Appendix V: Ecology

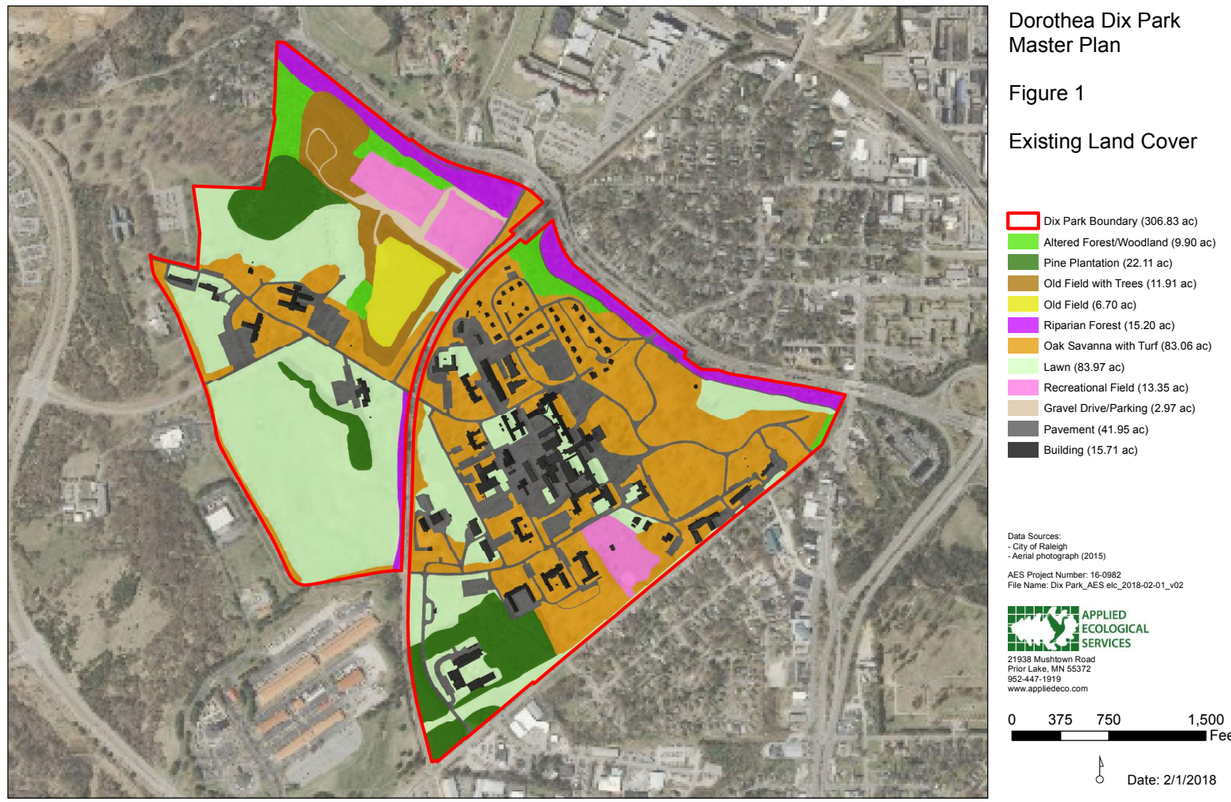
Authors:

Applied Ecological Services, Inc. (AES)

Michael Van Valkenburgh Associates, Inc.

The following section provides the details of the ecological site analysis performed for the Dix Park Master Plan.

Landcover Analysis



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MEMORANDUM

TO: Adrienne Heflich (MVVA)

FROM: Doug Mensing, Steve Apfelbaum (AES)

DATE: February 2, 2018

RE: Dix Park MP (AES 16-0982) – Summary of Existing Land Cover Types

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INTRODUCTION

In 2016, Applied Ecological Services (AES) was retained by Michael Van Valkenburgh Assoc., Inc. (MVVA) to provide ecological support for the Dorothea Dix Park Master Plan project in Raleigh, NC. On November 16 and 17, 2017, AES ecologists Steven Apfelbaum and Douglas Mensing conducted a field assessment of the Dix Park site, including site tours with other design team members. On December 5, 2017, AES submitted a memorandum to MVVA summarizing some of our initial observations from the initial Discovery phase of the project. This memorandum provides additional information and detail regarding our site assessment, focusing on existing land cover types and their condition.

REGIONAL CONTEXT

Formation of the Blue Ridge Mountains (beginning about 1,700 million year ago) set the stage for the formation of the Appalachian Mountains and the subsequent erosional processes that created the landforms of North Carolina today. Dix Park is located in the transition zone between the Piedmont and the Coastal Plain, known as the Fall Line. This zone, which runs roughly parallel to the Atlantic Ocean coast, is characterized by moderate slopes and waterfalls that lead down into the Coastal Plain. The hilly terrain of the region has resulted in erosion of swales and ravines. Dix Park drainage generally flows southeast via Rocky Branch and south via smaller drainageways. The site's location on the edge of the Piedmont region creates an opportunity to restore a wide range of native plant communities and habitats.

EXISTING CONDITIONS

Land Cover

AES reviewed existing geographic information system (GIS) data developed by others, including

- Dorothea Dix Park boundary
- Land ownership and parcel data

- Elevation contours and steep slopes
- USDA/NRCS National Land Cover Dataset (NLCD)
- USDA/NRCS soils survey (including hydric soils)
- FEMA floodplain mapping
- Greenways, open space, trails, and natural areas mapping
- Rare natural features data (including rare plants, animals, and plant communities)
- Water features (including streams and impaired waters)
- Urban forestry priority areas
- Historical (1938) through current (2017) aerial imagery

Existing data were used in conjunction with our November 2017 field observations to create a land cover map of existing site conditions (Figure 1). Most but not all portions of the site were verified in the field; therefore, interpretation of aerial photography and other data was used to extrapolate land cover mapping for the entire site. Table 1 presents a hierarchical land cover classification. Acreages and percentages of each numbered (and mapped) land cover type are presented in the table, followed by descriptions of each numbered land cover type.

Table 1. Existing Land Cover of Dorothea Dix Park

NATURAL LAND COVERS	DEFINING CHARACTERISTICS	ACRES	PERCENT OF STUDY AREA
Upland Plant Communities	**High, dry ground**		
Forest/Woodland	50-100% tree canopy		
1. Altered Forest/Woodland	Combination of mature trees (oaks, pecan) and younger trees (elm, sweetgum, pine)	9.90	3.23
2. Pine Plantation	Mature pine trees, mostly loblolly	22.11	7.21
Savanna/Brushland	5-50% tree/shrub canopy		
3. Old Field with Trees	Non-native grasses and weeds with patchy trees and shrubs	11.91	3.88
Grassland	<5% tree/shrub canopy		
4. Old Field	Non-native grasses and weeds	6.70	2.18
Lowland Communities	**Low areas, including wetlands/streams**		
5. Riparian Forest	50-100% tree canopy	15.20	4.95
CULTURAL LAND COVERS	**DEFINING CHARACTERISTICS**		
6. Oak Savanna with Turf	Mature native oaks with mowed turf beneath	83.06	27.07
7. Lawn	Turf lawn	83.97	27.37
8. Recreational Field	Soccer field	13.35	4.35
9. Gravel Drive/Parking	Roads and parking lots	2.97	0.97
10. Pavement	Roads and parking lots	41.95	13.67
11. Building	Building structures	15.71	5.12
Totals		***306.83***[1]	***100***[1]

[1] Numbers above were rounded

Natural Land Cover types are described in the following pages.

1. Altered Forest/Woodland (9.90 acres)

The site's Altered Forest/Woodland includes old fields that were invaded by woody growth many years ago as well as other disturbed woodlands. Non-native and invasive plants are common.

Characteristic Plant Species

- Sweetgum (*Liquidambar styraciflua*)
- American elm (*Ulmus americana*)
- Winged elm (*Ulmus alata*)
- Loblolly pine (*Pinus taeda*)
- European privet (*Ligustrum vulgare*) - invasive
- Ivy (*Hedera* sp) - invasive

Historical Conditions

- Formerly disturbed areas, like crop fields and rights of way, that were colonized by pioneering native woody species (dispersed by wind-blown seeds) as well as invasive woody species such as privet (dispersed by berry-eating birds).

Restoration Opportunities

- Moderate potential for restoring native savanna or woodland, depending on species present and seedbank.

Altered Forest/Woodland with intermittent drainage, located in northwest portion of site.

2. Pine Plantation (22.11 acres)

Several pine plantations exist in the west and south portions of the site; most of these are dominated by loblolly pine estimated to be 25 to 30 years old. Non-native and invasive shrubs and herbaceous species are common in the understory and ground plane.

Characteristic Plant Species

- Loblolly pine (*Pinus taeda*)
- Sweetgum (*Liquidambar styraciflua*)
- Burningbush (*Euonymus alatus*) – invasive
- European privet (*Ligustrum vulgare*) - invasive
- Bradford pear (*Pyrus calleryana*) – invasive
- Blackberry (*Rubus allegheniensis*)
- Ivy (*Hedera* sp) - invasive
- Sericea lespedeza (*Lespedeza cuneata*) - invasive

Historical Conditions

- Most are former cropland.

Restoration Opportunities

- Moderate potential for restoring savanna or woodland. This may require removal of existing pines, which could be phased in over time.

Pine Plantation, located in northwest portion of site.

3. Old Field with Trees (11.91 acres)

Old fields that have been invaded relatively recently by woody vegetation exist in the northwest portion of the site. The largest area of Old Field with Trees (in the northwest portion of the site) has developed on a closed landfill, where the topsoil was scraped away and the area seeded with stabilizing cover crop. Non-native and invasive plants are common.

Characteristic Plant Species

- American Sycamore (*Platanus occidentalis*)
- Loblolly pine (*Pinus taeda*)
- Sweetgum (*Liquidambar styraciflua*)
- Bradford pear (*Pyrus calleryana*) – invasive
- Winged elm (*Ulmus alata*)
- Eastern baccharis (*Baccharis* halimifolia)
- European privet (*Ligustrum vulgare*) - invasive
- Japanese honeysuckle (*Lonicera japonica*) - invasive
- Blackberry (*Rubus allegheniensis*)
- Sericea lespedeza (*Lespedeza cuneata*) - invasive
- Canada goldenrod (*Solidago canadensis*)
- Johnsongrass (*Sorghum halepense*) – invasive
- Bermudagrass (*Cynodon dactylon*)

Historical Conditions

- Most are former cropland.

