National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Natural Resource Condition Assessment

Ocmulgee National Monument

Natural Resource Report NPS/SECN/NRR—2017/1521

ON THE COVER
Wide expanse of beautiful wetlands in late summer at Ocmulgee National Monument
Photograph by: Elle Allen

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Natural Resource Report NPS/SECN/NRR—2017/1521

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September 2017

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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Please cite this publication as:

Burkholder, J. M., E. H. Allen, C. A. Kinder, and S. Flood. 2017. Natural resource condition assessment: Ocmulgee National Monument. Natural Resource Report NPS/SECN/NRR—2017/1521. National Park Service, Fort Collins, Colorado.

NPS 363/140239, September 2017

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Executive Summary

The two major goals of this report were (i) to locate and assess existing information pertaining to the natural resources in the Ocmulgee National Monument (Ocmulgee NM, or the monument), including synthesis of available information and collection of geospatial data layers and maps; and (ii) to develop a set of indicators, quantitative insofar as possible, for natural resource conditions that can be tracked over time. The evaluated natural resources included climate, air quality, geology and soils, groundwater, surface water, and terrestrial and wetland biota.

Ocmulgee National Monument is in Bibb County, central Georgia, within the Ocmulgee River basin. It consists of two small tracts of land that encompass 284 hectares (ha, 701.5 acres [ac]) in total and are separated by four kilometers (km; 2.5 miles [mi]): the main unit (265.7 hectares [656.5 ac]) and the much smaller Lamar Mounds Unit (18.2 hectares [45 ac]). Monument natural resources include mixed hardwood/pine forests mixed with grassy fields, two perennial streams, and numerous wetlands. Ocmulgee National Monument is a national historic treasure because it is the only known site in the eastern United States with a continuous history of American Indians over the last 12,000 years, including rich archeology of the first agrarian civilization in eastern North America. About 130,000 visitors per year come to see its historic features; including a reconstructed prehistoric ceremonial American Indian earth lodge, burial mound, other temple mounds, and prehistoric trenches. They also come to enjoy the monument greenspace—its hiking trails, diversity of bird species, and other natural resources. In fact, the monument is the most popular tourist destination in mid-Georgia, and it is projected to become increasingly important to the rapidly growing, greater Atlanta Metropolitan Area (hereafter referred to as Atlanta area) as a greenspace. The monument already sustains high visitation pressure, averaging 51 visitors per kilometer of trail per day (83/mi of trail/day) during the April–October period.

The overall assessment of this report is that the natural resources of this national park are threatened by encroaching urbanization, and by the multitude of water and air pollutants and other stressors associated with rapid human population growth and land development especially of the Atlanta Metropolitan area. The monument lies 80 kilometers (50 mi) downstream and down-airshed from Atlanta. In addition, the main unit of Ocmulgee National Monument is also located on the eastern edge of the City of Macon; the monument is partly within Macon city limits. The adjacent urbanization has directly affected the monument through illicit dumping of trash and other refuse, erosion/ washout of hiking trails that receive heavy use, potential adverse effects from application of herbicides to maintain the railroad bed, and spillover crime from the City of Macon. From a broader perspective, the Ocmulgee River watershed is about 15% developed more than a decade ago, and is increasing in development at a rate of 1% per year mostly as the Atlanta metropolitan area continues to expand southward.

The airshed is in violation of federal ozone and fine particulate standards that threaten the health of park staff and frequent visitors, and the high ozone concentrations may be damaging terrestrial plant foliage (GA DNR 2007d, 2012). Visibility is sometimes poor because of the air quality. The monument also lies in an area that is moderately prone to atmospheric acid deposition, and acidification, especially acid spates, which could is adversely affect its surface waters and plant communities (Haines 1981; Sullivan et al. 2011).

The hydrology of the Ocmulgee River—the largest flowing water body in the monument—was dramatically altered by construction of an upstream dam, and by construction of the Macon Levee in 1950. Further modifications raised the levee about one meter (three ft) 20 years later. The levee effectively cut the river off from its flood plain, with attendant negative, sustained impacts on water quality and aquatic communities. Atlanta is already relying on the Ocmulgee River for 8% of its water supply, and that demand may increase with the rapidly growing population. In addition, a USGS monitoring well near the monument shows that the groundwater level decreased by nearly 1.74 meters (57 ft) from the 1960s to the present, and decreased by 6 meters (19.7 ft) in the past decade alone, reflecting a rapidly escalating groundwater demand.

The majority of the soils in the Ocmulgee watershed are erodible, and the five streams that flow through the monument, including three perennial streams, are characterized by high streambank erosion and thick sediment deposits along with trash accumulation. The Ocmulgee River and Walnut Creek have been designated for the past decade as impaired waters for biota and/or general recreation. Causes of impairment have been identified as urban nonpoint source pollution, especially excessive sediment loading and high fecal coliform densities. The Ocmulgee River segment is also impaired for fish consumption because of high polychlorinated biphenyl (PCB) content. However, water quality data have been and continue to be collected at an inadequate frequency of only seasonally to once or twice per year. Information is lacking about stream sediment quality or wetland ecosystems.

While the herpetofauna and bird fauna of Ocmulgee National Monument have relatively high species richness, the fish fauna are depauperate based on a decade old survey, and 25% or more of the vascular plant flora (109 of 434 species) and the mammalian fauna (9 of 33 species) are exotic/ invasive species. The monument is home to eight of the top ten most noxious invasive plants in Georgia, including four terrestrial and four wetland species.

In selecting the suite of indicators developed for natural resource status at Ocmulgee National Monument, a foremost consideration was to ensure insofar as possible that the indicators are scientifically sound, clear to the general citizenry, and logistically assessable for park personnel with minimal time and additional resources required. We also strove to ensure that the indicators meet the specific needs of this park. A total of 52 indicators were used to evaluate 15 categories of natural resources for which sufficient information was available to allow some level of assessment. The overall condition was rated as poor for 12 categories; one was evaluated to be in fair condition and two were in good condition, as shown by the report card for the natural resource conditions in Ocmulgee National Monument:

Ocmulgee National Monument report card for natural resource conditions.

Natural resource category	Number of Indicator	Ocmulgee
Human Population Surrounding the Monument	5	poor
Visitation—Human Population in the Monument	3	poor
Land Use/Land Cover	2	poor
Air Quality	7	poor
Soundscape	3	poor
Lightscape	2	poor
Soil and Streambank Erosion	5	poor
Surface Water Quantity	2	poor
Groundwater Supply	2	poor
Surface Water Quality	8	poor
Vascular Flora	4	poor
Fish	1	fair
Herpetofauna	2	good
Birds	5	good
Mammals	1	poor

Importantly, the National Park Service can not control or directly influence most of these indicators. Major knowledge gaps prevented or seriously restricted evaluation of the present condition of several natural resource categories. These gaps, and efforts needed to fill them, include:

- *Air Quality*—An air quality monitoring stations is needed at Ocmulgee National Monument to facilitate tracking changes over time. In addition, among the vascular plant vegetation in the monument, 12 plant species have been described as especially sensitive to ozone (see Biological Resources section). The National Park Service should consider tracking selected populations of a subset of these species over time, as sentinels of potentially harmful ozone levels.

- *Soundscape*—Noise pollution should be measured at areas of concern in the monument.

- *Lightscape*—Light pollution should be measured at areas of concern in the monument.

- *Surface-Water Hydrology*—The Resource Stewardship Strategy being developed for this park is expected to identify additional hydrologic targets, such as an indicator for tracking undesirable high water conditions in Ocmulgee National Monument over time.

- *Surface-Water Quality and Stream Sediments*—Data for the nine parameters selected as indicators should be collected at least monthly every other year to enable reliable assessment of water quality conditions over time, from one station on each major stream in the monument. Data are also needed to assess the quality of surficial stream sediments, including quarterly measures of PCBs, mercury, lead, and nitrogen and phosphorus nutrients.

- *Groundwater Quality*—Monthly sampling at least every other year is needed to characterize the pH and track concentrations of contaminants such as nitrate+nitrite, sulfide, and metals (e.g.,iron, aluminum, manganese) in groundwater.

- *Streambank Erosion*—Information is needed to develop a Channel Stability Index for the Ocmulgee River and Walnut Creek stream segments within the monument. The Southeast Coast Network is currently working with the monument to evaluate stream conditions.

- *Stream Macroinvertebrate Communities*—Stream macroinvertebrates should be added as an important biological component, and should be sampled at five-year intervals to assess stream biological condition following well-established protocols.

- *Vascular Plant Communities*—Concerted studies of key vascular plant communities and key species of interest are needed, including quantitative abundance data and maps. The species-level studies should emphasize the dominant terrestrial and wetland vascular plants in each of the general habitat types found in the monument; the common category one invasive vascular plants; and the exotic/invasive fauna of most concern to park staff. In addition, supporting the recommendation of the NPS State of the Park Report for Ocmulgee National Monument, the next steps for managing the condition and health of plant communities in the monument should be to develop a long-term management plan for invasive plant control.

- *Ecological Studies*—Concerted studies are needed of key species of interest within each of the major groups of vertebrate biota, to obtain abundance data and improve diversity estimates.

- *Updated Biota Surveys*—Vouchered species lists should be updated on a decadal basis to assist in tracking the biological resource conditions in the monument.

Acknowledgments

This study was funded by the National Park Service. In addition to the individuals listed as interviewed, we thank Joe DeVivo of the National Park Service for facilitation and helpful review comments. We also extend special thanks to Guy Lachine, Chief Ranger at Ocmulgee National Monument, for providing helpful counsel and insights. The monument has been very fortunate to have him. We are also grateful to the following colleagues: Danny Tavakol, Interim Engineer for the City of Macon, who sent water quality data for Walnut Creek that were collected as part of the city's stormwater monitoring program. Mark Wyzalek, manager, and Leslie Carroll, supervisor of laboratory and environmental compliance at the Macon Water Authority, sent water quality data for sites near Ocmulgee National Monument that were sampled from 2005 through 2010. Barbara Stitt-Allen, GIS Branch Coordinator and Renee Alonso, GIS Specialist at the Watershed Protection Branch of the Environmental Protection Division at GA DNR, provided draft NPDES discharge data for the state of Georgia.

List of Terms

AQI—Air Quality Index (of the EPA)
ARD—Automated Recording Device (for vocal anuran amphibian study)
ATMSA—Atlanta metropolitan statistical area
Bd—*Batrachochytrium dendrobatidis* (chytrid fungal pathogen of amphibians)
BDSS—the Bortle Dark-Sky Scale (for light pollution at night)
BMP—best-management practice
BOD_5—biochemical oxygen demand (five-day testing duration)
brl—below reporting limit
CAAE—Center for Applied Aquatic Ecology (of North Carolina State University, NCSU)
CAFO—confined (or concentrated) animal feeding operation
CCC—criterion continuous concentration (EPA)
cfs—cubic feet per second
cfu—colony-forming units
CI—confidence interval (in statistical analysis)
cm—centimeter
CMAQ—Community Multiscale Air Quality (Model)
CMC—criterion maximum concentration (EPA)
cms—cubic meters per second
CO_2—carbon dioxide, a major greenhouse gas contributing to global warming
COD—chemical oxygen demand
CPU—chloroplatinate units (EPA) for water color
dB(A)—A-weighted decibels, wherein a decibel is a unit of sound production; decibel(A) refers to sound production level on an A-weighted scale according to sound frequency
dbh—diameter at breast height
dd—decimal degrees (regarding latitude and longitude)
DIP—dissolved inorganic phosphorus
DO—dissolved oxygen
DOC—dissolved organic carbon
DON—dissolved organic nitrogen
DOP—dissolved organic phosphorus
DP—dissolved organic phosphorus
Dv—deciviews
ECHO ICIS—Enforcement and Compliance History Online Integrated Compliance Information System (of the EPA)
EFC—Environmental Flow Component (in hydrologic analyses)
EPA—United States Environmental Protection Agency
EPMT—Exotic Plant Management Team (of the National Park Service)
EPPC—the Exotic Pest Plant Council (of Georgia)
FC—fecal coliform bacteria
FMU—fire management unit
ft—foot or feet

GA—Georgia
GA DNR—Georgia Department of Natural Resources
GDD—growing degree days
GIS—Geographic Information System
GM—Geometric mean
GRI—Groundwater Resources Inventory
Hz—cycles per second, a measure of pitch in noise analysis
I&M Program—Inventory and Monitoring Program (of the National Park Service)
IHA—Indicators of Hydrologic Alteration (software from the Nature Conservancy)
IPCC—United Nations Intergovernmental Panel on Climate Change
ITIS—Integrated Taxonomic Information System
kHz (or KHz)—kilohertz, unit of alternating current or electromagnetic wave frequency equal to one thousand hertz (Hz)
L—liter(s)
lat.—latitude
lb—pound
long.—longitude
Ma—megaannum (plural, Megaanums), a period of one million years from the present
µg/L—micrograms per liter (= parts per billion)
mg/L—milligrams per liter (= parts per million)
mgd—million gallons per day
mile^2—square mile
MNGWPD—Metropolitan North Georgia Water Planning District
monument—Ocmulgee National Monument (OCMU)
mph—miles per hour
MPN—most probable number (pertaining to fecal bacteria)
MS4—municipal separate storm sewer system
MSL—mean sea level
µg/L—micrograms per liter (= parts per billion, ppb)
MWA—Macon Water Authority
N—nitrogen (nutrient; excessive enrichment can degrade water quality)
NAAQS—National Ambient Air Quality Standards
NADP—National Atmospheric Deposition Program (of the EPA)
NCSU CAAE—North Carolina State University's Center for Applied Aquatic Ecology
NH_3—ammonia (gaseous form; can be an air or water pollutant)
NH_4^+N—ammonium (inorganic form of nitrogen, ionized from ammonia; excessive enrichment can degrade water quality)
nL—nanolamberts
NLCD—National Land Cover Data
NOAA—National Oceanic and Atmospheric Administration
$NO_3^- + NO_2^-$—nitrate + nitrite (inorganic forms of nitrogen; excessive enrichment can degrade water quality)

NO_x—nitrate + nitrite (inorganic forms of nitrogen; excessive enrichment can degrade water quality)
NO_y—"catch-all" for all atmospheric reactive oxides of nitrogen
NPC—Not possible for the National Park Service to control
NPCA—National Parks Conservation Association
NPDES—National Pollutant Discharge Elimination System
NPS—National Park Service
NRCA—Natural Resource Condition Assessment
NRS—National Resource Strategy (of parks in the National Park Service)
NTU—Nephelometric turbidity units
NWI—National Wetlands Inventory
NWIS—National Water Information System (of the U.S. Geological Survey)
NWS—National Weather Service (of NOAA)
OCMU—Ocmulgee National Monument (the monument, Ocmulgee NM)
O_3—ozone
P—phosphorus (nutrient; excessive enrichment can degrade water quality)
Pa—Pascal, a unit of pressure: 1 Pa = the pressure of 1 newton per square meter
PACE—park protected-area centered ecosystem
park—Ocmulgee National Monument (OCMU)
PCS—Permit Compliance System (of the EPA)
PDSI—Palmer Drought Severity Index (PDSI, a scale ranging from -3 to +3; sometimes called the Palmer Drought Index)
$PM_{2.5}$—particulate matter, diameter ≤ 2.5 µm (air pollutant)
PM_{10}—particulate matter, diameter ≤ 10 µm (air pollutant)
ppb—parts per billion (in water, the same as µg/L)
ppm—parts per million (in water, the same as mg/L)
QA/QC—quality assurance/quality control (refers to standardized procedures for ensuring acceptable quality of data)
RSS—Resource Stewardship Strategy (being developed for OCMU)
SAV—submersed aquatic vegetation
SECN—Southeast Coast Network (of the National Park Service)
SECP—Southeastern Coastal Plain aquifer system
SERCC—Southeast Regional Climate Center
SO_2—sulfur dioxide (air pollutant)
SSC—species of special concern (endangered, threatened, etc.—federal and/or state)
SOP—standard operating procedure
sq. mi.—square mile(s)
spec. cond.—specific conductivity
SRP—soluble reactive phosphorus
SSHS—Saffir/Simpson Hurricane Scale
STORET—STOrage and RETrieval Environmental Data System (of the EPA)
sv—single value

SVOC—semi–volatile organic compounds, also called polycyclic aromatic hydrocarbons (air pollutants)
TAP—toxic air pollutant
TCP—Traditional Cultural Property (Ocmulgee Old Fields)
TD—tropical depression
TKN—total Kjeldahl nitrogen
TMDL—total maximum daily load
Tonne—metric ton
TP—total phosphorus
TS—tropical storm
TSS—total suspended solids
UC—unacceptable condition(s)
UCC—unacceptable condition(s) common
USACE—United States Army Corps of Engineers
USDA—United States Department of Agriculture
USDI—United States Department of the Interior
USGS—United States Geological Survey
UWL—Unique Wetland
VCP—variable-circular plot (field sampling technique)
VOC—volatile organic compound
WUI—Wildland-Urban Interface
yr—year

1. NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks." NRCAs also report on trends in resource condition (when possible), identify critical data gaps, and characterize a general level of confidence for study findings. The resources and indicators emphasized in a given project depend on the park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators, and availability of data and expertise to assess current conditions for a variety of potential study resources and indicators.

> ***NRCAs Strive to Provide…***
>
> - *Credible condition reporting for a subset of important park natural resources and indicators*
> - *Useful condition summaries by broader resource categories or topics, and by park areas*

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement—not replace—traditional issue-and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

- Are multi-disciplinary in scope;[1]
- Employ hierarchical indicator frameworks;[2]
- Identify or develop reference conditions/values for comparison against current conditions;[3]
- Emphasize spatial evaluation of conditions and GIS (map) products; [4]
- Summarize key findings by park areas; and [5]
- Follow national NRCA guidelines and standards for study design and reporting products.

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context to

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[1] The breadth of natural resources and number/type of indicators evaluated will vary by park.

[2] Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures ⇨ conditions for indicators ⇨ condition summaries by broader topics and park areas

[3] NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions. Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-up response (e.g., ecological thresholds or management "triggers").

[4] As possible and appropriate, NRCAs describe condition gradients or differences across a park for important natural resources and study indicators through a set of GIS coverages and map products.

[5] In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on an area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

understand current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.
Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

The credibility of NRCA results is derived from the data, methods, and reference values used in the project work, which are designed to be appropriate for the stated purpose of the project, as well as adequately documented. For each study indicator for which current condition or trend is reported, we will identify critical data gaps and describe the level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject-matter experts at critical points during the project timeline is also important. These staff will be asked to assist with the selection of study indicators; recommend data sets, methods, and reference conditions and values; and help provide a multi-disciplinary review of draft study findings and products.

NRCAs can yield new insights about current park resource conditions, but, in many cases, their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is both credible and has practical uses for a variety of park decision making, planning, and partnership activities.

Important NRCA Success Factors

- *Obtaining good input from park staff and other NPS subject-matter experts at critical points in the project timeline*
- *Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ⇨ indicators ⇨ broader resource topics and park areas)*
- *Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings*

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities. What an NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park’s desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[6] and help parks to report on government accountability measures.[7] In addition, although in-depth analysis of the effects of climate change on park natural resources is outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

NRCAs also provide a useful complement to rigorous NPS science support programs, such as the NPS Natural Resources Inventory & Monitoring (I&M) Program.[8] For example, NRCAs can provide current condition estimates and help establish reference conditions, or baseline values, for some of a park's vital signs monitoring indicators. They can also draw upon non-NPS data to help evaluate current conditions for those same vital signs. In some cases, I&M data sets are incorporated into NRCA analyses and reporting products.

NRCA Reporting Products…

Provide a credible, snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:

- *Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations* ***(near-term operational planning and management)***
- *Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values* ***(longer-term strategic planning)***
- *Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public* ***("resource condition status" reporting)***

Over the next several years, the NPS plans to fund a NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information visit the NRCA Program website.

[6]An NRCA can be useful during the development of a park's Resource Stewardship Strategy (RSS) and can also be tailored to act as a post-RSS project.

[7] While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.

[8] The I&M program consists of 32 networks nationwide that are implementing "vital signs" monitoring in order to assess the condition of park ecosystems and develop a stronger scientific basis for stewardship and management of natural resources across the National Park System. "Vital signs" are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.

2. Introduction and Setting

2.1. Introduction

Ocmulgee (pronounced oak-mull-ghee) National Monument (OCMU, Ocmulgee NM, the monument) is a memorial to the early American Indians in the region. The Indian name is from the Hitchiti (oki, water, from the word och meaning in or down in; mulgis—boiling or bubbling). Ocmulgee NM is a national historic treasure because it is the only known site in the eastern United States with a continuous history of American Indians over the last 12,000 years, including rich archeology of the first agrarian civilization in eastern North America. The monument is a small park that encompasses 284 hectares (ha; 701.5 acres [ac]), which consist of two tracts of land located on the eastern edge of Macon (population 91,351 as of 2012; USCB 2015a) in Bibb County, central Georgia (Figure 1). Part of the monument is within the city limits of Macon (De Vivo et al. 2008). The monument is also 137 kilometers (km; 85 miles [mi]) south of the greater Atlanta metropolitan area. The main unit of Ocmulgee National Monument (266 hectares [656.5 ac]) in area is approximately 116 meters ([m] or 381 feet [ft] above mean sea level [MSL]) and is accessible from U.S. Route 80 off Interstate 16. It has 8.9 kilometers (5.5 mi) of walking trails, a reconstructed 1,000-year-old ceremonial earth lodge near the visitor center, the Great Temple Mound about 0.8 kilometers (0.5 mi) from the visitor center, a burial mound, other temple mounds, prehistoric trenches, and the site of a colonial British trading post. A second, much smaller, detached parcel, the Lamar Mounds Unit (or, the Lamar Mounds and Village Unit; 18.2 ha [45 ac], 85 meters[280 ft] above mean sea level; Figure 2), is about 4 kilometers (2.5 mi) downriver and southeast of the main unit in low-lying floodplain, accessible by an unnumbered county road called Confederate Way (DeVivo et al. 2008).

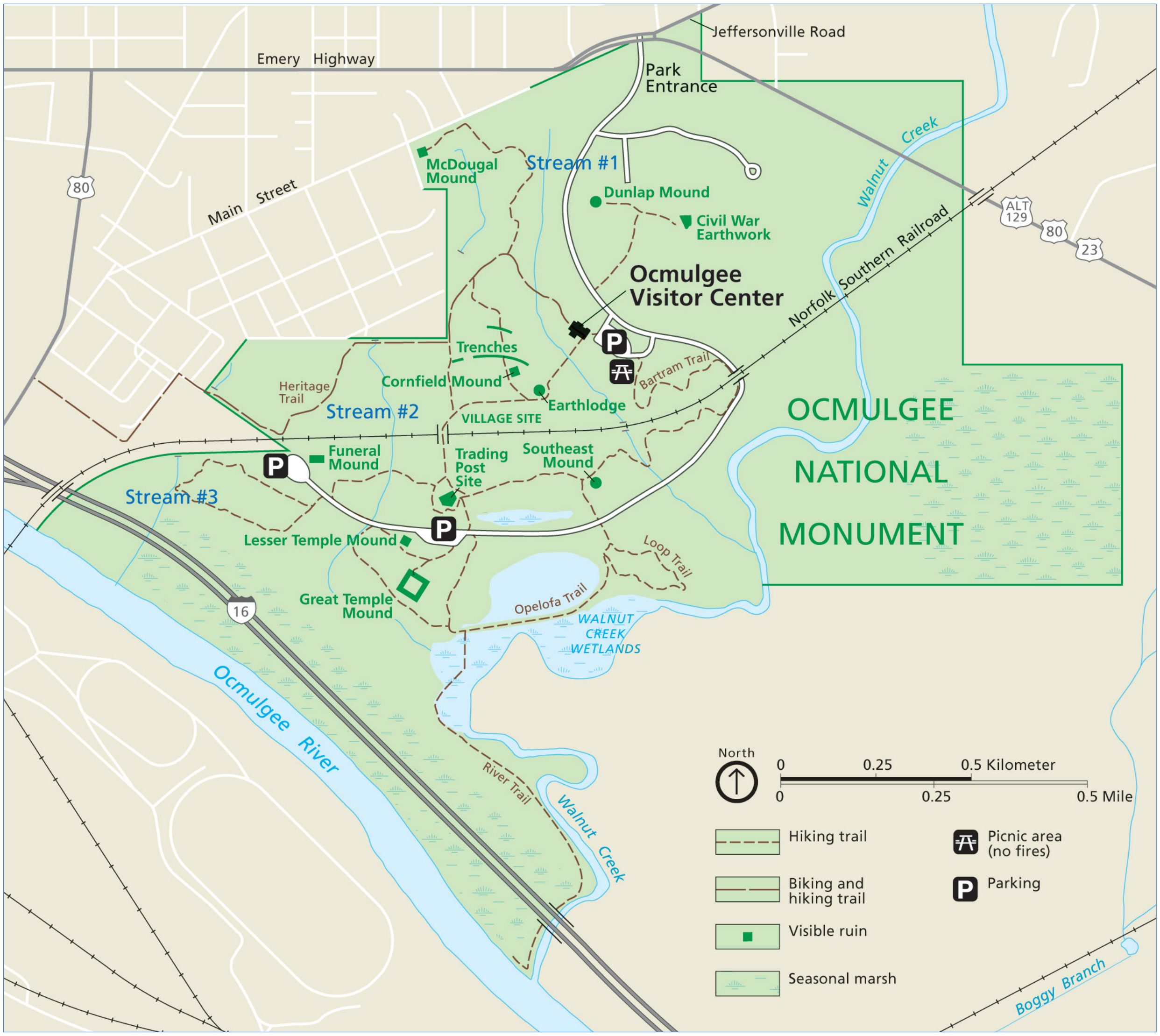


Figure 1. Map of the main monument unit, mostly surrounded by the City of Macon; a second, much smaller unit, the Lamar Mounds Unit, is located two miles south near the Ocmulgee River. The map also shows extensive wetlands and two major streams in the monument— the Ocmulgee River and its tributary Walnut Creek—as well as three smaller streams (NPS map).

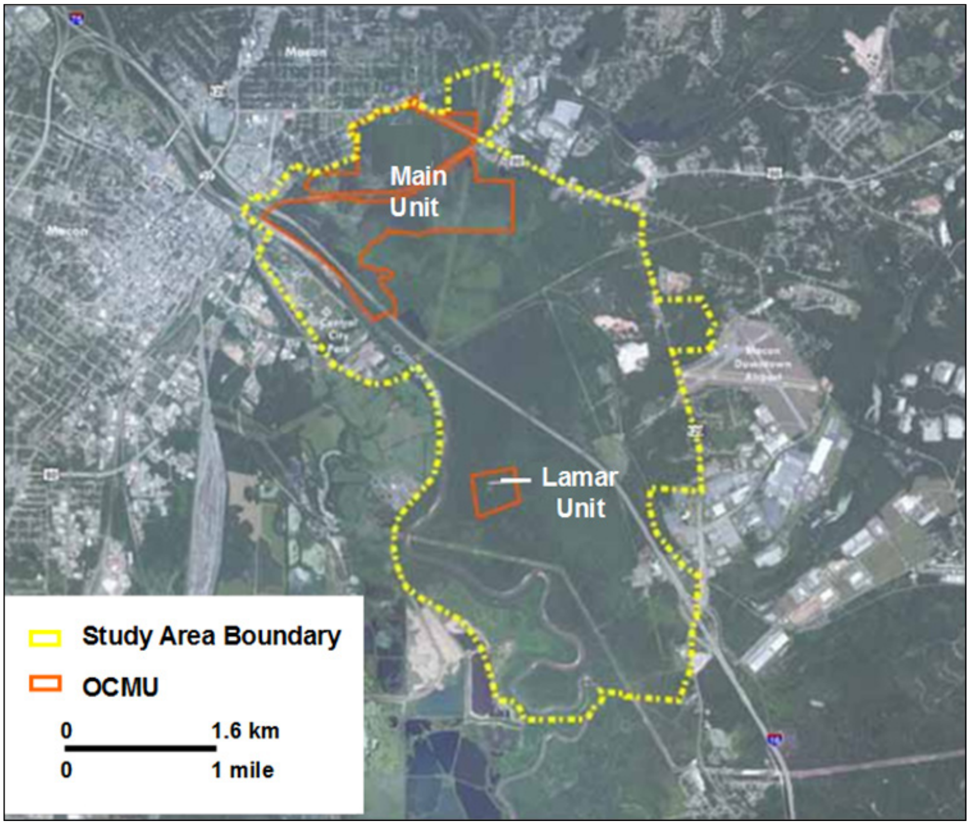


Figure 2. The land area considered in the boundary scoping study that was conducted by the National Park Service 2012–2013 (David 2012).

The Ocmulgee River forms the boundary of one side of Ocmulgee NM. The natural resources of the monument are heavily impacted by human activities, including an interstate highway (I-16) and associated berm, and a railroad, which bisect the monument (Figure 1). The highway has separated the river from its floodplain and disrupted natural flow (De Vivo et al. 2008). A sewage lift station and associated underground pipes are in the monument, as well as an underground storage tank. Despite these alterations and the immediately adjacent urban influence, Ocmulgee National Monument maintains surprising species diversity, likely because of a greenway corridor that connects the monument to large wooded wetland natural areas to the south. Threats affecting monument biota include air quality, water quality, urban encroachment, and exotic species. Until recently, there was very little information about natural resources in the monument. In the past five years the National Park Service has expended considerable effort to collect some baseline data that can be used to track changes over time.

Land use within monument boundaries is predominantly riverine emergent wetland, including one of the largest peat bogs in the Southeast (DeVivo et al. 2008), as well as some upland grassy fields and forests. The National Park Service maintains a visitor center, an updated archaeological museum, 9.7 kilometers (6 mi) of hiking trails linking historical monuments, a picnic area, and several archaeological ruins. The monument superintendent has an office on-site (NPS 2015d).

2.1.1. Enabling Legislation and Potential for Expansion

Ocmulgee National Monument illustrates a dual path to entry into the National Park System, having both legislation and an executive order in its creation history (NPS 2009). Congress authorized the creation of Ocmulgee National Monument on 14 June 1934 to protect historic American Indian settlements dating back 12,000 years including up to 809 hectares (2,000 ac) for the monument (NPS 2015d). However, Congress provided no funds to purchase land, and stipulated that land for the monument must be secured by public or private donations. Context is important: the monument was created during the Great Depression. By 23 December 1936, when President Roosevelt established Ocmulgee National Monument by Presidential Proclamation No. 2212, only 274.6 hectares (678.48 ac) had been acquired for the monument. President Roosevelt issued Proclamation No. 2493 in 1941, adjusting the monument boundaries. In 1991, Public Law 102-67 enlarged the monument by accepting a 7.5-hectare (18.60 ac) tract of land known as Drake Field.

At present Ocmulgee National Monument consists of only 284 hectares (702 ac) in two locations (units). The main unit (266 hectares [657 ac]), adjacent to downtown Macon, contains the earth lodge, seven temple mounds, and the funeral mound which has more than 100 burials. As mentioned, the second site (18.2 hectares [45 ac]), the Lamar mounds unit, is 4 kilometers (2.5 mi) southeast, separated from the main unit by privately owned lands that are mostly wetlands.

The monument was authorized by Congress to protect an area known as the Old Ocmulgee Field, a rich archaeological landscape of prehistoric cultural development including mound builders. Ocmulgee National Monument was added to the National Register of Historic Places in 1966, and the monument, together with the remainder of the Old Ocmulgee Field, contains a continuous record of human life from 17,000 years to the present (David 2012). In 1997, the National Park Service designated the monument as a Traditional Cultural Property (TCP), the first TCP recognized east of the Mississippi River. Moreover, the Keeper of the National Register of Historic Places has determined that 5,666 hectares (14,000 ac) of the Old Ocmulgee Field are also eligible for the National Register as a TCP because of the historical significance of the land to the Muscogee (Creek) American Indians, who were forced to abandon the lands in the early nineteenth century. To the south of the monument, the Bond Swamp National Wildlife Refuge protects part of the southern portion of the TCP.

The monument mission statement encompasses a dual conservation and education mission as mandated by The NPS Organic Act (1916) and the Historic Sites Act (1935): “The mission of the National Park Service at Ocmulgee National Monument is to protect and preserve lands known as the “Old Ocmulgee Fields” and promote understanding of and an appreciation for the 12,000-year continuum of American Indian-related cultural and natural resources.”

Efforts to add more land to the monument continue. The Archaeological Conservancy recently indicated willingness to donate 121.4 hectares (300 ac) to the monument, but the National Park Service cannot accept the land unless it is found to be appropriate for addition to the monument. In 2012–2013, the National Park Service engaged in a scoping study to assess whether certain lands around Ocmulgee National Monument should/can be included in a boundary expansion (Figure 2). The National Park Service can recommend a boundary revision for three reasons: To include significant resources/opportunities for public enjoyment related to the purpose for creating the monument; to address operational and management issues such as need for public access, or need for boundaries to correspond to logical boundary delineations; or to protect monument resources critical to the purpose for creating the monument. The National Park Service can recommend a boundary expansion or change only if it can demonstrate that the added lands will be feasible to administer considering factors such as size, configuration, and ownership costs; and if it can find that other alternatives for management and resource protection are inadequate.

The boundary study and environmental assessment were published in January 2014 (NPS 2014e). The study evaluated whether a boundary expansion is appropriate for the park and, if so, which properties would be suitable and feasible for inclusion within an expanded park boundary. It was reasoned that a revised, larger boundary could protect the park natural resources from further urban encroachment, and could create an important green corridor of public land between the park and other greenspaces. The NPS preferred alternative from this study would protect up to 850 hectares (2,100 ac) of additional important natural and cultural resources outside the existing park boundary, so that the park area would increase to 1,133 hectares (2,800 ac). The proposed expansion boundary would include (i) lands generally between the Main Unit of the park and the acquisition boundary of Bond Swamp National Wildlife Refuge on the south; (ii) specified lands to the east and north of the Main Unit; and (iii) the railroad corridor that transects the Main Unit. It was noted that the suggested boundary adjustment cannot be accomplished without legislation from the U.S. Congress, and that implementation of actions related to a boundary adjustment will depend on future funding and NPS priorities (NPS 2014e).

A multi-county partnership was recently formed to establish the Ocmulgee River Blueway paddle trail (NPCA 2017): Eleven counties have passed resolutions supporting the Blueway and establishment of new public access points for river- based recreation. An expanded Ocmulgee National Monument would be the key northernmost piece of the Blueway, and would offer additional publicly owned river frontage and the potential for new recreational features such as put-ins, trails, and camping facilities. Expansion of the monument boundaries would also enhance the scenic quality of the Ocmulgee River, and would help to support the designation of Ocmulgee National Monument as part of the National Water Trails System. This expansion would directly link the monument to other public lands along the Ocmulgee River such as the Bond Swamp National Wildlife Refuge, Oaky Woods, and Ocmulgee Wildlife Management Areas to the south.

2.1.2. Geographic Setting

Ocmulgee National Monument is located on the Macon Plateau at the Fall Line, where rolling hills of the piedmont meet the flatlands of the Atlantic coastal plain. The monument is just below the Ocmulgee River Fall Line, a 32-kilometer (20-mi) wide geological boundary separating the hilly terrain and crystalline rock of the Piedmont region from the flat terrain and sedimentary rocks of the Coastal Plain. The Fall Line extends from Columbus, Georgia to Augusta, Georgia and was given its name as a result of the waterfalls and rapids that are the inland barriers to navigation on Georgia's major rivers. The Fall Line can also be recognized by stream geomorphology. Streams and rivers above the Fall Line typically have small floodplains, and streams and rivers below it typically meander through floodplains or marshes (GA DNR 2004).

