree swallow	*Tachycineta bicolor*	breeder
Northern rough-winged swallow	*Stelgidopteryx serripennis*	breeder
Cliff swallow	*Petrochelidon fulva*	breeder
Barn swallow	*Hirundo rustica*	breeder
Bank swallow	*Petrochelidon pyrrhonota*	migrant
	Jays and crows	
Blue jay	*Cyannocitta cristata*	breeder
American crow	*Corvus brachyrhynchos*	breeder
	Titmice and chickadees	
Carolina chickadee	*Poecile carolinensis*	breeder
Tufted titmouse	*Baeolophus bicolor*	breeder
	Nuthatches	
Red-breasted nuthatch	*Sitta canadensis*	winter
White-breasted nuthatch	*Sitta carolinensis*	breeder
Brown-headed nuthatch	*Sitta pusilla*	breeder

Table D.1. Birds of the Oak Ridge Reservation and their status (continued)

Species		Status
	Creepers	
Brown creeper	*Certhia americana*	winter
	Wrens	
Carolina wren	*Thryothorus ludovicianus*	breeder
House wren	*Troglodytes aedon*	breeder
Winter wren	*Troglodytes troglodytes*	winter
Sedge wren	*Cistothorus platensis*	migrant
Marsh wren	*Cistothorus palustris*	migrant
	Kinglets, gnatcatchers, and thrushes	
Golden-crowned kinglet	*Regulus satrapa*	winter
Ruby-crowned kinglet	*Regulus calendula*	winter
Blue-gray gnatcatcher	*Polioptila caerulea*	breeder
Eastern bluebird	*Siala sialis*	breeder
Veery	*Catharus fuscescens*	migrant
Swainson's thrush	*Catharus ustulatus*	migrant
Hermit thrush	*Catharus guttatus*	winter
Wood thrush	*Hylocichla mustelina*	breeder
American robin	*Turdus migratorius*	breeder
Varied thrush	*Ixoreus naevius*	transient
	Pipits and wagtails	
American pipit	*Anthus rubescens*	migrant
	Trashers and mockingbirds	
Gray catbird	*Dumetella carolinensis*	breeder
Northern mockingbird	*Mimus polyglottos*	breeder
Brown thrasher	*Toxostoma rufum*	breeder
	Waxwings	
Cedar waxwing	*Bombycilla cedrorum*	breeder
	Shrikes	
Loggerhead shrike	*Lanius ludovicianus*	transient
	Starlings	
European starling	*Sturnus vulgaris*	breeder
	Vireos	
White-eyed vireo	*Vireo griseus*	breeder
Blue-headed vireo	*Vireo solitarius*	migrant
Yellow-throated vireo	*Vireo flavifrons*	breeder
Red-eyed vireo	*Vireo olivaceus*	breeder

Table D.1. Birds of the Oak Ridge Reservation and their status (continued)

Species		Status
	Vireos	
Warbling vireo	*Vireo gilvus*	casual visitor
	Wood warblers	
Blue-winged warbler	*Vermivora pinus*	breeder
Golden-winged warbler	*Vermivora chrysoptera*	migrant
Tennessee warbler	*Vermivora peregrina*	migrant
Nashville warbler	*Vermivora ruficapilla*	migrant
Northern parula	*Parula americana*	breeder
Yellow warbler	*Dendroica petechia*	breeder
Chestnut-sided warbler	*Dendroica pensylvanica*	migrant
Magnolia warbler	*Dendroica magnolia*	migrant
Cape may warbler	*Dendroica tigrina*	migrant
Black-throated blue warbler	*Dendroica caerulescens*	migrant
Yellow-rumped warbler	*Dendroica coronata*	winter
Black-throated green warbler	*Dendroica virens*	possible breeder
Blackburnian warbler	*Dendroica fusca*	migrant
Yellow-throated warbler	*Dendroica dominica*	breeder
Pine warbler	*Dendroica pinus*	breeder
Prairie warbler	*Dendroica discolor*	breeder
Palm warbler	*Dendroica palmarum*	migrant
Bay-breasted warbler	*Dendroica castanea*	migrant
Blackpoll warbler	*Dendroica striata*	migrant
Cerulean warbler	*Dendroica cerulea*	possible breeder
Black-and-white warbler	*Mniotilta varia*	possible breeder
American redstart	*Setophaga ruticilla*	possible breeder
Prothonotary warbler	*Protonotaria citrea*	breeder
Worm-eating warbler	*Helmitheros vermivorum*	breeder
Ovenbird	*Seiurus aurocapilla*	breeder
Northern waterthrush	*Seiurus noveboracensis*	migrant
Louisiana waterthrush	*Seiurus motacilla*	possible breeder
Kentucky warbler	*Oporornis formosus*	breeder
Common yellowthroat	*Geothlypis trichas*	breeder
Hooded warbler	*Wilsonia citrina*	breeder
Wilson's warbler	*Wilsonia pusilla*	migrant
Canada warbler	*Wilsonia canadensis*	migrant
Yellow-breasted chat	*Icteria virens*	breeder