Restoration Opportunities

- Moderate potential for restoring native savanna or prairie, but will require removal of non-native trees/shrubs and replacement of weedy ground plane vegetation. Soil amendments may be warranted on the landfill site.

Old Field with Trees, located in northwest portion of site.

4. Old Field (6.70 acres)

An Old Field exists in the northwest portion of the site; this area is just beginning to be invaded by woody vegetation. Non-native and invasive plants are common.

Characteristic Plant Species

- Eastern baccharis (*Baccharis* halimifolia)
- Blackberry (*Rubus allegheniensis*)
- Sericea lespedeza (*Lespedeza cuneata*) – invasive
- Broomsedge bluestem (*Andropogon virginicus*)
- Canada goldenrod (*Solidago canadensis*)
- Johnsongrass (*Sorghum halepense*) – invasive
- Bermudagrass (*Cynodon dactylon*)

Historical Conditions

- Former cropland.

Restoration Opportunities

- Moderate potential for restoring native savanna or prairie, but will require replacement of weedy ground plane vegetation.

Old Field, located near the center of the site.

5. Riparian Forest (15.20 acres)

Riparian Forest exists along Rocky Branch, the stream that flows west to east along the northern edge of the site. This plant community also exists along a drainageway in the south-center portion of the site, immediately west of the railroad corridor. While some Riparian Forest is situated above the floodplain, it is considered a Lowland Community due to the influence of the drainageways and runoff that flows into these low-lying areas.

Characteristic Plant Species

- American Sycamore (*Platanus occidentalis*)
- Pecan (*Carya illinoinensis*)
- Black locust (*Robinia pseudoacacia*)
- Bald cypress (*Taxodium distichum*)
- Sweetgum (*Liquidambar styraciflua*)
- American elm (*Ulmus americana*)
- Black willow (*Salix nigra*)
- Chinaberry (*Melia azedarach*) - invasive
- Sassafras (*Sassafras albidum*)
- White mulberry (*Morus alba*) - invasive
- Grapevine (*Vitis* sp)
- Trumpet creeper (*Campsis radicans*)
- Ivy (*Hedera* sp) - invasive
- North American bamboo (*Arundinaria* sp)
- Virginia wildrye (*Elymus virginicus*)
- Japanese stiltgrass (*Microstegium vimineum*) – invasive
- Violets (*Viola* sp)
- Sedges (*Carex* spp)

Historical Conditions

- Most of the site's Riparian Forest was formerly cropland. Sometime between 1959 and 1971, Rocky Branch was re-routed to the north (just south of Western Boulevard).

Riparian Forest, along Rocky Branch.

Cultural Land Cover types are described on the following pages.

6. Oak Savanna with Turf (83.06 acres)

Dorothea Dix Park's most defining land cover is probably its Oak Savanna with Turf. These areas contain the site's oldest, most majestic oaks, growing on well-drained sandy loam soils. In the 1938 aerial photograph, these areas were dominated by large-crowned trees, which created a broken canopy that allowed a moderate amount of light to reach the ground. A similar "parkland" structure is maintained today, with a broken canopy dominated by tall, mature native trees, no subcanopy or sapling/shrub layer, and a ground plane of mowed lawn. This is considered a cultural land cover type due to the regularly maintained (mowed) turf ground plane of non-native vegetation and the presence of ornamental tree and shrub plantings, particularly near site buildings.

Characteristic Plant Species

- White oak (*Quercus alba*), a native remnant of the site's former oak savannas
- Willow oak *(Q. phellos*), a rapidly growing oak, which has been planted at the site
- Red and scarlet oak (*Q. rubra and Q. coccinea*)
- Sweetgum (*Liquidambar styraciflua*)
- Ornamental trees and shrubs
- Bermudagrass (*Cynodon dactylon*)
- Other turf grasses

Historical Conditions

- Prior to European settlement in the region, oak savannas historically burned relatively frequently (approximately once every 5 to 10 years).
- Low-intensity surface fires were important for maintaining plant community structure and species composition. Without intermittent fire, sun-requiring species disappear, reducing the variety of plants and insects in the community.

Restoration Opportunities

- High potential for restoring native oak savanna through conversion of turf to native savanna grass, sedge, and wildflower species.

Oak Savanna with Turf, in north portion of site.

7. Lawn (83.97 acres)

Areas of open lawn exist throughout the site, with a large "great lawn" located in the west-central portion of the site. Occasional ornamental tree and shrub plantings exist within Lawn areas, particularly near site buildings. While a cultural land cover type, Lawn can be restored to prairie or other native landscapes.

Large Lawn, located in west portion of site.

8. Recreational Field (13.35 acres)

Recreational Fields exist in the northwest portion of the site (soccer fields) and southeast portion of the site (baseball field). The northwest Recreational Fields were constructed on a closed landfill; soils in this area appeared to be poor quality, and vegetation was sparse in areas. While a cultural land cover type, Recreational Fields can be restored to prairie or other native landscapes. Soil amendments may be warranted on the landfill site.

Recreational Field (background) and Gravel Drive/Parking (foreground), located in northwest portion of site.

9. Gravel Drive/Parking (2.97 acres)

Gravel parking lots and drives exist in the northwest portion of the site. While not completely impervious, these areas are typically heavily compacted and convey runoff in a manner similar to asphalt or concrete. Evidence of gully and rill erosion was observed in some of the site's gravel surfaces. See preceding photo for image of Gravel Drive/Parking.

10. Pavement (41.95 acres)

Consisting mostly of roads and parking lots, pavement is a primary contributor to urban runoff – a major stressor on surface water resources such as lakes and streams. Reducing the extent of or "breaking up" continuous impervious cover to interrupt and intercept stormwater flow is an effective strategy to reduce runoff.

Pavement (roads and parking lots), near the N.C. Division of Development and Early Education (image from Google Earth Street View).

11. Building (15.71 acres)

The site contains many buildings, most of which are associated with state social services. Rooftops of these buildings intercept precipitation and transfer it to the ground as concentrated runoff. Runoff is best managed in a diffuse and intentional manner, as close as possible to where it is generated. See preceding photo for an image of site Buildings.

Wildlife

AES did not conduct formal wildlife surveys during our November 2017 field assessment; however, Table 2 presents wildlife species that were documented. As indicated in the table, an impressive diversity of bird species was recorded in the "Old Field with Trees" land cover type. Common wildlife, such as crows, robins, and gray squirrels were observed in many portions of the site, but were not always documented.

Table 2. Anecdotal Wildlife Observations by Land Cover Type

LAND COVER TYPE	WILDLIFE OBSERVATIONS
1. Altered Forest/Woodland	none documented
2. Pine Plantation	Pileated woodpecker Red-bellied woodpecker
3. Old Field with Trees	American crow American robin Black-capped chickadee Blue jay Carolina wren House finch Northern cardinal Northern flicker Red-tailed hawk White-breasted nuthatch White-crowned sparrow White-throated sparrow
4. Old Field	none documented
5. Riparian Forest	Cooper's hawk Turkey vulture White-tailed deer
6. Oak Savanna with Turf	none documented
7. Lawn	none documented
8. Recreational Field	none documented
9. Gravel Drive/Parking	none documented
10. Pavement	none documented
11. Building	none documented

Restoring native plant communities and enhancing other natural areas at Dix Park would be expected to greatly increase the abundance and diversity of native wildlife. Habitat restoration work can be targeted at certain species or groups of species (e.g., rare or declining wildlife, such as pollinators). Conducting baseline wildlife surveys (such as those planned at Dix Park in early 2018) are important so wildlife populations are better understood prior to restoration and management. Subsequent wildlife monitoring, following ecological restoration and management, are an effective means of measuring restoration success and engaging the public and other stakeholders.

CLOSING

Thank you for the opportunity for AES to provide MVVA with these recommendations. Please contact us if you have any questions, comments, or additional needs, and we look forward to continuing our work with you on this project.

Sincerely,
Applied Ecological Services, Inc.

Steven I. Apfelbaum, MS
Senior Ecologist

Douglas M. Mensing, MS
Senior Ecologist

The Park and The Site

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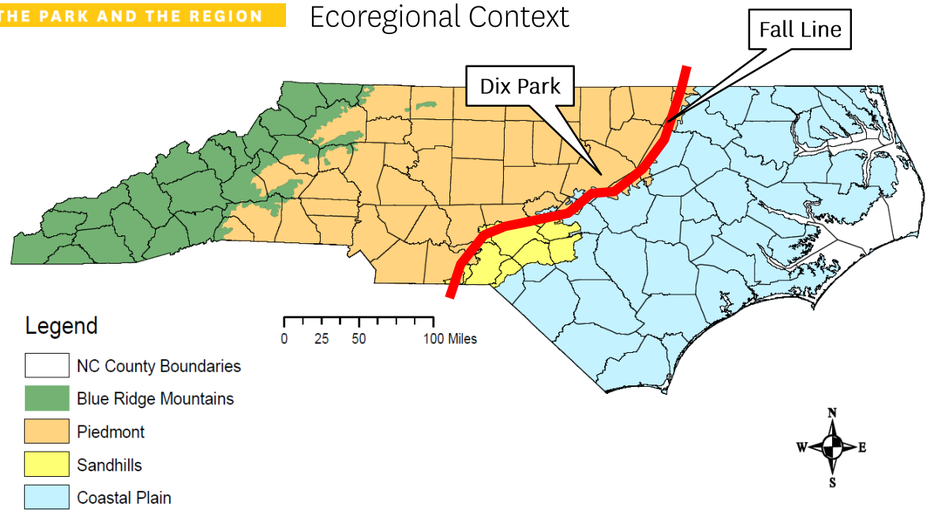
Ecoregional Context



Map adapted from "North Carolina Ecoregions" (Bailey 2009)

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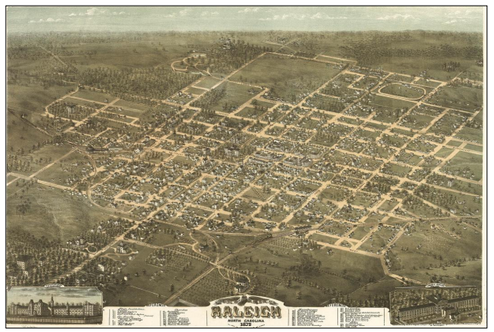
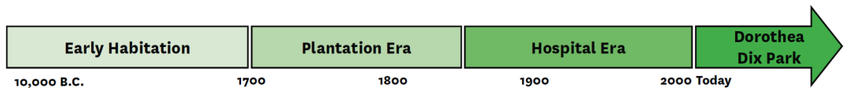
Historical Conditions