The monument lies within the Ocmulgee River watershed (area 16,006 square kilometers [180 mi^2]), which includes Ocmulgee National Monument at its southern end (Table 1, Figures 3 and 4). The most extensive urban development is concentrated in the upper watershed, from Atlanta influence (Figures 3 and 4), followed by the Macon area (Figures 4 and 5). At present the expanding Atlanta area has sprawled to such an extent that it is now separated from Ocmulgee National Monument by only one county (Atlanta Metropolitan Statistical Area—Figure 3). Thus, the watershed is strongly influenced by Atlanta, and increasing urbanization is already encroaching into the middle watershed because of it (Figure 4). During the roughly 30-year period from 1974 to 2005, low- and high-density urban development in the upper Ocmulgee River watershed tripled (increased by +336% and +280%, respectively) (Table 2). During the past 15 years, impervious area doubled. Near the monument, in contrast, maps of land use/land cover indicate little change between 2001 and 2006 (Figures 5 and 6). The land within a 5-kilometer (3.1-mi) radius of the monument already had been extensively urbanized by the City of Macon as of 2001 (Table 3).

The North Carolina State University Center for Applied Aquatic Ecology (NCSU CAAE) generated land use-land cover maps for the Ocmulgee River basin, and for the Walnut Creek sub-basin (Table 3, Figures 4 and 5), with the following procedure. The basin and sub-basin boundaries (8-digit hydrologic unit code) geographic information system (GIS) data layers were provided by the United States Geological Survey (USGS). National Land Cover Database (NLCD) data for 2006 (Fry et al. 2011) were downloaded from the USGS Seamless Data Distribution System (USGS 2015a). Using the Spatial Analyst extension of ArcGIS 9.1 (ESRI 2005), the land-use classification system was modified to include eight general categories: urban areas (sub-categories, high-intensity development and developed open space [low-intensity development], row crop agriculture, animal agriculture, forests, grasslands, water, wetland, and barren/disturbed). Once the grid was reclassified, the spatial analyst "tabulate area" function was used to calculate the area of each land class within the sub-basin.

Table 1. Land use/land cover in the entire Ocmulgee River (OR) and Walnut Creek (WC) watersheds as of 2006 (Fry et al. 2011)—corresponds to Figure 4.

Category	**OR Area (ha)**	**OR Area (ac)**	**Percentage**	**WC Area (ha)**	**WC Area (ac)**	**Percentage**
Open Water	12,964	32,035	1.7 %	601	1,485	1.0 %
Developed Open Space	89,453	221,043	11.6 %	5,810	14,357	9.7 %
Urban	87,410	215,995	11.5 %	3,048	7,532	5.1 %
Barren/Rock	5,250	12,973	0.7 %	698	1,725	1.2 %
Forest	382,320	944,733	49.8 %	37,607	92,929	63.3 %
Row Crops, Pasture	90,598	223,873	11.8 %	3,928	9,706	6.6 %
Shrub/Grassland	63,814	157,688	8.3 %	5,852	14,460	9.9 %
Woody Wetlands	34,509	85,273	4.5 %	1,796	4,438	3.0 %
Emergent Herbaceous Wetlands	960	2,372	0.1 %	201	497	0.2 %
Totals	**767,278**	**1,895,985**	**100.00%**	**59,541**	**147,129**	**100.00%**

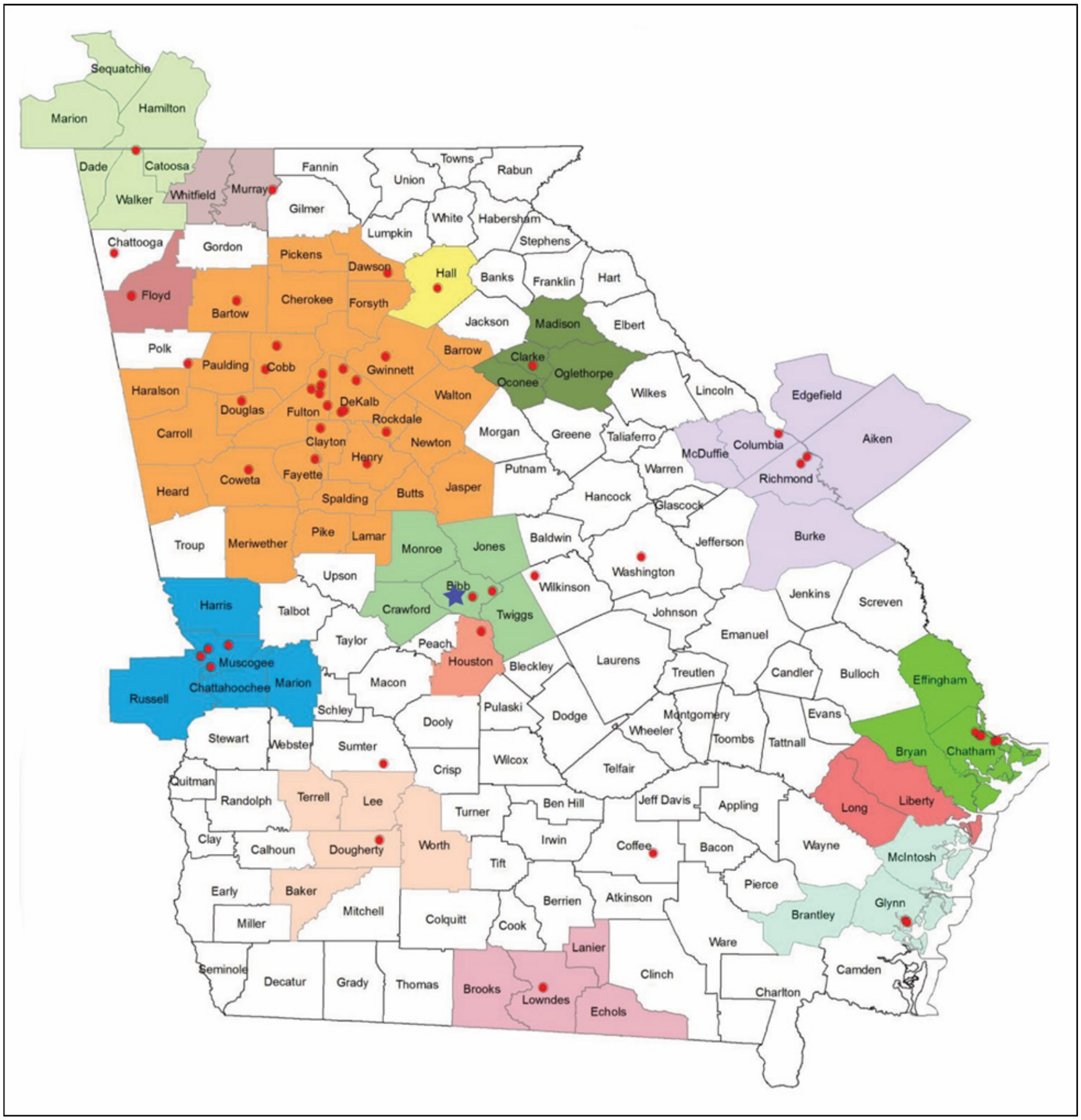


Figure 3. Map showing the proximity of Ocmulgee in Bibb County (blue star) to the Atlanta Metropolitan Statistical Area (ATMSA; orange area) as of 2008. Carbon monoxide air quality monitoring (red dots) and other metropolitan statistical areas are also shown (variously colored areas, as defined by the U.S. Census Bureau). From GA DNR (2012). Note that as of 2013, six more counties were included within the ATMSA, including Morgan, Oconee, Oglethorpe, Clarke, and Madison Counties (University of North Carolina Charlotte 2013).

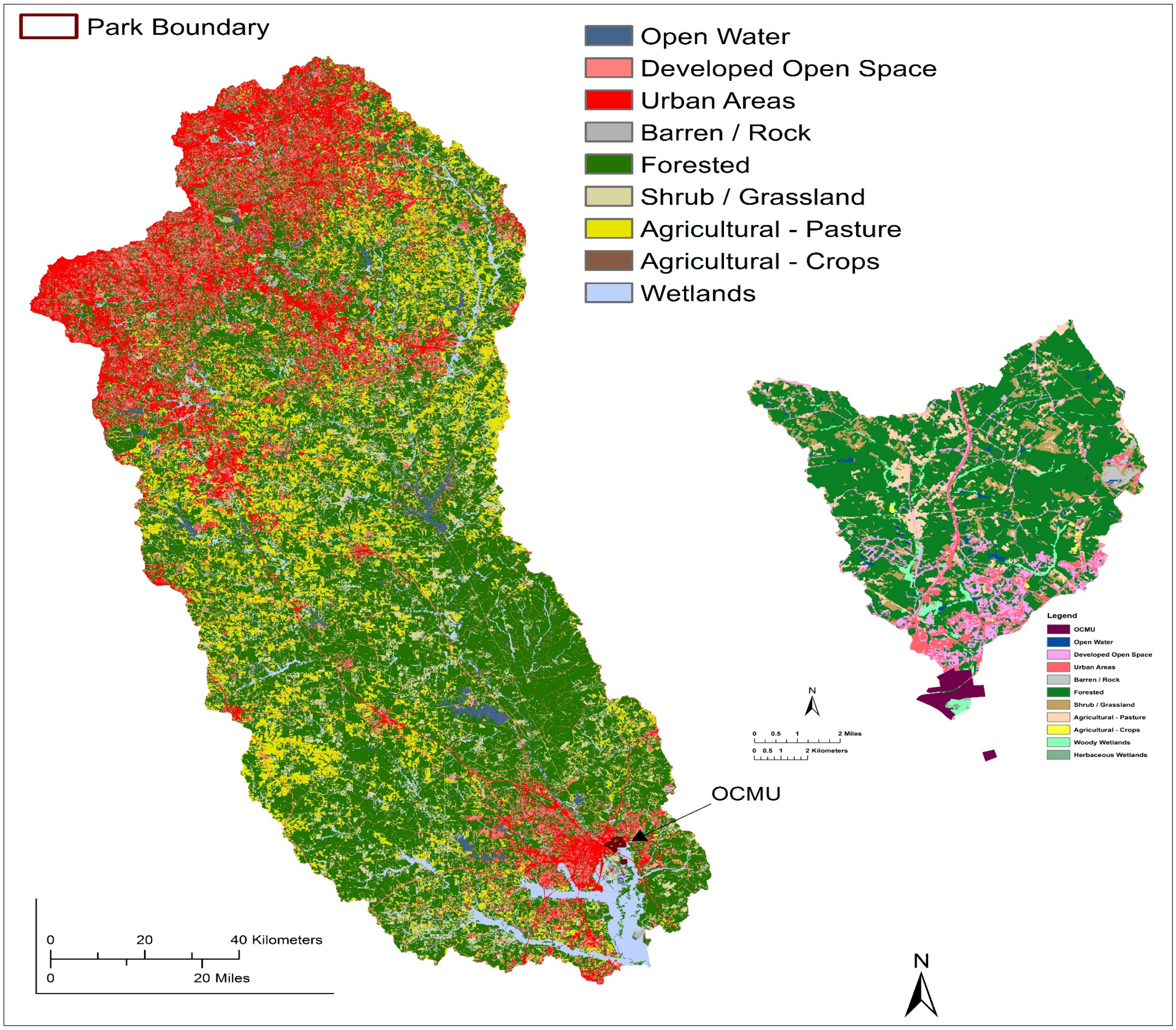


Figure 4. Map of land use/land cover as of 2006 in the Ocmulgee River watershed and the Walnut Creek watershed (inset). See Table 1 for corresponding percentages (Fry et al. 2011). Walnut Creek map NCSU CAAE (S. Flood), Ocmulgee NM map by the Southeast Coast Network.

Table 2. Changes in land use/land cover from 1974 through 2005 and 1991 through 2005 in the upper Ocmulgee River basin (data in acres). From the Natural Resources Space Analysis Lab, University of Georgia.

Class	**1974**	**1991**	**2005**	**% Change (1974–2005)**	**% Change (1991–2005)**
Beaches, dunes, mud	24	80	13	- 46%	- 84 %
Open water	13,756	29,896	35,486	+ 158%	+ 19 %
Low-intensity urban	76,010	207,333	331,803	+ 336%	+ 60 %
High-intensity urban	21,365	39,547	81,287	+ 280%	+ 106 %
Total urban	**97,375**	**246,880**	**413,090**	**+ 324%**	**+ 67 %**
Impervious area	–	63,284	127,988	–	+ 102 %
Clear cut, sparse	73,564	163,501	153,141	+108%	- 6 %
Quarries, strip mines, rocks	4,046	5,661	6,415	+ 59%	+ 13 %
Deciduous forest	590,356	501,129	366,393	- 38%	- 27 %
Evergreen forest	588,083	561,884	493,639	- 16%	- 1 %
Mixed forest	18,395	43,158	46,310	+ 152%	+ 7 %
Total forest	**1,196,834**	**1,106,171**	**906,342**	**- 24%**	**- 13 %**
Row crops and pasture	401,994	305,998	285,895	- 29%	- 7 %
Forested wetland	128,131	121,589	114,879	- 10%	- 6 %
Non-forested wetlands	79	–	543	+ 587%	–

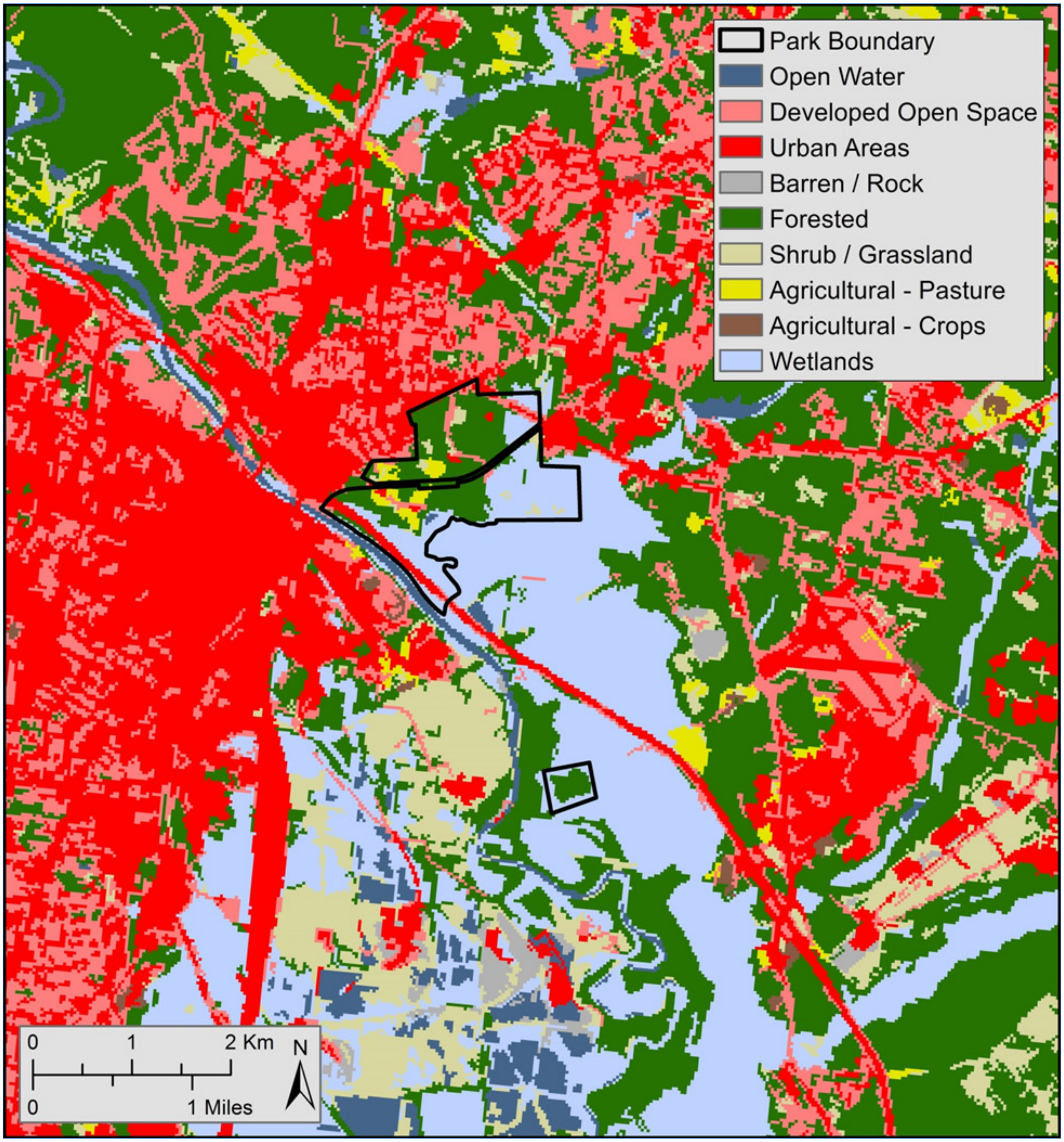


Figure 5. Magnified map of land use/land cover as of 2011 in the Ocmulgee and lower Walnut Creek watersheds near the monument (Homer et al. 2015). See Table 3 for corresponding percentages.

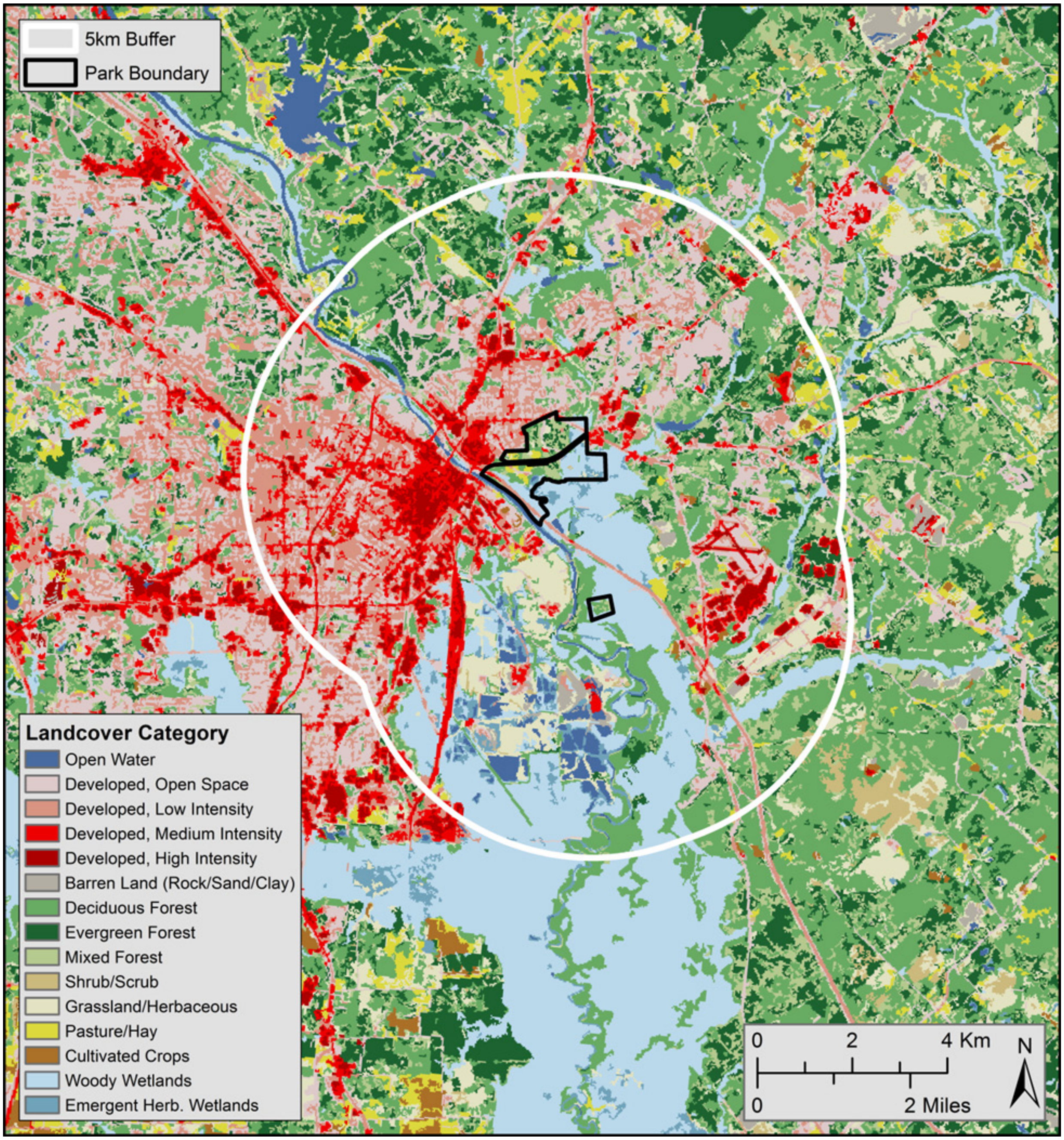


Figure 6. Close-up map of the area surrounding Ocmulgee NM within a 5-kilometer (3.1 mi) radius. The map of land cover/land use as of 2011 (Homer et al. 2015—most recent available NLCD), when compared to maps from the previous 5–10 years, indicates little overall change in developed land use/land cover over the past decade immediately adjacent to Ocmulgee NM, despite a 20% increase human population within that area (NPS 2014d).

Table 3. Land use/land cover in the upper Ocmulgee River basin near the monument based on 2011 NLCD data (Homer et al. 2015). These data correspond to Figure 5.

Land Use/Land Cover (2011 NLCD)	Area (hectares)	Area (acres)	Percent of Total
Open Water	**832.2**	**2056.4**	**1.8 %**
Developed (open space)	5,021.6	12,408.6	10.7 %
Developed (low intensity)	2,214.3	5,471.7	4.7%
Developed (medium intensity)	1,279.7	3,162.2	2.8 %
Developed (high intensity)	502	1,240.5	1.1 %
Total Developed	**9,017.6**	**22,283**	**19.3 %**
Barren/Rock	616.6	1,523.7	1.3 %
Forest (deciduous)	11,756.6	29,051.2	25.1 %
Forest (evergreen)	5,866.4	14,496.2	12.6 %
Forest (mixed)	2,965.2	7,327.2	6.3 %
Total Forest	**20,588.2**	**50,874.6**	**44.0 %**
Shrub/Scrub/Grassland	6,418.1	15,859.5	13.7 %
Agriculture (hay/pasture)	1,632.6	4,034.1	3.5 %
Agriculture (crops)	284.8	703.8	0.6 %
Total Agriculture	**1,917.4**	**4,738.0**	**4.1 %**
Wetlands (woody)	6,802.7	16,809.8	14.5 %
Wetlands (emergent herbaceous)	618.8	1,529.1	1.3 %
Total Wetlands	**7,421.5**	**18,338.9**	**15.8 %**
Totals:	**46,811.6**	**115,674.0**	**100.0 %**

2.1.3. Demographics

The land use/land cover information from 2001 versus 2006 did not show much change in the Macon area (Table 3) because the population of Macon has decreased in recent years in contrast to growth of Atlanta. Bibb County had a total population of 155,547 as of 2010 (U.S. Census data) with a density of 244 people per square kilometer [626 people per mi^2] (Figure 7). The population had been projected to grow only by 1.3% to 158,426 by 2005 (Macon-Bibb County Planning & Zoning Commission 2006); thus, population growth has lagged behind even the modest projections.

Bibb County was predicted to increase in population by 11% between 2010 and 2020 (State of Georgia Office of Planning and Budget 2010). The population density in the City of Macon is 633 people per square kilometer [1,639 people per mi^2] (Figure 7). As of 2010–2012 the population of the City of Macon was 91,416, which is 8.6% less than it was in 2000 (USCB data). This population growth rate is much lower than the state average (+18.34%), and much lower than the national average (+9.71%). The population as of 2012 was mostly African American (67.9%), Caucasian (28.6%), and Hispanic (2.5%). The median income was $26,758.

2.1.4. Visitation Statistics

Ocmulgee NM has an estimated 120,000 recreationist visitors per year (Chief Ranger G. Lachine, pers. communication, April 2013; and NPS 2016). The number has been relatively steady for the past decade, with a median of 119,295 recreationist visitors per year (range 102,631 to 174,340 during 2001–2012, with the maximum in 2003 and the minimum in 2008). The monument has been identified by the National Parks Conservation Association (NPCA) as mid-Georgia's most popular tourist destination, adding an estimated $5.4 million to the local economy in 2010 (NPCA 2017). Its anticipated land expansion is expected to significantly increase its beneficial economic effects on the surrounding economy. Ocmulgee NM is expected to become increasingly important to Atlanta as a greenspace, as it is only a two-hour drive from parts of the metropolitan area (NPCA 2017; Ocmulgee National Park & Preserve Initiative 2017).

Ocmulgee National Monument is popular for hikers and other visitors to the Macon area. The monument's Ocmulgee Indian Celebration attracts large crowds every September, and park staff also engage in various other education outreach activities such as ranger-led walks, exhibits, and the Lantern Light Tours in March.

The National Park Service plans to expand the network of trails within the main unit of the monument to link to the Ocmulgee Heritage Trail, a greenway trail along the Ocmulgee riverfront (NPS 2007). The trail will provide additional recreational opportunities for the entire population, including disabled people. Signs have been added to the boardwalk area, with other features to assist in educating visitors about the value of wetlands. There is public interest, as well, in the remote Lamar mounds unit, and the National Park Service hopes to provide additional educational and interpretative opportunities there (NPS 2007).

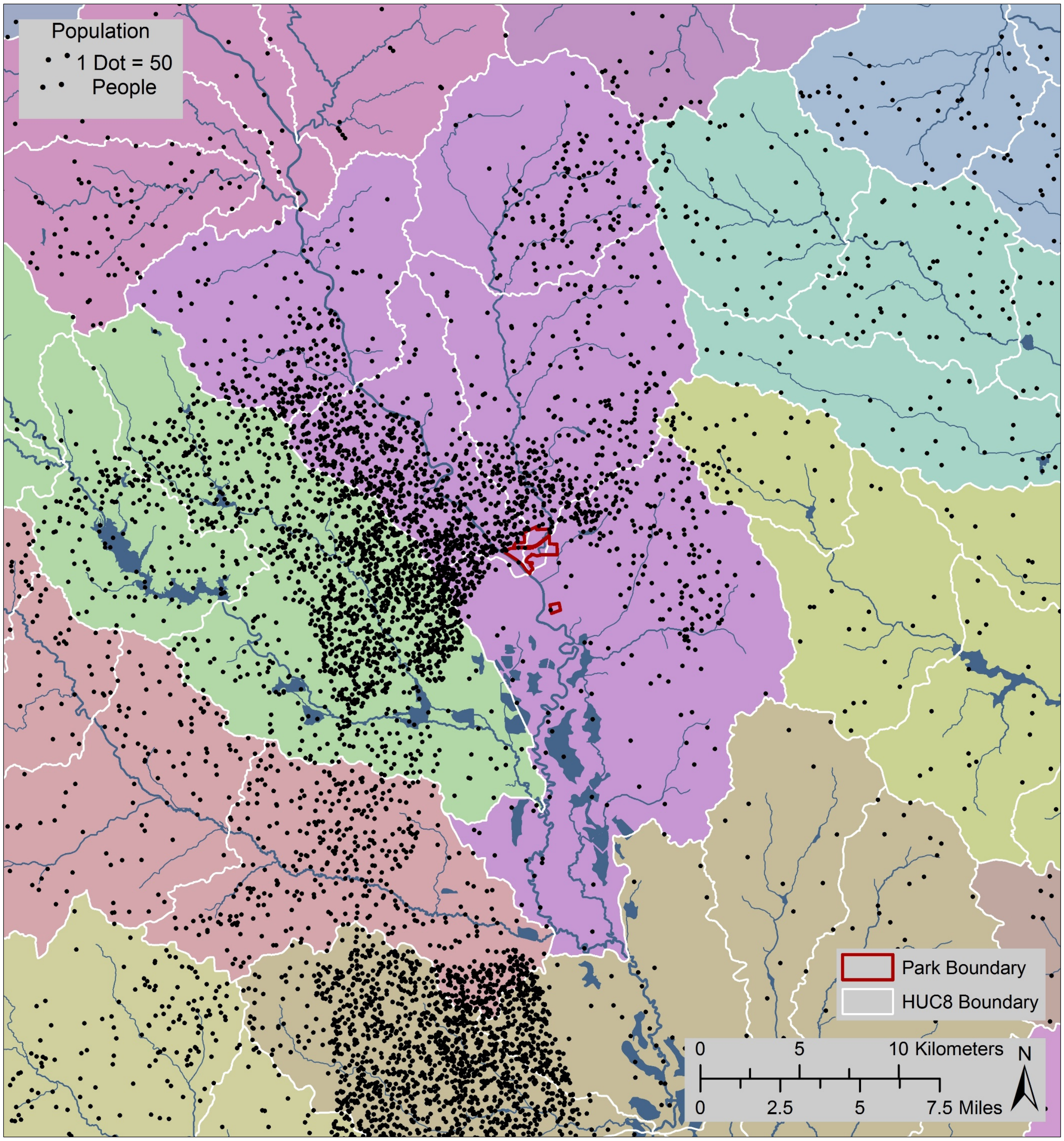


Figure 7. Map of population density as of 2010 in the sub-watershed containing Ocmulgee. Map by Southeast Coast Network.

2.2. Natural Resources

2.2.1. Watersheds

The headwaters of the Ocmulgee River system consist of three streams—Tussahaw Creek, to the Yellow River/South River (same stream; northern portion is the Yellow River), and the Alcovy River (Figure 8). These three streams drain the eastern and southeastern Atlanta metropolitan area, and southeast of Atlanta they flow into an impoundment called Lake Jackson. The Ocmulgee River begins at the outflow of this impoundment. It flows southward, converges with the Little Ocmulgee River at Lumber City in Telfair County, and about 13 kilometers (8 mi) farther downstream it converges with the Oconee River to form the Altamaha River. In the monument area, the Ocmulgee has a gentle slope, flows through a wide floodplain, and meanders between sand bars, willow thickets, steep banks, and backwater sloughs (GA DNR 2004).

2.2.2. Natural Resources Inventory

Air Quality

Federal Criteria for Major Air Pollutants, and a Federal Index Scale

The United States Environmental Protection Agency (EPA) maintains national ambient air Quality Standards (NAAQS) under the federal Clean Air Act (see EPA 2016a). The Clean Air Act has set standards for six criteria pollutants (including two categories for particulate matter, Table 4). The regulatory air quality standards are health-based, and concentrations above the standards are considered unhealthy for sensitive groups. For example, the eight-hour (hr) ozone standard is attained when the average of the fourth highest concentration measured is equal to or below 0.08 parts per million (ppm; 0.075 ppm with the EPA rounding convention), averaged over three years. The standards for the six criteria pollutants are fairly straightforward except for the $PM_{2.5}$ standard: To be in compliance with the federal air $PM_{2.5}$ standard, an area must have an annual arithmetic mean concentration of less than or equal to 15 µg $PM_{2.5}/m^3$. An additional requirement imposed a stricter standard for fine particulate matter as of 2007, wherein the 98th percentile 24-hour concentration must be ≤ 35 µg $PM_{2.5}/m^3$ to protect sensitive groups (Table 5).

Ozone is monitored March–October, when most ozone production occurs (EPA 1994). This pollutant is a serious health concern because it attacks the mammalian respiratory system, causing coughs, chest pain, throat irritation, increased susceptibility to respiratory infections, and impaired lung functioning. In fact, moderate ozone levels can interfere with performance of normal daily activities by people who have asthma or other respiratory diseases. More concerning than acute affects are the chronic effects of repeated exposure to ozone, which can lead to lung inflammation and permanent scarring of lung tissue, loss of lung function, and reduced lung elasticity.

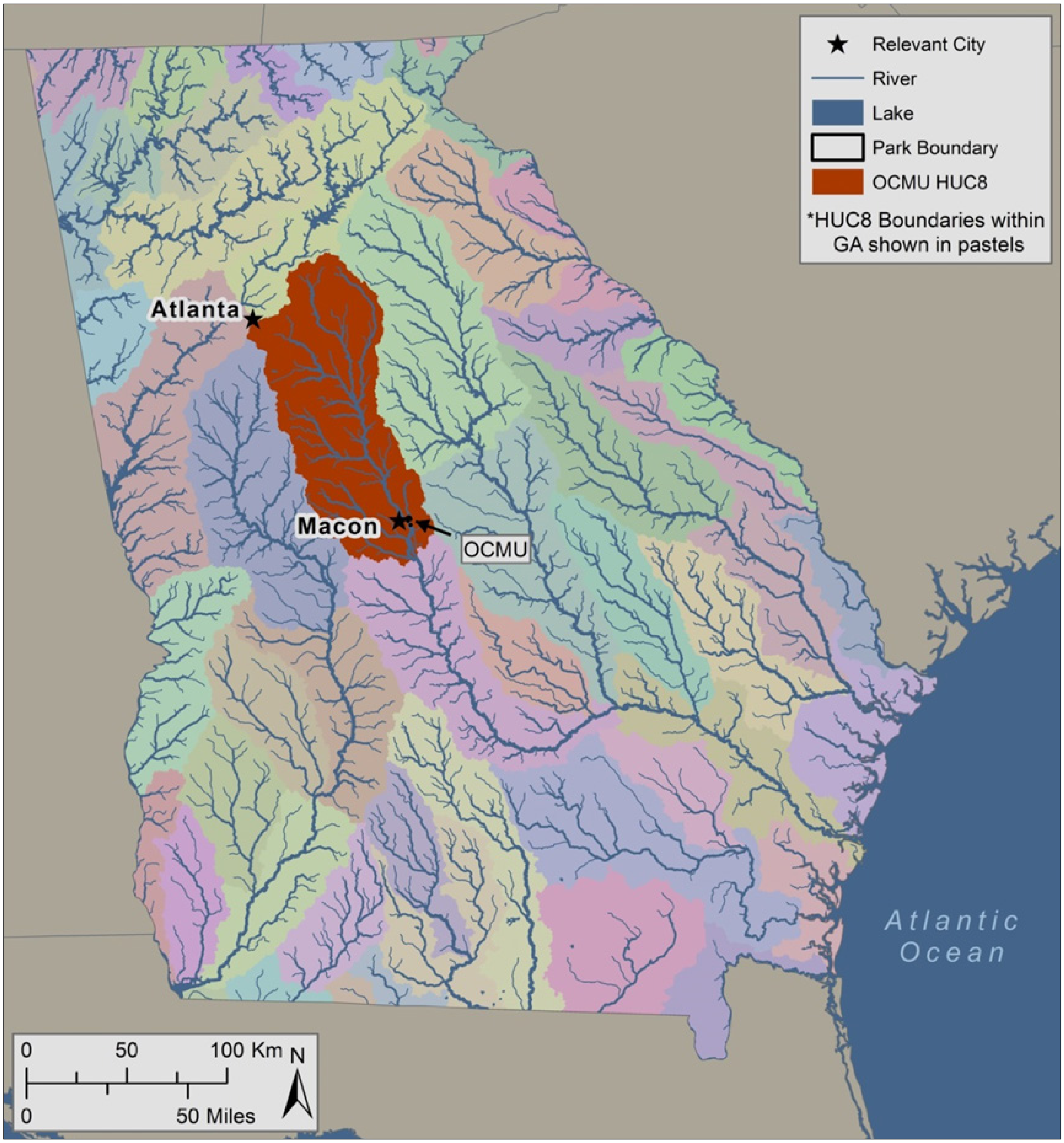


Figure 8. Map showing the Ocmulgee, Oconee, and Altamaha Rivers in Georgia. Map by SECN.

Table 4. National ambient air quality (AQ) standards (NAAQS, 40 CFR part 50), set by the EPA (2014) for six principal ("criteria") pollutants considered harmful to public health and the environment (P—primary; S—secondary).