Table D.1. Birds of the Oak Ridge Reservation and their status (continued)

Species		Status
	Tanagers	
Summer tanager	*Piranga rubra*	breeder
Scarlet tanager	*Piranga olivacea*	breeder
	Cardinals, grosbeaks, and allies	
Northern cardinal	*Cardinalis cardinalis*	breeder
Rose-breasted grosbeak	*Pheucticus ludovicianus*	migrant
Blue grosbeak	*Passerina caerulea*	breeder
Indigo bunting	*Passerina cyanea*	breeder
Dickcissel	*Spiza americana*	casual visitor
	Towhees, sparrows, and allies	
Eastern towhee	*Pipilo erythrophthalmus*	breeder
Chipping sparrow	*Spizella passerina*	breeder
Field sparrow	*Spizella pusilla*	breeder
Savannah sparrow	*Passerculus sandwichensis*	migrant+winter
Grasshopper sparrow	*Ammodramus savannarum*	breeder
Fox sparrow	*Passerella iliaca*	winter
Song sparrow	*Melospiza melodia*	breeder
Swamp sparrow	*Melospiza georgiana*	winter
White-throated sparrow	*Zonotrichia albicollis*	winter
White-crowned sparrow	*Zonotrichia leucophrys*	migrant
Vesper sparrow	*Pooecetes gramineus*	migrant
Dark-eyed junco	*Junco hyemalis*	winter
	Blackbirds and allies	
Bobolink	*Dolichonyx oryzivorus*	migrant
Red-winged Blackbird	*Agelaius phoeniceus*	breeder
Eastern meadowlark	*Sturnella magna*	breeder
Common grackle	*Quiscalus quiscula*	breeder
Brown-headed cowbird	*Molothrus ater*	breeder
Orchard oriole	*Icterus spurius*	breeder
Baltimore oriole	*Icterus galbula*	breeder
	Finches	
Purple finch	*Carpodacus purpureus*	winter
House finch	*Carpodacus mexicanus*	breeder
Pine siskin	*Carduelis pinus*	winter
American goldfinch	*Carduelis tristis*	breeder

Table D.1. Birds of the Oak Ridge Reservation and their status (continued)

Species		Status
Finches (cont.)		
Evening grosbeak	*Coccothraustes vespertinus*	migrant
Old world sparrows		
House sparrow	*Passer domesticus*	breeder

Note: List provided by Neil Giffen and Marti Salk, May 2005

APPENDIX E

TERRESTRIAL VERTEBRATES ENCOUNTERED DURING THE SURVEY OF PROTECTED TERRESTRIAL VERTEBRATES

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The following is a list of terrestrial vertebrates that were encountered during the survey of protected terrestrial vertebrates on the Oak Ridge Reservation (ORR) (Mitchell et al. 1996). Additional species are undoubtedly present; thus, this listing should not be considered a complete inventory of ORR terrestrial vertebrate fauna.