- Over the centuries, land cleared for:
  - crops
  - pine plantations
  - buildings & development



Raleigh Map (1872)



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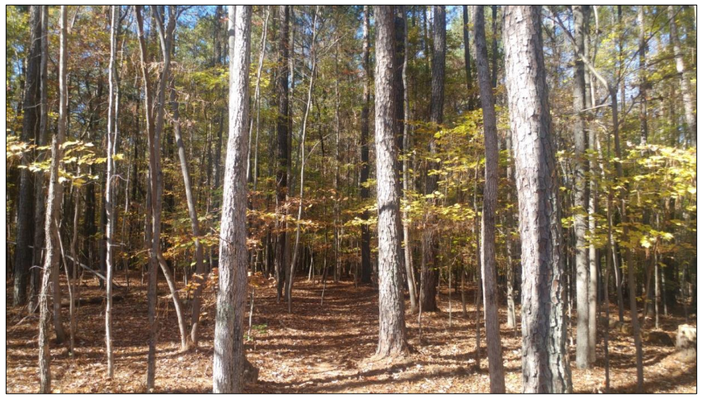
Historical Conditions

- Historical mixed pine & hardwood forest, with other interspersed vegetation types responding to geologic, soils, moisture, slope and aspect conditions



Annie-Louise Wilkerson Nature Preserve, Raleigh

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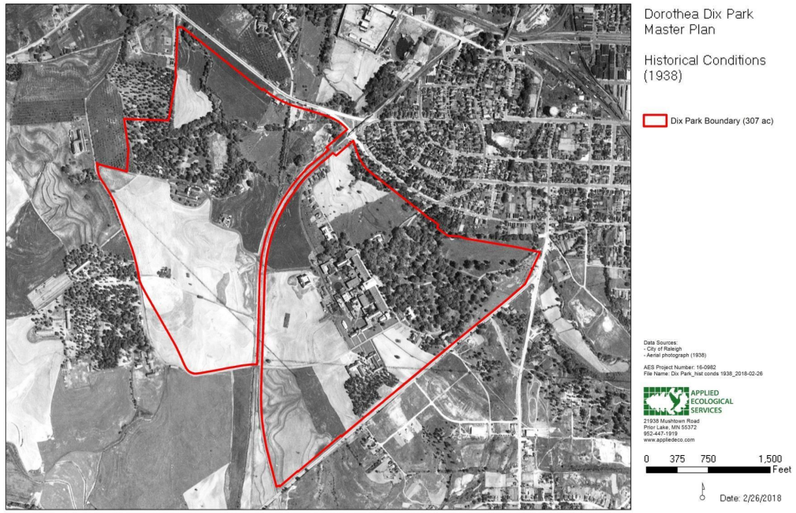
Historical Conditions

- Current park boundary on 1938 aerial photograph



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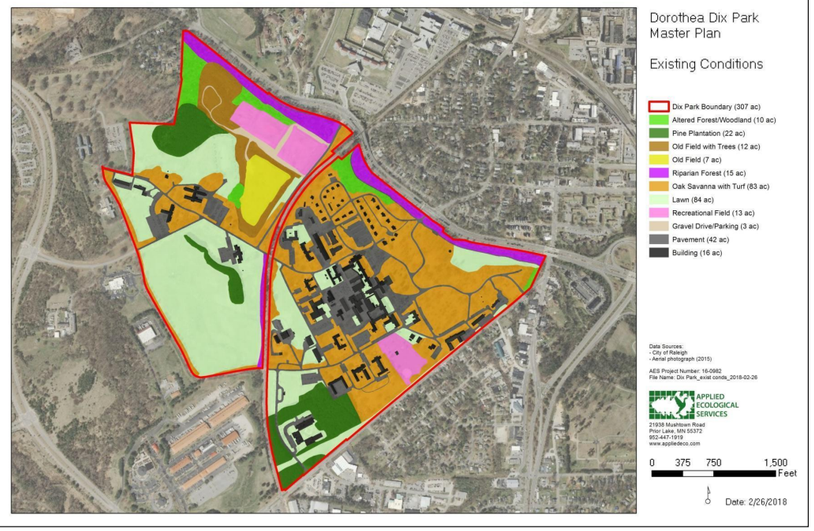
Existing Conditions

- Results of 2017 field assessment



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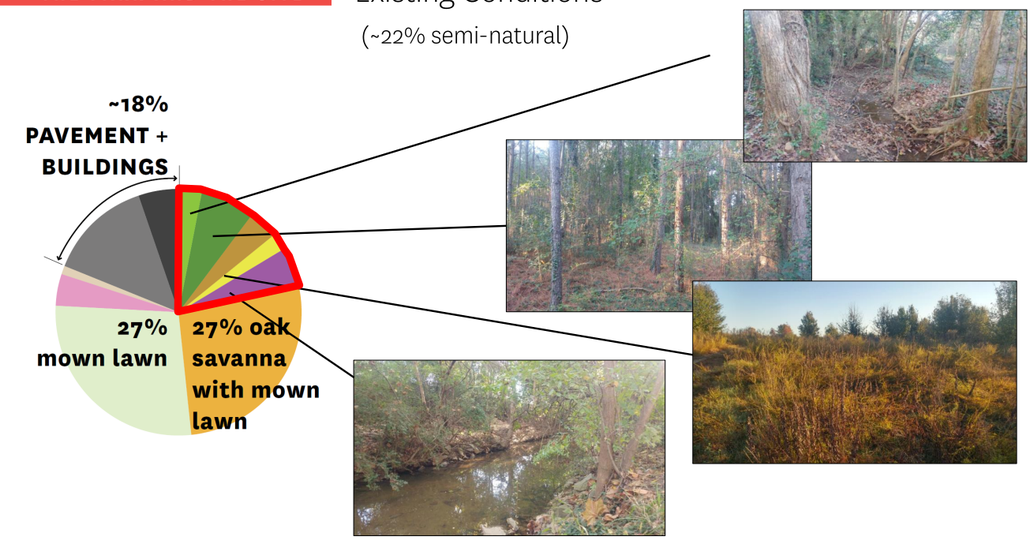
Existing Conditions

(~22% semi-natural)



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Existing Conditions

(~78% cultural)

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Existing Conditions

- Park characteristics
  - Little natural habitat
  - Little structural diversity (i.e., habitat diversity)
  - Low native plant species diversity
  - Poor habitat connectivity
  - Poor-moderate wildlife diversity
- Many invasive plants
  - White mulberry
  - Callery pear
  - Chinaberry
  - European privet
  - Multiflora rose
  - Japanese honeysuckle
  - English Ivy
  - Sericea lespedeza
  - Johnsongrass
  - Japanese stiltgrass
- Mostly "generalist" wildlife species
  - White-tailed deer
  - American crow
  - American robin
  - Black-capped chickadee
  - Blue jay
  - Carolina wren
  - House finch
  - Northern cardinal

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Existing Maintenance Regimes

- Cultural areas
  - Extensive mowing of lawns, including beneath mature oaks
  - Tree pruning/removal as needed
- Semi-natural areas
  - Invasive brush removal
  - Native seeding
  - Native tree planting

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Existing Maintenance Regimes - Volunteers

Volunteers removing invasive brush – Dix Park

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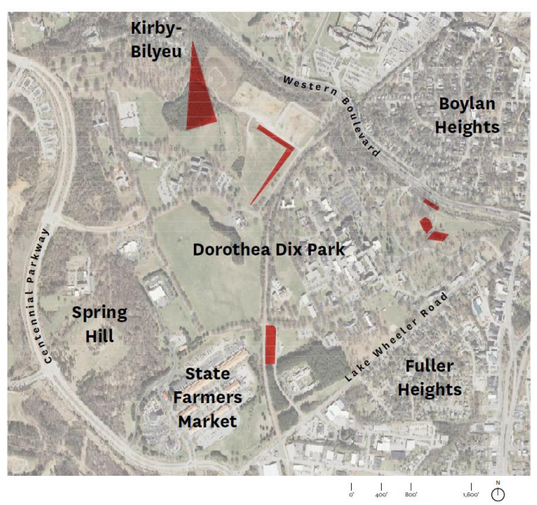
Existing Maintenance Regimes - Volunteers

Dorothea Dix Park
Invasive Species Removal

Areas of Invasive Species Removal
2016 to 2018



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Existing Maintenance Regimes - Volunteers

Before (Feb. 2018)

After (Mar. 2018)

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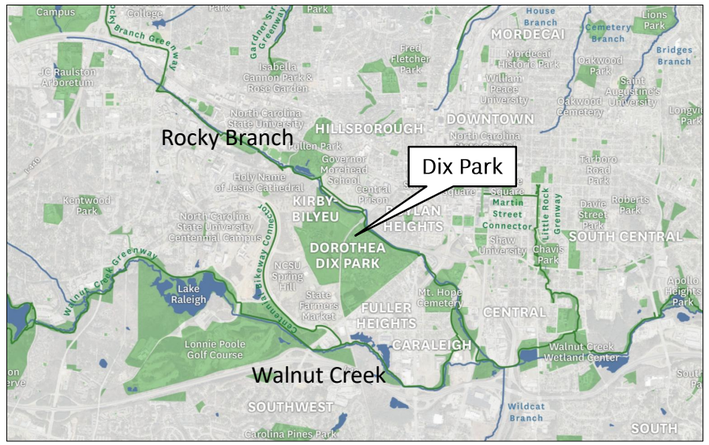
Regional Connectivity

- Dix Park plays an important role in existing regional greenways/connectivity...but this could be greatly enhanced



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Existing Conditions Summary

- Land use history of the park has resulted in the loss of almost all natural communities
- Maintenance in cultural areas limits natural habitat
- Limited maintenance in semi-natural areas insufficient for invasive plant species and other stressors
- Some connectivity to other natural open space, but limited

- All of these factors have resulted in limited site biodiversity...

...but, Dix Park presents a unique opportunity to restore healthy and diverse native Piedmont habitats and species, as well as enhance connectivity for regional ecological improvement.