Pollutant [final rule cited]	Primary / Secondary[a]	Averaging Time	Level	Form
Carbon Monoxide [76 FR 54294, Aug 31, 2011]	P	8-hour	9 ppm	Not to be exceeded more than once per year
		1-hour	35 ppm	Not to be exceeded more than once per year
Lead [73 FR 66964, Nov 12, 2008]	P and S	Rolling 3 month average	0.15 μg/m[b, c]	Not to be exceeded
Nitrogen Dioxide [75 FR 6474, Feb 9, 2010] [61 FR 52852, Oct 8, 1996]	P	1-hour	100 ppb	98^{th} percentile, average over 3 years
	P and S	Annual	53 ppb[d]	Annual Mean
Ozone [73 FR 16436, Mar 27, 2008]	P and S	8-hour	0.075 ppm[c]	Annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years
Particle pollution Dec 14, 2012	P ($PM_{2.5}$)	Annual	12 μg/m[c]	annual mean, averaged over 3 years
	S ($PM_{2.5}$)	Annual	15 μg/m[c]	annual mean, averaged over 3 years
	P and S ($PM_{2.5}$)	24-hour	35 μg/m[c]	98^{th} percentile, average over 3 years
	P and S (PM_{10})	24-hour	150 μg/m[c]	Not to be exceeded more than once per year on average over 3 years
Sulfur Dioxide [75 FR 35520,June 22, 2010]	P	1-hour	75 ppb[e]	99^{th} percentile of 1-hour daily maximum concentrations, averaged over 3 years
[38 FR 25678, Sept 14, 1973]	S	3-hour	0.5 ppm	Not to be exceeded more than once per year

[a]The Clean Air Act identifies two types of national ambient AQ standards: Primary standards provide public health protection, including protecting the health of "sensitive" populations such as asthmatics, children, and the elderly. Secondary standards provide public welfare protection, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings (EPA 2011).

[b] Final rule signed October 15, 2008. The 1978 lead standard (1.5 μg/m^3 as a quarterly average) remains in effect until one year after an area is designated for the 2008 standard, except that in areas designated nonattainment, the 1978 standard remains in effect until implementation plans to attain or maintain the 2008 standard are approved.

[c] Final rule signed March 12, 2008. The 1997 ozone standard (0.08 ppm, annual fourth-highest daily maximum eight-hour concentration, averaged over three years) and related implementation rules remain in place. In 1997, the EPA revoked the one-hour ozone standard (0.12 ppm, not to be exceeded more than once per year) in all areas, although some areas have continued obligations under that standard ("anti-backsliding"). The one-hour ozone standard is attained when the expected number of days per calendar year with maximum hourly average concentrations higher than 0.12 ppm is one day or less.

[d] The official level of the annual NO_2 standard is 0.053 ppm, equal to 53 ppb, which is shown here for the purpose of clearer comparison to the one-hour standard.

[e] Final rule signed June 2, 2010. The 1971 annual and 24-hour SO_2 standards were revoked in that same rulemaking. However, these standards remain in effect until one year after an area is designated for the 2010 standard, except in areas designated non-attainment for the 1971 standards, wherein the 1971 standards remain in effect until implementation plans to attain or maintain the 2010 standard are approved.

Table 5. EPA Air Quality Index (AQI) criteria (modified from AirNow 2015).

$PM_{2.5}$ (24 hr) µg/m3	PM_{10} (24 hr) µg/m3	SO_2 (1 hr) ppm	O_3 (8 hr) ppm	CO (8 hr) ppm	NO_2 (1 hr) ppm	ACI Value	Descriptor	EPA Health Advisory
0.00–15.4	0–54	0–0.035	0.00–0.059	0.0–4.4	0.0–0.053	0–50	GOOD	Air quality satisfactory; little or no risk from air pollution
15.5–40.4	55–154	0.036–0.075	0.060–0.075	4.5–9.4	0.054–0.100	51–100	MODERATE	Air quality acceptable, but for some pollutants there may be a moderate health concern for a small number of unusually sensitive people
40.5–65.4	155–254	0.0766–0.185	0.076–0.095	9.5–12.4	0.101–0.360	101–150	UNHEALTHY for Sensitive Groups	Sensitive groups (people with greater risk from exposure to particulate pollution, ozone
65.5–150.4	255–354	0.186–0.304	0.096–0.115	12.5–15.4	0.361–0.64	151–200	UNHEALTHY	Everyone may begin to sustain health effects; members of sensitive groups may experience more serious health impacts
150.5–250.4	355–424	0.305–0.604	0.116–0.374	15.5–30.4	0.65–1.24	201–300	VERY UNHEALTHY	AQI values trigger a health alert; everyone sustains more serious health effects. If related to high ozone, outside activities should be restricted to morning or late evening to minimize exposure
250.5–500.4	425–604	0.605–1.004	None	30.5–50.4	1.25–2.04	301–500	HAZARDOUS	AQI values over 300 trigger health warnings of emergency conditions; the entire populace is more likely to be affected

Fine particulate matter ($PM_{2.5}$) is produced by various sources including industrial combustion, residential combustion, and vehicle exhaust, or when combustion gases are chemically transformed into particles. Recent research has indicated that $PM_{2.5}$ is a human health concern because it can penetrate into sensitive areas of the lungs and cause persistent coughs, phlegm, wheezing, more serious respiratory and cardiovascular disease, cancers, and premature death at particle levels well below the existing standards (EPA 1994; Schwela 2000). Mounting evidence indicates that $PM_{2.5}$ enhances delivery of other pollutants and allergens deep into lung tissue where the effects are exacerbated. Especially sensitive groups include children, the elderly, and people with cardiovascular or lung diseases such as asthma. $PM_{2.5}$ also impairs visibility and contributes to haze in the humid conditions that characterize the eastern North Carolina climate (EPA 1994).

The EPA air quality index (AQI; scale from 0 to 500 with lower values indicating less pollution) was designed to help inform the general citizenry about potential health impacts from air quality degradation (Tables 5 and 6). The goal is to provide accurate, timely, easily understandable information about daily levels of air pollution with a uniform system for the major air pollutants regulated under the Clean Air Act (GA DNR 1994). The index allows the general citizenry to assess whether air pollution levels in the location of interest are good, moderate, unhealthy for sensitive groups, or worse. For example, an AQI value of 50 indicates good air quality with low potential for adverse public health effects, whereas an AQI of more than 300 indicates hazardous air quality. An AQI less than 100 is generally used as the acceptable level set by the EPA to protect public health (AirNow 2015). Information is also provided about precautions that should be taken if air pollution levels are unhealthy or worse.

NPS Indices for Air Quality

The National Park Service has developed guidance for assessing air quality (AQ) conditions within its parks (NPS 2011). A recent revision of the guidance (NPS 2011) also provided information to evaluate O_3 as related to plant responses. The Air Resources Division of the National Park Service used all available monitoring data over the 2005–2009 period to generate interpolations for the parks throughout the continental United States. The National Park Service then determined an index for each type of air-quality data considered. This included ozone concentrations and exposures (mean annual fourth highest eight-hour ozone concentrations), nitrogen wet deposition; sulfur wet deposition; and visibility condition (group 50 visibility minus estimated annual average natural conditions, where group 50 is the mean of the 40^{th} to 60^{th} percentiles of observed measurements in deciviews [dv]). Park AQ interpolated values are then assigned to one of three condition categories for each NPS AQ index:

- Air quality is in good condition
- Air quality is in moderate condition
- Air quality is a significant concern

Table 6. The AQI translated into actions the general citizenry can take to protect their health from potentially harmful levels of major air pollutants (particle pollution and ozone). From AirNow 2015.

AQI Value	**Actions To Protect Your Health From Particle Pollution**	**Actions to Protect Your Health From Ozone**	**Actions To Protect Your Health From Carbon Monoxide**	**Actions to Protect Your Health From Sulfur Dioxide**
Good (0-50)	None	None	None	None
Moderate (51-100*)	Unusually sensitive people should consider reducing prolonged or heavy exertion.	Unusually sensitive people should consider reducing prolonged or heavy outdoor exertion.	None	None
Unhealthy for Sensitive Groups (101-150)	The following groups should reduce prolonged or heavy outdoor exertion: - People with heart or lung disease - Children and older adults Everyone else should limit prolonged or heavy exertion.	The following groups should reduce prolonged or heavy outdoor exertion: - People with lung disease, such as asthma - Children and older adults - People who are active outdoors	People with heart disease, such as angina, should reduce heavy exertion and avoid sources of carbon monoxide such as heavy traffic.	People with asthma should consider reducing exertion outdoors.
Unhealthy (151-200)	The following groups should avoid all physical activity outdoors: - People with heart or lung disease - Children and older adults Everyone else should avoid prolonged or heavy exertion.	The following groups should avoid prolonged or heavy outdoor exertion: - People with lung disease such as asthma - Children and older adults - People who are active outdoors Everyone else should limit prolonged outdoor exertion.	People with heart disease, such as angina, should reduce moderate exertion and avoid sources of carbon monoxide such as heavy traffic	Children, asthmatics, and people with heart disease should reduce exertion outdoors
Very Unhealthy (201-300)	The following groups should remain indoors and keep activity levels low: - People with heart or lung disease - Children and older adults Everyone else should avoid all physical activity outdoors.	The following groups should avoid all outdoor exertion: - People with lung disease, such as asthma - Children and older adults - People who are active outdoors Everyone else should limit outdoor exertion.	People with heart disease, such as angina, should avoid exertion and sources of carbon monoxide such as heavy traffic	Children, asthmatics, and people with heart or lung disease should avoid outdoor exertion. Everyone else should reduce exertion outdoors.

Ozone Condition

The O_3 human health standard (EPA 2016b) requires that the three-year average of the fourth highest daily maximum eight-hour average ozone concentrations measured at each monitor within the area of interest over each year must not exceed 75 parts per billion (ppb). Accordingly, the National Park Service assigned five-year average values as in Table 7:

Table 7. The NPS ranks for air quality ozone concentrations to protect human health. From NPS (2011).

Ozone Condition (Human Health)	Ozone Concentration
Significant Concern	≥ 76 ppb
Moderate	61–75 ppb
Good	≤ 60 ppb

Note that the "moderate" and "good" conditions are assigned to parks with average five-year fourth-highest eight-hour ozone concentrations > 80% of the standard and < 80% of the standard, respectively.

The National Park Service has incorporated vegetation sensitivity, as well as human health, into its park air quality rating—in consideration of the fact that some plant species have been shown to be more sensitive to O_3 than humans—so use of an O_3 standard for humans would not be sufficiently protective of those plant species. The National Park Service Air Resoures Division issued guidance (NPS 2011) that details the assessment of air quality conditions at park units. Parks are placed at low, moderate, or high risk for ozone injury to vegetation based on the presence of sensitive plant species, O_3 exposures, and environmental conditions (especially soil moisture). For O_3 condition assessment, parks that were evaluated at high risk are moved into the next-worse condition category. For example, a park with an average O_3 concentration of 72 ppb, but evaluated at high risk for vegetation injury, would be moved from "moderate condition" to "significant concern."

The National Park Service also developed a method for rating O_3 condition considering only plant response, based on the EPA's proposed approach—use of the metric W126 for a secondary O_3 standard designed to protect vegetation. The W126 measures cumulative O_3 exposure over the growing season and is considered a better predictor of plant response than the eight-hour human health standard metric. A similar metric, SUM06, also measures cumulative exposure. The thresholds below for both metrics are based on recommendations from an expert workgroup (Table 8): W126 in the range of 7–13 ppm-hour would protect growth effects to tree seedlings in natural forest stands, whereas W126 ranging from 5–9 ppm-hour would protect plants in natural ecosystems from foliar injury (Heck and Cowling 1997; EPA 2007).

Table 8. The NPS ranks for air-quality ozone concentrations to protect sensitive plant species (NPS 2011).

Ozone Condition (Ecological)	Ozone Exposure—W126	Ozone Exposure—SUM06
Significant Concern	> 13 ppm-hr	>15 ppm-hr
Moderate	7–13 ppm-hr	8–15 ppm-hr
Good	< 7 ppm-hr	<8 ppm-hr

Nitrogen and Sulfur Condition

Wet deposition is calculated by multiplying the N or S concentration in precipitation by a normalized precipitation amount (note: dry deposition data are not available). Factors considered in rating the deposition condition include natural background deposition estimates (0.25 kilograms per hectare per year [kg/ha/yr] for either N or S), and deposition effects on ecosystems. Certain sensitive ecosystems respond to levels of N or S deposition at 1.5 kg/ha/yr, whereas information is not available indicating that wet deposition of < 1 kg/ha/yr causes ecosystem harm. Therefore, the National Park Service ranks parks with wet N or S deposition as in Table 9:

Table 9. The NPS ranks for wet deposition of nitrogen (N) or sulfur (S) in air quality condition assessment, in order to protect park ecosystems (NPS 2011).

Deposition Condition	Wet Deposition of N or S (kg/ha/yr)
Significant Concern	> 3
Moderate	1–3
Good	< 1

Note that the basis for the level of deposition ranked as Significant Concern was not given by National Park Service (2011b). Values for parks with ecosystems that are potentially more sensitive to N or S are adjusted up one category.

Visibility Condition

This rating is based on the deviation of the current Group 50 visibility conditions from the estimated Group 50 natural visibility conditions, where Group 50 is the mean of the visibility observations within the range from the 40th through the 60th percentiles. Current visibility is estimated from interpolating the five-year averages of the Group 50 visibility. Visibility is expressed in terms of a Haze Index (derived from calculated light extinction—see EPA 2003b), in dv, according to the following equation:

Visibility = present Group 50 Condition visibility – estimated Group 50 visibility under natural conditions

The dv ranges for these categories were described as subjective, but selected to reflect the variation in visibility conditions across the monitoring network. The NPS criteria for visibility were finalized as shown in Table 10:

Table 10. The NPS ranks for air quality—visibility to protect park ecosystems (NPS 2011).

Visibility Condition	Current Group 50—Estimated Group 50 Natural (dv)
Significant Concern	> 8
Moderate	2–8
Good	< 2

Air Quality in Ocmulgee National Monument and Vicinity

The Robert W. Scherer coal-fired power plant, operated by Georgia Power, is just north of Macon, Georgia in the City of Juliette. Until 2008, the Scherer coal-fired power plant emitted 25.3 million tons of carbon dioxide (CO_2) per year, more than Brazil's entire power sector (Goodell 2006), and it was ranked twentieth in the world for CO_2 emissions (Center for Global Development 2007). In addition to CO_2 emissions, this power plant also discharges substantial sulfur dioxide (SO_2, involved in acid deposition—see below), mercury, and other toxic pollutants to the airshed.

Georgia was ranked as the ninth most toxic state for electric-sector air pollution in 2009 (NRDC 2011). Plant Scherer—37 kilometers (23 miles) from Macon—is one of the largest toxic emission sources in the state. This plant was ranked second in the U.S. for various human health impacts such as asthma, bronchitis, pneumonia, heart disease, and deaths (Clean Air Task Force 2010). Regarding carbon dioxide (CO2) emissions, based on 2011 data, plant Scherer was ranked as the number one emission source (21 million metric tons) in the U.S. (Schneider and Boggs 2013). The Scherer plant ranked fifth among industrial air pollution sources in the state, emitting 580.1 U.S. tons of all air pollutants, including 403.2 kg (889 lb) of mercury (NRDC 2011). Deposition of airborne toxic substances from various sources can contribute to elevated concentrations of certain heavy metals, such as lead and zinc, which have been detected in surface waters upstream from the park (Burkholder et al. 2010). Installed scrubbers divert the toxins to coal ash ponds which also pose many environmental and human health risks via leachate and spills to ground- and surface waters (Carlson and Adriano 1993; The Environmental Integrity Project and Earthjustice 2009).

Cities have also been ranked nationwide for emissions of selected air pollutants, as reported by the American Lung Association annually in its "State of the Air" report (ALA 2013). As of 2012, Atlanta was the 28th most polluted city in the United States for ozone. Atlanta was also ranked as the 18th most polluted city for particle pollution.

Ocmulgee National Monument, downstream from Atlanta, is within a class II airshed under the Clean Air Act (DeVivo et al. 2008; GA DNR 2007d). In Class II airsheds, "modest" increases in air pollution are allowed beyond baseline levels for particulate matter, sulfur dioxide (SO_2), and nitrogen and nitrogen oxides (NOx), provided that federal ambient air quality standards are not exceeded. Air quality is a concern in Ocmulgee NM because violations of the federal/ state ozone standard have been occurring in the Atlanta area—and all of Bibb County—for nearly a decade (2005–2014; GA DNR 2007d, 2012). In consideration of the fact that Atlanta metropolitan population center is projected to continue rapid growth (Burkholder et al. submitted, and references therein). The entire county has also been in violation of the annual arithmetic mean $PM_{2.5}$ concentration ($\leq$15 µg $PM_{2.5}$ /m^3) (GA DNR 2007d, 2012). It is anticipated that air quality, including smog, ozone, particulates, and many other contaminants (GA DNR 2007d), will continue to degrade with increasing population growth (Atlanta Regional Commission 2007).

Acid deposition is another general air-quality issue of concern for Ocmulgee National Monument. Acid precipitation can adversely affect or kill aquatic life and harm human health (Abelson 1987; Herlihy et al.1991; Baker and Christensen 1992), and can act synergistically with ozone to harm human health as well (Abelson 1987). The major pollutants from coal-fired power plants, including those involved in acid deposition (SO_2, mostly from coal-fired power plants, and NO_x from coal-fired power plants, car exhausts and other sources) can be transported long distances across airsheds (Schwela 2000). There are four acid deposition tracking sites in Georgia (Figure 9), including three in north Georgia (Summer, Dawsonville, and Hiawassee), and one in central eastern Georgia (McDuffie County). The four sites monitor acid deposition weekly. As of 2015, precipitation in northern Georgia had a pH of 5.4 (NADP 2015), an improvement from the 2006 measurement of 4.5(NADP 2006).

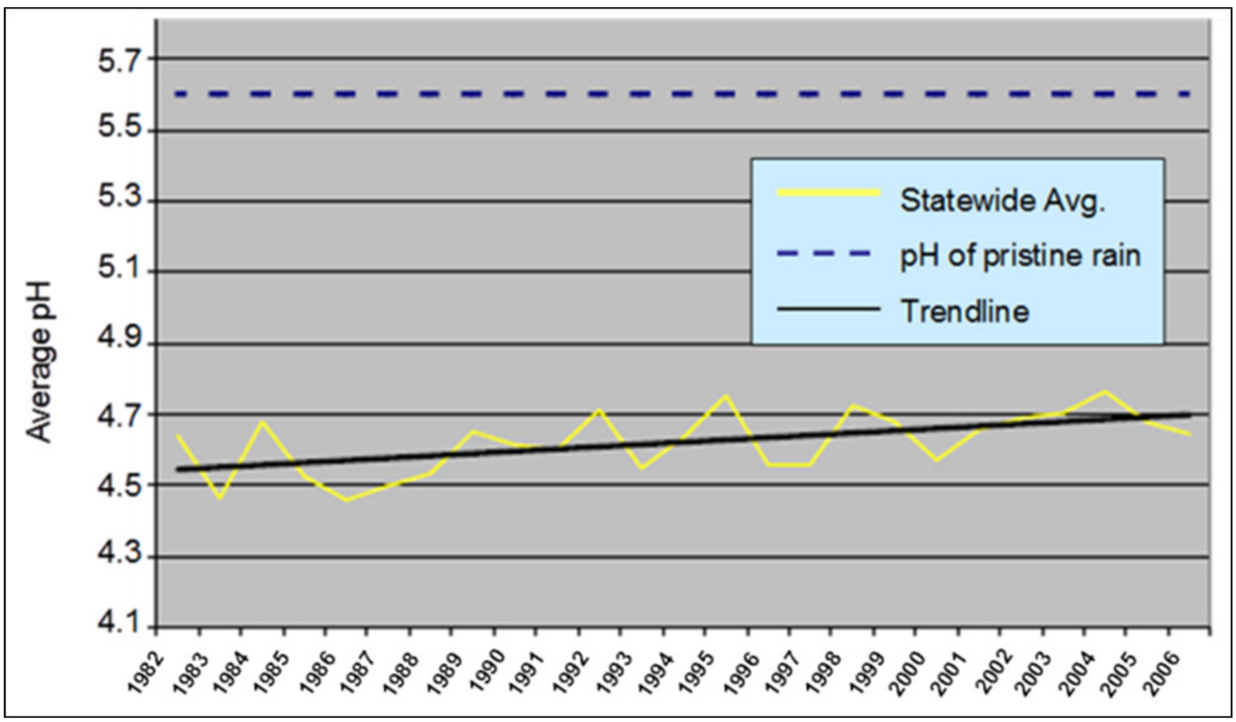


Figure 9. Increasing pH in statewide precipitation (1982–2006). From GA DNR (2007d).

More specific to northwestern Georgia, Sullivan et al. (2011) assessed the threat of acid deposition to national parks across the nation, including Ocmulgee National Monument. First, they compiled and mapped data for total sulfur and total nitrogen emissions from the EPA (2002a; National Emissions Inventory dataset—tons per mile^2 per year); from the National Atmospheric Deposition Program (NADP) for wet deposition (2001–2003—kg/hectare/yr); and from the 12-kilometer Community

Multiscale Air Quality (CMAQ) Model projections for dry deposition for 2002. Then, they ranked the 32 NPS networks and the individual parks within each network considering four metrics: pollutant exposure, ecosystem sensitivity, park protection, and an overall metric, summary risk to acid deposition. This 2011 analysis indicated that the Southeast Coast Network ranked at the top of the second highest quantile in pollutant exposure among the NPS networks. Emissions and deposition of S and N within the network were evaluated as fairly high. The SECN ecosystem sensitivity ranking was very low, in the bottom quintile among the networks, and at the bottom of the second lowest quintile in park protection because it has only limited amounts of protected lands. The network's overall summary risk ranking was relatively low among the networks. However, Ocmulgee National Monument ranked in the highest quintile for pollutant exposure (Figures 10a–10d)). The monument also ranked very low in ecosystem sensitivity, but moderate in both park protection from acidification, and overall summary risk.

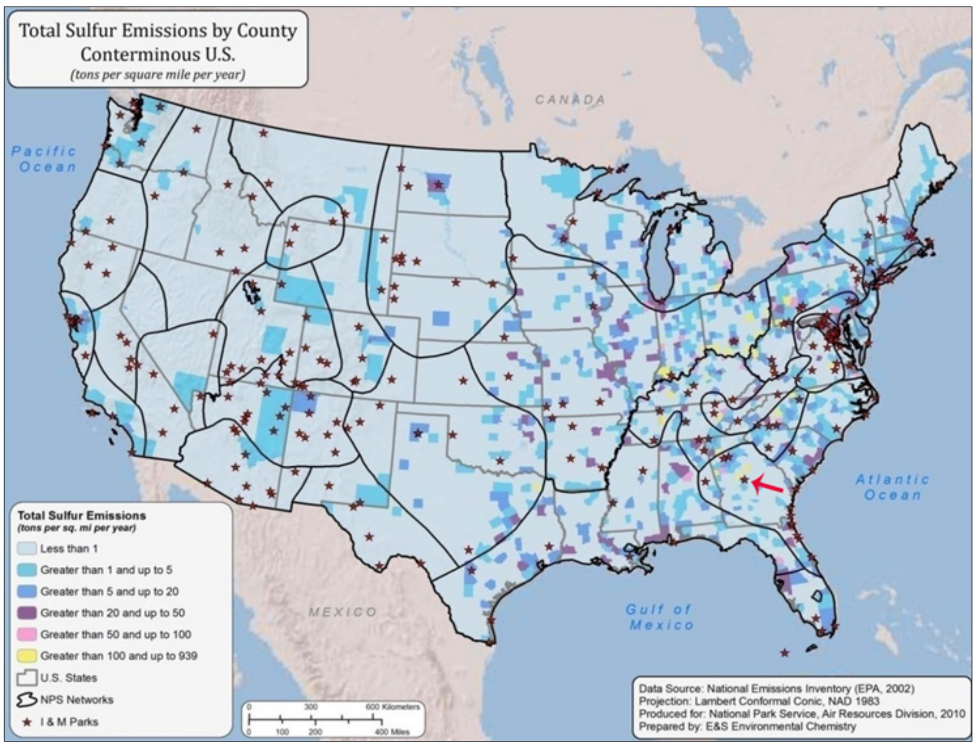


Figure 10a. Map of total sulfur (S) emissions (tons/mi^2/yr) by county as of 2002 (Ocmulgee NM—red arrow).From Sullivan et al. (2011).

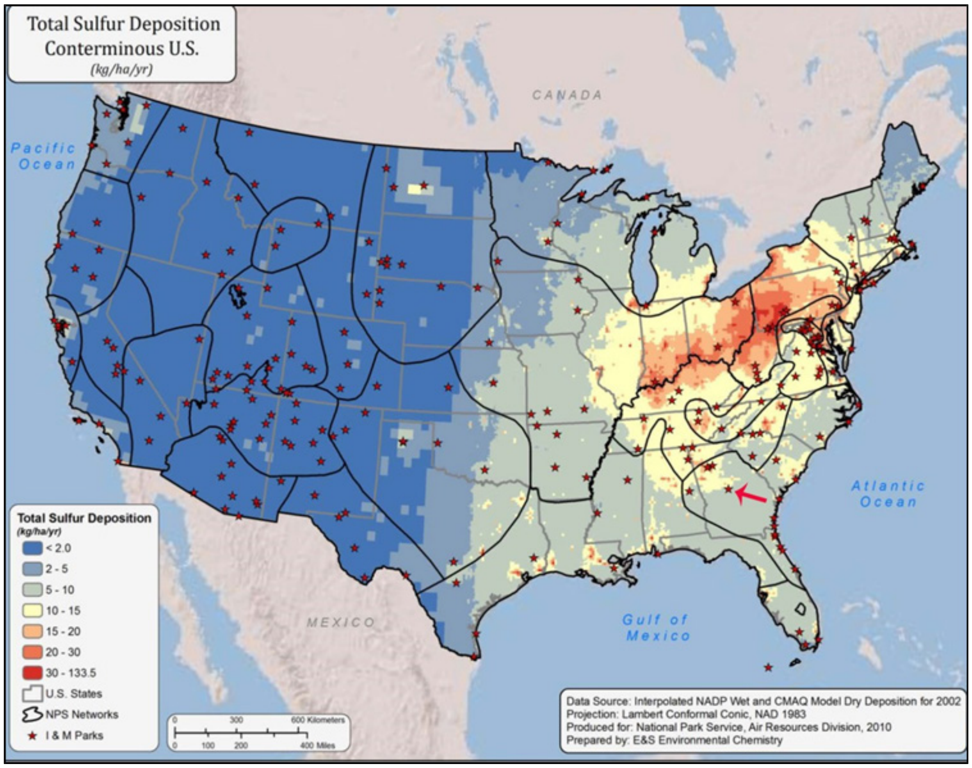


Figure 10b. Map of total sulfur (S) emissions (kg/ha/yr) by county as of 2002 (Ocmulgee NM—red arrow).From Sullivan et al. (2011).

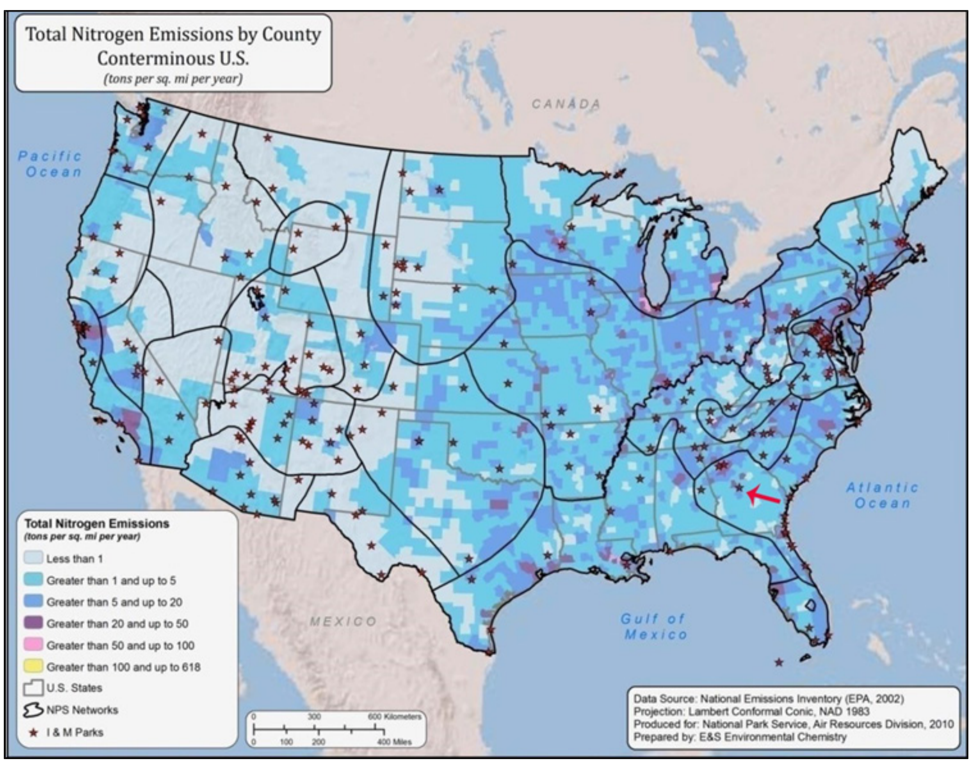


Figure 10c. Map of total nitrogen (N) emissions (tons/mi^2/yr) by county as of 2002 (Ocmulgee NM—red arrow).From Sullivan et al. (2011).

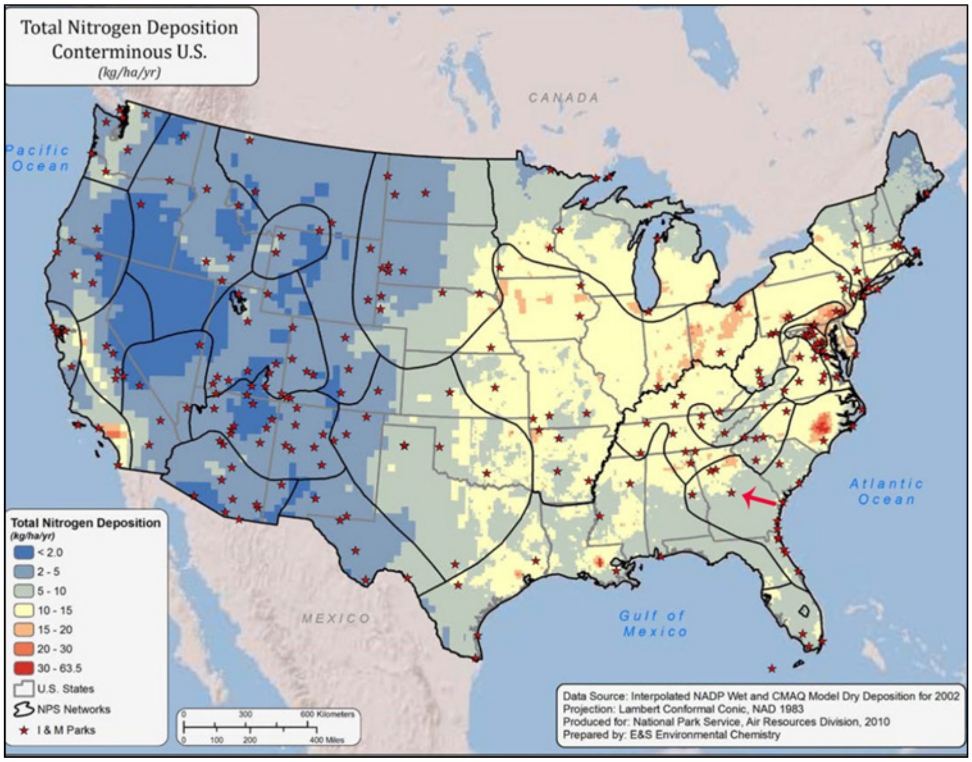


Figure 10d. Map of total nitrogen (N) emissions (kg/ha/yr) by county as of 2002 (Ocmulgee NM—red arrow).From Sullivan et al. (2011).

The Georgia Department of Natural Resources monitors air quality at three sites in Macon near Ocmulgee National Monument. (1) Allied Chemical (site 130210007; parameters PM2.5, 24-hr Federal reference method [FRM] and speciation; PM_{10}), (2) Georgia Forestry Commission (site 130210012: parameters $PM_{2.5}$, 24-hr FRM; SO_2; volatile organic compounds [VOCs], semi-volatile organic compounds, SVOCs; and trace metals), and (3) Lake Tobesofkee (site 130110013; parameters ozone, NOx) (GA DNR 2007d). The area has been in compliance with existing air quality standards for those parameters except for ozone and $PM_{2.5}$. The Macon metropolitan area, including Bibb County, was evaluated for the first time in 2005 as a non-attainment area (2006 Georgia Annual Air Quality Report, described in GA DNR 2007d). In addition, all of Bibb County remains a non-attainment area for $PM_{2.5}$ (GA DNR 2012).

Several air-quality issues were identified for Ocmulgee NM in DeVivo et al. (2008), including potential aerial deposition of (toxic) metals, high risk of foliar injury depending on the air quality conditions, and Sum06 and W126 indices that frequently surpassed the NPS air-quality thresholds identified in Table 11. In 2012, ozone at site 130210012 (GA Forestry Commission) in Macon was monitored for 236 days, and exceeded the eight-hour average standard of 0.075 ppm on six days (GA DNR 2012). Overall, the National Park Service has evaluated the air quality of 0.075 ppm on 6 days (GA DNR 2012). Overall, the National Park Service has evaluated the air quality of Ocmulgee National Monument to be of Significant Concern based on the four NPS indices (Table 11). This evaluation was supported by a recent report by the American Lung Association (2013), which ranked

Macon-Warner Robbins-Fort Valley in a three-way tie for the 14th most polluted city in the nation for average annual levels of particle pollution.

Table 11. Evaluation of air quality conditions (2005-2009) at OCMU (NPS 2009b).

Parameter	Condition
Ozone Condition[a]	Significant concern
N Deposition Condition[b]	Significant concern
S Deposition Condition[c]	Significant concern
Visibility Condition[d]	Significant concern

[a] Ozone condition assessments are derived from interpolated five-year (2005-2009) values of the mean annual 4th-highest 8-hour ozone concentrations.

[b] Nitrogen (N) deposition condition assessments are derived from interpolated five-year (2005-2009) values of nitrogen wet deposition.

[c] Sulfur (S) deposition condition assessments are derived from interpolated five-year (2005-2009) values of sulfur wet deposition.

[d] Visibility condition assessments are derived from interpolated five-year (2005-2009) values of Group 50 visibility minus estimated annual average natural conditions, where Group 50 is the mean of the 40^{th}-60^{th} percentiles of observed measurements in deciviews(dv).

Soundscape

Definitions and Interpretations

Sound is defined as an auditory sensation perceived by humans, and created by pressure variations that move in waves through a medium such as air or water (NPS 2014c). Sound is measured in terms of frequency and amplitude. Noise is defined as sound(s) that is unwanted or inappropriate in an environment. Frequency (sometimes referred to as pitch; units, hertz [Hz]) is the number of times per second that a sound pressure wave repeats itself. Humans with normal hearing can hear sounds ranging from 20 to 20,000 Hz; bats can hear up to 120,000 Hz. Amplitude is defined as the relative strength of sound waves (or transmitted vibrations), perceived as loudness or volume. Amplitude, or the sound pressure level (intensity), is measured in decibels (dB). The terms dB(A) or dB(C) designate two frequency-response functions (weighting characteristics) that filter sounds detected by a microphone in a sound-level meter. Each emphasizes or de-emphasizes sounds of certain pitches relative to others (Figure 11).