Common name	Scientific name
Reptiles and amphibians	
Spotted salamander	*Ambystoma maculatum*
Marbled salamander	*Ambystoma opacum*
Eastern tiger salamander	*Ambysto ma tigrinum*
Red spotted newt	*Notophthalmus viridescens*
Dusky salamander	*Desmongnathus fuscus*
Two-lined salamander	*Eurycea bislineata*
Longtail salamander	*Eurycea longicauda*
Cave salamander	*Eurycea lucifuga*
Spring salamander	*Gyrinophilus porphyriticus*
Slimy salamander	*Plethodon glutinosus*
Four-toed salamander[a]	*Hemidactylium scutatum*
Red salamander	*Pseudotriton ruber*
Eastern spadefoot toad	*Scaphiopus holbrookii*
American toad	*Bufo americanus*
Spring peeper	*Pseudacris crucifer*
Gray treefrog	*Hyla versicolor*
Eastern narrow mouth toad	*Gastrophryne carolinensis*
Chorus frog	*Pseudacris triseriata*
Bull frog	*Rana catesbeiana*
Green frog	*Rana clamitans*
Southern leopard frog	*Rana utricularia*
Snapping turtle	*Chelydra serpentine*
Stripeneck musk turtle	*Sternotherus minor*
Stinkpot	*Sternotherus odoratus*
Eastern box turtle	*Terrapene Carolina*
Map turtle	*Graptemys geographica*
Painted turtle	*Chrysemys picta*
Red-eared slider	*Trachemys scripta elegans*
Cumberland slider	*Trachemys scripta troosti*
Spinny softshell	*Apalone spinifera*
Fence lizard	*Sceloporus undulatus*
Six-lined racerunner	*Cnemidophorus sexlineatus*
Ground skink	*Scincella lateralis*
Five-lined skink	*Eumeces fasciatus*
Worm snake	*Carphophis amoenus*
Black racer	*Coluber constrictor*
Ringneck snake	*Diadophis punctatus*
Corn snake	*Elaphe guttata*
Rat snake	*Elaphe obsoleta*

Common name	Scientific name
Reptiles and amphibians (cont.)	
Black king snake	*Lampropeltis getula*
Northern water snake	*Nerodia sipedon*
Brown snake	*Storeria dekayi*
Eastern garter snake	*Thamnophis sirtalis*
Smooth earth snake	*Virginia valeriae*
Copperhead	*Agkistrodon contortrix*
Mammals	
Opposum	*Didelphis virginian*
Southeastern shrew[a]	*Sorex longirostris*
Shorttail shrew	*Blarina brevicauda*
Least shrew	*Cryptotis parva*
Eastern mole	*Scalopus aquaticus*
Gray bat[b]	*Myotis grisescens*
Eastern pipistrel	*Pipistrellus subflavus*
Eastern cottontail	*Sylvilagus floridanus*
Eastern chipmunk	*Tamias striatus*
Groundhog	*Marmota monax*
Eastern gray squirrel	*Sciurus carolinensis*
Southern flying squirrel	*Glaucomys volans*
Beaver	*Castor Canadensis*
Eastern harvest mouse	*Reithrodontomys humulis*
White-footed mouse	*Peromyscus leucopus*
Golden mouse	*Peromyscus nuttalli*
Deer mouse	*Peromyscus maniculatus*
Hispid cotton rat	*Sigmondon hispidus*
Pine vole	*Pitymys pinetorum*
Meadow vole	*Microtus pennsylvanicus*
Muskrat	*Ondatra zibethica*
Norway rat	*Rattus norvegicus*
House mouse	*Mus musculus*
Coyote	*Canis latrans*
Red fox	*Vulpes vulpes*
Gray fox	*Urocyon cinereoargenteus*
Raccoon	*Procyon lotor*
Mink	*Mustela vison*
Striped skunk	*Mephitis mephitis*
Whitetailed deer	*Odocoileus virginianus*

[a]A state listed in need of management species.
[b]A federally listed endangered species.

REFERENCES

Mitchell, J. M., E. R. Vail, J. W. Webb, J. W. Evans, A. L. King, and P. A. Hamlett. 1996. *Survey of protected terrestrial vertebrates on the Oak Ridge Reservation*. ES/ER/TM-188/R1. Lockheed Martin Energy Systems, U.S. Department of Energy, Oak Ridge, TN.

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