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Potential Future Conditions

- Convert underutilized turf areas to more diverse, soil stabilizing, lower maintenance prairies and savannas

Existing

Proposed

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Potential Future Conditions

Existing

Proposed

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Potential Future Conditions

Existing

Proposed

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Potential Future Conditions

- Increase invasive plant removal efforts and replant with appropriate, local ecotype native species

Existing

Proposed

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Additional Restoration Opportunities

- Plant native oaks, shortleaf pine and other species in existing pine plantations and near old trees to facilitate more natural succession
- Enhance Rocky Branch riparian corridor, including channel habitat diversification and bank vegetation restoration
- Construct naturalized stormwater best practices to better manage runoff and increase habitat diversity (e.g., wetlands)
- Manage and monitor efforts to ensure conservation goals are met
- Engage partners and the public to assist with stewardship

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Additional Restoration Opportunities

- Maintain site integrity
  - Collect and grow local ecotype, wild-type native plant species (including rare species)
  - Opportunities for on-site nursery
  - Opportunities for partnerships

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Additional Restoration Opportunities

- Increase park complexity and diversity
  - Restore the structure, composition and function of native plant communities:
    - Oak-hickory forest
    - Beech forest
    - Pine forest
    - Oak & pine savanna/barrens
    - Piedmont prairie/meadow
    - Perched wetlands
    - Seeps
    - Floodplain forest
  - Results in more resilient, lower-maintenance landscapes that will persist under environmental change

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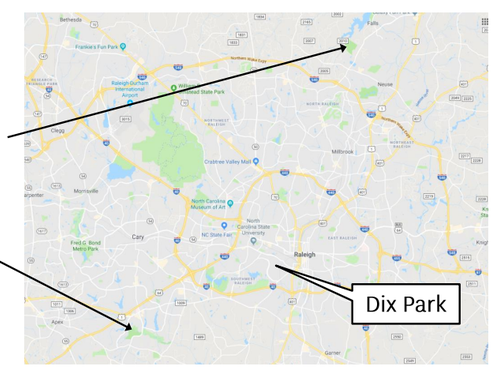
Potential Future Maintenance

- Prescribed burning an important ecological management tool
  - initial restoration efforts
  - long-term maintenance
- Prescribed burning is used locally
  - Annie Louise Wilkerson, MD Nature Preserve Park (Raleigh) - Spring 2017
  - Hemlock Bluffs (Cary, NC) – since 2012



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Potential Future Maintenance

- Annie Louise Wilkerson, MD Nature Preserve Park – Spring 2017 Burn

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Potential Future Maintenance

- Hemlock Bluffs (Cary, NC) – Spring 2017 Burn

Photos: Michael Papich

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Potential Future Maintenance

- Hemlock Bluffs (Cary, NC) – Spring 2017 Burn

Photos: Michael Papich

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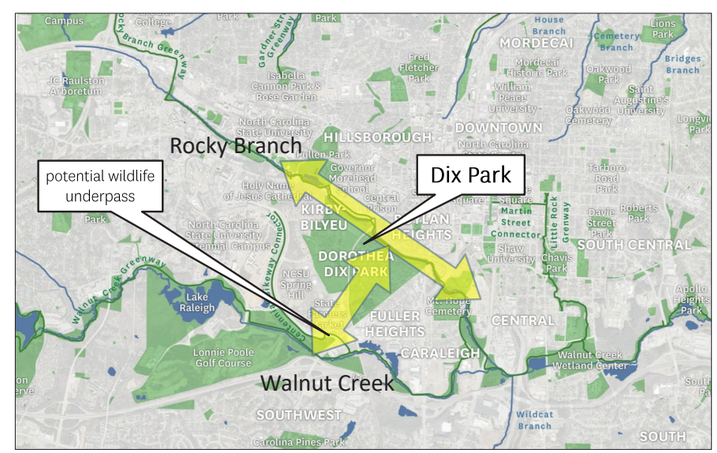
Regional Connectivity Considerations

- Park restoration will consider regional context and connectivity opportunities



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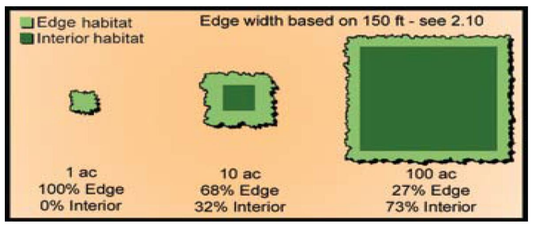
Site Restoration Considerations

- Identify/restore **large contiguous blocks** of habitat with minimal "edge effect"
- Provide **critical patch size of different habitats** to attract and sustain maximum species diversity of plants and animals
- Provide **habitat mosaics** that fulfill life-cycle needs of species :
  - Adjacent wetlands and woodlands for amphibians
  - Open basking areas and hibernacula for reptiles



Graphic: Bentrup 2008

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Site Restoration Considerations

- Restored **forests** should have continuous/closed canopy for interior forest birds
- Restored **savannas** should have patches of shrubs mixed among the trees and groundlayer species
- Restored **prairies** should:
  - have a diversity of continuously flowering (early spring through late fall) species for pollinators
  - retain dead prairie vegetation over winter to allow spring emergence of larvae
- Restored **perched wetlands** and **seeps** should have areas of open water, emergent vegetation, and native upland buffer prairie/savanna

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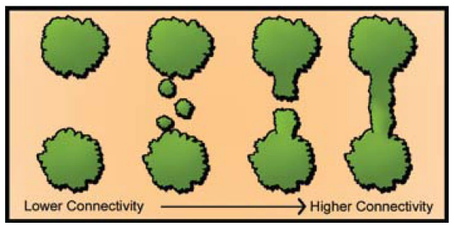
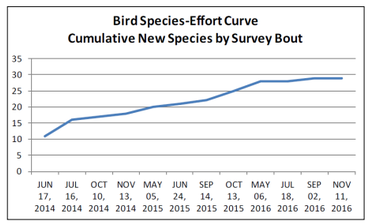
Potential Future Conditions

- Indicators of restoration success (and how measured)
  - Increased **area** of natural habitat (mapping, acres)
  - Increased **structural/habitat diversity** (visual, vegetation plots, mapping)
  - Increased native plant **species diversity** (plant surveys/monitoring)
  - Increased **habitat connectivity** (mapping of natural areas and connections)
  - Increased wildlife **species diversity**, including pollinators (animal surveys/monitoring)



Graphic: Bentrup 2008



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Potential Future Conditions

- Potential indicator species
  - **Pollinators**, conveying restored prairie, savanna and forest (perhaps bumble bees, Monarch butterfly, and/or the Zebra swallowtail, which is dependent on pawpaw)
  - **Amphibians**, conveying restored aquatic habitats and adjacent woodlands and meadows (perhaps Upland chorus frog, Cope's gray treefrog, Southern leopard frog, and/or Spotted salamander)
  - **Birds**, conveying restored habitats (perhaps Red-eyed vireo, Brown thrasher)

Direction Memorandum

APPLIED ECOLOGICAL SERVICES

SPECIALISTS IN ECOLOGICAL SCIENCE, RESTORATION, MANAGEMENT, AND RESEARCH

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MEMORANDUM

TO: Adrienne Heflich (MVVA)

FROM: Doug Mensing, Steve Apfelbaum (AES)

DATE: January 30, 2019

RE: Dix Park MP (AES 16-0982) – AES Direction Memorandum

INTRODUCTION

This memorandum conveys Applied Ecological Services, Inc. (AES) project deliverables on the following subject matters:

I. Information on native planting compatibility on landfills,
II. Native plant community restoration and management recommendations and considerations (focused on six areas of Dix Park),
III. Potential sources of native plant material, and
IV. Next steps, including soils sampling program, geotechnical borings, inventory/assessment, baseline monitoring, and design refinement.

I. NATIVE PLANTINGS OVER LANDFILLS

Background

Landfills present important opportunities for restoration of native plant communities. Healthy native plant communities stabilize slopes, minimize soil erosion from wind and water, provide important habitat for pollinators and other wildlife, and can be aesthetically attractive landscapes to support future beneficial recreational uses.

AES has worked on numerous landfill projects and conducted technical literature reviews focused on the planting of native communities on closed landfill sites. AES's early national work on Fresh Kills Landfill (Staten Island, NY), Countryside Landfill (Grayslake, IL), and others had to address the regulatory and engineering concerns with landfill cap (or geomembrane liner) integrity in conjunction with normally deep rooted native herbaceous and woody vegetation. Some regulators expressed concerns that root systems would grow down and puncture the clay cap/liner, or that trees uprooted by windthrow could damage this protective layer. Compromising the landfill cap/liner could facilitate exposure of underlying

contained wastes, and introduce stormwater runoff into the waste, increasing the production of leachate and potential for contaminant migration, or could result in the undesirable release of landfill gases. AES's research and project experience indicate that no known violations had been previously documented where native grass, forb, shrub, or tree species planted on landfills actually resulted in a compromised landfill cap or liner system.

Justification that Native Plantings are Compatible with Landfills

The primary concerns regarding cap/liner impacts are related to the growth of root systems, especially woody roots. We learned root growth (as well as above ground plant growth) is significantly diminished in compacted soils, whether native or engineered. Therefore, well-compacted clay caps (even without the presence of a geomembrane liner system) have been documented to provide an effective barrier to root penetration. In order to grow, a root pushes through the soil with an extending root tip with a diameter of 0.1 to 3mm. To move through soil, which generally contains pores of 0.002 to 0.2 mm or less, the root grows by turgor (osmotic-hydraulic) pressure; it must therefore push aside soil materials. Resistance to root penetration simultaneously increases in the immediate vicinity of root growth due to soil materials being pushed aside and further compacted near the root tip. Compacted cap/liner soils (particularly clay and clay loam soils) have a very small average soil pore size, which restricts root penetration. This increased soil compaction in the growing region of an already compacted soil environment halts root growth, causing the root to redirect its growth horizontally along the surface of the compacted layer or geomembrane system. Such a barrier limits root growth to shallower depths and a lateral direction. Consequently, the nonporous, compacted clay soils and geomembrane liner have been found to represent an impenetrable barrier to root growth and penetration. On engineered clay caps with heavy soil compaction, the paucity of vegetation is related to this inability of roots to penetrate the substrate to find adequate moisture and nutrients.

The only documented cap and liner intrusions by vegetation occurred where the cap/liner was previously ruptured by mowing damage, side slope solifluction or mass wasting, shrink-swell substrate movement, or animal burrows. And, in all documented cases, plant root growth only surficially colonized the discontinuity. In any landfill containing demolition debris to municipal wastes, the methane outgassing typically measured in such discontinuities prevented anything but surficial colonization by plant roots. Methane is highly toxic to plant roots, and its presence displaces oxygen (needed for plant root growth), restricting further root growth.