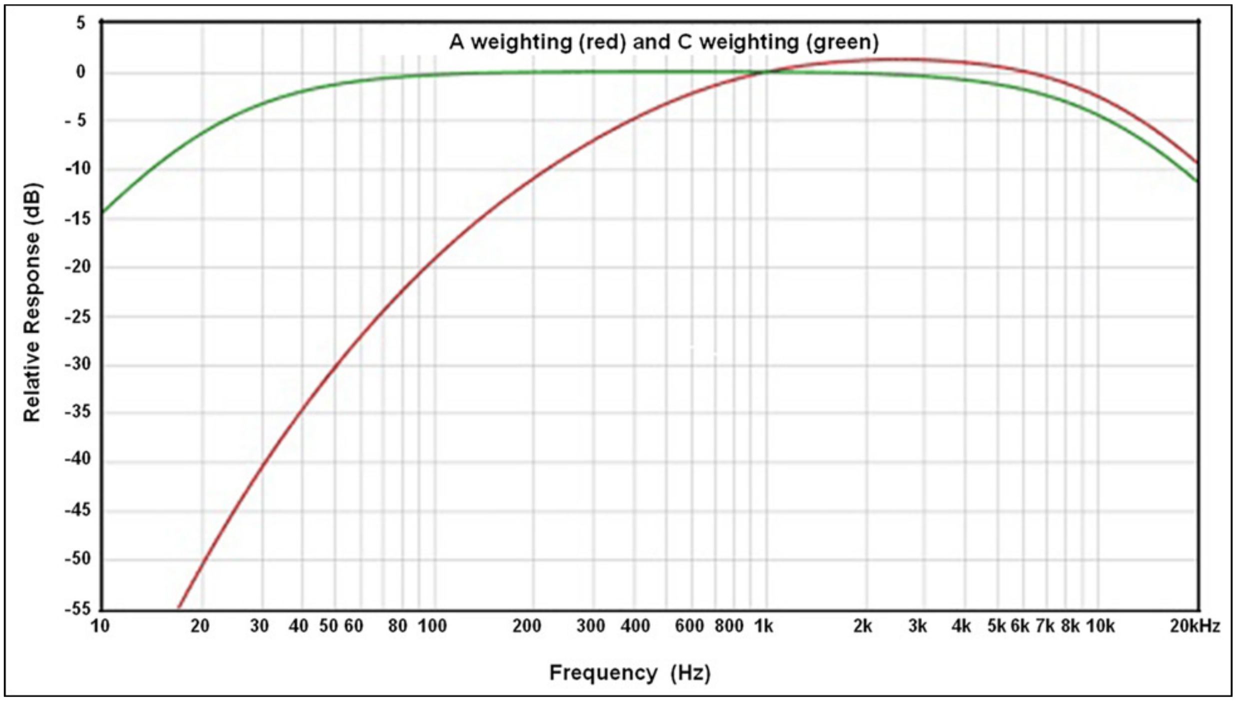


Figure 11. Influence of A- and C-weighting curves on the relationship between dB and frequency (pitch, Hz; modified from Sengpiel 2016).

The "A" weighting, germane to Ocmulgee NM, filters out the low frequencies and slightly emphasizes upper-middle frequencies at two–three kilohertz (kHz). A-weighting, used to assess noise impacts on wildlife, measures hearing risk and compliance with Occupational Safety and Health Administration (OSHA) and Mine Safety and Health Administration (MSHA) regulations that specify permissible noise exposures as a time-weighted average sound level or daily noise "dose" that can be tolerated without appreciable health risks. Thus, the World Health Organization (WHO) has recommended that outdoor environmental noise should not exceed 55 dB(A) and 40 dB(A) for daytime and nighttime activity, respectively, to prevent potential adverse psychosocial and physiological effects. For perspective, the lower threshold of human hearing is 0 dB; moderate sound levels (e.g.,normal speaking voice) are less than 60 db; a typical suburban area is 50–60 dB(A); thunder is 100 dB(A); and a military jet flying at 100metersabove ground level is 120 dB(A) (NPS: see above website, and Crocker 1997).

Because dB are on a logarithmic scale, an increase of 10 dB causes a doubling of perceived loudness and represents a ten-fold increase in sound level. Sound levels adjusted for human hearing are expressed as dB(A). "Soundscape" is used here in accord with the NPS definition, that is, the human perception of these physical sound resources. The acoustical environment is the combination of all of the acoustic resources within a given area, including both natural and non-natural (human-caused) sounds. Thus, it is important to consider the entire acoustical environment in efforts to protect natural sounds.

Sound is an important component of natural park ecosystems; the acoustical environment influences a wide array of animal behavior, such as finding desirable habitat and mates, avoiding predators, protecting young, and establishing territories (Lynch et al. 2011; NPS 2015a). National parks in all regions of the United States are under increasing noise pressure from ground transportation, air transportation, and other human activities (Monroe et al. 2007; Bell et al. 2009; Lynch et al. 2011). For example, noise levels in park transportation corridors are 1,000-fold higher than natural sound levels (Barber et al. 2009). Noise from airplanes can cause as much as a 70% reduction in the size of the hunting area where predatory animals are able to hear their prey (Barber et al. 2009). Parks are becoming noisier from human activities, even in remote areas, in conflict with the fact that 70% of Americans have indicated that one of the most important reasons for preserving national parks is to provide opportunities to experience natural peace and the sounds of nature (Haas and Wakefield 1998). Thus, the National Park Service has determined that "Increasingly, careful consideration of the impacts of human-generated noise on wildlife is a critical component of management for healthy ecosystems in our parks" (NPS 2015a).

Wildlife, like humans, is stressed by the increasing noise and must adapt. For example, robins in suburban and urban environments are now singing at night to be heard by other members of their population (Fuller et al. 2007). Additionally, males of at least one frog species have adapted to traffic noise by calling at a higher pitch, although females have been shown to prefer lower-pitched calls which apparently are indicative of larger, more "fit" males, and bats avoid hunting in areas with road noise (Barber et al. 2009; Parris et al. 2009). Noise stress can exacerbate the impacts of other stressors in national parks, with important ramifications for wildlife populations.

The Soundscape of Ocmulgee National Monument

Urban environmental noise reaches Ocmulgee NM from sources such as aircraft, construction, trains, and road traffic. The NPS Management Policies and Director's Order #47, *Sound Preservation and Noise Management*, called for and directed the protection of the natural ambient soundscape so as to minimize and optimally manage noise, defined as unwanted sound, especially dissonant human-caused sounds. However, most noise sources measured in national parks (e.g.,highways, airplane traffic) originate outside park boundaries, beyond NPS management jurisdiction (Bell et al. 2009; Lynch et al. 2011). The National Park Service recognizes that no single metric is adequate to characterize acoustic resources; thus, the Natural Sounds and Night Skies Division of the National Park Service works with several metrics and considers SPL data, spectral data, audibility data, source identification data, and meteorological data (Lynch et al. 2011).

In its location on the fringe of the Atlanta area and immediately adjacent to/within the City of Macon, the monument has been degraded by anthropogenic noise through increased motorized recreation and urban development (Seong et al. 2011). Robbins Air Force Base, 22.9 kilometers (14.2 mi) south of the Lamar mounds unit, contributes both noise and air pollution from incoming/ outgoing flights. The World Health Organization has recommended that outdoor environmental noise should not exceed 55 dB(A) and 40 dB(A) for daytime and nighttime activity, respectively, to prevent potential psychosocial effects. A wide array of wildlife can also be significantly adversely impacted by chronic noise pollution. As summarized by Barber et al. (2011), noise inhibits the perception of sounds, an effect called masking. Compromised hearing can adversely alter acoustical communication (birds, frogs) and negatively affect sleeping and hibernating animals (Parris et al. 2009; Barber et al. 2010, and references therein). Noise also impacts animal physiology and behavior, and chronic stress from noise can adversely affect an animal's energy budget, reproductive success, and long-term survival (Barber et al. 2010; Shannon et al. 2016).

Somewhat analogously, although data specific to the area are not available (Chief Ranger Guy Lachine, pers. comm., 30 April 2013), substantial road noise from cross-cutting and adjacent highways and streets has been reported to affect Ocmulgee National Monument; interstate traffic volume is increasing and perimeter vegetation is dying, thus reducing its capacity as a sound barrier.

Lightscape

Light pollution is defined as the upward "spill" of light that is scattered and reflected by water vapor, dust, and other particles to create "sky glow" (NPS 2007). The National Park Service uses the term "natural lightscape" to describe resources and values that exist in the absence of human-caused light at night.

Management Policies (NPS 2006) directs the National Park Service to conserve natural lightscapes, in part because protection of natural darkness is important for ecological integrity and sustainability. Light from cities can be visible from more than 322 kilometers (200 mi) away (Rich and Longcore 2006; NPS 2007). Thus, to maintain a natural nocturnal lightscape, it is essential to minimize the sky glow from artificial light. There is evidence that human circadian rhythms, melatonin production, and breast cancer rates are adversely impacted by artificial light (Stephens 2009). Although research on light pollution versus wildlife is relatively sparse, the available studies suggest that artificial light also adversely affects the natural environment and the biological rhythms of flora and fauna. Nocturnal predators are especially affected, with "cascading" effects on prey species. Many bird species migrate at night and, thus, are prone to disorientation by artificial lights. Some biomes are more sensitive than others, such as wetlands, ponds, and shorelines.

The National Park Service is committed to minimizing light from park facilities at night, and to restricting the use of artificial light insofar as possible. However, as with noise pollution, the problem of artificial light pollution at night is caused by sources beyond NPS control, such as highways and the general night sky glow from Macon (Figure 12). The burgeoning light pollution of the eastern United States has been increasing over time, and became especially noticeable in the 1970s for the Atlanta area (Figure 13). Significantly increasing light pollution has been forecast for the Atlanta/Macon region by 2025 (Cinzano et al. 2001).

Figure 12. Macon, Ga. at night (2010). From William Haun Photography, with permission.

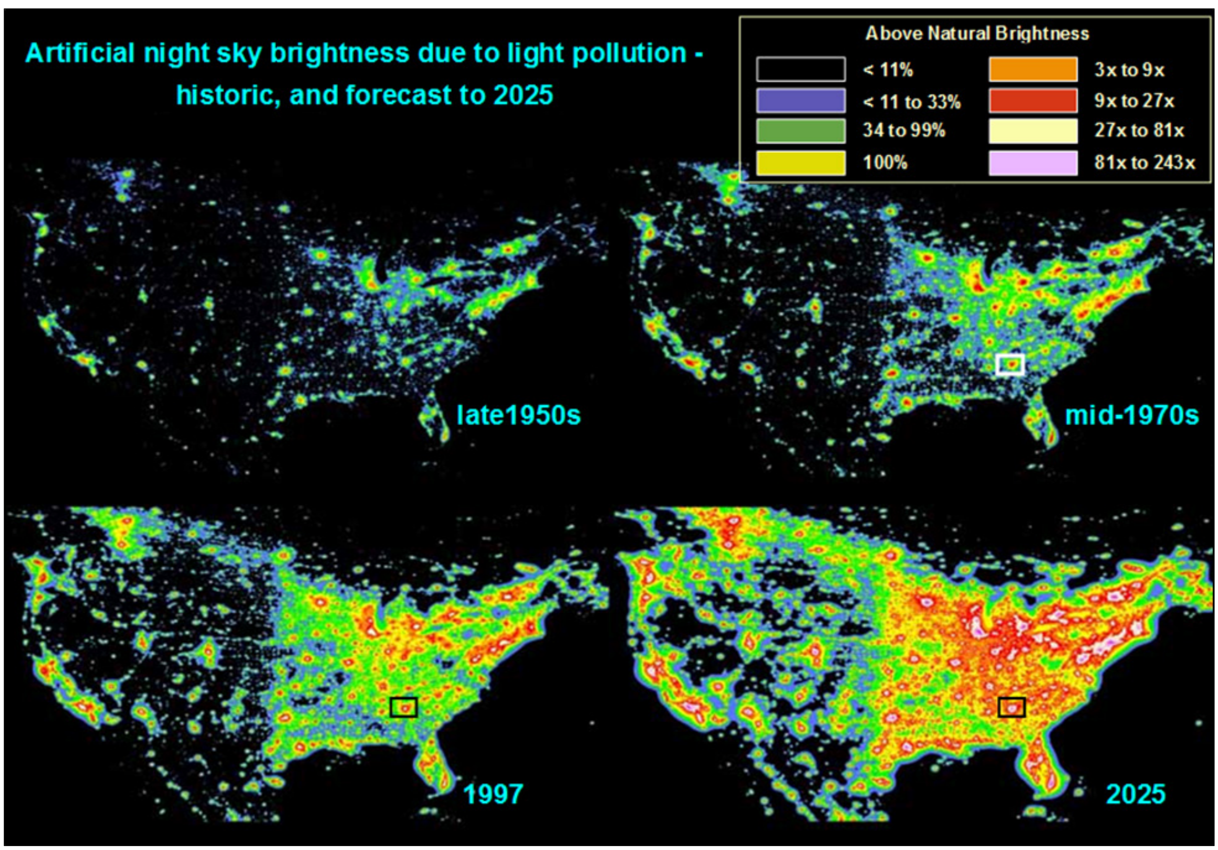


Figure 13. Map of artificial night sky brightness due to light pollution in the 1950s, 1970s, 1997, and projected to 2025. The box highlights the Atlanta Metropolitan area north of OCMU. Modified from Cinzano et al. (2001).

Although various instruments are available for measuring light in the night sky (NPS 2012c), few such data have been collected as of yet for national parks in much of the network. Two alternatives for providing baseline information are considered here: First, the Bortle Dark-Sky Scale (BDSS, range 1–9) was developed to assess light pollution using a numerical scale that is easily understood by the general citizenry, policymakers, etc. (Table 12). Truly dark skies typically have a BDSS of 7.1 to 7.5. The larger the magnitude number, the dimmer the star. Each whole number represents a factor of 5 in brightness—thus, a magnitude-5 star appears to be five-fold brighter than a magnitude 6 star, whereas a magnitude-4 star appears to be ten-fold brighter than a magnitude-6 star (see Bortle 2001 and Bortle 2006). According to Chief Ranger Guy Lachine (30 April 2013), parts of Ocmulgee NM can have artificial light equivalent to rural/suburban transition (6.1–6.5), bright suburban sky (5.1 to 5.5) and the suburban/urban transition (4.6 to 5.0).

Second, the National Park Service has begun to use the Anthropogenic Light Ratio (ALR) to assess the lightscape of national parks (Moore et al. 2013). For its State of the Parks Program, the National Park Service recently developed a stoplight indicator system (green—good, amber—fair, red—poor) to evaluate the overall light regime condition using a single parameter, the amount of anthropogenic light averaged over the entire sky, measured in the green (human visual) spectral band. If the horizon is fairly unobstructed while the measurement is taken, the measure will not vary significantly because of the microenvironment where it was taken. The average anthropogenic light (anthropogenic quanta) is calculated as the total observed sky brightness minus the natural night sky environment where it was taken. The average anthropogenic light (anthropogenic quanta) is calculated as the total observed sky brightness minus the natural night sky component (average brightness, 78 nanolamberts [nL], a measure of luminance by starlight). A ratio of 0.0 would indicate pristine natural conditions (anthropogenic component, 0 nL; natural component, 78 nL). A ratio of 1.0 would indicate that anthropogenic light was 100% brighter than natural light from the night sky, equating to a situation where both the anthropogenic component and the natural component equal 78 nL.

The average anthropogenic sky luminance is derived from ground-based empirical data if available or, alternatively from a GIS model (calibrated to other ground-based measures) derived from data in the 2001 World Atlas of Night Sky Brightness (Cinzano et al. 2001). The World Atlas depicts zenith sky brightness, that is, the brightness of the sky directly above the observer. A neighborhood analysis is applied to determine the anthropogenic sky brightness over the entire sky. The modeled anthropogenic light over the entire sky is presented as the ALR.

Table 12. The Bortle Dark-Sky Scale for assessing artificial light pollution. The column labeled "naked-eye limiting magnitude" indicates the dimmest stars visible under each class of light pollution [NELM—Naked-eye limiting magnitude].

Class	Color Key	NELM	Sky Description	Milky Way (MW)	Astronomical Objects	Zodiacal Light/Con-stellateing	Airglow and Clouds	Night Time Scene
1		7.6–8.0	Excellent, truly dark skies	MW shows great detail and light from the Scorpio/Sagittarius region—casts obvious shadow on the ground	M33 (Pinwheel Galaxy) is an obvious object	Zodiacal light has an obvious color and can stretch across the entire sky	Bluish airglow is visible near the horizon and clouds appear as dark blobs against the backdrop of the stars	The brightness of Jupiter and Venus is annoying to night vision; ground objects are barely lit and trees and hills are dark
2		7.1–7.5	Typical, truly dark skies	Summer MW shows great detail and has veined appearance	M33 is visible with direct vision, as are many globular clusters	Zodiacal light bright enough to cast weak shadows after dark and has an apparent color	Airglow may be weakly apparent and clouds still appear as dark blobs	Ground is mostly dark, but objects projecting into the sky are discernible
3		6.6–7.0	Rural sky	MW still appears complex, dark voids and bright patches and meandering outline are all visible	Brightest Globular Clusters are distinct, but M33 only visible with averted vision; M31 (Andromeda Galaxy) obviously visible	Zodiacal light is striking in spring and autumn, extending 60 degrees above the horizon	Airglow is not visible and clouds are faintly illuminated, except at the zenith	Some light pollution evident along the horizon; ground objects are vaguely apparent
4		6.1–6.5	Rural/ suburban transition	Only well above the horizon does the MW reveal any structure; fine details lost	M33 is difficult to see, even with averted vision; M31 still readily visible	Zodiacal light is clearly evident, but extends less than 45 degrees after dusk	Clouds faintly illuminated except at the zenith	Light pollution domes are obvious in several directions; sky is noticeably brighter than the terrain
5		5.6–6.0	Suburban sky	MW appears washed out overhead and is lost completely near the horizon	The oval of M31 is detectable, as is the glow in the Orion Nebula	Only hints of zodiacal light in spring and autumn	Clouds are noticeably brighter than the sky, even at the zenith	Light pollution domes are obvious to casual observers; ground objects are partly lit
6		5.1–5.5	Bright suburban sky	MW only apparent overhead and appears broken as fainter parts are lost to sky glow	M31 is detectable only as a faint smudge; Orion Nebula is seldom glimpsed	Zodiacal light is not visible; constellations are seen and not lost against a starry sky	Clouds anywhere in the sky appear faintly bright as they reflect back light	Sky from horizon to 35 degrees glows with grayish color; ground is well lit
7		4.6–5.0	Suburban/ urban transition	MW is totally invisible or nearly so	M31 and the Beehive Cluster are rarely glimpsed	The brighter constellations are clearly recognizable	Clouds brilliantly lit	Entire sky background appears washed out, with a grayish or yellowish color
8		4.1–4.5	City sky	MW is not visible at all	The Pleiades Cluster is visible, but very few other objects can be detected	Dimmer constellations lack key stars	Clouds brilliantly lit	Entire sky background has an orangish glow and it is bright enough to read at night
9		4.0 at best	Inner city sky	MW is not visible at all	Only the Pleiades Cluster is visible to all but the most experienced observers	Only the brightest constellations are discernible and they are missing stars	Clouds brilliantly lit	Entire sky background has a bright glow, even at the zenith

The ALR has two levels of sensitivity, based on NRSS I&M Division natural resource designations (Table 13): Level 1 parks, including Ocmulgee National Monument, have significant natural resources considering its value as a greenspace in the Atlanta area, so that the nighttime photic environment has a greater potential influence on the natural resources and ecosystems (Moore et al. 2013). These areas tend to have higher-quality night sky conditions and lower levels of light pollution (anthropogenic light), and tend to be more sensitive to light pollution effects. The threshold separating green from amber conditions is set at an ALR of 0.33 (i.e., one-third brighter than natural conditions), corresponding to the point wherein portions of the sky become sufficiently bright that humans cannot fully adapt to the dark when looking toward them (condition known as scotopic vision, an attribute of human night vision). Above this threshold, humans lose visual sensitivity and require time under dark conditions to re-adapt their eyes. This threshold also corresponds to the transition between Bortle Class 3 (rural and dark) and Class 4 (suburban skies). The threshold separating amber from red conditions is set at an ALR of 2.0, corresponding to the point wherein portions of the sky cast shadows so that the entire Milky Way cannot be seen, the Zodiacal light is seldom seen, and full dark adaptation is not possible regardless of which direction the observer looks (Table 14).

Table 13. Thresholds for the Anthropogenic Light Ratio (ALR)[a] for Level 1 and Level 2 national parks. From Moore et al. (2013, and references therein).[b]

Threshold for Level 1 Parks	Additional Threshold for Areas Managed as Wilderness	Threshold for Level 2 Parks
ALR < 0.33 (< 26 nL avg. anthropogenic light in sky); ≥ 50% of the park area should meet this criterion	ALR < 0.33 (< 26 nL avg. anthropogenic light in sky); ≥ 90% of the wilderness area should meet this criterion	ALR < 2.00 (< 156 nL avg. anthropogenic light in sky); ≥ 50% of the park area should meet this criterion
ALR < 0.33 to 2.00 (26 to 156 nL avg. anthropogenic light in sky); 50% of the park area should meet this criterion	ALR < 0.33 to 2.00 (26 to 156 nL avg. anthropogenic light in sky); ≥ 90% of the wilderness area should meet this criterion	ALR 2.00 to 18.00 (< 156 to 1,404 nL avg. anthropogenic light in sky); ≥ 50% of the park area should meet this criterion
ALR > 2.00 (> 156 nL avg. anthropogenic light in sky); ≥ 50% of the park area should meet this criterion	ALR > 2.00 (> 156 nL avg. anthropogenic light in sky); ≥ 90% of the wilderness area should meet this criterion	ALR 2.00 to 18.00 (> 1,404 nL avg. anthropogenic light in sky); ≥ 50% of the park area should meet this criterion

[a] ALR = average anthropogenic all-sky luminance average (natural all-sky luminance, wherein the average natural all-sky luminance = 78 nL). Light flux is totaled above the horizon (the terrain is omitted) and the anthropogenic and .natural components are expressed as a unit less ratio.

[b] Note that the 90% confidence interval (CI) for the ground-based data = + 8 nL (+ 0.1 ALR); the 90% CI for modeled data = + 40%; and 1 nL = 0.0031831 millicandelas (mcd)/m2.

Table 14. Functional impacts of light regime determinations. From Moore et al. (2013, and references therein).

Qualitative Description	Sensitivity	Good Condition (Green)	Moderate Condition (Amber)	Poor Condition (Red)
Bortle Class	More Sensitive	Bortle Class 1–3	Bortle Class 4	Bortle Class 5–9
	Less Sensitive	Bortle Class 1–4	Bortle Class 5–6	Bortle Class 7–9
Typical Limiting Magnitude	More Sensitive	6.8–7.6	6.3–6.7	< 6.2
	Less Sensitive	6.3–7.6	5.6–6.2	< 5.6
Sky Quality Meter	More Sensitive	≥ 21.60	21.20–21.59	< 21.20
	Less Sensitive	≥ 21.20	19.70–21.19	< 19.70
Celestial Feature Appearance	More Sensitive	Zodiacal light can be seen under favorable conditions; Milky Way shows detail and stretch from horizon to horizon	Milky Way has lost most detail and is not visible near the horizon; Zodiacal light is rarely seen	Milky Way may be visible when directly overhead—otherwise not apparent; Andromeda Galaxy may be barely visible
	Less Sensitive	Milky Way is frequently visible	Milky Way is only visible when it is directly overhead, and is not generally apparent	No extended celestial features are visible; only the brightest constellations are visible
Lightscape Appearance	More Sensitive	Most observers feel they are in a natural environment, with natural features of the night sky readily visible	Anthropogenic light dominates natural celestial features; some shadows from distant lights may be seen	Little sense of naturalness remains in the night sky; the landscape is clearly shadowed or illuminated and the horizon is aglow from light pollution
	Less Sensitive	From within a built environment, the sky appears largely intact	Discoloration of the sky is likely apparent; shadows are seldom noticed from within a built environment	The sky has lost all aspects of naturalness except for a few hundred (or less) visible stars
Human Vision	More Sensitive	Negligible impact to dark adaptation looking in any direction	Dark adaptation possible in at least some directions, although visible shadows likely are present	Full dark adaptation is not possible; substantial glare may be present; circadian rhythms may be disrupted
	Less Sensitive	Full dark adaptation possible in at least some direections, although visible shadows may be present	Full dark adaptation is not possible; shadows are obvious at night from light sources in the sky or along the horizon; circadian rhythms may be disrupted	Full dark adaptation is not possible; there is significant glare from the sky or sources near the horizon; and there is higher concern over impact to circadian rhythms
Sky Quality Index	More Sensitive	> 75	50–74	< 50
	Less Sensitive	> 50	25–49	< 25

Level 2 parks have fewer natural resources; thus, light pollution has less of an influence on biota and ecosystems. Although Level 2 parks themselves can be relatively dark, the night skies tend to be degraded from surrounding urban development contributing high levels of light pollution. The threshold separating green from amber conditions is set at an ALR of 2.0 (characteristics as described above). The threshold separating amber from red conditions is set at an ALR of 18.0, corresponding to the point wherein extended features of the night sky (e.g., the Milky Way and the Andromeda Galaxy) are invisible in nearly all situations, constellations are difficult to identify, and the sky is colored by the light from numerous light pollution sources. At this level of light pollution, photographs at night easily capture the altered appearance of the night sky. Level 2 parks are usually near urban or suburban areas, which also describes Ocmulgee National Monument except for its significance as a greenspace. Because the monument provides habitat for some species of special concern (SSCs) that are threatened or endangered, Ocmulgee National Monument is considered to have a higher-sensitivity (Level 1) photic environment (NPS 2014d).

These ALR thresholds are applied spatially to NPS park units; the designated condition corresponds to the ALR level that exists in at least half of (as the median condition) the park landscape, except for wilderness/proposed wilderness areas wherein the ALR level exists in more than 90% of the area. The recently modeled ALR for Ocmulgee National Monument was 7.5, which is considered to be of significant concern (NPS 2014d) and was expected considering that the monument is within the City of Macon and also within 100 kilometers (62 mi) of the Atlanta metropolitan area (Figure 14).

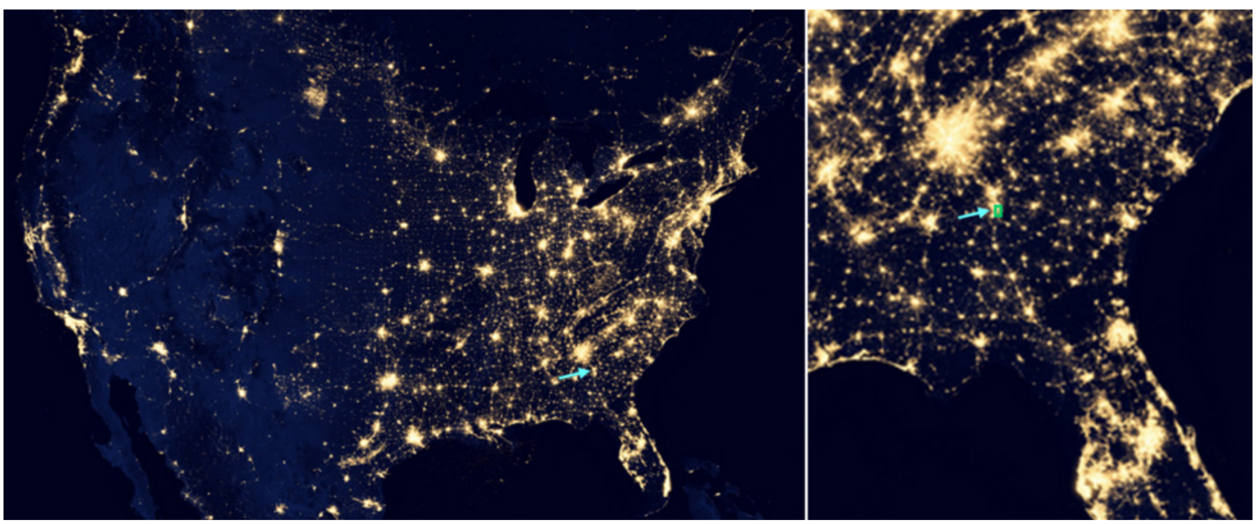


Figure 14. NASA satellite images of the continental U.S. and the Macon, Ga. and OCMU area. Left: NASA satellite image of the continental U.S. at night, representing a composite of data from April and October 2012. Right: Close-up of the same satellite image showing the Macon area (arrow), and OCMU (within the green square) within it. The large, lit area to the northwest is Atlanta. Modified from the NASA Earth Observatory/NOAA National Geophysical Data Center (NGDC) (NASA 2015).

Geology and Soils

Geologic Resources and Dynamics

Ocmulgee National Monument straddles a geologically fascinating area, along the inner margin of the coastal plain physiographic province, but also in very close proximity to the Fall Line, a low, east-facing scarp that parallels the Atlantic coastline (KellerLynn 2013) (Figures 15 and 16). The Fall Line is actually the boundary between two physiographic provinces—the predominantly crystalline rocks of the Piedmont-Blue Ridge (or Piedmont) physiographic province, and the sedimentary rocks of the Coastal Plain. Its name refers to the river rapids and falls that occur as the water flows down-elevation from the higher Piedmont rocks onto the Coastal Plain.

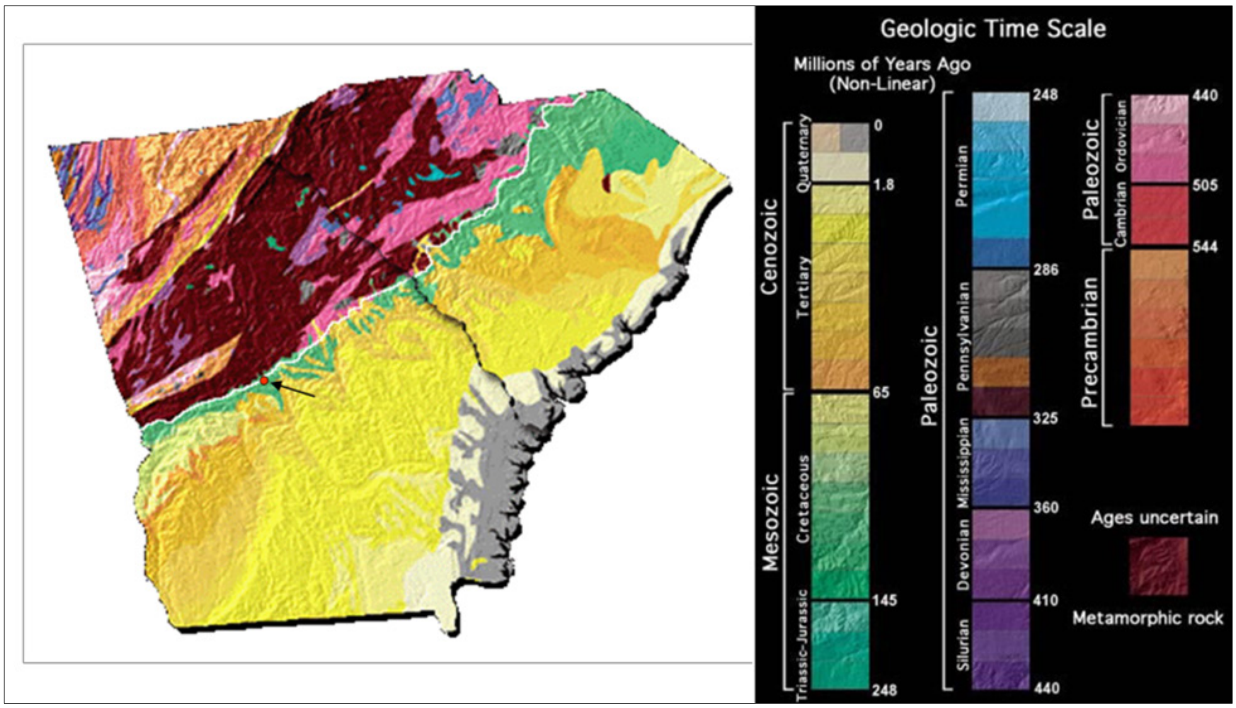


Figure 15. Depiction of the Fall Line and its geology in Georgia and South Carolina (Vigil et al. 2000).

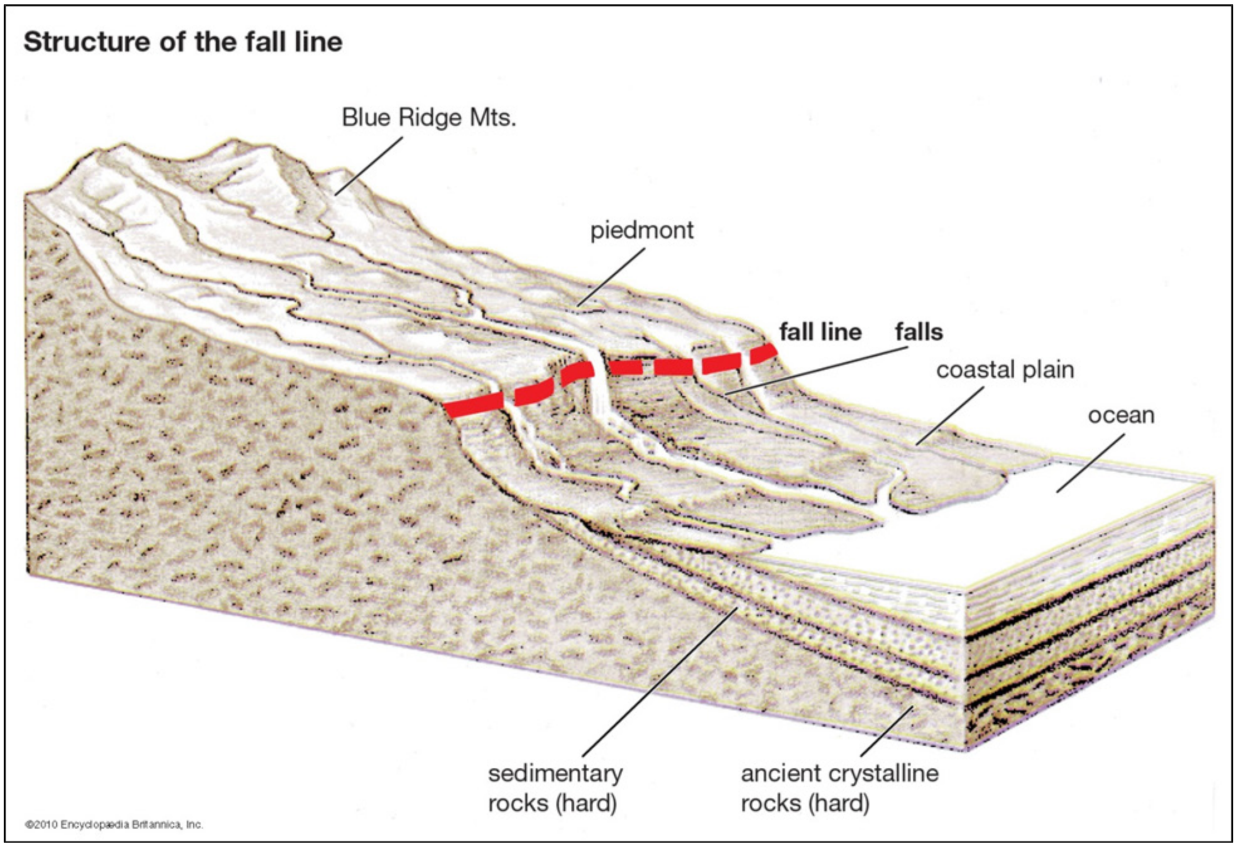


Figure 16. Change in elevation at the Fall Line (Encyclopedia Britannica 2015).

The geological location of the Fall Line demarks the resistant, metamorphic and igneous Paleozoic rocks of the Piedmont physiographic province (542 to 251 million years ago) from the softer, gently dipping Mesozoic (251 to 65.5 million years ago) and Tertiary (65.5 to 2.6 million years ago) sedimentary rocks of the Coastal Plain (LeGrand 1962; Hetrick and Friddell 1990 in KellerLynn 2013). The Paleozoic rocks form outcrops north of Ocmulgee NM. Overall, the geology in the area of the monument is relatively young, of Upper Cretaceous to Holocene age (past 90 million years) (Figure 17). In that region the Coastal Plain consists of thick, relatively unconsolidated strata to partially cemented sands, silts, and clays that slope gently to the southeast. The geology is of Upper Cretaceous to Holocene age (the past 90 million years). These strata slope gently to the southeast and include sand, clay, and gravel as well as Quaternary alluvium (sand, clay, lenses of gravel, and some organic material) along major streams (LeGrand 1962; Hetrick and Friddell 1990 in KellerLynn 2013; Miller 1990).

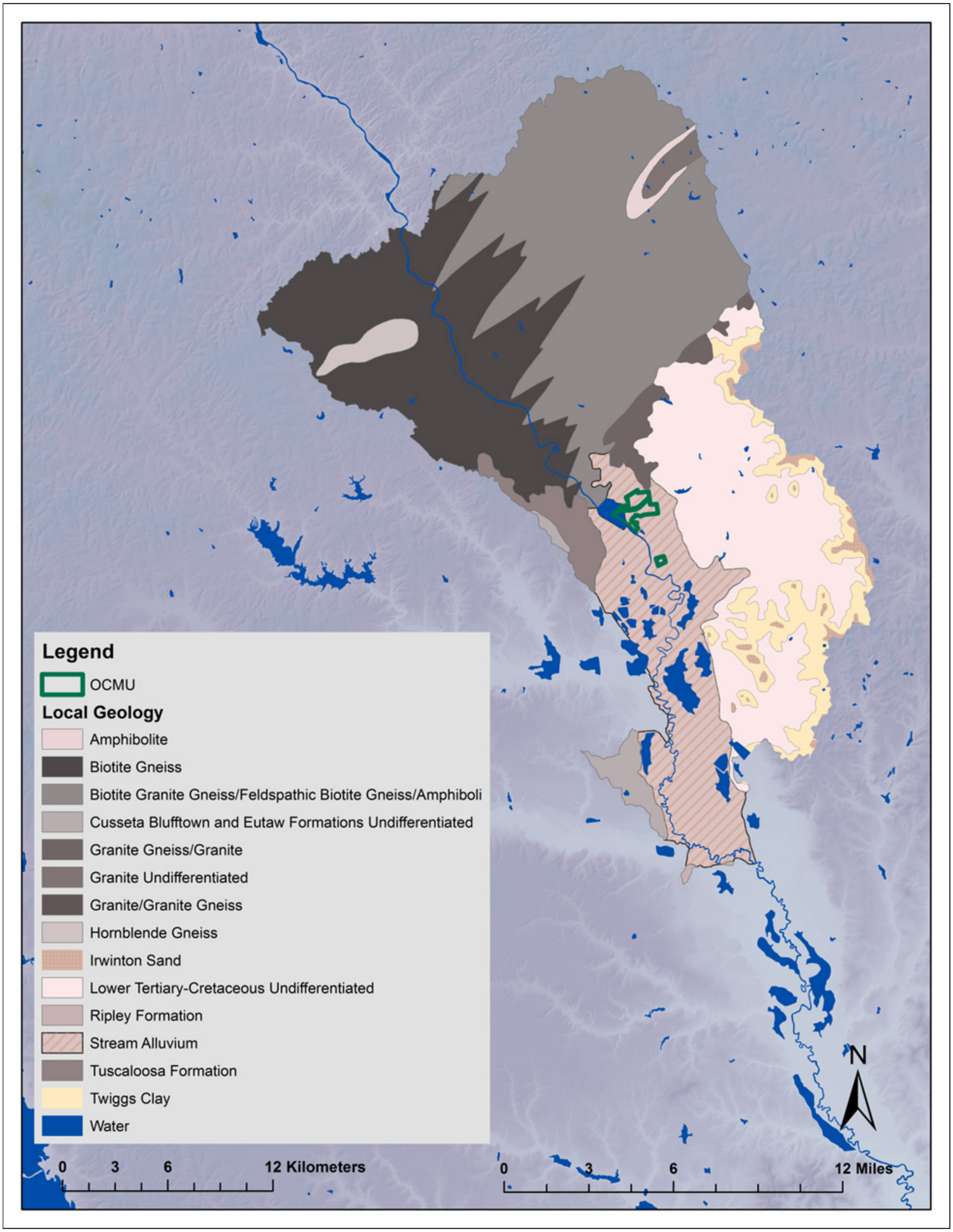


Figure 17. Map of the regional geology, including Ocmulgee NM (both monument units outlined in green). From the NCSU CAAE (S. Flood).

All of the geological units present at the surface or shallow subsurface of the monument, and formations that can occur in the undifferentiated Cretaceous-lower Cenozoic rocks eroded by the streams of Ocmulgee NM, are potentially fossiliferous (Tweet et al. 2009). These include the Upper Cretaceous Tuscaloosa Formation, undifferentiated Upper Cretaceous rocks, the Barnwell Formation, and Quaternary rocks and sediments. Nearby formations that can occur in the undifferentiated deposits (listed from oldest to youngest) include the Tuscaloosa Formation, Eutaw Formation, Blufftown Formation, Cusseta Sand, and Ripley Formation of the Upper Cretaceous, and the Twiggs Clay and Irwinton Sand of the late Eocene Barnwell Formation (Lawton et al. 1976 in KellerLynn 2013).

Within the monument, the upper 12 meters (40 ft) of sediments along the Ocmulgee River and Walnut Creek consist of unsorted clay, sand, and gravel (LeGrand 1962), documenting a long record of flooding through the last 2.6 million years of the Quaternary Period (Cosner 1973 in KellerLynn 2013). The flooding can cause the streams to alter course; for example, in 1994 Tropical Storm Alberto dropped 58 centimeters (23 in) of rain and Walnut Creek cut a new course through unconsolidated sediments (KellerLynn 2013).

A groundwater resources Inventory (GRI) scoping study was conducted in Ocmulgee NM in 2012 (KellerLynn 2013), to identify geologic mapping coverage and needs, distinctive geologic processes and features, geologic resource management issues, and geologic monitoring and research needs. The NPS GRI Geology (GIS-compatible) Geodatabase Data Model incorporates the standards of digital map creation for the GRI and allows for rigorous quality control (KellerLynn 2013). Existing maps can be digitized or digital data can be converted to the GRI digital geologic map using ArcGIS software. The final digital geologic map produces include data in geodatabase and shapefile format, Federal Geographic Data Committee (FGDC)-compliant metadata, a PDF help file that captures ancillary map data, and a document that displays the map. The data model is available through the NPS I&M Division (NPS 2014a). GIS products for the eastern and western areas of interest for Ocmulgee National Monument are available from the NPS Integrated Resource Management Applications (IRMA) portal (NPS GRI 2012a,b). These products are also available in KMZ/KML format for use in Google Earth. Google Earth software is available for free (Google 2015).

Soils and Erosion

Ocmulgee NM lies in the heavier soil class of the Piedmont region in northern Bibb County (1926 Soil Survey). The soils of this well-developed group include all types of Cecil, Davidson, Appling, Norfolk, Orangeburg, Ruston, Greenville, Kalmia, and Wickham series (Table 15, Figure 18). The Davidson and Cecil soils are the most productive soils in that area. These soils are characterized by a surface layer or horizon relatively light in texture comprised of clay loams to sands; an underlying layer relatively “heavy” in texture, ranging from clays to very light sandy loams; and a third, more variable horizon that is usually lighter in texture than the second horizon but heavier than the first. The three layers also vary substantially in thickness, ranging from several centimeters in the clay loams to 0.6 meters (2 ft) in the mostly-sandy soils. The critical shear stress value that has been reported for the surface layer is nearly 10 pascals (Pa) (Navarro 2004); the second layer is only at 2.5 Pa; and the third, deepest layer (deeper than 9 m) has a critical shear stress value of 16.5 Pa.

In general, the area soils are classified as “Bibb typic, fluvaquent,” characteristic of floodplains for streams in the Coastal Plain (Rasmussen et al. 2009). These soils are very deep, poorly drained, and moderately permeable, and they formed in stratified loamy and sandy alluvium. The Bibb typic, fluvaquent soil is on the State of Georgia’s list of hydric soils; they are generally flood-prone and indicative of wetland conditions (Rasmussen et al. 2009).

The high erodibility of these soils (Figure 19) can result in rapid sedimentation within the Ocmulgee River floodplain (e.g., Figure 20). Cosner (1973) reported that more than three meters (10 ft) was deposited along this stream in the main unit of Ocmulgee National Monument in the eighteenth to the twentieth centuries. In the flooding that resulted from Tropical Storm Alberto (1994), 1.7 meters (5.5 ft) of silt accumulated on the floodplain (KellerLynn 2013). This rapid sedimentation in the floodplain would be exacerbated by runoff from upstream urban areas adjacent to the monument. Stormwater may also be driving sedimentation patterns along the unnamed intermittent stream between Funeral Mound and the trading post site in the monument. That stream originates at a culvert on the edge of East Macon, and it is rapidly filling in from sedimentation (KellerLynn 2013). Moreover, siltation within culverts at the main unit has been identified as a concern for maintenance of the monument road (KellerLynn 2013).

Table 15. Percentage of soil types and water in the Main Unit of OCMU (total area, 279.7 hectares [691.2 ac]).

Soil Name	Area (hectares)	Area (acres)	Percent of Total
Chewada association	94.3	233.0	33.7%
Congaree silt loam	57.7	142.6	20.6%
Cowarts sandy loam (2–5% slopes)	6.4	15.9	2.3%
Orangeburg sandy loam (2–5% slopes)	34.1	84.3	12.2%
Orangeburg sandy loam (5–8% slopes)	33.5	82.8	12.0%
Orangeburg-Urban land complex (0–8% slopes)	0.3	0.7	0.1%
Vauduse loamy sand (8–17% slopes)	45.7	113.2	16.4%
Vauduse-Urban land complex (2–8% slopes)	2.1	5.3	0.8%
Water	5.4	13.3	1.9%

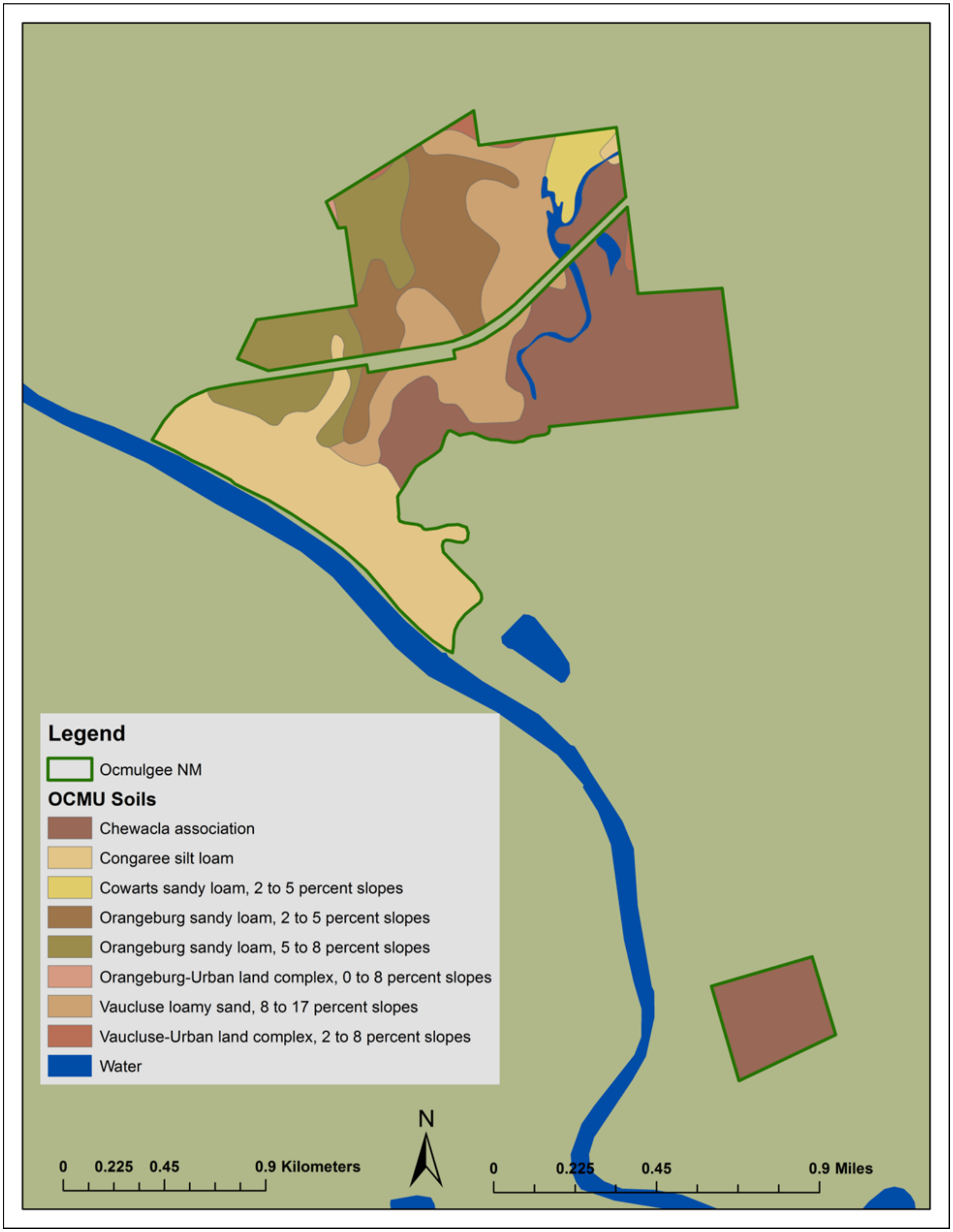


Figure 18. Simplified map of soils within OCMU (see Appendix A for the detailed soil layers in GIS). From the NCSU CAAE (S. Flood).

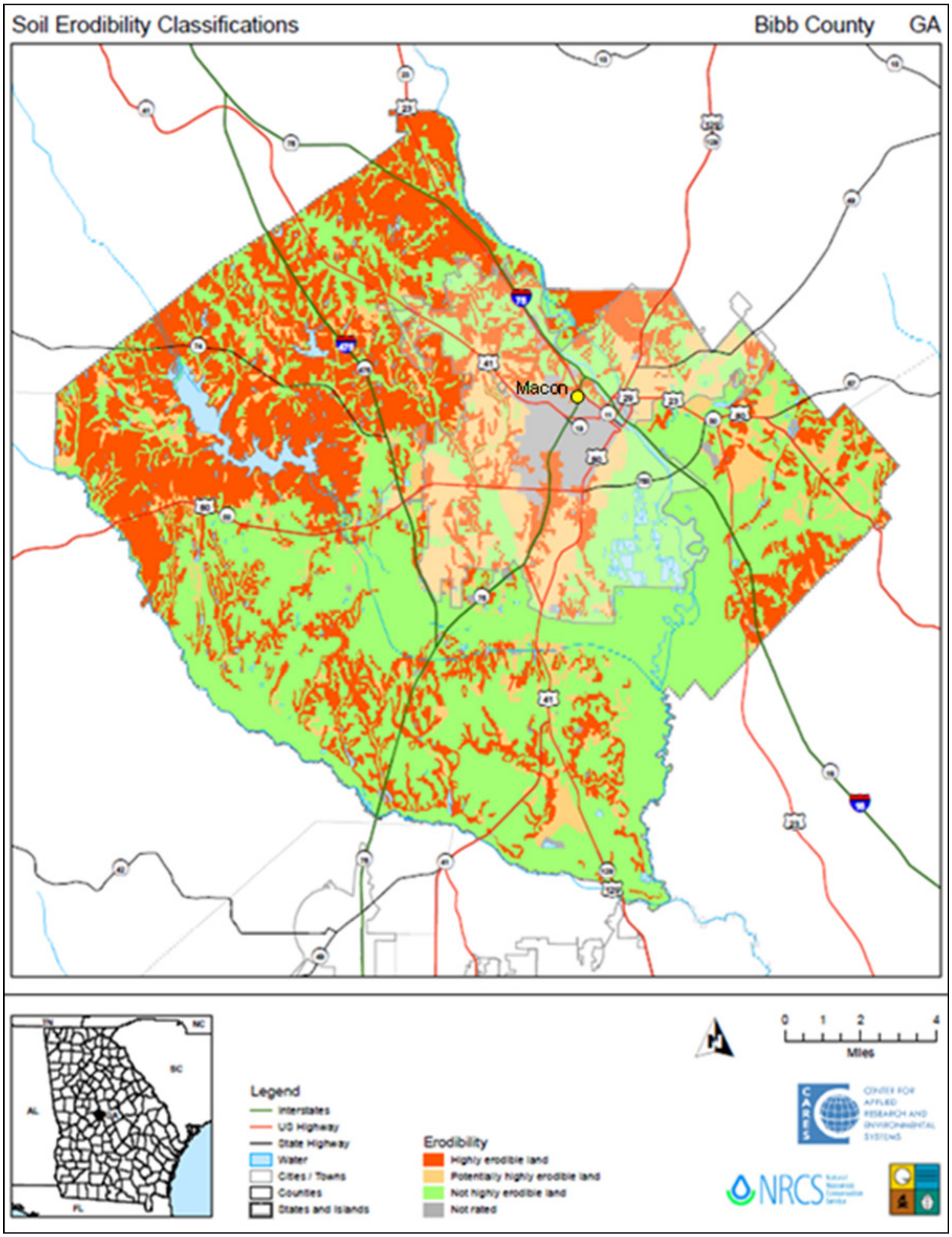


Figure 19. Map showing soil erodibility in Bibb County; although the land specifically east of Macon (yellow dot) was not rated, the area lies within a large tract of "potentially highly erodible land" (light orange) interspersed by narrow tracts of "highly erodible land" (orange–red) (USDA NRCS 2013).

Streambank erosion occurs when stream channels widen to accommodate and transport increased, sudden (“flash-flood” or “flashy”) runoff and higher stream flows from developed areas with elevated impervious area (GA DNR 2001). The runoff events scour and undercut the lower areas of the streambank, causing steeper banks to “slump” and collapse during moderate and major storms. The soil loss from eroded banks contributes to already-high sediment loads, much of which are deposited during larger storms. The higher flow velocities that typically occur in urbanized watersheds with high impervious area exacerbate the problem and increase streambank erosion rates. As an overall result, streams in urbanized watersheds commonly widen to many times their original width (e.g., see Figure 20); their banks become steep and undercut as they are eroded by the higher-volume, flashy runoff; and the sediment from the large “sandbars” and other accumulations. Walnut Creek fits this description (DeVivo et al. 2008).

Figure 20. Streams in the monument, showing substantial siltation and streambank erosion: (a) Walnut Creek near its confluence with the Ocmulgee River, showing signs of heavy siltation and streambank erosion. (b) Walnut Creek delta at its confluence with the Ocmulgee River, showing extensive silt deposits. (c) Channel of a small intermittent stream in the monument (referred to as stream #3 by Burkholder et al. 2010), showing signs of heavy siltation. (d) The channel of stream #3 just outside Ocmulgee, deeply incised by streambank erosion. From Burkholder et al. (2010).

A once-small stream, Walnut Creek, now drains a large part of east Macon (Figure 21), bringing large amounts of trash, pollution, and occasionally raw sewage into the monument. This has raised questions regarding water quality, groundwater quality, and where the pollution goes. Trees along the streambanks become weakened as the erosion progresses, so that some of their major roots are exposed and they can be more easily uprooted and washed away, further destabilizing the streambank. The floodplain elevation for the stream commonly increases as the watershed is developed, due to higher peak flows. This problem is exacerbated by building and filling in floodplain areas.

Figure 21. Walnut Creek, viewed from the railroad bridge in OCMU, historically described as much smaller. From Burkholder et al. (2010).

From a perspective of counseling developers, the Macon-Bibb County Planning and Zoning Commission (2006) reviewed the soils of the area: Soils with “high suitability” for urban development included the Norfolk-Orangeburg, Orangeburg-Faceville, and Vaucluse-Cowarts-Ailey associations. The Vauclus-Lake-land, Lakeland-Ailey, Cowarts-Norfolk-Fuquay, Cecil-Davidson, and Wilkes-Vance soil associations were described as having “intermediate suitability” for urban development because of “moderate to severe erosion problems” and slow subsoil percolation for septic tanks. The Cecil-Vance and Vance-Helena-Wilkes soil associations were also characterized as having “low suitability” for urban development because of “moderate to severe erosion problems, slow subsoil percolation, and shrink-well problems.” Finally, developers were counseled to avoid the Chewacla-Congaree-Hydraquents soil association, located in the floodplain areas, because of “potential severe flooding conditions.” It is noteworthy that about 40% of the soils in Ocmulgee National Monument would be evaluated by the above information as having high suitability for development, underscoring the importance of protecting the land as a national park. Chief Ranger Guy Lachine, who has more than 20 years of experience at Ocmulgee National Monument, described the monument as sustaining "consistent steady soil erosion," and identified stream sedimentation as a management concern (e.g., at the Park Road culvert between the Funeral Mound and the Great Temple Mound).

Water Resources

Drinking water for Ocmulgee National Monument is supplied from the Ocmulgee River by the Macon Water Authority (MWA). It is noteworthy that as of 2009, the Atlanta area already used the Ocmulgee River for 8% of its water supply (Atlanta Regional Commission 2013; see MNGWMD 2009).

Surface Water Hydrology

The dynamic hydrologic framework of Ocmulgee National Monument includes the perennial streams Ocmulgee River and Walnut Creek, intermittent (ephemeral) streams, wetlands, and ponds: Clay Hole Pond is an oxbow of Walnut Creek, and the site of an old clay mine, and there are also two unnamed ponds. In addition, prehistoric ditches still exist at an archeological site, and one ephemeral spring is located on one of the American Indian mounds. Hydrologic features such as stream flow characteristics provide "some of the most appropriate and useful indicators for assessing aquatic ecosystem integrity, and for monitoring environmental changes over time. [They] also provide key support data for other vital signs indicators including water quality, threatened and endangered aquatic species, wetlands, and riparian habitat. THydrologic variation plays a key part in structuring the biotic diversity within river ecosystems by controlling critical habitat conditions within the river channel, the floodplain, and hyporheic zones" (Gregory et al. 2012).

The natural hydrology of Ocmulgee National Monument is poorly understood (DeVivo et al. 2008). The water that once flowed via sheet-flow through wetlands is now diverted through four culverts, and the berm surrounding I-16 (Figure 1) potentially diverts stream flows to a point that influences natural wetland communities (below; DeVivo et al. 2008). Construction of I-16 in the 1960s, directly through the monument's mile-long river boundary, severed the main unit from the Lamar mounds unit and from the Ocmulgee River, and destroyed several archeological sites such as Adkins mound (Obey 2002). Thus, although the National Park Service owns 1.6 kilometers (1 mi) of riverfront, the monument is effectively cut off from it by the highway. In addition to these alterations, flows in the Ocmulgee River near Ocmulgee NM have been impacted for more than 100 years by the construction of Lloyd Shoals Dam (Lake Jackson) in 1911, about 63 kilometers (39 mi) upstream from the monument.

Streams

The Ocmulgee River forms the southwestern border of Ocmulgee National Monument, and Walnut Creek (total length, 32 kilometers [20 mi]; watershed area 130 km^2 [50.2 mi^2]), its largest tributary in the monument, forms part of its southeastern border (Figure 1). An 1827 map shows a smaller stream with a different meandering pattern and a broader floodplain, and a series of oxbow lakes that no longer exist (Figure 22). Creation of the Macon levee in 1950 dramatically altered flooding patterns of the Ocmulgee River (Figure 22). The levee effectively channelized the river, separated it from its floodplain, increased its flow velocity and its depth, increased scouring and erosion, and increased the severity of flooding along the opposite, eastern shore by Ocmulgee National Monument. In addition, about 20 years later the Macon levee was raised 0.9 meters (3 ft) as mitigation for construction of interstate I-16, because that highway raised the projected 100-year flood level by that much (Joe DeVivo, former SECN program manager, pers. comm.). Around 1960, road materials for construction of Interstate 16 were extracted in the vicinity of the Lamar Mounds Unit, which consistently had more standing water than before highway construction. The interstate and associated berm disrupted natural sheet flow in the area. Before construction, water would have flowed freely across the land surface. Now, the berm blocks sheet flow, and water is concentrated and channeled through four culverts through the berm. The ecological impacts of these modifications, particularly to wetlands and natural flood frequency, are poorly understood (DeVivo et al. 2008).

Walnut Creek meanders through the eastern part of the main unit and then along the south-eastern boundary of the monument, where it flows into the Ocmulgee River. Portions of the Ocmulgee River basin, including the Macon area, were affected by massive flooding from Tropical Storm Alberto in 1994 (DeVivo et al. 2008). As a result of this storm, Walnut Creek “jumped channel” and was substantially altered as mentioned (DeVivo 2008 et al.), and a pond (oxbow) near the railroad tracks was destroyed (Chief Ranger G. Lachine, pers. comm.). Floodplain development in this area remains a serious concern (Arcadis 2003; GA DNR 2004). Recently a major attempt to construct another major highway (the Fall Line Freeway, an extension of the Eisenhower Parkway), was stopped. The planned four-lane highway would have run between the two park units and bisected the Ocmulgee Old Fields Traditional Cultural Property (Burkholder et al. 2010). This additional development/ fragmentation will not occur, but the situation exemplifies a state of repeated, concerted efforts to continue to develop the historically important area.

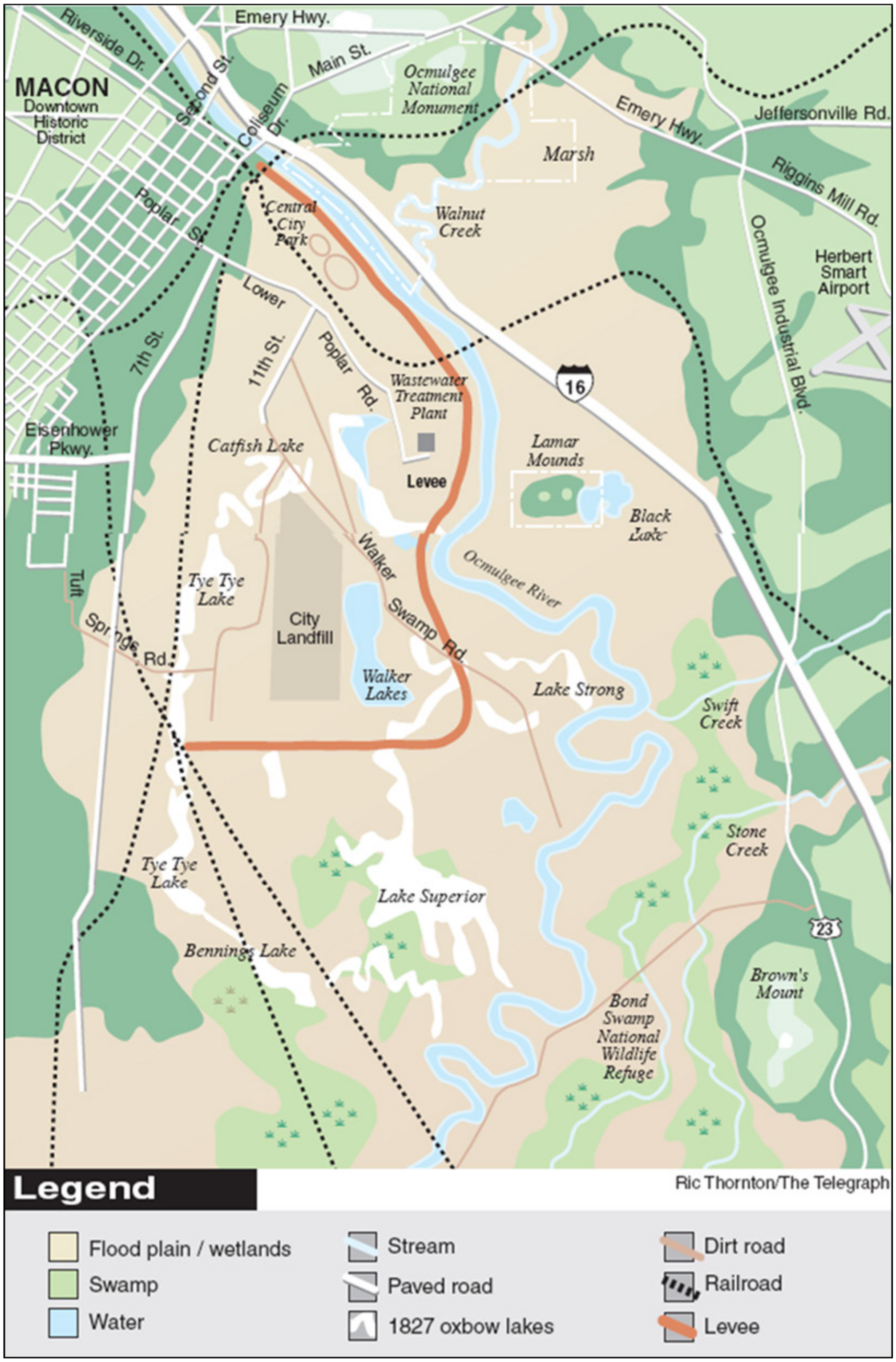


Figure 22. Map showing present-day general features of the Ocmulgee River floodplain near Ocmulgee. Note the meandering channel below the Macon levee, vs. the channelized river in the Ocmulgee area. Other features include the City of Macon landfill across from the Lamar Unit, and the Macon water pollution control plant, which discharges 0.29 kilometer (0.18 mi) below the Lamar Unit. Map by R. Thornton, with permission from The Telegraph.

Walnut Creek and the three smaller streams in Ocmulgee National Monument are characterized by severe streambank alteration and sedimentation. Two of the smaller, unnamed streams are intermittent; one is partly intermittent (Figures 1 and 20). Neither hydrologic nor water quality data are available for these streams. All three are of urban origin and affected by garbage and other wastes (Chief Ranger G. Lachine, pers. comm.). Small stream #1 flows between the Visitors Center and the Earth Lodge, and is a tributary of Walnut Creek. This intermittent stream originates as the outflow of a storm sewer (Chief Ranger G. Lachine, pers. comm.). It is prone to flash floods and also receives runoff from the Ocmulgee parking lot and road. The National Park Service maintained the channel of stream #2 by ditching until about a decade ago, and cessation of that practice has promoted more wetland formation (Chief Ranger G. Lachine, pers. comm.). During wet periods, stream #2 originates from a paved urban culvert in east Macon, goes underground, emerges at the edge of Ocmulgee property, flows through the monument for a short distance, leaves the monument and flows through an economically depressed part of Macon, re-enters the monument, and becomes a tributary of wetlands adjacent to Walnut Creek. The stream can carry a substantial sediment load that has caused major erosion and cut a 20-foot-deep channel. Its deposits have created a large silt plain (Chief Ranger G. Lachine, pers. comm.).

Stream #3 originates in Macon and is fed by the city's storm sewer system. It flows along the Ocmulgee periphery (Figure 20c), flows through an inaccessible area of the monument, and then enters the Ocmulgee River directly. This stream has been the focus of major urban debris cleanup efforts by concerned citizens (Chief Ranger G. Lachine, pers. comm.). It is heavily silted and deeply eroded. It should be noted that there also may be an additional, very small intermittent spring near the central area of the Main Unit of Ocmulgee National Monument, which may flow under the railroad tracks during prolonged wet periods (Chief Ranger G. Lachine, pers. comm.).

Of the two USGS gaging stations near the monument, this report considers station no.02213000 which is on the Ocmulgee River upstream from the monument (Figure 23). It should be noted that the USGS also previously maintained a flow station on Walnut Creek (NAD27, station no. 02213050 in Jones County near Gray, Georgia), 7.2 kilometers (4.5 mi) upstream from the northern boundary of Ocmulgee National Monument (data available from 1961–1994; Figure 23).

Station no. 02213000 is upstream from the Macon levee, and monitors discharge and stage height. Daily discharge data are available from February 1893 to the present, except for a 15-year gap in the early 1900s; gage height has been recorded since October 1992. Real-time data (previous 60 days) have more recently become available as well. Analysis of the data through 2008 by Burkholder et al. (2010) indicated high variation in daily discharge over the past 15 years, ranging from 200 to 50,000 cfs, except for the major flood from Tropical Storm Alberto (1994) when daily discharge was 100,000 cfs. High variation in gage height also was apparent (range 1.5–8.8 meters [4.9–29 ft]; median values at 1.8–3.6 meters [6–12 ft]). USGS data generally have indicated maximal average monthly discharge in winter and minimal average monthly discharge in late summer–early fall.

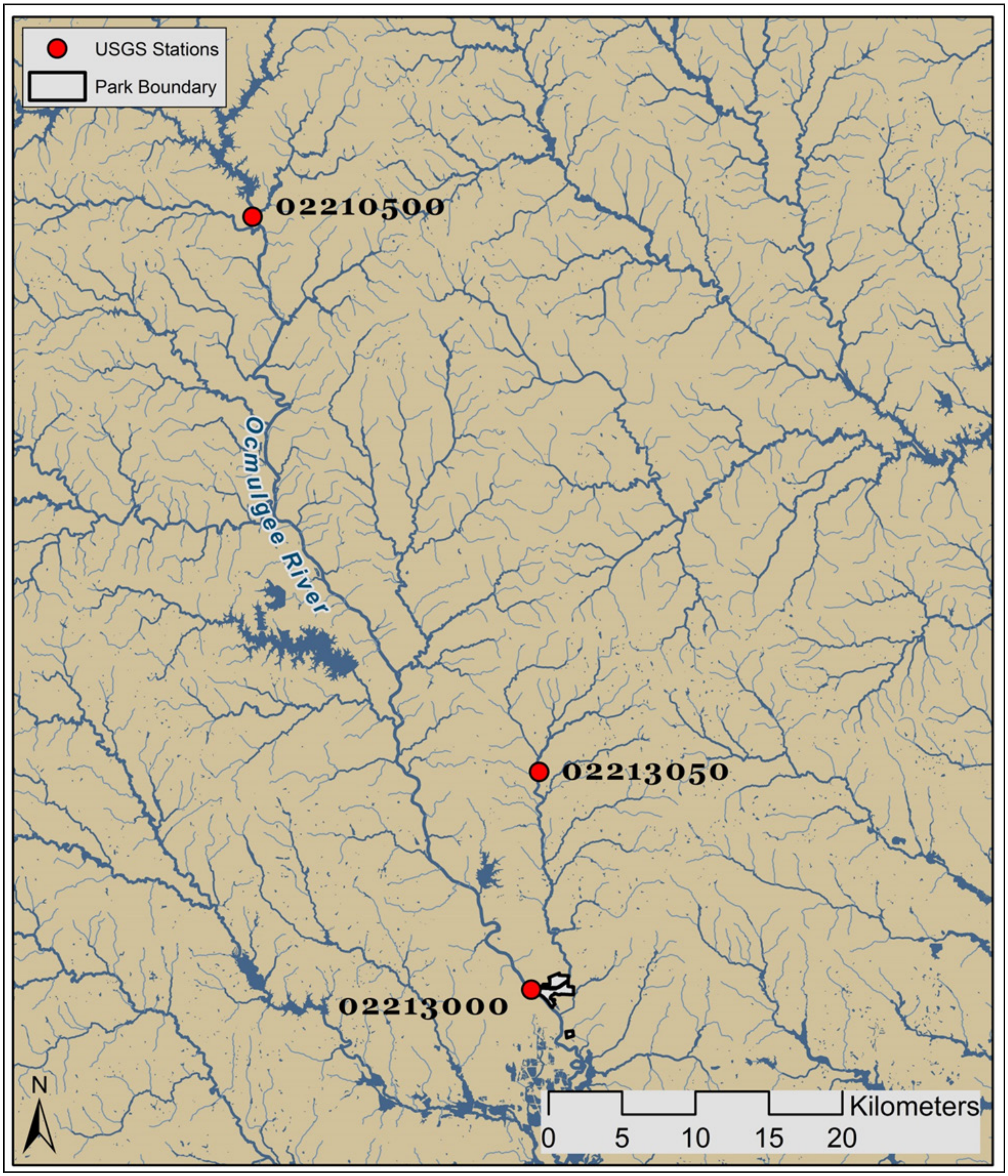


Figure 23. Map showing locations of the three USGS gaging stations nearest Ocmulgee. Station #02213050 is a USGS gaging station on Walnut Creek that was not evaluated. Station #02213000 is on the Ocmulgee River just upstream from the monument. Note that the park is shown in the black outline near station #02213000. Map by Southeast Coast Network.