Also, contrary to popular thought, most tree species have shallow root systems. Dobson (1995) found that 90% of all roots, and virtually all the large structural supporting roots, are in the upper 60cm of soil. He went on to state that roots spread outwards to at least three times the tree's height, and those roots that are distant from the trunk are close to the soil surface. Coile (1937) found that 99% of a tree root system is within the top meter (3.3ft) of soil, and Day et al (2010) concluded that tree roots are primarily concentrated in the upper 0.3 m (1 ft) of soil.

Precedent Native Plantings on Landfills

Table 1 presents projects where native plant communities have been established on top of closed landfills; AES was directly involved in most of these projects. AES has also been involved in capped mine closures and hazardous waste sites where native prairie herbaceous and woody plantings have been successfully established. Projects include the Kennecott Company Flambeau Copper Mine (Ladysmith, WI), five zinc-lead mines (SW Wisconsin), and others.

Table 1. Closed landfills planted with native vegetation.

Landfill Name	Landfill Location	Acres of Restoration on Landfill	Woody and/or Herbaceous Plantings	Cap/Liner Damage Prevention Strategy	Other Notes
Countryside Landfill (AES project)	Grayslake, IL	80 acres	Trees, shrubs and prairie vegetation	Part 360 clay and geotextile cap	Includes 3-4 ft deeper soils along greenway trail, which traverses landfill cap and has been planted to heavy tree/shrub cover
Rapp Road Solid Waste Management Facility (AES project)	Albany, NY	5-acre test plot; 100-acre approved plan for entire landfill closure	Herbaceous and woody (trees & shrubs)	Adequate rooting zone above clay (18-24 in)	Test plot study completed 2016; outcomes guiding entire landfill closure, which is underway with native vegetation
La Crosse County Landfill (AES project)	La Crosse, WI	2 acres	Woody (trees)	unknown	Also conducted prescribed burn on landfill
Mallard Ridge Landfill (AES project)	Delevan, WI	>100 acres	Herbaceous (native grasses)	Part 360 clay and geotextile cap	Also conducted prescribed burn on landfill
Fresh Kills Landfill (Handel et al 1997)	Staten Island, NY	>200 acres	Woody (trees & shrubs)	Adequate rooting zone above clay (75 cm)	AES created plans for native planting over entire landfill
Stafford Landfill (Arsenault 2010)	Stafford Township, NJ	unknown	Herbaceous (warm-season grasses)	Adequate rooting zone above liner (depth unknown)	
Former Eastview Landfill (City of Guelph 2018)	Guelph, Ontario Canada	>40 acres	Herbaceous (including native wildflowers)	unknown	

Select Annotated Bibliography Related to Use of Native Vegetation on Landfills

In addition to the actual landfill examples in the table above, the following research and guidance documents support the use of native vegetation on landfills.

Holl, K.D. and S. McStay. 2014. Roots of Chaparral Shrubs Still Fail to Penetrate a GeoSynthetic Landfill Liner after 16 Years. Ecological Restoration 32:2.

Experimental site established at former Fort Ord Army Base (Marina, CA). Shrubs, including taproot species, planted over a landfill liner. After 16 years, liner still not penetrated.

Mihaly Land Design. No date. Plant Species Suitable for Landfill Containment Remedies – Task Order 679MIS – North Carolina Coastal Plain.

Recommendations include native woody and herbaceous species appropriate for use on landfills in North Carolina's coastal plain.

North Carolina Department of Environmental Quality, Carolina Silvics, and S&ME. 2017. Plants Suitable for Revegetation of Pre-Regulatory Landfill Sites with Soil Cover Systems in the North Carolina Coastal Plain & Piedmont.

Recommendations include native woody and herbaceous species appropriate for use on North Carolina landfills. Recommended that shrubs have rooting depths less than 18 inches.

Design Considerations for Plantings on Landfills

Landfill types, contents, cap/liner/drainage design, soil type, and climate conditions should all be considered when designing an appropriate vegetative cover. On most landfills where native herbaceous plantings have been used, a 6" thick drainage layer is designed over the cap/liner, and then an additional 12-18 inch thick "rooting medium" is specified. Conservative guidance for soil depth over the landfill cap/liner follows:

- At least 2 feet, if planting herbaceous species
- At least 4-5 feet, if planting shrubs
- At least 6 feet, if planting shallow- to moderate-depth rooting tree species. Deep-rooted tree species (e.g., tap-rooted species) generally should not be planted on landfills. If cover above the cap/liner is less than 6 feet thick, tall tree species (which could become subject to windthrow) should also be avoided.

Planting designs should use species native to the local region and selected to match the significantly drier and more exposed environmental conditions typical on landfills. Environmental variables influencing plant selection include soil texture, moisture regime, slope, and aspect. Selection of tree species should consider rooting habits; this issue is discussed further and project-specific recommendations are provided later in this memorandum under the "Restored Plant Communities on Landfill" section.

II. NATIVE PLANT COMMUNITY RESTORATION & MANAGEMENT

The Dix Park Master Plan recommends ecological restoration and establishment of a variety of native plant communities. AES was asked to address six areas of particular interest, and each is discussed below. For each area we present plant community terminology, characteristic/recommended plant species, characteristic animal species, reference sites (if identified), and notes on ecological restoration and management practices specific to the plant community and/or project area.

The following is based on technical documents, recommendations by local experts, and AES's observations during field work at Dix Park and visits to reference sites for many of the ecosystem types described below. We also include examples of some typical plant and animal species associated with each ecosystem as identified in regional reference documents.

1. Piedmont Prairie

Piedmont Prairie is an appropriate and versatile native plant community to restore in many portions of Dix Park, including the edge of the large proposed Meadow. These prairies are dominated by native grasses, but also contain a diversity of sedges and wildflowers (i.e., forbs). Piedmont Prairies can be designed to be taller (~4-6 feet) or shorter (generally ≤3 feet) herbaceous plant communities, depending on the desired aesthetics and viewshed. Characteristic plant species follow.

Select Taller Piedmont Prairie Species:

Grasses & Sedges	
Andropogon gerardii	Big blue stem/Turkeyfoot
Sorghastrum nutans	Indian grass
Forbs	
Rudbeckia laciniata	Cutleaf coneflower
Silphium terebinthinaceum	Prairie dock

Select Shorter Piedmont Prairie Species:

Grasses & Sedges	
Aristida purpurea	Purple three awn
Elymus canadensis	Canada wild rye
Elymus virginicus	Virginia wild rye
Eragrostis spectabilis	Purple love grass
Schizachyrium scoparium	Little blue stem
Tridens flavus	Purple top
Forbs	
Agalinis purpurea	Purple false foxglove
Allium cernuum	Nodding Onion
Antennaria plantaginifolia	Pussytoes (woman's tobacco)
Asclepias tuberosa	Butterfly milkweed
Asclepias verticillata	Whorled milkweed
Baptisia australis abberans	Blue wild indigo
Chamaecrista fasciculata	Partridge pea
Cirsium carolinianum	Soft thistle
Echinacea purpurea	Purple coneflower
Eryngium yuccifolium	Rattlesnake master
Eupatorium hyssopifolium	Hyssopleaf thoroughwort
Heliopsis helianthoides	Rough ox-eye
Houstonia caerulea	Bluets
Lespedeza virginica	Slender lespedeza
Liatris squarrosa	Scaly blazing star
Oenothera biennis	Common evening primrose
Oenothera fruticosa	Narrowleaf evening primrose
Packera anonyma	Appalachian ragwort
Parthenium integrifolium	Wild Quinine
Rudbeckia hirta	Blackeyed susan
Solidago speciosa	Showy goldenrod
Symphyotrichum concolor	Eastern silver aster
Symphyotrichum dumosum var. dumosum	Bushy/rice button aster
Symphyotrichum pilosum	Frost aster
Tragia urticifolia	Nettleleaf noseburn
Verbena simplex	Narrowleafed vervain

Characteristic Piedmont Prairie Wildlife
There are many dozens of wildlife species—snakes and other reptiles, insects, spiders, mammals, and birds—historically found in the Piedmont Prairie. Some of these species include:

- Bumble bees
- Monarch butterfly
- Carolina chickadee
- Carolina wren
- Field sparrow
- Grasshopper sparrow
- Eastern meadowlark
- Northern bobwhite

Potential Piedmont Prairie Reference Sites (*not necessarily high quality*)

Remnant Prairie

- Duke Forest (Chapel Hill, NC) – referenced by others

Restored Prairie

- Sarah P. Duke Gardens' Blomquist Garden (Durham, NC)
- Annie Louise Wilkerson Nature Preserve Park (Raleigh, NC)
- Horton Grove (Bahama, NC) – referenced by others
- Penny's Bend (Durham, NC) – referenced by others
- Prairie Ridge Ecostation (Raleigh, NC) – referenced by others
- Temple Flat Rock (Wendell, NC) – referenced by others
- Horseshoe Farm Nature Preserve (Wake Forest, NC)

Restored Piedmont Prairie (Blomquist Garden) at Sarah P. Duke Gardens.

Restored prairie along trail at Horseshoe Farm Nature Preserve.

Piedmont Prairie Restoration & Management Notes
Old fields or turf areas can be converted to prairie; however, proper site preparation is critical to restoration success. This typically entails using broadcast herbicide to kill existing weedy perennial vegetation. Two or three treatments are typically necessary, and depending on site conditions, tillage of the soil may or may not be beneficial prior to seeding/planting. A no-till seed drill may be used if conditions do not warrant tillage; tillage disturbs the soil, which encourages weedy species to colonize. Grasslands with some existing desirable native vegetation can be transformed over time to native prairies, but this requires a site-specific restoration regime that may employ prescribed burning, herbicide treatments, mowing, overseeding, and/or interplanting over several years.

Prairies can be restored using seed and/or live plant materials. Seed is considerably cheaper, but plant plugs provide more rapid establishment. When feasible, local ecotype, native plant materials should be used, ideally from within the Piedmont-Coastal Plain transition zone within 100 miles of Raleigh. Cultivated varieties (designated with a variety name in quotes, such as *Schizachyrium scoparium* 'Carousel') and hybrids (designated with a "x" signifying the genetic crossing) should be avoided. Rather, "wild-type" species native to the region should be used. Potential sources of native seed and plant materials are provided later in this memorandum.