The NPS Vital Signs Monitoring Program evaluated stream flow variation and the magnitude and timing of specific flow at that USGS station during 2010. Flow patterns were characterized within the context of USGS stream flow, the Nature Conservancy's (2009) Indicators of Hydrologic Alteration (IHA) software, and the program Flow (Dowd 2011) (Tables 16a–16b). The IHA software used single-period daily values in cubic feet per second (cfs) to calculate nonparametric and parametric statistical metrics including mean monthly flow values and extreme event characterization and timing. IHA was also used to calculate Environmental Flow Components (EFCs), used to characterize natural flow and departures from natural conditions. EFCs characterize flow events that have become typical (over a long period such as many years) since perturbations such as diversions or development occurred (Tables 16a–16b). The EFC procedure used by Gregory et al. (2012) set initial high flows as 75% of daily flows for the period of record used, and included the following definitions:

- Small floods—events with a 2-year return interval;
- Large floods—events with a 10-year return interval; and
- Extreme low flows—less than 10% of all flows for the period.

The algorithm makes three passes through the data: first pass—each day is assigned to either low flow or high flow initial event types; second pass—all days initially assigned as high flows are re-assigned to 1, 2, or 3 high flow classes (small floods, high flow pulses etc.); and third pass—some of the initial low-flow days are re-assigned to the extreme low flow class (TNC 2009). Annual stream flow features were described within historical flow context using daily flow graphs (median monthly flow, interquartile range, and daily flow).

Table 16a. Indicators of Hydrologic Alteration (IHA) Metrics, including potential ecosystem influences modified from the IHA User's manual (The Nature Conservancy 2009).

Parameter Type	Definition	Potential Ecosystem Influences
Median Monthly Flow Conditions	Median daily value for each calendar month	Habitat availability for aquatic organisms Soil moisture availability for plants Availability of water for terrestrial animals Availability of food/cover for furbearing mammals Reliability of water supplies for terrestrial animals Access by predators to nesting sites Water temperature, oxygen levels, photosynthesis in water column
Extreme flow conditions	1 to 90 day minimum and maximum flows	Balance of competitive, ruderal, and stress- tolerant organisms Creation of sites for plant colonization Structuring of aquatic ecosystems by abiotic vs. biotic factors Structuring of river channel morphology and physical habitat conditions Soil moisture stress in plants Dehydration in animals Anaerobic stress in plants Volume of nutrient exchanges between rivers and floodplains Duration of stressful conditions such as low oxygen and concentrated chemicals in aquatic environments Distribution of plant communities in lakes, ponds, floodplains Duration of high flows for waste disposal, aeration of spawning beds in channel sediments
Magnitude of extreme flow conditions	Magnitude of 1 to 90 day high and low	Compatibility with life cycles of organisms Predictability/avoidability of stress for organisms Access to special habitats during reproduction or to avoid predation Spawning cues for migratory fish Evolution of life history strategies, behavioral mechanisms
Extreme low flow and low-flow Pulses	Frequency, duration and timing of low flows and low-flow pulses	Enable recruitment of certain floodplain plant species Purge invasive, introduced species from aquatic and riparian communities Concentrate prey into limited areas to benefit predators
High flow pulses	Frequency, duration and timing of high flow pulses	Shape and physical character of river channel, including pools and riffles Determine size of streambed substrates (sand, gravel, cobble) Prevent riparian vegetation from encroaching into channel Restore normal water-quality conditions after prolonged low flows, flushing away waste products and pollutants Aerate eggs in spawning gravels, prevent siltation Maintain suitable salinity conditions in estuaries Influences bedload transport, channel sediment textures, and duration of substrate disturbance high pulses
Small floods	Frequency, duration and timing of small floods	Provide migration and spawning cues for fish Trigger new phase in life cycle (i.e., insects) Enable fish to spawn in floodplain, provide nursery area for juvenile fish Provide new feeding opportunities for fish, waterfowl Recharge floodplain water table Maintain diversity in floodplain forest types through prolonged inundation (i.e., different plant species have different tolerances) Control distribution and abundance of plants on floodplain Deposit nutrients on floodplains

Table 16b. Environmental Flow Components, including potential ecosystem influences modified from the IHA User's manual (The Nature Conservancy 2009).

Parameter Type	Definition	Potential Ecosystem Influences
Monthly low flows	Median low-flow daily value for each calendar month	Provide adequate habitat for aquatic organisms Maintain suitable water temperatures, dissolved oxygen, and water chemistry Maintain water table levels in floodplain, soil moisture for plants Provide drinking water for terrestrial animals Keep fish and amphibian eggs suspended Enable fish to move to feeding and spawning areas Support hyporheic organisms (living in saturated sediments)

Flow Conditions in the Ocmulgee River at Ocmulgee National Monument in 2010—
In 2010 Gregory et al. (2012) found that flow was highest in winter (January–March), and low during most of summer–early fall (Figure 24—upper panel). Based on IHA analysis, flow metrics were as follows: Monthly median flow and low flow ranged from 26.2 cubic meters per second (m^3/s, or 926 cubic feet per second [cfs]) in October) to 165 m^3/s (5,790 cfs) in February (Table 17). Monthly low flow ranged from 26.3 m^3/s (924 cfs) in October to 77.0 m^3/s (2,720 cfs) in February (Table 17). The minimum 1- to 90-day extreme flow ranged from 22.6 m^3/s (792 cfs) for one day) to 34.0 m^3/s (1195 cfs) for 90 days; the maximum 1- to 90-day extreme flow ranged from 703.7 m^3/s (24,700 cfs) for one day to 184.0 m^3/s (6,458 cfs) for 90 days (Table 18). The peak in extreme low flow conditions (0.1 m^3/s or 3.25 cfs, four events) lasted 10.5 days; the peak in high flow pulses (145.2 m^3/s or 5,095 cfs) lasted 3.5 days; and one small low-flow event lasting 44 days occurred in February–March 2010, with peak flow at 29.1 m^3/s (1,020 cfs) (Table 19).

A final point about the hydrology of Ocmulgee National Monument and the surrounding area is that, as noted, the most extensive development in the Ocmulgee River watershed, the Atlanta Metropolitan area, is concentrated in the upper watershed. With increasing population growth in Atlanta, the demands for freshwater supplies are expected to increase (Burkholder et al. 2010).

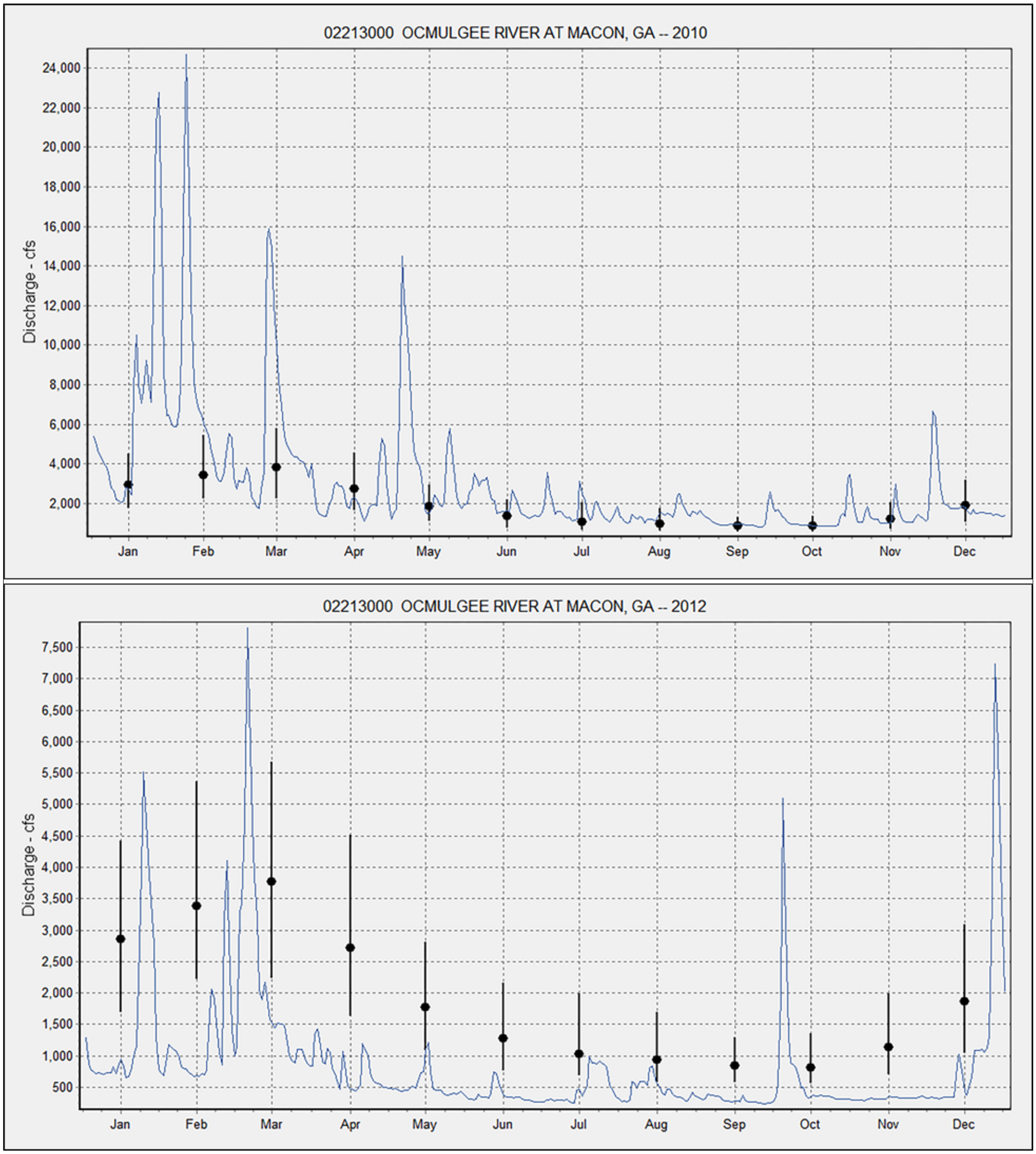


Figure 24. Stream flow at the USGS station on the Ocmulgee River at Macon, just upstream from the monument. Figure shows daily flow (discharge in cfs—blue line), historical median monthly flow (dots), and interquartile range (error bars) in the baseline year 2010 (upper panel) and in 2012 (lower panel; sized to the same scale for comparison). From Gregory et al. (2012).

Table 17. Monthly median and low flow magnitudes during 2010 for the Ocmulgee River (USGS Macon station ID 2213000). These metrics were calculated with the IHA (The Nature Conservancy 2009) using daily data from the USGS (values are in cfs). From Gregory et al. (2012).

Flow	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Median	5,410	5,790	4,040	1,945	2,450	1,635	1,430	1,400	947	926	1,195	1,690
Low	2,420	2,720	2,110	1,910	1,910	1,570	1,390	1,400	947	924	1,195	1,530

Table 18. One- to 90-day extreme flow magnitudes during 2010 at the USGS Macon gaging station. Metrics were calculated using IHA software (The Nature Conservancy 2009); data are from the USGS in cfs. From Gregory et al. (2012).

Flow	1-day	3-day	7-day	30-day	90-day
Minimum	792	803	849	1,050	1,195
Maximum	24,700	20,630	14,150	10,340	6,458

Table 19. Environmental Flow Components during 2010 at the USGS Macon station just upstream from OCMU (Station ID 02213000) (The Nature Conservancy 2009). Timing refers to the date of the first peak event if more than one occurred (EFCs—Environmental Flow Components; NC—metric not calculated). From Gregory et al. (2012).

Component	Extreme Low Flow	High Flow Pulses	Small Flood
Frequency	2	12	0
Peak (cfs)	510	5,095	NC
Duration (days)	4	3.5	NC
Timing	16-Sep	29-May	NC

Flow Conditions in the Ocmulgee River at Ocmulgee National Monument in 2012—
Data for these EFCs were collected at the same USGS station in 2012 (Jones and Gregory 2013). The two years, 2010 and 2012, were strikingly different (Figure 24, upper vs. lower panels): Monthly median flow was two- to four-fold higher in all months of 2010, in comparison to monthly median flow in 2012 (Table 17 vs. Table 20; note that monthly low flow values were not available). In the much drier year 2012, the minimum 1- to 90-day extreme flows were much lower than in the 2010 baseline year (Table 18 vs. Table 21). The maximum 1- to 90-day extreme flow in 2012 was 12.7 m^3/s (447 cfs, 1-day), versus 28.9 m^3/s (1,020 cfs—1 day) in 2010. The peak extreme low flow conditions were somewhat comparable in the two years (2010—510 cfs; 2012—319 cfs), but there were 11 such events in 2012 versus only two in 2010 (Table 19 vs. Table 22). As another difference, the peak extreme low flow, on average, lasted more than twice as long in 2010 than in 2012 (9 days versus 4 days, respectively). There were also more high flow pulses in 2010 than 2012 (12 versus 5, respectively).

Table 20. Monthly median flow magnitudes during 2012 for the Ocmulgee River near OCMU (Station ID 2213000). Median flow was calculated with IHA (The Nature Conservancy 2009) using USGS data collected daily (values are in cfs). From Jones and Gregory (2013).

Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
830	970	1,520	660.5	458	341.5	376	427	298	330	284	789

Table 21. One- to 90-day extreme flow magnitudes during 2012 in the Ocmulgee River near the monument (in cfs). Metrics were calculated using IHA software (The Nature Conservancy 2009); data (in cfs) are from the USGS. (Jones and Gregory 2013).

Flow	1-day	3-day	7-day	30-day	90-day
Minimum	258	261.3	264.4	281.4	430.9
Maximum	7,810	6,380	4,939	2,600	1,710

Table 22. Environmental flow components for flows during 2012 in the Ocmulgee River near the monument (in cfs) (The Nature Conservancy 2009). Timing refers to the average date (i.e., average of Julian dates) of a peak event if more than one occurred. NC—average timing was not calculated due to the distribution of Julian dates (Jones and Gregory 2013).

Component	Extreme Low Flow	High Flow Pulses	Small Flood
Frequency	11	5	0
Peak (cfs)	319	5,570	NC
Duration (days)	9	5	NC
Timing	2-Aug	24-Jan	NC

Wetlands and Ponds

About 40% of the existing acreage of Ocmulgee National Monument is wetlands (Figures 1 and 25), and the large tract of undeveloped wetlands along the southeastern edge of the main unit is considered one of the biggest, oldest peat bogs in the Southeast (DeVivo et al. 2008). The Lamar mounds unit lies on the Ocmulgee River floodplain, and historically the river in this area was a meandering stream with oxbows as mentioned. Bond Swamp National Wildlife Refuge, which contains high diversity of habitat types ranging from mixed hardwood/pine ridges to bottomland hardwoods and swamp forests mixed with creeks, beaver swamps, and oxbow lakes, is also in the general area, about 9.7 kilometers (6 mi) south of Macon and Ocmulgee National Monument. Thus, the monument is along a fragmented greenway corridor for wetland species. The potential addition of the land area considered in the boundary scoping study would unify these greenspaces and wetland areas.

Monument wetlands are diverse in size and origin (Burkholder et al. 2010). For example, the small Clay Hole Pond on monument property was an open pit mine in the late 1800s–early 1900s (Chief Ranger G. Lachine, pers. comm.). This depression, bisected by the Ocmulgee road, is very shallow (usually less than 0.3 meters [1 ft] deep) and its water is from Walnut Creek. The largest wetland on the monument grounds developed since the 1994 flood; it previously was seasonally wet, but now has standing water year-round (Chief Ranger G. Lachine, pers. comm.) (Figure 26). After completing an environmental assessment, the National Park Service recently constructed a substantial boardwalk to/across it as part of a hiking trail. This large pond/wetland area is popular with visitors (Chief Ranger G. Lachine, pers. comm.).

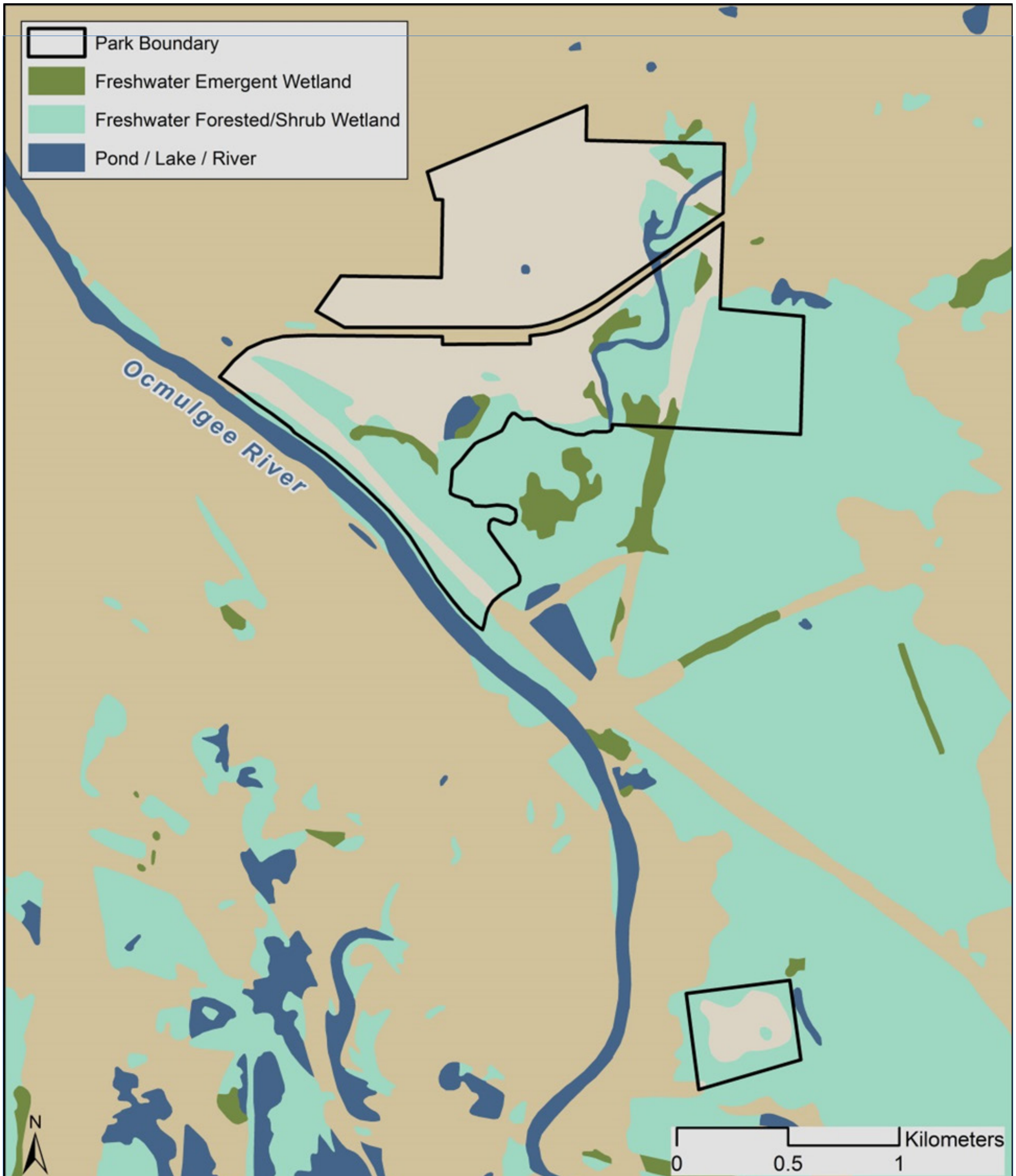


Figure 25. Map of wetlands and waters in and around the monument with simplified key. Categorical definitions of wetland areas were extracted from the 2006 NLCD layer and compared with the most recently available NWI data.

Figure 26. The largest wetland in the monument, viewed from atop the Great Temple Mound in autumn. From Burkholder et al. (2010).

Surface Water Quality

Surface Water Quality Criteria—Following the Clean Water Act (33 U.S.C. 1251 et seq., the Federal Water Pollution Control Act as amended through P.L. 107-303, November 27, 2002), the state of Georgia has developed various standards (criteria) applicable to the surface waters of Ocmulgee National Monument with designated use for fishing. These are presented in Tables 23 and 24, and show parameters for which information from the past decade (1999/2000 to 2010) is available from the two perennial streams in the monument. Samples that have a geometric mean (GM) fecal coliform count exceeding 200 mpn/100 mL during May through October, or exceeding 1,000 mpn/100 mL during November through April, are in violation of the bacteria water quality standard.

Table 23. Georgia water use classifications and in-stream water quality standards for each use (GA DNR 2008a, 2008c, 2008d, 2016). Wild and Scenic Rivers do not allow any alteration of natural water quality.

Use classification	Bacteria (fecal coliforms) 30-day GM[a]	Bacteria (fecal coliforms) Maximum	DO (except trout streams[b]) Daily Avg. (mg/L)	DO (except trout streams[b]) Minimum (mg/L)	pH	Temp (except trout streams[b]) Maximum Rise (F°)	Temp (except trout streams[b]) Maximum (F°)
Drinking Water requiring treatment	1,000 Nov–Apr	4000 Nov–Apr	5.0	4.0	6.9–8.5	5	90
	200 May–Oct	–	–	–	–	–	–
Recreation	200 (freshwater)	–	5.0	4.0	6.0–8.5	5	90
	100 (coastal)	–	–	–	–	–	–
Fishing	1,000 Nov–Apr	4,000 Nov–Apr	5.0	4.0	6.0–8.5	5	90
	200 May–Oct	–	–	–	–	–	–
Coastal Fishing[c]	–[c]	–[c]	–[c]	–[c]	–[c]	–[c]	–[c]

[a] Fecal coliform densities are in units of number/100 mL (GM—geometric mean). Geometric means should be "based on at least 4 samples collected from a given sampling site over a 30-day period at intervals not less than 24 hours". The geometric mean of a series of N terms is the Nth root of their product. Example: the geometric mean of 2 and 18 is the square root of 36. Note: EPA (2003a) recommends consideration of 400 mpn/100 mL as the highest acceptable level of fecal coliforms if samples are taken less frequently.

[b] Standards for Trout Streams for dissolved oxygen are an average of 6.0 mg/L and a minimum of 5.0 mg/L. No temperature alteration is allowed in Primary Trout Streams, and a temperature change of 2°F is allowed in Secondary Trout Streams.

[c] Standards are the same as for fishing with exception of dissolved oxygen, which is site-specific.

Table 24. Summary of Georgia state standards for acceptable water quality in waters classified as Fishing designated use (GA DNR—excluding temperature); summary of conditions for acceptable water quality that have been recommended by other sources; and summary of the status of the Ocmulgee River and Walnut Creek in or near Ocmulgee within the past decade (1999–2010).

Category	Parameter	GA DNR	Other Recommendation(s) or Guideline(s)	Ocmulgee NM
General Water Quality	Dissolved oxygen (mg/L)	≥ 5 daily avg.; minimum 4	≥ 4 mg/L (EPA 2000)	98% compliance (285 of 288 samples)
	pH	≥ 6.0, ≤ 8.5	> 6.5, and < 9.0 (EPA 2000)	100% compliance
	Fecal Coliforms (mpn/100 mL)	≤ 1000 Nov–Apr. ≤ 200 May–Oct (GM)	400 for data collected with insufficient frequency to calculate g.m.s by the State's criteria (EPA 2003b)	74% compliance (192 of 258 samples)
	Nutrients	–	< 30 µg TP/L; < 177 µg NO_3^-+NO_2^-/L (EPA 2000)	65% met the TP recommendation; 23% met the NO_x recommendation
	Biochemical oxygen demand	–	< 3.0 mg/L as the 5-day biochemical oxygen demand (BOD_5) (Mallin et al. 2006)	95% met the recommendation
	Total suspended solids (TSS)	–	≤ 25 mg/L; and < 10 mg/L increase from a sudden spike (EPA 2000)	84% were ≤ 25 mg/L
Toxic metals[a] (µg/L—water column)[b]	Lead	–[2]	CMC 65 µg/L, CCC 2.5 µg/L (EPA 2000, 2002b)	42-71% met the recommendation (location-dependent)
	Zinc	–[2]	CMC 120 µg/L, CCC 87 µg/L (EPA 2000, 2002b)	70% met the recommendation

[a] Dissolved concentrations; equations have been developed that express the total recoverable concentration depending upon the water hardness or pH.

[b] 14 samples and 10 samples were available for lead and zinc, respectively. Water quality guidelines (reference condition, 25th percentile - also see Byrne 2004). CMC—the criterion maximum concentration; CCC—the criterion continuous concentration, within a pH range of 6.5–9.

Georgia's Rules and Regulations for Water Quality Control, Chapter 391-3-6-.03(5)(c) also states that, "All waters shall be free from material related to municipal, industrial or other discharges which produce turbidity, color, odor or other objectionable conditions which interfere with legitimate water uses." Stream segments are placed on the state's Impaired Waters (303(d)) list based on water quality and biota sampling data. For the water use classification of fishing, the criterion violated is listed as Biota Impacted (Bio(F)), reflecting the fact that studies have shown a significant impact of water quality related habitat degradation on fish (GA DNR 2008a,b). Potential causes may be urban runoff, (other) nonpoint sources, and/or a municipal facility(s) (point sources). For fecal coliforms (microbial pathogens), the standards were developed in consideration of general recreational uses, although the state's general policy is not to encourage swimming in any surface waters (GA DNR 2003).

Other recommended guidelines for acceptable water quality in waters designated for use as fishing and general recreation have been published by the EPA (2000, 2002b, 2003b) and other sources (Table 25). The Clean Water Act requires the EPA to develop criteria (i.e., recommendations) for water that are designed in part to protect aquatic life. The criteria are supposed to reflect accurately the up-to-date scientific knowledge. Whereas the State of Georgia has imposed regulations, an EPA water quality recommendation is not a regulation; it does not impose legally binding requirements on the EPA or the states. States have discretion to adopt approaches that differ from the EPA water quality criteria, but these criteria are meant to provide useful guidance.

Table 25. EPA recommendations for reference (minimally impacted) conditions for nutrients, turbidity, and suspended microalgal biomass as chlorophyll a concentrations (F—fluorometric technique; S—spectrophotometric technique) in streams in level III nutrient sub-ecoregion #45, which includes Ocmulgee (EPA 2000). These recommendations were based on the 25th percentile of all available streams data for the previous decade.

Parameter	Number of Streams	25th Percentile-all seasons
TKN (mg/L)	338	0.234
NO_2+NO_3 (mg/L) = NO_x	327	0.177
TN (mg/L)—calculated	NA	0.411
TN (mg/L—reported	18	0.615
TP (µg/L)	436	30
Turbidity (NTU)	35	5.713
Turbidity (FTU)	356	7.488
Turbidity (JCU)	10	5.95
Chlorophyll *a* (µg/L)—F	33	3.3
Chlorophyll *a* (µg/L)—S	11	3.493

In addition to these standards, Phase I NPDES permits regulate stormwater discharges associated with specific industrial activities (including construction sites ≥ one acre in area) and large and medium municipal separate storm sewer systems (MS4s) that serve populations of 100,000 or more. MS4 permits prohibit non-stormwater discharges (i.e., illicit discharges) from entering into storm sewer systems and require controls or best-management practices to reduce pollutant discharges to the "maximum extent practicable" (GA DNR 2003). The intent is to reduce exposure of stormwater to pollution. Ocmulgee National Monument is near MS4 permittees (Phase I permits) in the City of Macon.

Finally, the lack of numeric criteria for nutrients merits explanation: Fully half of U.S. freshwaters and two-thirds of U.S. coastal waters have been evaluated as degraded by nutrient pollution (EPA 2000; National Research Council 2000; also see Barvenik et al. 2009). At present Georgia has only a narrative criterion for nutrient pollution, despite the fact that at the turn of the century, the EPA (2000) mandated the states to develop numeric nutrient criteria (also see Barvenik et al. 2009). An exception to the lack of numeric nutrient criteria in Georgia is that in 1990 the state developed and implemented water quality standards (suspended algal chlorophyll *a*, total phosphorus [TP] loading from major tributaries, total TP loading in pounds per acre-foot per year—but not concentration criteria, total nitrogen [TN] concentration, dissolved oxygen [DO] concentration, water temperature, pH, and fecal coliform bacteria) for selected publicly owned reservoirs (with surface area > 1,000 acres) on a site-specific basis (Georgia's "Lake Law," Senate Bill O.C.G.A 12-5-23.1). A plan for Georgia to develop numeric nutrient criteria was developed in 2008 (GA DNR 2008d; GA EPD 2013), but little progress has been made beyond it. Therefore, this report interprets water quality relative to nutrients using the EPA (2000) recommendations for reference conditions in its level III nutrient ecoregion 9—sub-ecoregion 45, which includes Ocmulgee National Monument.

Surface-Water Quality near Ocmulgee National Monument and Pollution Sources

Monument staff identified surface water quality as a major concern, in recognition of the fact that the streams flowing through the monument enter from developed areas. Despite the fact that Ocmulgee National Monument is immediately adjacent to the City of Macon and historically has sustained sewer overflows, stormwater impacts and reports of other serious water quality problems, little water quality monitoring has been conducted within the past decade. The information in this sub-section was taken or updated as necessary from Burkholder et al. (2010). Locations for sampling stations near or within the monument, discussed in this section, were obtained from EPA STORET. Latitudes and longitudes for these sites were imported from Microsoft Excel into ArcMap and converted to GIS point files.

Ocmulgee National Monument does not have a water resources management plan. Available data sources for surface water quality in or near the monument are at least a decade old, or sparse and infrequently collected (Burkholder et al. 2010). The Ocmulgee River and Walnut Creek historically were impacted by high fecal coliform bacteria and low pH from pollution associated with watershed development and airshed acidification. This report focuses on data taken in the past decade (1999–2010) (Table 24); from those data, surface waters near Ocmulgee National Monument were in compliance with the dissolved oxygen (DO) standard 98% of the time (n = 285 of 288 samples), and 95% of the 43 samples analyzed for BOD_5 (total n = 43 samples) met Mallin et al.'s (2006) recommendation of ≤ 3 mg/L. However, based on EPA (2000) guidance regarding acceptable nutrient levels in the level III nutrient sub-ecoregion that includes Ocmulgee National Monument, only 65% of samples collected for total phosphorus (TP) analysis met the recommendation, and only 23% of samples met the recommendation for nitrate+nitrite concentrations (total n = 43 samples).

About 74% of the samples collected for analysis of fecal coliform bacteria densities were in compliance with the state of Georgia standards (total n = 258). The data were also troubling for water-column concentrations of heavy metals: Only 42 to 71% of the samples met the EPA recommended concentration for lead (Pb; 6 to 10 of 14 samples), and about 70% met the EPA recommendation for zinc (7 of 10 samples). Thus, Ocmulgee National Monument is heavily impacted by human activity and runoff from the City of Macon. The surface waters at and near the monument are degraded from suspended sediments, nutrient over-enrichment, fecal coliform bacteria, and toxic metals. Metals have also apparently affected the largest pond at Ocmulgee National Monument, which has been reported to possibly have mercury pollution (Chief Ranger Guy Lachine, pers. comm.).

Based on state (GA DNR) and federal (EPA) sources, only one major point source discharger holding an active NPDES permit for discharge to surface waters presently exists upstream from or adjacent to Ocmulgee National Monument: Plant Scherer (#GA0026069) is about 15.3 kilometers (9.5 mi) upstream from the main unit of the monument (Figure 27). Because of the distance, this point source is not considered to be a major influence on the monument. The MWA site mentioned above is slightly downstream from the Lamar Mounds Unit, as mentioned; a second site (#GA0024546, MWA—Rocky Creek) also is downstream (2.6 kilometers [1.6 mi]) and southwest from the Lamar Mounds Unit. Thus, the water resource degradation at Ocmulgee National Monument is mainly being caused by nonpoint sources. It should also be mentioned that the monument has one above-ground storage tank with containment cover. The storage tank consists of two compartments, with diesel on one side and unleaded gasoline on the other (Chief Ranger Guy Lachine, pers. comm.). There is also a gas station with underground storage tanks very near the monument.

The overwhelming cause of water quality degradation for surface waters in and near the monument is nonpoint source pollution. Urban land cover comprises 20% of the Ocmulgee River Basin. The City of Macon is the major source of non-point source contaminants into the Ocmulgee River, Walnut Creek, and the three smaller streams in Ocmulgee National Monument. In addition, the uppermost portion of the Ocmulgee River basin contains part of the rapidly expanding wastewater discharges, stormwater runoff, agricultural and timbering operations, mining and quarrying activities, recreational use, and atmospheric deposition (NPS 2002). For example, an auto salvage/junkyard is adjacent to the monument Main Unit (Figure 27), and tires from the junkyards have sometimes washed into monument property, suggesting that dissolved pollutants from these operations are also affecting the monument. The junkyard is immediately adjacent to 121.4 hectares (300 ac) of wetlands and to one of the ponds in the monument that is difficult to access. Macon's 11th Street Phase I sanitary landfill is in the floodplain near the western shore of the Ocmulgee River opposite the Lamar Mounds Unit (Figure 27). This landfill stopped accepting wastes in 1982, but is likely contaminating groundwater that provides part of the Ocmulgee River flow. Several Superfund sites that may be affecting water resource quality at the monument are also in the Macon area (Figure 27), the closest of which is the Macon Gas Light and Water Company across the Ocmulgee River from the Main Unit.

Impervious surface coverage, which concentrates pollutants and increases stormwater runoff pollution (Table 26), is high surrounding Ocmulgee National Monument and in the upstream Ocmulgee River and Walnut Creek watersheds (Figure 6). The Ocmulgee River and Walnut Creek segments upstream from and adjacent to the monument boundaries are degraded from the City of Macon's urban development. Ocmulgee National Monument has no direct control over various factors that influence its surface water resources. Even stream #1, once much smaller, now drains a large part of eastern Macon and sometimes carries large amounts of trash and pollution, as well as occasional raw sewage into the monument (Chief Ranger G. Lachine, pers. comm., 2009).

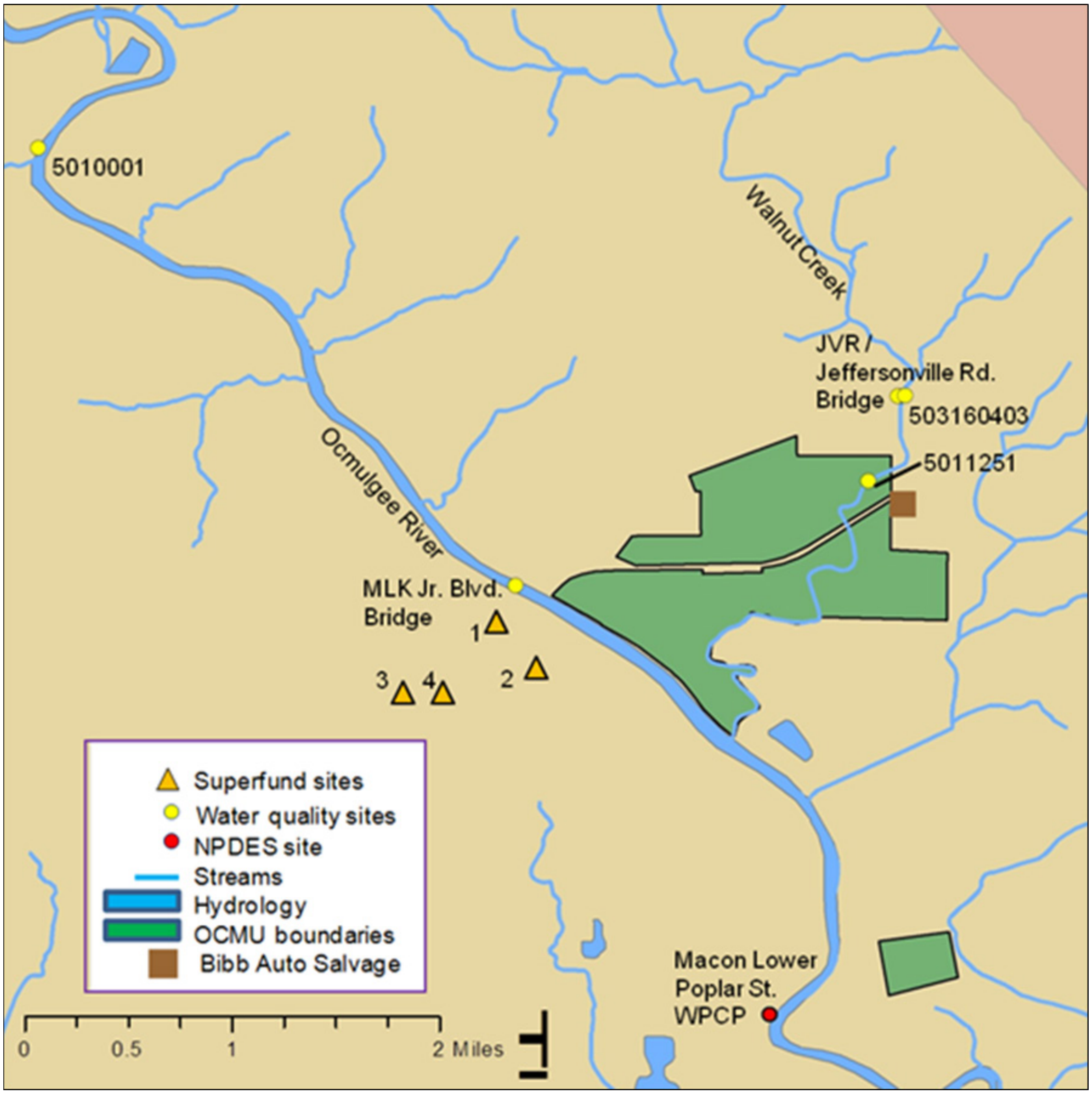


Figure 27. Map of the Macon area showing OCMU, surface waters, and various pollution sources, as well as present water-quality sampling stations (note: Plant Scherer's NPDES site is north of the area shown, whereas the MWA and Macon wastewater treatment plant major point sources are slightly downstream (0.3 km [0.18 mi]) from the Lamar Mounds Unit). Superfund sites in the area include (1) Macon Gas Light & Water Company (0.8 km [0.5 mi] west of the monument boundary bordered by the Ocmulgee River), (2) Walker Lakes Dump Site (1.2 km [0.75 mi] west of Ocmulgee), (3) Ash & Broadway, and (4) Archer Daniels Midland (ADM) Inc. (both 3.2 km [2 mi] west of Ocmulgee). Source: NCSU CAAE (E. Allen).

Table 26. Mean concentrations of pollutants in precipitation events, depending upon the amount of impervious surface area. From Arcadis (2003) [imperv.—imperviousness; TDS—total dissolved solids; COD—chemical oxygen demand; TKN—total Kjeldahl nitrogen; TCu—total copper; TZn—total zinc; BOD—biological oxygen demand; TSS—total suspended solids; TP—total phosphorus; NO_3—nitrate; NO_2—nitrite].).

Land use	% Imperv.	BOD	TDS	COD	TSS	TP	TKN	No_3-N + $N0_2$-N	TCu	TZn	NH_4+N
Forest/open	0.50	8	100	51	216	0.09	0.46	0.25	0.00	0	0
Agriculture	0.50	4	678	72	400	0.4	209	0.5	0.04	0.1	0.001
Large-lot single family (> 2 acres)	10.00	10.1	91	58	235	0.19	0.66	0.34	0.01	0.04	0
Low-density single family (1–2 acres)	12.00	11	100	190	280	0.67	0.2	2.85	0.03	0.22	0.004
Low- to medium-density single family (0.5–1 acres)	19.00	15	71	75	279	0.47	1.37	0.69	0.04	0.12	0.004
Medium-density single family (0.5–1 acre)	26.00	10.8	100	83	140	0.47	2.36	0.96	0.05	0.12	0.003
Townhouse/apartment	48.00	10.8	51	70	109	0.19	1.24	0.69	0.02	0.14	0.003
Commercial	85.00	9.71	100	190	248	0.66	3.2	1.18	0.04	0.28	0.005
Office/light industrial	70.00	15	58	77	93	0.66	3.2	1.18	0.04	0.19	0.003
Heavy industrial	80.00	9.7	100	61	91	0.24	1.28	0.63	0.04	0.19	0.001
Average:	35.10	10.41	145	93	209	0.36	22.1	0.87	0.03	0.14	0.0024

The location of Ocmulgee National Monument downstream and down-wind from the greater Atlanta area, as well as immediately surrounded by the City of Macon, makes it extremely vulnerable to water quality degradation from air pollution as well as water pollution. The wide range of urban land uses and activities occurring in the watersheds are harmful to Ocmulgee water resources. As mentioned, these sources also contribute to acid deposition, which can contribute to acidification and nutrient over-enrichment of surface waters (Baker and Christensen 1992).

Considering all of the pollutants—from suspended sediments to nutrients to a wide array of toxic substances—that are known to be contained in urban runoff and air pollution, data to evaluate the effects on monument aquatic resources from upstream water quality and atmospheric deposition are sparse, and have not been collected with adequate frequency to capture loadings from storm events or spills. The most easily detected among these pollutants, however, has left clear visible signs (Figure 20). Excessive sediment loading has been related mostly to urban runoff, industrial/mining activities, and agricultural land uses (Table 27). It can make streams shallower and wider, and more susceptible to flooding. Stream temperature, dissolved oxygen, flow rate, and velocity are affected as well. Benthic flora and fauna can be buried, spawning habitat destroyed, and aquatic plants eliminated because of the light reduction imposed by high turbidity. The suspended sediments also add nutrients such as adsorbed phosphorus and ammonium, as well as toxic substances such as heavy metals and pesticides.

Table 27. Estimated contributions of various land use/land cover categories to suspended sediment loading (GA DNR 2007a) [N.A.—not available].

Land Use	Average Land Cover (%)	Average Sediment Load (%)	Average Sediment Load Tons/acre/year
Open Water	0.7	0.0	0.01
Urban	13.3	14.7	0.27
Roads	N.A.	29.9	N.A.
Bare Rock, Sand and Clay	0.4	0.0	0.00
Quarries, Strip Mines, Gravel Pits	0.4	9.3	7.92
Forest	55.3	3.2	0.03
Pasture/Hay	13.6	10.8	0.09
Row Crops	3.6	20.0	1.33
Grasses, Wetland	11.5	11.4	0.32

The net effect is depressed biodiversity and loss of beneficial aquatic life (Olsen 1984, Hadley and Ongley 1989). The effects of high suspended sediment loading from upstream and adjacent urban sources on degradation of stream habitats within Ocmulgee National Monument are visibly obvious and Walnut Creek, including the Ocmulgee segments, are impaired and, as of 2012, only partially supporting their designated uses for fish/fishing because of habitat degradation from excessive sedimentation and other urban runoff effects (see Table 28). Both Walnut Creek and the Ocmulgee

River in the vicinity of Ocmulgee National Monument are impaired, as well, because of excessive fecal coliforms. Fecal coliform loads can be contributed by domestic animals, leaks and overflows of sanitary and storm sewers, illicit waste discharges, leaking septic tanks, and wildlife and waterfowl (GA DNR 2004, 2008d,e). In addition, the Ocmulgee River in the vicinity of the Lamar Mounds Unit is impaired for excessive polychlorinated biphenyls (PCBs) in fish tissues. There is no natural source for this group of toxic substances; rather, PCB contamination is of industrial origin (GA DNR 2007b).

The most recent GA DNR (2008d,e) 303(d) list of impaired streams contains Walnut Creek (headwaters down to its confluence with the Ocmulgee River—20 miles of stream length). This stream is not meeting its designated use for recreational fishing [fish habitat degradation—failure to support fish communities, Bio(F)] because of suspended sediment loading and high fecal coliform densities. The potential cause listed for the degradation is urban runoff. Probable sources of the sediment loads are listed in Table 29; such partitioning among land use types was not attempted for sources of fecal coliforms. It is likely that the major source of the sediment is indicated as industrial mining activities.

Walnut Creek has a TMDL targeting sediment loads and a second TMDL for fecal coliforms (GA DNR 2007a,c; Table 28). The Ocmulgee River (segment from Beaverdam Creek to Walnut Creek—10 miles), including the main unit of Ocmulgee National Monument, is listed as impaired because of fecal coliform bacteria. This segment is classified for use as drinking water. The segment of the Ocmulgee River from Walnut Creek to Tobesofkee Creek (11 miles), including the Lamar Mounds Unit of the monument, is also impaired and only partially supporting its designated uses for fishing (recreational fishing and protection of fish life, Bio(F)) because of polychlorinated biphenyl (PCB) contamination of fish tissues (GA DNR 2007b). Fish consumption guidelines have been issued as a result of PCBs in flathead catfish (GA DNR 2007b). PCB exposure has been related to an array of adverse health effects in fish, birds and mammals, including toxic effects on liver, gastrointestinal system, blood, skin, endocrine system, immune system, nervous system, and reproductive system, as well as developmental effects and malignant tumors (GA DNR 2007b, and references therein; Adams et al. 1999; GA DNR 2007b).

Table 28. TMDLs for the Ocmulgee River and Walnut Creek, including stream segments within or near OCMU (GA DNR 2012).

Category	Stream	Present Load	Reduction Needed	Allowable Avg. Load (TMDL)
Sediment TMDL (Biota-Impacted, Not Supporting, 2002)	Walnut Creek	6,491.6 tons/year	83.6%	1,067.3 tons/year
Fecal Coliform TMD (General Recreation, Partially Supporting, 2012)a	Ocmulgee River	4.55 x 1014 counts/30 days	25%	3.41 x 1014 counts/30 days
	Walnut Creek	1.47 x 1013 counts/30 days	72%	4.07 x 1012 counts/30 days
PCB TMDL (Fish Consumption, Partially Supporting, 2012)	Ocmulgee River	0.26 mg/kgb	62%	1.1 x 10-3 kg/dayb

[a] 30-day geometric mean for bacterial counts (cfu).

[b] Average fathead catfish tissue concentration in 1999. Georgia fish consumption guidelines are conservatively triggered at more than 0.1 milligram per kilogram (mg/kg) (vs. the Food and Drug Administration action level of 2.0 mg/kg). Based on the EPA published PCBs bioaccumulation factor, the TMDL can be attained at water concentrations less than 0.0032 µg PCBs/L. This TMDL is based upon the EPA human health criterion of 0.00017 µg PCBs/L.

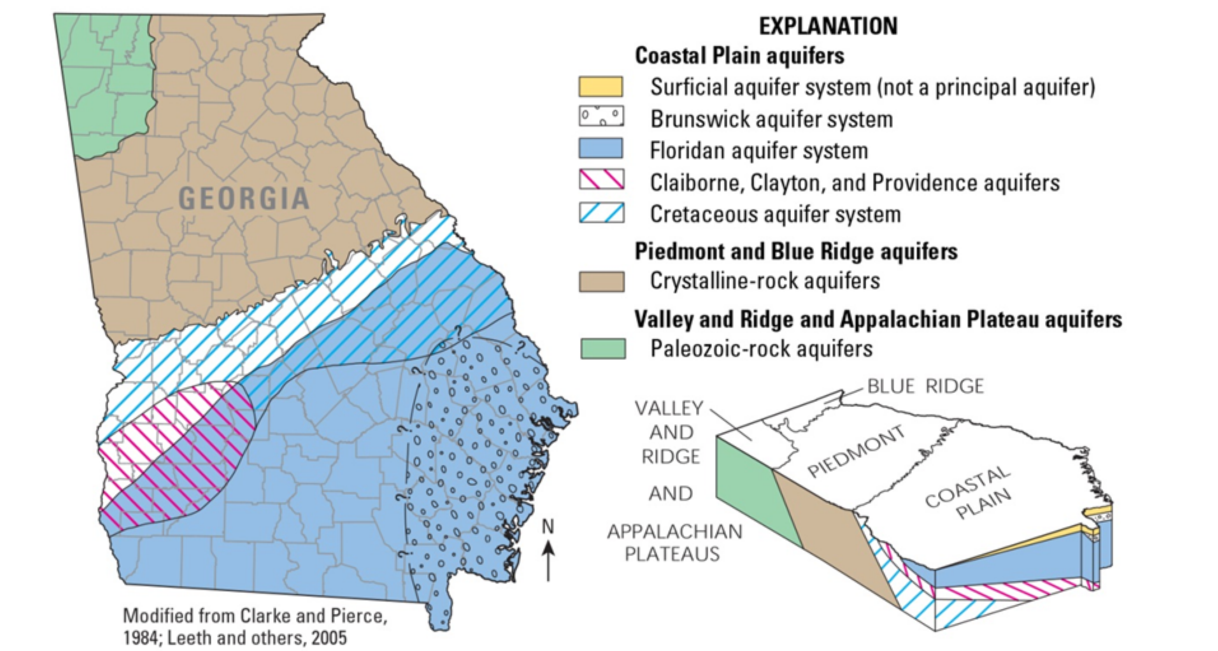
Table 29. Estimated contribution of land use type to sediment loading in Walnut Creek. From GA DNR (2012).

Land use type	Tons per year	Percent of total
Open water	0.0	0.0%
Low-intensity residential	115.2	1.8%
High-intensity residential	2.5	–
High-intensity commercial/industrial/transportation	0.3	–
Clearcut, sparse	–	–
Quarries, strip mines, rocks	5,145.3	79.3%
Roads	545.1	8.4%
Transitional	24.9	0.4%
Deciduous forest	14.5	0.2%
Evergreen forest	4.2	0.1%
Mixed forest	0.5	–
Row crops, pasture	322.5	5.0%
Other grasses (urban, recreational)	123.1	1.9%
Woody wetland	193.6	3.0%
Non-forested wetland (fresh)	–	–

Groundwater

Knowledge of groundwater supplies and quality is critically important to enable sound assessment of the status of water resources in most ecosystems: Groundwater-level and groundwater-quality data are essential for water-resource assessment and management. Water-level measurements from observation wells are the principal source of information about the hydrologic stresses on aquifers and how these stresses affect groundwater recharge, storage, and discharge. Long-term, systematic measurements of water levels provide essential data needed to evaluate changes in the resource over time; develop groundwater models and forecast trends; and design implement, and monitor the effectiveness of groundwater management and protection programs (Taylor and Alley 2001). Ground-water quality data are necessary to ensure that public water supplies meet health standards; deterioration of ground-water quality may be virtually irreversible, and treatment of contaminated groundwater can be expensive (Alley 1993) [in USGS 2008].

Unfortunately, data are not available to assess groundwater quality in Ocmulgee National Monument. Water from the Cretaceous aquifer system underlying the monument often is acidic (pH below 7.0) because of substantial carbon dioxide, and can be corrosive (Tyson 1993). The regional geology controls the aquifer types present, and influences the natural quantity and quality of the groundwater. The aquifers underlying the monument and vicinity are fairly well known: A surficial aquifer system, not a principal aquifer, covers the state (USGS 2008). The surficial aquifer is comprised of relatively permeable sand and gravel, with lesser amounts of clay, and it ranges in age from Pliocene to Holocene. It is recharged by rainfall and mostly contains water under unconfined conditions (Renken 1996). The major aquifer in the monument area is the Southeastern Coastal Plain Aquifer System (SECP), although just to the north also lies the southernmost extension of the Piedmont (Piedmont and Blue Ridge) Aquifer (Figure 28). Thus, the site hydrogeology consists of both Piedmont (in the uplands) and upper Coastal Plain (in the lowlands) characteristics (Rasmussen et al. 2009). In the Ocmulgee area, the SECP consists of three layers: The uppermost part of the aquifer is the Barnwell Formation, from rocks of the late Eocene (Jacksonian) age, consisting of deep red, fine to coarse arkosic quartz sand. Beneath this layer is the Blufftown Formation from rocks of Paleocene and Cretaceous age (Renken 1996; Rasmussen et al. 2009). The Blufftown overlies the base of the SECP aquifer, which is formed from pre-Cretaceous rocks consisting of undifferentiated crystalline rocks; saprolite; sedimentary red beds, basalt, and diabase of early Mesozoic age; sedimentary rocks of Jurassic age; and sedimentary rocks of Paleozoic age (Renken 1996).



Principal aquifers of Georgia. The most productive aquifers are in the Coastal Plain province where thick, permeable sedimentary deposits have formed several layers of aquifers. The surficial aquifer system is present throughout the State and is not shown on the map at left.

Figure 28. Principal aquifers of Georgia, excluding the surficial aquifer system which is relatively minor and present throughout the state. The most productive aquifers are in the Coastal Plain physiographic province where thick, permeable sedimentary deposits have formed several layers of aquifers. OCMU is just within the northern Cretaceous aquifer system of the SECP. Modified from Clarke and Pierce (1984) and Leeth et al. (2005), in USGS (2008).

Ocmulgee National Monument has no operating wells. Two inactive wells (formerly farm wells) are not capped and are covered by wooden pallets. A USGS well (Blufftown Formation, #323302083263401, code 06S001, latitude 32.34194, longitude -84.98611, depth 173 meters [568 ft], elevation 78 meters [255 ft]) is located 30 kilometers (18.6 mi) from the monument (Figure 29). This well has been monitored since May of 1950, with 17,846 observations as of the Rasmussen et al. (2009) report.

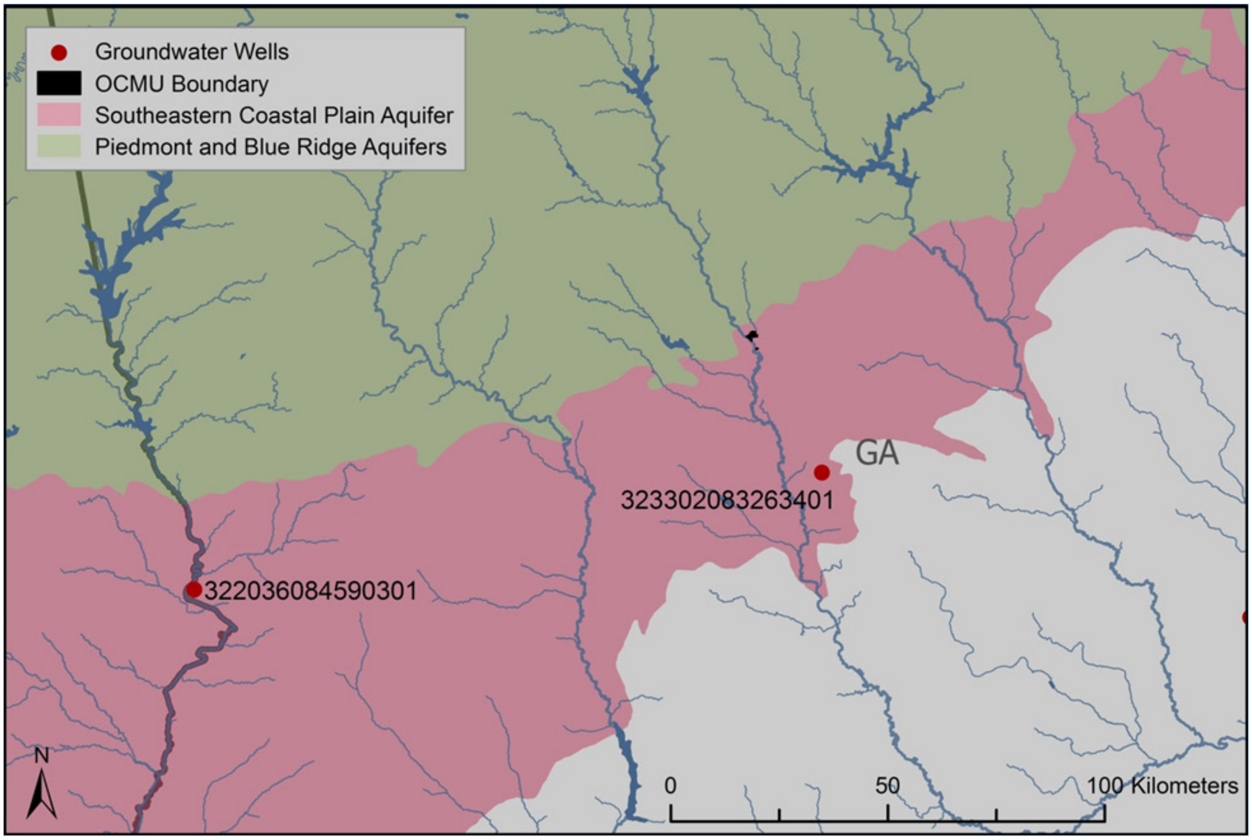


Figure 29. Location of the USGS wells near Ocmulgee in the Southeastern Coastal Plain aquifer system. Map by Southeast Coast Network.

Water levels in the aquifers fluctuate seasonally, and generally rise in winter/spring because of increased recharge from precipitation and less evapotranspiration and pumping (Leeth et al. 2005). The magnitude of fluctuations varies substantially across seasons and year to year in response to climatic conditions and also to human use, which influences the amount of groundwater in storage and the rate of discharge (Taylor and Alley 2001). As storage is depleted within the radius of pumping influence from a well, the water level declines and forms a "cone of depression" around the well. In areas with high concentrations of wells, multiple cones of depression form and cause water level declines across large areas. These declines can change the groundwater flow direction, reduce flow to streams, capture water from a stream or adjacent aquifer, and/or alter groundwater quality (USGS 2008). Rasmussen et al. (2009) conducted long-term statistical trend analysis on the water level in the well near Ocmulgee National Monument, and found that it has significantly declined over time ($p < 0.01$). This analysis was updated and supported by Wright (2012b) (Figure 30).

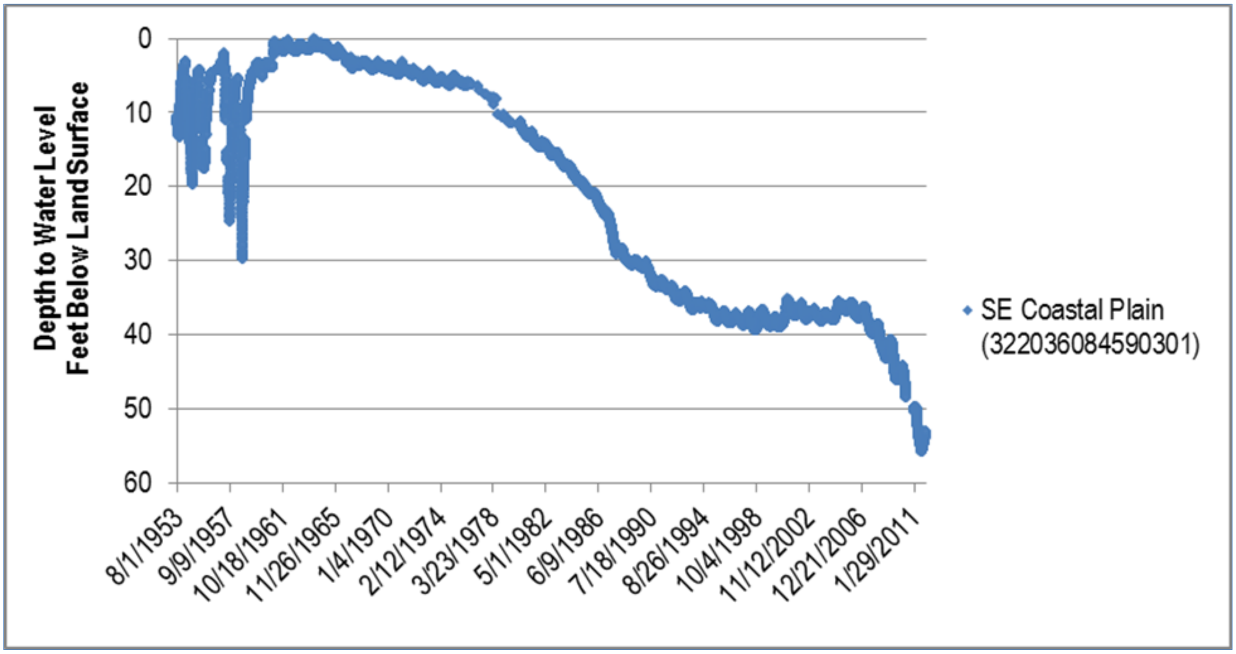


Figure 30. Statistically significant decrease in water level ($p < 0.01$) over time in the USGS groundwater monitoring well installed in the SECP aquifer west of OCMU (USGS ID #322036084590301). The data show a substantial drop in water level over the period of record (1953–present; data shown through 2011). From Wright (2012b).

2.2.3. Biological Resources

Overview

The National Park Service is charged to preserve the natural resources of the United States, insofar as possible, through protection of its national parks. Thus, a long-term agency goal is to restore and maintain natural community composition, structure, and diversity, and natural ecosystem balance. As part of this challenge, the National Park Service has developed a National Fire Plan for its parks. In addition, the National Park Service is engaged in major efforts, as funding permits and depending on the needs of individual parks, to protect and/or restore sensitive species and control exotic/ invasive species. Exotic species are a concern for Ocmulgee National Monument (e.g., Figure 31). Several years ago park staff launched a successful effort to greatly reduce the feral pig population at Ocmulgee National Monument, which had caused extensive damage especially to the wetlands east of Walnut Creek and in the Lamar Mounds unit. These feral boar hybrids are thought to be descendants of escaped and deliberately introduced individuals (Mayer and Brisbin 1991).

Figure 31. Two vegetated stands in OCMU, showing Chinese privet overgrowth (left), and after clearing of invasive species (right). Photos courtesy of NPS staff, Ocmulgee National Monument.

In its location adjacent to the Ocmulgee River, Ocmulgee National Monument acts as an important corridor for various wildlife species and facilitates their movement to other protected lands north or south of the monument (Byrne et al. 2011b). The monument has a “prominent wildland-urban interface” (Byrne et al. 2011b), as Interstate 16 is on the western edge of the monument, a major railroad traverses it, and part of the monument is actually within the city limits of Macon. The monument, including the Ocmulgee River, has sustained many human-related impacts: Prior to its channelization by the Macon levee, the river was more variable in depth, and had more woodfall debris, more slowly moving side channels, and more oxbows as habitat for various aquatic fauna. Sediments settled out along a broad floodplain and left clay deposits for making bricks. Historic reports describe high numbers of specialized fish species, and oxbows and side channels with river bottom covered with mussels that helped stabilize the sediments and enhanced water clarity via their filtering activity. The present-day river is turbid with a high sediment load, few mussels, and low fish species richness (Wisniewski et al. 2005; see below).

At present the biota at Ocmulgee National Monument are mostly known only through species lists, with very few ecological studies available historically or recently. In recognition of this substantial knowledge gap, the network has begun to characterize the amphibians and birds of the monument, as well as presence of a chytrid fungus (*Batrachochytrium dendrobatidis*) that causes amphibian disease worldwide (Byrne and Moore 2011; Byrne et al. 2011a,b). Diversity indices based on species richness have been developed for amphibians and birds.

As of 2013, a total of 713 taxa have been reported in Ocmulgee National Monument (NPS 2013a), including 276 fauna (26 amphibians, 35 reptiles, 11 fish [based on the most recent survey in 2003], 172 birds, and 32 mammals) and 437 taxa of vascular flora (190 terrestrial plants, 245 wetland plants, and 2 aquatic plants). At least three mammalian species have been extirpated from the monument, and various stream macroinvertebrates (bivalve mollusk species in particular) and fish taxa also have been extirpated. At present, only six taxa (four birds, one mammal, and one wetland plant) occur as species of concern (SSCs) in the monument (Table 30). A seventh species, Swainson's warbler, is an SSC according to the Georgia Department of Natural Resources (Chafin 2011). Thus, in total, 1% of the known taxa are SSCs. This low number likely reflects the fact that the biological resources of the monument have been heavily impacted by surrounding urbanization and degradation of the Ocmulgee River watershed (Burkholder et al. 2010).

As another telling sign of human impact on the natural resources of Ocmulgee National Monument, exotic/invasive species comprise 15% of the total species, and fully 25% (109 species) of the vascular plant species, which are vitally important to the terrestrial and wetland ecosystems of the monument. Exotic species additionally include three birds, nine mammals (28% of the total), and two of the most highly damaging insects known worldwide (fire ants and southern pine beetle). Among the vascular plant communities at Ocmulgee National Monument, 12 species have been identified as especially sensitive to ozone, including redbud (*Cercis canadensis*), green ash (*Fraxinus pennsylvanica*), sweetgum (*Liquidambar styraciflua*), tulip tree (*Liriodendron tulipifera*), Virginia creeper (*Parthenocissus quinquefolia*), loblolly pine (*Pinus taeda*), American sycamore (*Platanus occidentalis*), black cherry (*Prunus serotina*), American elder (*Sambucus canadensis*), sassafras (*Sassafras albidum*), crownbeard (*Verbesina occidentalis*), and northern fox grape (*Vitis labrusca*). Porter (2003) assessed the risk of foliar ozone injury to plants at the monument, in general, as high.

Table 30. Species of concern (SSCs) reported to occur in Ocmulgee NM.[a]

Biota Group	Species	Common Name	Status[b]
Wetland Plants	*Cayaponia quinqueloba*	Five-lobe mellonleaf	SSC (Special Concern—at risk but not formally protected)
Birds	*Charadrius wilsonia*	Wilson's plover	State—T
	Dendroica cerulea	Cerulean warbler	State—R
	Mycteria americana	Wood stork	Federal, State—E
	Vermivora chrysoptera	Golden-winged warbler	State—E
	Limnothlypis swainsonii	Swainson's warbler	GA DNR Chafin 2011
Mammals	*Corynorhinus rafinesquii*	Eastern big-eared bat	State—R

[a] The aquatic plant, *Najas filifolia* (needle-leaved waternymph—State status, endangered) is included in the NPS Certified Species List (NPS 2013a), and may be present in the monument but was not found by Zomlefer et al. (2013) and, so, is not included here.

[b] Federal: E—endangered. State of Georgia: E—endangered; T—threatened; R—rare.

Characteristics Used for Inventory

The NPS Omnibus Management Act of 1998, and other reinforcing policies and regulations, require park managers "to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources" (Title II, Sec. 204). A first step toward meeting that mandate is to inventory the species diversity of park biota. This information is valuable because measures of community composition are often good indicators of abiotic variability, disturbance, and/or other stressors (Byrne et al. 2011a, b).

Understanding changes in species distributions is integral to informed management of species and their habitats—changes in species distributions over time provide valuable insights at local and landscape scales about how species respond to influences such as changing land use, climate, hydrology, or habitat quality/availability. Climate change, for example, influences the distribution, phenology, population demographics, and abundance of individual species. In turn, the cascading effects through altered species interactions and altered food web structure can impact ecosystem processes (Montoya and Raffaelli 2010 in Byrne et al. 2011b). It is also valuable to capture the number of species (species richness) and their relative abundance (species evenness or dominance) within a given community. These two components describe the species diversity, often communicated as various diversity indices.

Diversity, defined as "the variety and abundance of species in a defined unit of study" (Magurran 2004 in Byrne et al. 2011b), is a community property that is broadly related to trophic structure, productivity, stability (McIntosh 1967; McNaughton 1977), immigration/emigration (Colwell and Lees 2000), and ecological condition (i.e., ecological integrity as defined by Karr and Chu 1995). Diversity indices respond differently to various mechanisms that influence community structure, so the National Park Service uses a suite of alpha diversity indices (the diversity of species within a defined area, community or ecosystem—Whittaker 1972) in order to fully characterize diversity in SECN parks (Haedrick 1975; Boyle et al. 1984 in Byrne et al. 2011b).

Vascular Plants

Of the total number of species included in the NPSpecies list for Ocmulgee National Monument (NPS 2013a), 60% are vascular plants. Most are angiosperms (flowering plants), but two gymnosperms and 11 monilophytes (ferns and allies—four terrestrial and seven wetland) are also present. Though a small group in species numbers, the ferns include two exotic species, one of which (*Lygodium japonicum*, Japanese climbing fern) is among the worst known exotic/invasive species worldwide. As mentioned, the monument flora consists of 190 terrestrial (43%), 245 wetland (56%), and two aquatic (< 1%) species. The wetland flora occur in bottomland swamp forests mainly along the Ocmulgee River floodplain and in other scattered habitats (Figure 32). The five largest vascular plant families found in the monument in Zomlefer et al.'s (2013) work were the Poaceae (53 species), Asteraceae (36 species), Cyperaceae (33 species), Fabaceae (21 species), and Rosaceae (18 species).

Figure 32. Examples of wetlands at OCMU: A) Duckweed (*Lemna*) wetland north of the road to Great Temple Mound. (B) The large, recently established wetland east of Great Temple Mound. (C) Wetland area north of the railroad tracks. (D) Small sedge wetland between Great Temple Mound and Funeral Mound. From Burkholder et al. (2010).

Historically, oak-hickory-pine forests, largely deciduous, once covered broad slopes of the southern Piedmont in Georgia, varying in vegetation composition depending on aspect, elevation, bedrock, soil type, and proximity to water (Chafin 2007). More terrestrial plant diversity occurred along the fall-line border of the two physiographic provinces, including agricultural land use. Typical canopy trees include oaks (scarlet—*Quercus coccinea*, black—*Quercus velutina*, etc.), pignut and mockernut hickories (*Carya glabra* and *Carya tomentosa*, respectively), loblolly and shortleaf pines (*Pinus taeda* and *Pinus echinata*, respectively), winged elm (*Ulmus alata*), and black gum (*Nyssa sylvatica*) (Chafin 2007). In the sub-canopy, dogwoods (*Cornus florida*) and redbuds (*Cercis canadensis*) are common; and moister terrestrial sites can have abundant beeches (*Fagus grandifolia*), tulip poplars (*Liriodendron tulipifera*), and black cherries (*Prunus serotina* var. *serotina*).