Prairie restoration recommendations based on the Blomquist Garden prairie restoration follow:

- Herbicide existing vegetation to clear area
- If necessary, adjust soil pH (e.g., add lime)
- If not seeding, install live plant plugs in July using an augur
- Live plant plugs should be installed as follows: up to 100 4" pots in each 12'x12' section

Management during the first 3 years of prairie restoration is critical to success, especially when using seed as opposed to live plugs. During this initial establishment period, prairie management typically

focuses on control of invasive species, such as Sericea lespedeza (*Lespedeza cuneata*), Johnsongrass (*Sorghum halepense*), and other aggressive/weedy, non-native plants. Initial prairie management often follows the following regimen:

- Management Year 1: mow 2x; spot herbicide weeds 1x
- Management Year 2: mow 1x; spot herbicide weeds 2x
- Management Year 3: spot herbicide weeds 2x; conduct first prescribed burn

Prairies take time to establish. The first year, cover crop and weeds are often very prevalent as the native species put their resources largely into underground (root) growth. Some natives, like Black-eyed Susan (*Rudbeckia hirta*) and Partridge pea (*Chamaecrista fasciculata*), may bloom the first growing season, but most species will not. During the second growing season, natives become a bit more apparent, but weed cover can continue to be significant. By the third growing season, natives should be very apparent, although persistent weeds may continue to necessitate focused management.

Herbicide applicators should be properly trained and licensed to use the appropriate chemical(s) in the appropriate manner to effectively protect the people conducting the application, control target species, and minimize collateral damage to desirable vegetation. Prescribed burns are important for fire-dependent plant communities (including prairies and savannas). These burns require a well thought out burn plan, secured permits, public notifications, and a properly-trained/licensed/equipped burn crew to achieve ecological goals and to protect people and property.

Long-term (perpetual) management of prairies usually consists of rotational burns and intermittent spot herbicide or other invasive plant control. Most prairies need only be burned every three years, and rotational burning (burning only a portion of the prairie each year, rotating through "burn units") is recommended to provide refugia for prairie wildlife that may be displaced by the burn. Now that is has become well established, the Blomquist Garden (a highly-maintained botanic planting) is burned every year in February, and winter mowing is conducted as needed.

Piedmont Prairie restoration on the western edge of Dix Park has been identified as an opportunity for early stewardship. Little if any grading will occur here, and lessons learned from restoring this initial area of prairie on the site will inform subsequent prairie restoration efforts at Dix Park. Over time, it could also become a source for native seed collection, used to restore other portions of the site. Detailed records should be kept regarding all restoration and management work conducted in this area, and vegetation monitoring plots should be established, inventoried for baseline conditions, and routinely monitored throughout restoration and management activities. Monitoring data collected for each plot should include all plant species present, percent areal cover each species, percent cover of bare soil, and percent cover of fine fuel (for planning prescribed burns).

2. Piedmont Savanna, Perched Wetlands and Seepage Wetlands at the Grove

Piedmont Savanna is similar to Piedmont Prairie with the addition of scattered oaks, other trees, occasional shrub copses, and some shade-tolerant species in the ground layer. Savannas are typically defined as having between 10% and 50% canopy cover (whereas a forest typically has >90% canopy cover). Piedmont Savannas are appropriate in many portions of Dix Park, especially if mature trees already exist (e.g., in the Grove) or if more structure and or screening is desired (e.g., west of the Meadow). Areas currently lacking trees can be restored to savanna over time through installation of native seed, live plant plugs, and woody plantings. Herbaceous plants should include some shade tolerant species to thrive under tree canopies. As with Piedmont Prairies, Piedmont Savannas can be designed with taller (~4-6 feet) or shorter (generally ≤3 feet) herbaceous species. For herbaceous species, see Piedmont Prairie species lists above. Additional Piedmont Savanna plant species follow.

Select Piedmont Savanna Species (additional to Piedmont Prairie species, above):

Trees	
Quercus alba	White oak
Quercus bicolor	Swamp white oak
Quercus coccinea	Scarlet oak
Quercus rubra	Red oak
Shrubs	
Ceanothus americanus	New Jersey tea
Cornus florida	Flowering dogwood
Grasses & Sedges (with some shade tolerance)	
Carex radiata	Eastern star sedge
Carex rosea	Rosy sedge
Chasmanthium latifolium	River oats
Elymus hystrix	Eastern bottlebrush grass
Tridens flavus	Purpletop tridens
Shade-Tolerant Forbs (with some shade toler-ance)	
Blephilia ciliata	Downy wood mint
Helianthus strumosus	Pale leaved sunflower
Scutellaria incana	Downy skullcap

Not listed above are trees (e.g., American beech, *Fagus grandifolia*), shrubs, and herbaceous species appropriate for the Grove's slightly cooler and moister north-facing slopes. These species could be used to create more of a savanna structure or more of a forest, depending on project goals in this portion of the park. If these slopes are restored to a beech savanna or forest, only very low intensity ground fires (using very cool prescribed burning techniques) would be used, and only occasionally—about once per decade.

Perched wetlands in the Grove are envisioned to be small, subtle depressions in the upper elevations. These depressions may or may not hold standing water for extended periods of time, depending on final design. The proposed seepage wetlands (near the toe of the Grove slope) would be an expression of local shallow groundwater and would be wet to moist most of the year. The perched and seepage

wetlands would provide wetter microhabitats in the larger Grove savanna, inviting a mix of plant and animal species currently uncommon at Dix Park. Native wetland plant species appropriate for these wetlands follow.

Select Perched and Seepage Wetland Species:

Trees (adjacent to wet areas)	
Carya ovata	Shagbark hickory
Quercus alba	White oak
Quercus lyrata	Overcup oak
Salix nigra	Black willow
Ulmus americana	American elm
Shrubs	
Cephalanthus occidentalis	Common buttonbush
Cornus foemina	Stiff dogwood
Ilex decidua	Possumhaw
Ilex verticillata	Common winterberry
Salix caroliniana	Coastal plain willow
Grasses & Sedges	
Carex lupulina	Hop sedge
Carex tribuloides	Blunt broom sedge
Elymus virginicus	Virginia wild rye
Glyceria striata	Fowl mannagrass
Juncus effusus	Common rush
Scirpus cyperinus	Woolgrass
Forbs	
Arisaema triphyllum	Jack-in-the-pulpit
Helenium autumnale	Common sneezeweed
Impatiens capensis	Jewelweed
Iris cristata	Dwarf crested iris
Lobelia puberula	Downy lobelia
Pycnanthemum tenuifolium	Narrowleaf mountainmint
Vernonia noveboracensis	New York iron weed

Characteristic Piedmont Savanna and Wetland Wildlife

Wildlife species typical of Piedmont Savanna and central North Carolina wetlands include:

Piedmont Savanna

- Brown thrasher
- Various woodpeckers

Perched and Seepage Wetlands

- Upland chorus frog
- Southern leopard frog
- Marbled salamander
- Red-winged blackbird

Potential Piedmont Savanna and Wetland Reference Sites (*not necessarily high quality*)

Piedmont Savanna

- Raleigh Lake Woods (Chapel Hill, NC) – recommended by others
- Kendall Circle (Raleigh, NC) – adjacent to northwest of Dix Park

Perched and Seepage Wetlands

- Historic Yates Mill County Park (Raleigh, NC)
- Fred Fletcher Park (Raleigh, NC)

Native oaks and savanna structure of Kendall Circle (just northwest of Dix Park). Ground layer not native.

Small constructed wetland at Historic Yates Mill County Park.

Another small constructed wetland at Historic Yates Mill County Park. Note turbid water near top.

Constructed wetland at Fred Fletcher Park.

Piedmont Savanna and Wetland Restoration & Management Notes

Piedmont Savanna

Savanna restoration and initial management is similar to what is described above for prairie restoration. The main difference is establishment of woody vegetation in the savanna. Typically, herbaceous vegetation is established first by seeding, followed by installation of trees and shrubs. Care must be taken during woody plant installation to minimize disturbance of previously seeded/planted areas. To control costs and expedite growth of woody vegetation, we recommend installation of moderate-sized trees and shrubs at Dix Park. This approach would entail 2” caliper trees and 5-gallon container shrubs (or similar stock). If perennial weed pressure is low, one can also distribute tree, shrub, and herbaceous seed over the ground after prescribed burning has been used as a management treatment. Seeding can be done directly in the newly burned landscape, into the ashes.

Initial management of Piedmont Savanna is similar to that described for the Piedmont Prairie. However, prior to conducting prescribed burns, fire breaks, spray down, or other protection of young tree and shrub plantings will be required. As woody vegetation matures, these plants will require less or no protection from prescribed fires. Savannas, like prairies, are often burned on a three-year rotation. As with prairie management, herbicide applications and prescribed burning should be conducted by trained and licensed personnel only.

As with the western portion of the park’s Piedmont Prairie, the Piedmont Savanna restoration at the Grove has been identified as an opportunity for early stewardship. Little if any grading will occur here, and lessons learned from restoring this initial area of savanna on the site will inform subsequent savanna restoration efforts at Dix Park. As with the Piedmont Prairie early stewardship area, detailed records should be kept and vegetation monitoring plots should be established and monitored. See Piedmont Prairie section for more monitoring recommendations.

Perched and Seepage Wetlands

Due to fine clay particles in the region's soils, ponds in central North Carolina often appear turbid and unsightly; therefore, for aesthetic reasons, construction of open bodies of water should be avoided. Rather, perched and seepage wetlands should be designed as mostly vegetated, subtle depressions in the landscape. Water depths should not exceed 3 to 4 feet, and hydrologic bounce (even after major rain events) should be less than 2 feet. Side slopes leading from the uplands to the wetlands should be very gentle, such as 10:1 or 20:1 (horizontal to vertical). Providing a variety of water depths results in habitat complexity and allows for greater plant and animal species diversity. Close attention should be paid to local soils so that the wetland design responds appropriately to infiltration rates to achieve the desired hydrologic regime.

Restoration of wetlands is typically done during seasonal low-water conditions, before basins are connected to their water source, or by using mechanical drawdown (when feasible). This enables use of (more affordable) native seed, whereas areas of standing water typically require installation of live plant plugs (which are more expensive). Management of wetlands is usually focused on control of invasive species using spot treatments; however, prescribed burning may also be used. As with prairie and savanna management, herbicide applications and prescribed burning should be conducted by trained and licensed personnel only. To protect wildlife and the environment, use only aquatic-approved herbicides over and near open water and wetland habitats.

3. Restored Plant Communities on Landfill

A variety of native plant communities could be restored on top of the existing Dix Park landfill. Due to the constraints (discussed above, in part), AES recommends a Piedmont Prairie or Piedmont Savanna with sparsely planted trees (less than 10 trees per acre) or copse plantings to create groves of trees and shrubs. This plant community would be restored using Piedmont Prairie and Savanna species, such as those listed above.

The landfill setting calls for tree species that exhibit relatively shallow root growth (to minimize concerns regarding maintaining the landfill cap's integrity). Also, since prescribed fire is a preferred management technique for prairies and savannas (and assuming this will be permitted on the Dix Park landfill), woody species should have some tolerance of intermittent fire. Considering these criteria, native tree species that would be appropriate for planting on the Dix Park landfill include:

- Swamp white oak (*Quercus bicolor)*
- Downy serviceberry *(Amelanchier arborea)*
- Other native trees and shrubs that are shallow-rooted and fire-tolerant

Tree species that should not be used on the landfill (unless rooting medium is ≥6 feet thick over the cap/liner) include:

- Bur oak (*Quercus macrocarpa)*
- White oak *(Quercus alba)*
- Scarlet oak *(Quercus coccinea)*
- Longleaf pine (*Pinus palustris)*
- Shortleaf pine (*Pinus echinata)*
- Sweet gum (*Liquidambar styraciflua)*

Wildlife species typical of Piedmont Prairie and Savanna (listed above) would be expected to use the restored landfill cap. See above for Piedmont Prairie and Savanna reference sites.

Restored Plant Communities on Landfill Management Notes

Prairie and savanna restoration and management guidance is provided above. Management of the Dix Park landfill's restored prairie and savanna would be most efficient using prescribed burning. Fire has been used effectively and safely on other landfills; however, coordination with the North Carolina Department of Environmental Quality and City of Raleigh will be necessary to ensure if and how prescribed fire can be used safely at the Dix Park landfill.

4. Rocky Branch Riparian Corridor

The Rocky Branch is an important natural element at Dix Park, and its realignment and restoration will provide significant functional lift to this stream and its adjacent riparian forests. Unlike most of the prairie and savanna restoration areas described above, this riparian corridor (consisting of both bottomland and upland forest) contains significant native vegetation, much of which should be preserved. Plant species appropriate for the restored/enhanced forested riparian corridor follow.

Select Riparian Corridor Species:

Trees	
Acer rubrum	Red maple
Betula nigra	River birch
Carpinus caroliniana	American hornbeam
Carya ovata	Shagbark hickory
Fagus grandifolia	American beech
Gleditsia triacanthos	Honeylocust
Juglans nigra	Black walnut
Liquidambar styraciflua	Sweetgum
Morus rubra	Red mulberry
Platanus occidentalis	American Sycamore
Prunus serotina	Black cherry
Quercus lyrata	Overcup oak
Salix nigra	Black willow
Sassafras albidum	Sassafras
Taxodium distichum	Bald cypress
Ulmus alata	Winged elm
Ulmus americana	American elm
Shrubs/Vines	
Asimina triloba	Pawpaw
Campsis radicans	Trumpet creeper
Ilex verticillata	Common winterberry
Lindera benzoin	Spicebush
Viburnum prunifolium	Blackhaw
Vitis rotundifolia	Muscadine grape
Grasses & Sedges	
Arundinaria tecta	Switchcane
Chasmanthium latifolium	River oats
Elymus virginicus	Virginia wildrye
Forbs	
Asarum canadense	Wild ginger
Eupatorium rugosum (now *Ageratina altissima*)	White snakeroot

The stormwater ponds proposed along the Rocky Branch would be restored with vegetation similar to the species recommended above for perched and seepage wetlands; however, pond-specific criteria

(e.g., water depths, angle of side slopes, hydrologic bounce, etc.) will dictate the most appropriate species for each restoration zone within each stormwater pond.

Characteristic Riparian Corridor Wildlife

Wildlife species typical of Piedmont riparian corridors include:

- Zebra swallowtail (dependent on Pawpaw)
- Cope's gray treefrog
- Spotted salamander
- Indigo bunting
- Red-eyed vireo
- Yellow-rumped warbler
- Little brown bat

Potential Riparian Corridor Reference Sites (*not necessarily high quality*)

- Sarah P. Duke Gardens (Durham, NC) – botanical garden
- Walnut Creek (Raleigh, NC) – not high quality
- Durant Nature Preserve (Raleigh, NC) – quality not confirmed

Riparian forest at Sarah P. Duke Gardens.

Riparian vegetation and trail along Walnut Creek.

Riparian Corridor Restoration & Management Notes

Given the prevalence of native vegetation in the Rocky Branch riparian corridor, restoration and initial management will focus on removal of invasive species and planting of appropriate native vegetation. Most of these removals will require cutting and stump-treating with herbicide. Herbaceous removals will likely require spot herbicide treatments. As with prairie and savanna management, herbicide applications should be conducted by trained and licensed personnel only, and only aquatic-approved herbicides should be used near open water and flow paths to the creek. The majority of the riparian corridor is not a fire-dependent plant community; therefore, long-term management will mostly consist of localized management of invasive vegetation (e.g., spot herbicide or manual removal).

5. Railroad Corridor

Dix Park's existing railroad corridor contains mature native trees as well as a mixture of younger, weedy vegetation and invasive plants. Aesthetics and desired degree of visual screening will guide the ultimate planting design and species palette in this portion of the site. Some potential plant species for the railroad corridor follow.

Select Railroad Corridor Species:

Trees	
Castanea pumila	Chinkapin
Diospyros virginiana	Common persimmon
Liquidambar styraciflua	Sweetgum
Malus angustifolia	Southern crab apple
Morus rubra	Red mulberry
Quercus montana	Chestnut oak
Shrubs	
Rubus allegheniensis	Allegheny blackberry
Sassafras albidum	Sassafras
Grasses & Sedges	
Elymus virginicus	Virginia wild rye
Forbs	
Eupatorium rugosum (now *Ageratina altissima*)	White snakeroot

Wildlife use along the railroad corridor will be limited due to its narrow geometry and small acreage. However, the corridor likely is, and will continue to be, used by wildlife as a travel corridor. Due to its anthropogenic character, no specific reference sites have been identified. Restoration and management of this area will follow most of the recommendations provided for the Riparian Corridor forests.

As with the western portion of the park's Piedmont Prairie and the Grove's Piedmont Savanna, restoration along the railroad corridor has been identified as an opportunity for early stewardship. As with other early stewardship areas, detailed records should be kept and vegetation monitoring plots should be established and monitored. See Piedmont Prairie section for more monitoring recommendations.

6. Pine Forest around the Event Hub

The Pine Forest proposed around the Event Hub would re-introduce into Dix Park a Piedmont ecosystem once prominent in the region. Specifically, it is a desire of the project team to restore longleaf pine (*Pinus palustris*) to Dix Park. Longleaf pine forests were once abundant in much of the southeastern U.S., but they have been almost completely lost due to logging, fire suppression, replacement by loblolly pine, and other land management practices. The following section explores the feasibility of restoring this species to Dix Park.

Longleaf Pine Restoration Criteria (sources: North Carolina Forest Service 2011a and 2011b)
In North Carolina, most longleaf pine forests are found below 300 feet in elevation; Dix Park ranges from approximately 300 to 400 feet above mean sea level. Longleaf pine is found most often in soils that are sandy on the surface and low in organic matter; however, this pine can grow in soils that range from coarse, excessively drained sands to poorly drained clays. Longleaf pine forest soils typically have a pH of 5.0-5.5; problems with nutrient uptake and tree health occur when pH exceeds 6.5. Longleaf soils can be seasonally wet but not saturated for a long time, and this species does not tolerate frequent flooding. The next planning phase for Dix Park (discussed in the Next Steps section of this memorandum) will include soil investigations that will help determine the feasibility of establishing longleaf pine on the site. Some potential plant species for the proposed Pine Forest follow.

Select Pine Forest Species:

Trees	
Acer rubrum	Red maple
Liquidambar styraciflua	Sweetgum
Pinus palustris	Longleaf pine
Pinus echinata	Shortleaf pine
Pinus taeda	Loblolly pine
Quercus laevis	Turkey oak
Shrubs	
Vaccinium spp	Blueberries
Sambucus nigra L. ssp. canadensis	American black elderberry
Gaylussacia spp	Huckleberries
Grasses & Sedges	
Aristida stricta	Wiregrass
Forbs	
Asclepias tuberose var. tuberosa	Common butterfly milkweed
Baptisia australis abberans	Blue wild indigo
Ageratina altissima	White snakeroot
Mitchella repens	Partridgeberry
Tipularia discolor	Crippled cranefly

Characteristic Pine Forest Wildlife
Wildlife species typical of Piedmont pine forests include:

- Pileated woodpecker
- Red-bellied woodpecker

Potential Pine Forest Reference Sites (*not necessarily high quality*)

- Annie Louise Wilkerson Nature Preserve Park (Raleigh, NC)
- Historic Yates Mill County Park (Raleigh, NC) – relatively small stand(s)

Small stand of pine forest at Historic Yates Mill County Park.

Pine Forest Restoration & Management Notes
More so than other proposed plant communities, establishment of pine forest around the Event Hub may necessitate soil modifications to achieve the appropriate texture, pH, and other characteristics amenable to pines – especially species such as longleaf. This may entail deep chisel plowing of the soil and adding/incorporating sand. In some soils it may also be desirable to acidify the soil, such as by adding ammonium sulfate or sulfur-coated urea as soil amendments. This can help accelerate the establishment and improve long-term success of pine and ericad shrubs (e.g., blueberries, huckleberries).

In addition to the proposed pine forest around the Event Hub, Dix Park has several existing stands of pine trees, consisting mostly of planted loblolly. Restoration/enhancement of these existing pines stands would entail selective thinning of loblolly, interplanting with other native tree species (both pines and deciduous species), and seeding native groundlayer species. As new tree plantings grow, additional loblolly pines can be selectively removed so the resulting pine forest becomes more natural and diverse over time.

Other Pine Forest restoration and management practices are similar to those presented under Piedmont Savanna. As with that plant community, young plantings susceptible to fire damage will require protection during prescribed burns during the early years of establishment.

III. POTENTIAL SOURCES OF NATIVE PLANT MATERIAL

Native seed and live plant material are commercially available from the following regional sources (Table 2). However, discussions with local native plant enthusiasts and experts during the master plan phase of Dix Park indicated that most of the native herbaceous species listed above were not available from nurseries. Partnerships with North Carolina State University, Duke Gardens, City of Raleigh Recreation and Cultural Resources Department, Taylor Creek Restoration Nurseries, other organizations, and volunteers could help to overcome this lack of commercially-available native plant material. One proven technique is to harvest native seed from local reference natural areas. This seed can used to propagate live plant plugs and young woody plants necessary to support the restoration of native plant communities at Dix Park. Early restorations at Dix Park, such as the early stewardship Piedmont Prairie west of the Meadow, could be used for seed collection several years after planting. This seed could then be used for growing plugs or for seeding of other prairie restorations on the site.

Table 2. Potential sources of native plant material for Dix Park.

Nursery Name	**Nursery Location**	**Distance from Raleigh (mi)**	**Native Seed**	**Native Plugs**	**Native Trees/ Shrubs**	**Notes** (from various sources)
Taylor's Nursery	Raleigh, NC	0		X	X	Skilled propagator https://www.taylorsnursery.com/ Phone: 919-231-6161
Hoffman Nursery	Rougemont, NC	35	X	X		Large selection of grasses http://hoffmannursery.com/ Phone: 919-471-3100
Niche Gardens	Chapel Hill, NC	39		X	X	Specializing in native perennials www.nichegardens.com Phone: 919-967-0078
Cure Nursery	Pittsboro, NC	45		X	X	Native and wetland trees & shrubs grasses, ferns and bog plants www.curenursery.com Phone: 919-444-9902
Mellow Marsh Farm	Siler City, NC	49	X			Provide custom seed mixes https://www.mellowmarshfarm.com/ Phone: 919-742-1200
Lumber River Native Plants	Gibson, NC	110	X	X	X	Native herbaceous perennials, grasses, grass-like plants, aquatic plants, trees and shrubs, live stakes, and bare root trees/shrubs Native NC/SC Ecotype Seeds and Seed www.ncnativeplants.com Phone: 336-601-8787
Campbell Family Nursery	Harmony, NC	140		X	X	Native perennials and shrubs https://www.facebook.com/Campbellfamilynursery/ Phone: 704-775-2425
Coastal Plain Conservation Nursery, Inc. (renamed "Wetland Plants, Inc.)	Edenton, NC	149	X	X		Provides native herbaceous wetland plants. Plants are container grown, of North Carolina, South Carolina, and southeastern Virginia genetic origin and propagated by seed whenever possible. https://www.wetlandplantsinc.com/ Phone: 252-482-5707

IV. NEXT STEPS

The Dix Park Master Plan represents a well thought-out and publicly-vetted vision of what this park can become. To take ecological restoration planning to the next level, additional work is essential.

Soil Sampling Program

While general soils data are available for the site, the history of land alteration/use and the important role that soils play in plant communities necessitate a robust soil sampling program. This program will:

1. Define general soil sampling regions of the park, based on proposed vegetation strategies.
2. Determine soil analysis parameters (e.g., texture, pH, percent organic matter, bulk density).
3. Develop a stratified soil sampling plan to ensure efficient and adequate collection of samples.
4. Confirm reference sites and/or remnant plant communities outside of the park for soil sampling, analysis, and comparisons.
5. Conduct soil sampling and laboratory analyses.
6. Culminate in a summary report, including stratification and sampling methods, findings (e.g., laboratory results), maps, and recommendations for proposed plant communities.

Geotechnical Borings

The soil sampling described above would be conducted with a hand-held soil core sampler, used for assessing shallow soil conditions. Geotechnical borings would use vehicle-mounted sampling equipment that would document deeper subsurface conditions, including depth to groundwater, depth to bedrock (where relatively shallow), and continuous sampling of the soil profile for texture classification and other characterization. These borings will be particularly important in constructed wetland and stormwater management areas to understand if and how runoff will infiltrate into the basin, where and how it will discharge, etc.

Natural Resource Inventory & Assessment and Baseline Monitoring

AES's research and field work to date has enabled general mapping of the park's major plant communities and development of a conceptual restoration plan. A more robust Natural Resource Inventory and Assessment (NRIA) would benefit design refinement and provide important baseline data regarding the presence, absence, abundance, and frequency of plant and animal species at the site. Collection of such data *before* restoration and enhancement is initiated enables more accurate assessment of project success with regard to ecological goals. At a minimum, vegetation sampling of representative plant communities by qualified botanists would provide baseline data regarding existing habitat conditions, including invasive plant species present and their abundance. In addition, baseline surveys of select animal groups (e.g., dragonflies/damselflies, frogs/toads, birds) by qualified wildlife experts would be valuable in establishing what wildlife species are currently using the park's different habitats. The true value of baseline vegetation and wildlife monitoring is realized by comparing baseline data with subsequent monitoring efforts conducted during and after restoration and initial management activities. This enables measurement of performance standards and provides a feedback loop to inform changes to the restoration and management program (known as "adaptive management").

Project Area Design Refinement

This memorandum provides general guidance for ecological restoration in select portions of the Dix Park site. However, the specific design of these areas is still evolving, as will the details related to their restoration. Design refinement will occur through an iterative process that takes into account environmental conditions and limitations (defined, in part, through execution of the Next Steps presented above), desired site modifications, aesthetic considerations, designing for low maintenance,

available native plant materials, and many other factors. Design refinement will entail more detailed restoration zones, site-specific plant species lists, more specific restoration/enhancement/management tasks (e.g., site preparation, seeding versus live plantings), and estimated costs useful for planning and budgeting.

CLOSING

We appreciate the opportunity to present to you this memorandum. Please let us know if you have any questions or additional needs, and we look forward to working with MVVA in the next phase of the project.

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Dix Park Ecology
The Trees of Dix Park

These maps were prepared using data gathered in a tree inventory conducted by Davey Trees in 2017. Davey Research Group inventoried over 5,000 trees with a diameter at breast height (DBH) greater than or equal to 3 inches. In some of the densest thickets of the greenway easement, a slightly greater DBH threshold was used for selecting trees. Within the boundaries of wooded areas (shown on the map), a traditional forest plot analysis was conducted using 25 plots at 1/10-acre each, in lieu of mapping every tree.

Concerning tree health as shown on map 2, common tree problems include dead limbs, trunk decay, root damage, mechanical wounds, stump sprouts, and threatening vine growth.

The following lists the species associated with the different plant communities shown on map 3:

- **Riparian Forest:** Box elder, River Birch, Pawpaw, River Birch, Green Ash, Red Mulberry, American-Sycamore, Eastern Cottonwood,Swamp White Oak, Water Oak, Pin Oak, Willow Oak, Black Walnut, Hackberry, American Hornbeam, Black Willow, Winged Elm, American Elm
- **Oak-Hickory Forest:** White Oak, Scarlet Oak, Southern Red Oak, Post Oak, Black Oak, Black-jack Oak, Mockerut Hickory, Bitternut Hickory, Blackgum
- **Pine Forest:** Loblolly Pine
- **Basic Mesic Forest:** American Beech, Northern Red Oak
- **Generalists:** Red Maple, Eastern Red Cedar, Eastern, Redbud, Flowering Dogwood, American Persimmon, Sweetgum, Tuliptree, Cherrylaurel, Black Cherry, Wild Plum, American Holly, Black Locust, Sassafras
- **Mountain Species:** Sugar Maple, Serviceberry, Eastern Hemlock, Chestnut, White Ash, Crab apple, Fire Cherry, American Linden
- **Coastal Plain Species:** Dahoon Holly, Yaupon, Shumard Oak, Silky Camellia, Bald Cypress
- **Non-native Species:** Hedge Maple, Japanese Maple, Mimosa, Pecan, Atlas Cedar, Austrian Pine, Arborvitae, Leyland Cypress, Catalpa, Kousa Dogwood, Fig, Gingko, Honey Locust, Rose-of-Sharon, Golden Rain Tree, Crape Myrtle, Star Magnolia, Saucer Magnolia, Chinaberry, Dawn Redwood, White Mulberry, Japanese Flowering Cherry, Callery Pear, Japanese Zelkova

1. TREES BY SIZE CLASS

KEY

- Large Tree
- Medium Tree
- Small Tree

- Mature
- Maturing
- Established
- Young

2. TREE HEALTH

KEY

- Good
- Fair
- Poor
- Dead

3. PLANT COMMUNITY ASSOCIATIONS

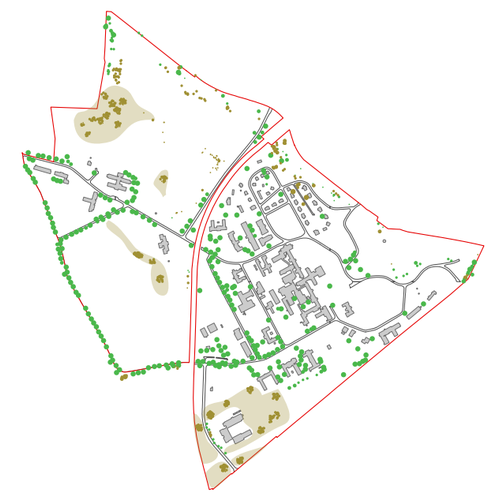
KEY

- Riparian Forest
- Oak-Hickory Forest
- Pine Forest
- Basic Mesic Forest
- Generalists
- Mountain Species
- Coastal Plain Species
- Non-native Species

4. DECIDUOUS + CONIFEROUS TREES

KEY

- Deciduous Tree
- Coniferous Tree



5. SIGNATURE SPECIES OF THE PARK

KEY

- Willow Oak, *Quercus phellos*
- Loblolly Pine, *Pinus taeda*

N

0 300' 600'

EXISTING TREES BY SIZE AT MATURITY

Around 20-25 plant communities are found within the Triangle Region alone and yet, the Dix Park site today is particularly lacking in understory (small-sized tree and shrub) diversity. Limited plant species, in turn, limit the diversity of animal life.

Large Sized Trees include:

- Carya, Castanea, Juglans, Liriodendron, Metasequoia, Pinus, Platanus, Populus, Quercus, Tilia, Tsuga

Medium Sized Trees include:

- Acer, Ailanthus, Betula, Carya, Catalpa, Celtis, Fagus, Fraxinus, Ginkgo, Gleditsia, Koelreuteria, Liquidambar, Magnolia, Melia, Morus, Paulownia, Pinus, Prunus, Robinia, Taxodium, Ulmus, Zelkova

Small Sized Trees include:

- Albizia, Amelanchier, Asimina, Carpinus, Cedrus, Cercis, Chamaecyparis, Cornus, Cryptomeria, Cupressocyparis, Diospyros, Ficus, Hibiscus, Ilex, Juniperus, Lagerstroemia, Ligustrum, Magnolia, Nyssa, Prunus, Pyrus, Salix, Sassafras, Stewartia, Thuja, Ulmus