Until September 2013, the only information available about vegetation specific to the monument was species lists pieced together from mostly unvouchered plants (e.g.,Froeschauer 1989; Puckett 1997). In 1999 the National Park Service began a long-term ecological Inventory and Monitoring (I&M) Program to establish baseline conditions for national parks and thereby assist resource management decisions (Fancy et al. 2009). This effort supported a comprehensive and vouchered floristic survey of the monument by Gaddy and Nelson (2004). The Zomlefer et al. (2013) survey updates that work; it strengthens the valuable baseline on higher plant species presently occurring in the monument and also provides a more accurate, vouchered species list as a reference for ongoing invasive species control and monument vegetation mapping/research. The recent survey was based on site visits and collections conducted in 2008 (27 May, 25 July, 1 October), 2009 (9 April), and 2012 (7 August). In our evaluation, the Zomlefer et al. (2013) survey is so fundamentally important to natural resource assessment for the monument and development of indicators that it was essential for us to include it in this report.

We detailed all differences between the NPS Certified Species List (NPS 2013a) and the Annotated List compiled by Zomlefer et al. (2013) (Appendix C). In addition, our determination of terrestrial versus wetland status was made following Godfrey and Wooten (1979, 1981), the USDA Plants Database (also called the PLANTS Database or National Plants Database) of USDA's Natural Resources Conservation Service (NRCS 2015), and The National Wetland Plant List (Lichvar 2013 see USACE 2015). This was necessary because many vascular plants in Ocmulgee National Monument are facultative wetland or facultative upland taxa; they tolerate a wide range of conditions ranging from mesic to hydric, and are listed as occurring in upland forest as well as various wetland, aquatic, and disturbed habitats. The NPS Certified Species List (NPS 2013a) uses the Integrated Taxonomic Information System online database (ITIS 2012); we noted only three problems with species names and therefore used the names for those taxa that were provided by the PLANTS Database. These changes are also detailed in Appendix C.

We provided corrective adjustments to Zomlefer et al. (2013) on only one point: Bald brome (*Bromus racemosus*) also an exotic taxon, was described to occur in the monument (Zomlefer et al. 2013, p.463) but was inadvertently omitted from the Annotated Species List by those authors. The one SSC vascular plant found in Ocmulgee National Monument, fivelobe cucumber (*Cayaponia quinqueloba*), is a wetland plant that is State-ranked as S2 (imperiled: at risk but not formally protected; GA DNR 2008b). Its global rank is G4 (apparently secure globally; no immediate conservation concern). This species was vouchered from the western margin of Walnut Creek wetlands and from the apex of Mound A at the Lamar Mounds Unit (Zomlefer et al. 2013).

In compiling the annotated species list from the recent survey, Zomlefer et al. (2013) verified many taxa from previous works which had been included in the NPS Certified Species List (NPS 2013a), whereas other species were omitted and considerable numbers were added as species that were newly detected for the monument. Table 31, which summarizes numbers of species previously reported versus documented from efforts in the recent survey, does not include these specifics. Overall, the total number of vascular plant species in the monument increased by 10%. Remarkably, the total number of exotic/invasive vascular plant species increased by 70%, from 65 species previously known to 109 now known to thrive in disturbed habitats of Ocmulgee NM. As Zomlefer et al. (2013) noted, the monument "has a long history of disturbance that has drastically altered the vegetation, especially over the last two centuries." The main unit is now mostly grassy fields, upland woods, and forested or open wetlands. The Lamar mounds unit is mostly swamp along with some open, disturbed areas bordering the overgrown logging road and cleared mound areas. Four general plant communities which sometimes inter-grade were identified in Ocmulgee National Monument (Figure 33), described as follows:

Table 31. Comparison of vascular plant species known at Ocmulgee previously as compiled in the NPS Certified Species List (NPS 2013a), versus in the recent survey by Zomlefer et al. (2013) Change column shows number of species (percent change).

Plant Type	NPSpecies 2013	Zomlefer 2013	Change (%)
Total Vascular Plants	407	434	+ 27 (+ 7%)
Terrestrial	182	190	+ 8 (+ 4%)
Wetland	219	245	+ 25 (+ 12%)
Aquatic	6	2	- 4 (-200%)
Terrestrial	64 taxa omitted	65 taxa added	–
Wetland	47 taxa omitted	49 taxa added	–
Total	65 total	109 total	+ 44 (+ 68%)
Terrestrial	39	69 (2 cultivated)	+ 30 (+77%)
Wetland	25	38 (1 cultivated)	+ 13 (+ 52%)
Aquatic	1	2	+ 1 (+50%)

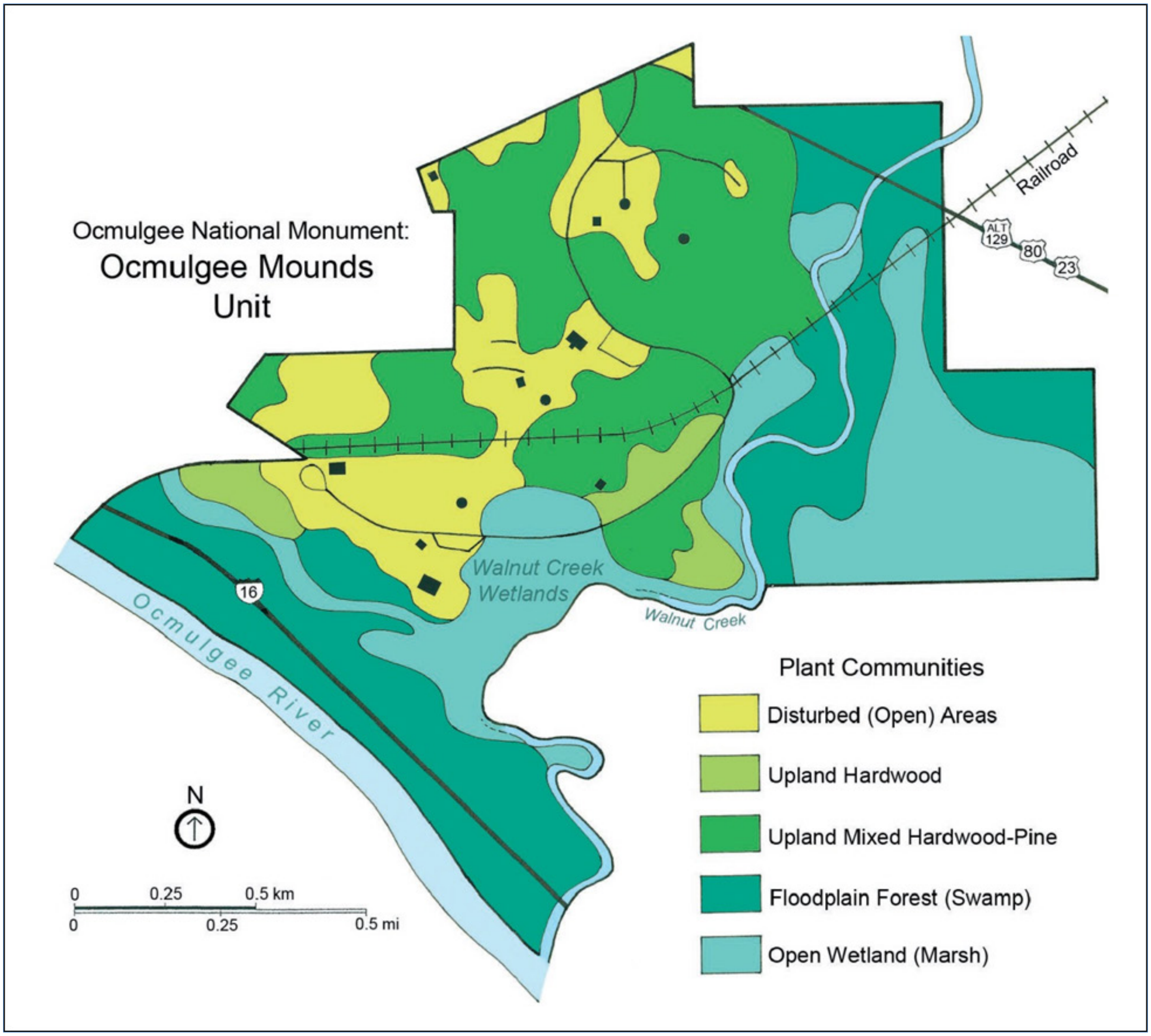


Figure 33. General vegetation map of the monument main unit, including locations of other major monument features for reference. From Zomlefer et al. (2013).

1. Upland forest (mixed hardwood and mixed hardwood-pine, combining two of the community types shown in Figure 33) communities have been modified by disturbance. At present the dominant taxa include oaks (e.g., southern red oak—*Quercus falcata,* water oak—*Q. nigra,* willow oak—*Q. phellos*), hickories (e.g., pignut hickory—*Carya glabra,* common shagbark hickory—*C. ovata*), and loblolly pine *(Pinus taeda*). Other abundant trees include maples (*Acer* spp.), American beech (*Fagus grandifolia*), sweetgum (*Liquidambar styraciflua*), tulip trees (*Liriodendron tulipifera*), southern magnolias (*Magnolia grandifolia*), and American elm (*Ulmus americana*). Understory shrubs and shrubby trees vary in composition, largely depending on the overstory, and is also much more diverse in the mixed hardwood forests than in pine-dominated areas. Early spring flora prior to closure of the hardwood canopy include trout lily (*Erythronium umbilicatum*), little brown jug (*Hexastylis arifolia*), melic

grass (*Melica mutica*), bigseed forget-me-not (*Myosotis macrosperma*), May-apple (*Podophyllum peltatum*), small Solomon's-seal (*Polygonatum biflorum* var. *biflorum*), and common blue violet (*Viola sororia*). Other woodland species such as ebony spleenwort (*Asplenium platyneruon*), mistflower (*Conoclinium coelestinum*), variable witch grass (*Dichanthelium commutatum* var. *commutatum*), leafy elephant's-foot (*Elephantopus carolinianus*), wood's grass (*Oplismenus hirtellus*), asters (*Symphyotrichum* spp.), and cranefly orchid (*Tipularia discolor*) appear later in the season.

2. Floodplain Forest (bottomland hardwood forest generally with closed canopy). Swamp or bottomland hardwood (floodplain, alluvial, or palustrine forest) occurs along the Ocmulgee River and Walnut Creek in the southwestern and eastern sections of the main unit in the monument, mostly bordering open marsh areas. The land consists of seasonally inundated, mesic lowland that generally remains moist throughout the year (Zomlefer et al. 2013). The Lamar Mounds unit is also virtually covered by dense floodplain forest, partly because of the levee (Zomlefer et al. 2013).

   Even more than 20 years ago, bottomland hardwood forests were identified as among the most rapidly diminishing wetland ecosystems remaining in the United States (Gosselink et al. 1990). Also at that time, Georgia's Forest Legacy Program (1990) listed the Upper Ocmulgee and the Lower Ocmulgee as 2 of the 17 Category 1 watersheds across the state that were impaired and most in need of restoration. Ocmulgee National Monument serves to protect this unique habitat. While not known for especially high plant diversity, bottomland hardwood ecosystems provide significant habitat for migratory birds, wildlife corridors for mammalian species, and spawning habitat for fish. They also assist in natural flood control by spreading/slowing flow, and they act as sediment and pollutant "sinks" (Gosselink et al. 1990).

   The vegetation of bottomland hardwood forests has been categorized within four different "zones" (II through V), also characterized by differences in hydrology and soils (adapted from Cowardin et al. 1979 and Larson et al. 1981 as described in Gosselink et al. 1990). These zones are part of a six-zone system: The wettest zone, Zone I, is permanently flooded; the driest zone, Zone VI, is a transition zone to dry uplands and contains several species of oak, ash and hickory that are intolerant of soil saturation. Ocmulgee National Monument no longer contains Zone II of bottomland hardwood forests, although the monument previously had oxbows and still has major tracts of wetlands. The classically defined Zone II has surface water present throughout the year except in years of extreme drought, and vegetation is in saturated or flooded soil for the entire growing season. The dominant canopy species of such habitats are bald cypress (*Taxodium distichum*) and water tupelo (*Nyssa aquatica*), but neither species occurs at present in the monument, likely because its open-water areas tend to dry out completely in most years because of altered hydrology. Instead, tall trees such as maples, river birch (*Betula nigra*), green ash (*Fraxinus pennsylvanica*), sweetgum, tulip trees, swamp tupelo (*Platanus occidentalis*), and oaks (*Quercus* spp.) predominate and often form a closed canopy over an almost impenetrable shrub understory.

Thus, three of the four classic zones of bottomland hardwood forest persist in Ocmulgee National Monument: Zone III is semi-permanently flooded, characterized by surface water or soil saturation that persists for at least 25% of the growing season in most years. This zone contains black willow (*Salix nigra*), silver maple (*Acer saccharinum*), and overcup oak (*Quercus lyrata*), along with several other species of ash, maple, and birch. New bars that form in the stream channels typically are in this zone. Zone IV has a variety of trees and shrubs, such as laurel oak (*Quercus laurifolia*), green ash (*Fraxinus pennsylvanica*), American elm, and sweetgum (*Liquidambar styraciflua*), together with other species of oaks such as willow oak (*Quercus phellos*). Zone V is only temporarily flooded, with surface water or soil saturation present for brief periods in the growing season. This zone has the most favorable soil-air-water conditions for root respiration. Oaks and hickories (*Quercus* spp. and *Carya* spp., respectively) usually are dominant at this level of the floodplain; species of pine such as loblolly can also be present.

3. Open Wetlands (Marshes). In a large portion of the monument, the canopy is lacking or sparse and standing water typically is present at least part of the year. This habitat is found along floodplain areas of the Ocmulgee River and Walnut Creek. The large marsh known as Walnut Creek Wetlands developed from hydrologic changes related to construction of the I-16 highway (Burkholder et al. 2010). Until 1994, this open wetland was forested and seasonally flooded, but now it contains standing water throughout the year. Sedges and grasses dominate this habitat, along with other common herbaceous species. Woody vines, scattered shrubs, and some tree species occur along the wetland margins.

4. Disturbed (Ruderal) Areas. Most of these habitats in the monument consist of cleared sections around public access areas such as parking lots, roadsides, trails, and the railroad right-of-way, and also mowed fields surrounding historic sites. These exposed sites are inhabited by wetland species such as late eupatorium (*Eupatorium serotinum*), dwarf St.-John's-wort (*Hypericum mutilum*), the exotic/invasive species longbristle smartweed (*Persicaria longiseta*), and greenbriers (*Smilax* spp.). The variable, diverse flora commonly includes many species that are exotic/invasive, and abundant graminoids; the Asteraceae are also well represented. The borders of these areas often include woody species such as red mulberry (*Morus rubra*), black cherry (*Prunus serotina* var. *serotina*), southern dewberry (*Rubus trivialis*), poison ivy (*Toxicodendron radicans* ssp. *radicans*), and grapes (*Vitis* spp.).

Fish

More than 20 years ago, Evans (1991) reported that the diverse fish fauna of the Ocmulgee River basin included 105 species representing 21 different families (GA DNR 2004). However, the only information available about fish species in Ocmulgee National Monument—a survey conducted only once a decade ago (2003)—indicated sparse fish diversity consisting of only 11 species (Johnston 2006). The 11 species were of uncertain abundance and health. They included the bluefin stoneroller (*Campostoma pauciradii*), bandfin shiner (*Luxilus zonistius*), blackbanded darter (*Percina nigrofasciata*), bluegill (*Lepomis macrochirus*), bluehead chub (*Nocomis leptocephalus*), creek chub (*Semotilus atromaculatus*), Dixie chub (*Semotilus thoreauianus*), green sunfish (*Lepomis cyanellus*), redbreast sunfish (*Lepomis auritus*), spotted sunfish (*Lepomis punctatus*), and yellow bullhead (*Ameiurus natalis*). Twenty additional species were described as "probably present," defined as having been documented through one or more types of evidence as references, vouchers, and observations (NPS 2013a). All 31 species are included in the NPSpecies List (NPS 2013a) for Ocmulgee, including a state-listed SSC, the shoal bass (*Micropterus cataractae*). Thus, of that list, only 11 species were actually documented in the monument a decade ago when the fish community was last surveyed; among others, the SSC was not found.

GA DNR (2004) reported at least 15 species of exotic fish species in the entire Ocmulgee River watershed, many of which had become well established and detrimental to native fish populations. Ocmulgee National Monument had only one exotic species indicated from the NPS Certified Species List (NPS 2013a), the common (European) carp, but this species was not found in the most recent survey (Johnston 2006). Recreational fishing is allowed at the monument, and largemouth bass and carp are common catches (Watson 2005).

Herpetofauna

Amphibian communities in the southeastern United States are widely considered to be among the most diverse in the world, and they are a valued resource in network parks (Byrne et al. 2011a). According to information gathered in 2004, Ocmulgee National Monument contains twenty-seven native species of amphibians and thirty-five native species of reptiles. The amphibians include seventeen species of frogs and toads, and nine species of newts and salamanders. The reptiles include eight species of lizards (including the American alligator), twenty snakes, and seven turtles. One exotic/invasive snake species, the rough green snake (*Opheodrys aestivus*), occurs in the monument. In a comparison of 16 parks in the region, including Ocmulgee National Monument, Tuberville et al. (2005) noted that larger parks had higher species richness (Figure 34). Nevertheless, the herpetofauna species richness at Ocmulgee National Monument was among the highest of the network parks (Tuberville et al. 2005) and was comparable in species richness to much larger parks (Figure 34), expected since much of this park area consists of diverse freshwater wetlands.

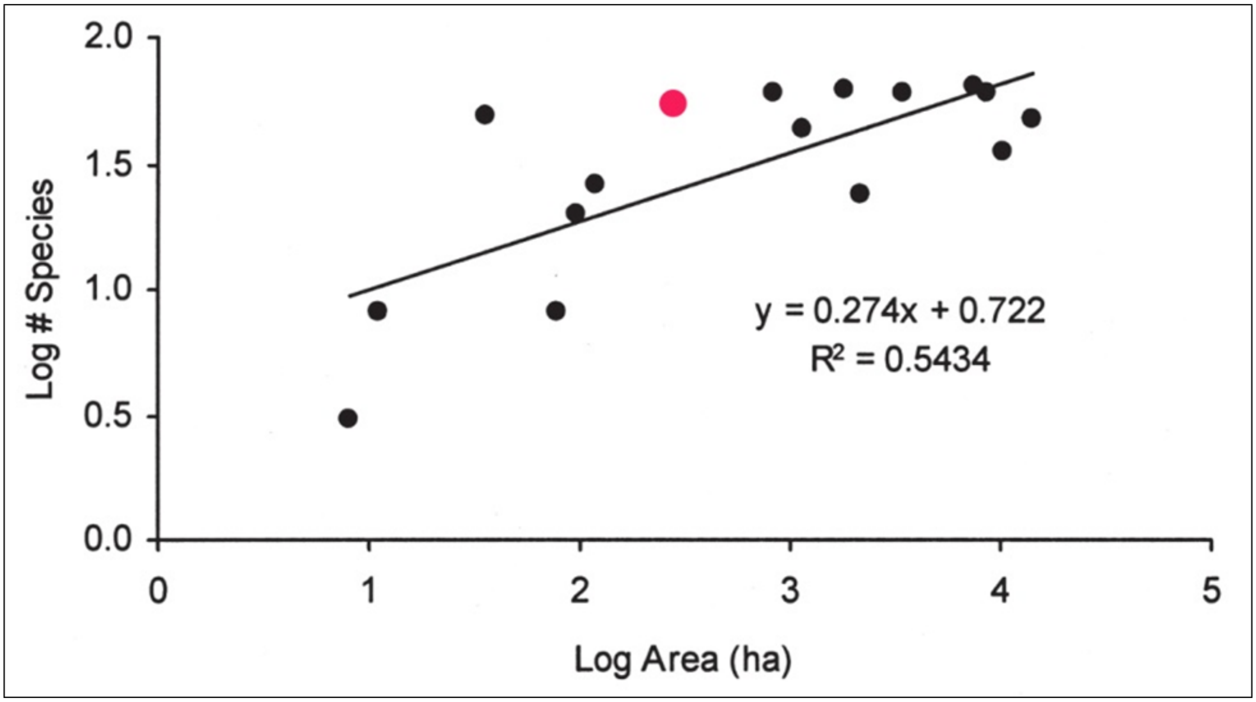


Figure 34. Relationship between land area (in hectares) and herpetofauna species richness, excluding exotic (introduced) species, among 16 parks within the SECN, including OCMU, showing the strong positive linear relationship between (log-transformed) land area and species richness (P = 0.001). Note that 55 herpetofauna species (24 amphibians, 31 reptiles) were considered to occur in Ocmulgee NM during the time of that survey (2001–2003). From Tuberville et al. (2005), with permission from Southeastern Naturalist. Red dot—Ocmulgee NM.

An Amphibian Community Monitoring Protocol is available for use in all network parks (Byrne et al. 2013). Byrne et al. (2011a) described partial implementation and test application of Standard Operating Procedure (SOP) 1.4.22 of the protocol, the automated recording device (ARD) SOP, to monitor vocal anuran amphibians (frogs and toads) at Ocmulgee NM in 2009, and this effort was repeated and expanded in 2011 as described below. In addition, a brief survey was conducted in 2006 in an effort to determine whether a chytrid fungal pathogen of amphibians is present in the monument (below).

NPS 2009 Study of Vocal Anuran Amphibians

Data were collected by Byrne et al. (2011a) from 5 to 15 May 2009 at 30 spatially balanced, random locations in the monument (Figure 35). A sample size of 20 was chosen after consideration of the monument size, hypothesized variability, and logistical issues. A total of 5,760 minutes were recorded by the ARDs when deployed in the monument. ARDs provide only detection versus non-detection information; thus, data on abundance could not be obtained with this SOP.

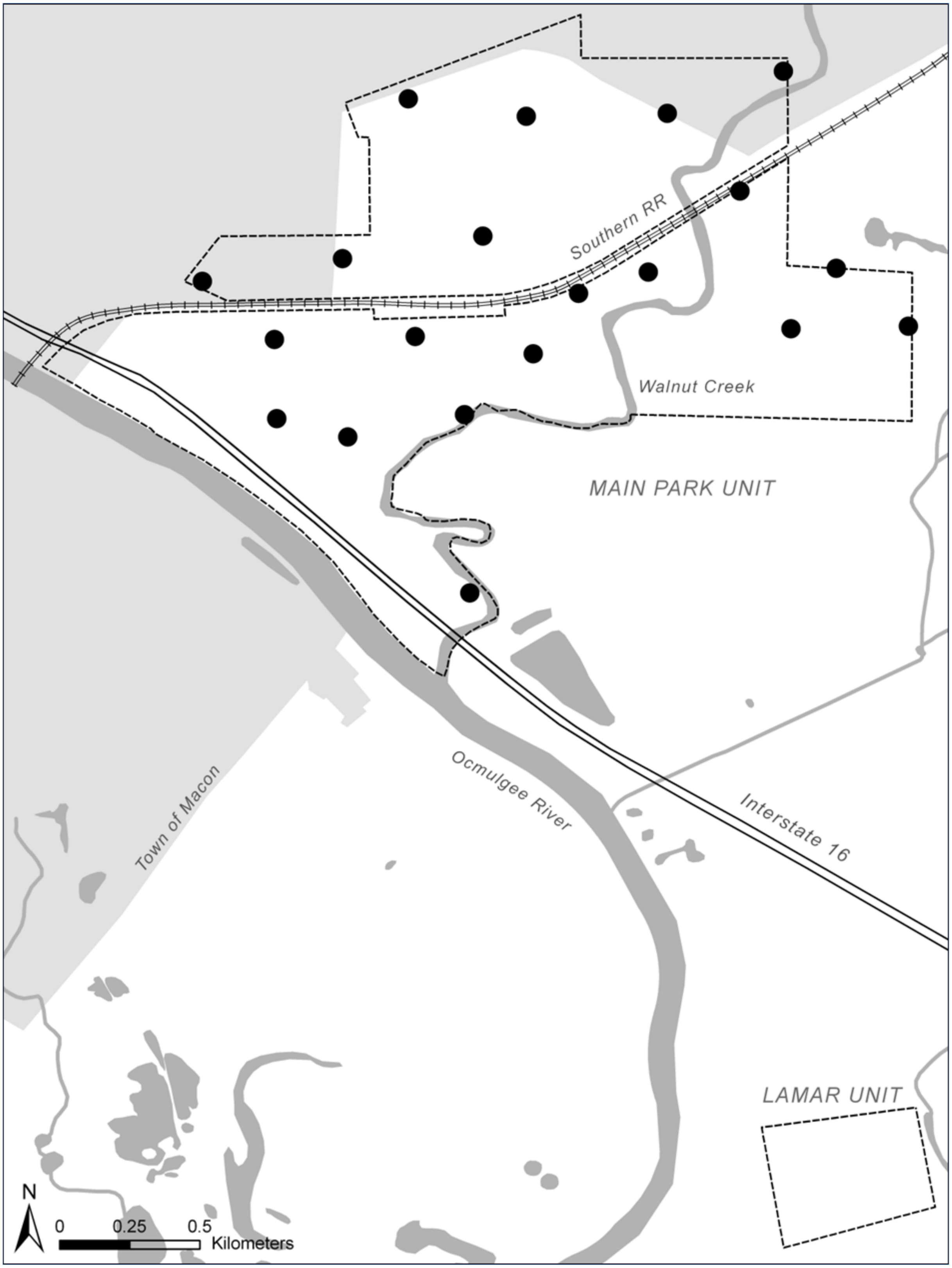


Figure 35. The spatially balanced random sampling locations used in the 2009 preliminary study of vocal anurans (frogs, toads), mostly in the northern half of the OCMU Main Unit. From Byrne et al. (2011a).

The study detected 11 of the 16 vocal anuran species known to occur at Ocmulgee National Monument. The most widely detected species was the bird-voiced treefrog (*Hyla avivoca*). The species accumulation curve generated from the data asymptotes at 18, which was the number of actual samples collected because 2 of the 20 devices malfunctioned. The ARD results were considered to be adequate to characterize vocal anuran community diversity at Ocmulgee National Monument.

The diversity indices estimated from this study and related interpretations will be considered as an information baseline for comparison with future efforts to track the amphibian communities of the monument. All diversity indices were consistent with one another and appeared to perform well with the (small) dataset, considering the low uncertainty that was indicated by small 95% CIs. Estimates of true vocal anuran species richness ranged from 11 to just under 12.88.

NPS 2011 Study of Amphibians and Reptiles
In 2011 another sampling was completed at Ocmulgee National Monument by the National Park Service (NPS 2013b) and considered both reptiles and amphibians. The 21 spatially balanced random sampling locations differed somewhat from those used in 2009 (Figure 35 vs. Figure 36). Visual encounter surveys (VESs) and ARDs were used to collect data; auditory recordings were collected from 8 March through 27 May, and visual surveys were conducted from 19–29 May. A total of 391 vocal detections were made using the ARD recordings; each detection was an identifiable observation of a species or species group during one night at a given sampling location.

Throughout the study 15 amphibian species were detected, including anuran vocalization from 14 species. During the VESs, 95 post-metamorphic amphibians in 15 identifiable taxa and 85 larval-stage amphibians representing 3 taxa were detected. All were native to the region. The cricket frog (*Acris* sp.) and bird-voiced treefrog (*Hyla avivoca*) had the highest relative frequency of detection from anuran vocalizations. The Ocmulgee slimy salamander (*Plethodon ocmulgee*) had the highest relative abundance during the VESs. The southern toad (*Anaxyrus terrestris*) had the highest frequency of occurrence, and was also the most widely distributed amphibian. One species, the upland chorus frog (*Pseudacris feriarum*), was newly documented for the monument. The data analysis indicated that the sample size is sufficiently large to characterize amphibian diversity. Amphibian monitoring at Ocmulgee National Monument is planned at three-year intervals.

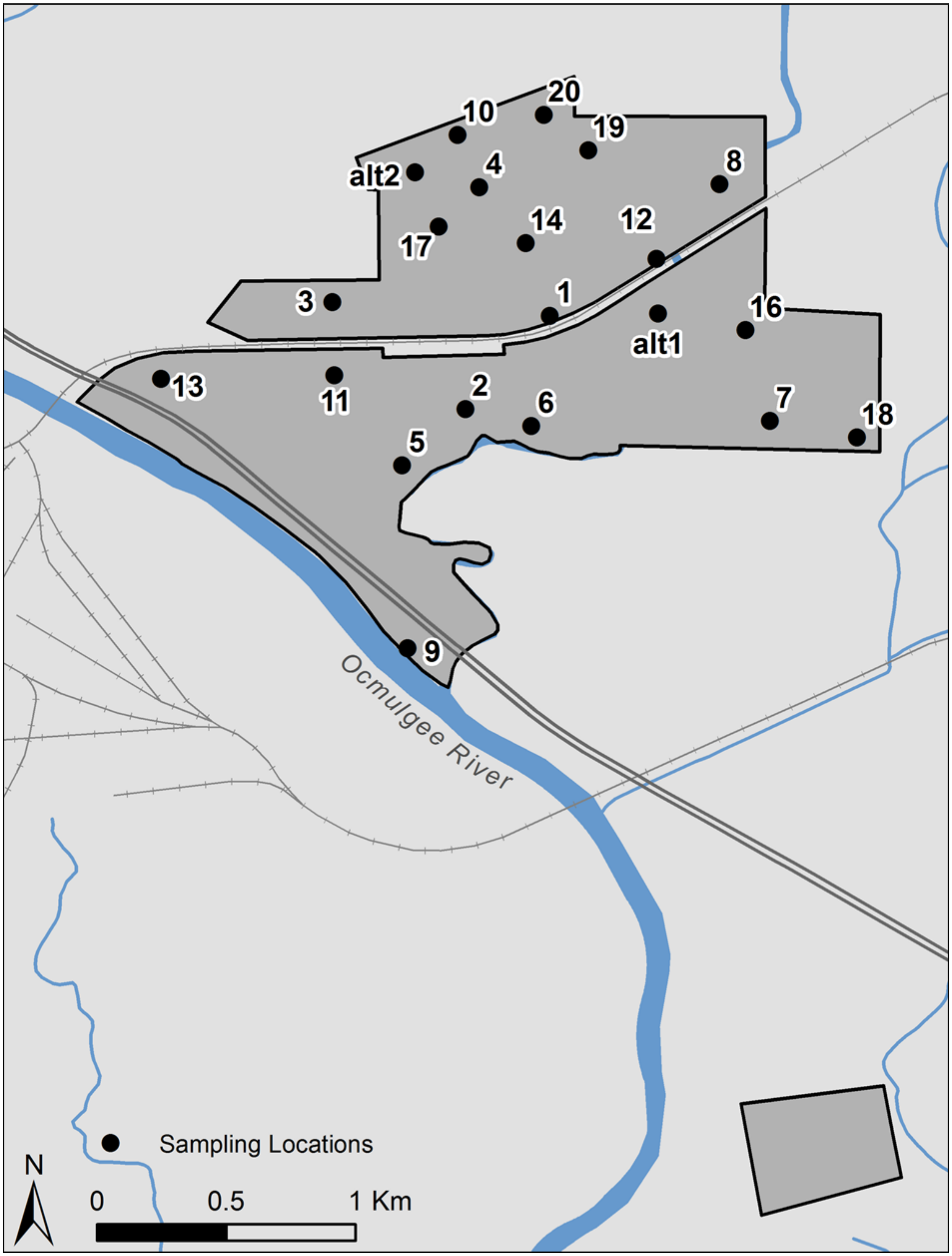


Figure 36. The spatially balanced locations used to sample anuran amphibians at Ocmulgee in 2011 (NPS 2013b).

Birds

Birds are an important component of park ecosystems, and their high body temperature, rapid metabolism, and high ecological position in most food webs make them a good indicator of the effects of local and regional changes in ecosystems. Long-term trends in the community composition, relative abundance, distribution, and occurrences of breeding bird populations provide a measure for assessing the ecological integrity and sustainability in southeastern systems (Byrne et al. 2011b).

As of 2013, 172 species of birds have been reported from Ocmulgee National Monument (NPS 2013a), including 36 species (21% of the total) that are mostly associated with wetland/aquatic habitats. Wading birds are abundant at the monument (Chief Ranger Guy Lachine, pers. comm.). The monument has four state-listed SSCs (Table 30—three state-listed rare or threatened species, the cerulean warbler (*Dendroica cerulea*), golden-winged warbler (*Vermivora chrysoptera*), and Wilson's plover (*Charadrius wilsonia*); and the endangered wood stork (*Mycteria americana*) which is both state- and federally listed). The GA DNR also described Swainson's warbler as a SSC in Coastal Plain seepage swamps and shrub bogs, bottomland hardwood forests, river bank and levee forests, and small stream floodplain forests (Chafin 2011), habitats which occur in the park. The Audubon WatchList (Butcher et al. 2007) previously indicated that the cerulean warbler was declining. Only two species, the English sparrow (*Passer domesticus*) and the European starling (*Sturnus vulgaris*), are exotic/invasive avian taxa. Numerous bird species are present in the monument, either feeding or nesting or both; these include the wood stork which feeds at Ocmulgee National Monument during the summer season. In addition, migratory birds use the monument and nearby refuge habitats as a stopover during spring and fall. An Avian Conservation Implementation Plan has been developed for the monument and is designed to help identify and prioritize bird conservation opportunities (Watson 2005).

Byrne et al. (2011b) conducted a survey of birds at the main unit of Ocmulgee National Monument in 2009. The objective was to determine trends in landbird species occupancy, distribution, diversity, and community composition in the monument. The data collection (conducted April–June) maximized detection of species that reproduce in the monument as well as migratory birds; the time of day that monitoring was conducted (0530–1100 hr) was selected to maximize detection during periods of high activity. Data were collected at the same 20 spatially balanced random locations as the vocal anuran study (Figure 36). Each site was sampled twice during the sampling period, at least three weeks apart, in an attempt to detect migrants or breeding birds that arrived at different times of year. At each station, counts were separated into four time segments of equal duration (0–3 minutes, 3–6 minutes, 6–9 minutes, 9–12 minutes) to allow comparisons with data from the North American Breeding Bird Survey. Relative abundance was assessed as the proportion of the total observations that was represented by each species.

The 2009 survey indicated high diversity of birds at Ocmulgee National Monument: A total of 663 individual birds representing 71 species were detected, including only two exotic species (the European starling and the house finch). Three species, the alder flycatcher (*Empidonax alnorum*), cliff swallow (*Petrochelidon pyrrhonota*), and tree swallow (*Tachycineta bicolor*), were new reports for the monument. The most widely distributed species were the Carolina wren (*Thryothorus ludovicianus*), northern cardinal (*Cardinalis cardinalis*), and tufted titmouse (*Baeolophus bicolor*), which were found at all of the sampling locations. The second most widely distributed species group included the red-bellied woodpecker (*Melanerpes carolinus*), Carolina chickadee (*Poecile carolinensis*), American crow (*Corvus brachyrhynchos*), and white-eyed vireo (*Vireo griseus*), which were detected in 70 to 90% of the sampling sites.

A total of 25 priority species, as identified by Watson and Malloy (2006), were detected during the 2009 survey, including the Acadian flycatcher (*Empidonax virescens*), American coot (*Fulica americana*), brown-headed nuthatch (*Sitta pusilla*), cerulean warbler, chimney swift (*Chaetura pelagica*), eastern kingbird (*Tyrannus tyrannus*), eastern towhee (*Pipilo erythrophthalmus*), eastern wood-pewee (Contopus virens), great egret (*Ardea alba*), hooded warbler (*Wilsonia citrina*), indigo bunting (*Passerina cyanea*), Kentucky warbler (*Oporornis formosus*), mallard (*Anas platyrhynchos*), northern flicker (*Colaptes auratus*), northern parula (*Parula americana*), pine warbler (*Dendroica pinus*), prairie warbler (*Dendroica discolor*), prothonotary warbler (*Protonotaria citrea*), red-bellied woodpecker, red-headed woodpecker (*Melanerpes erythrocephalus*), red-shouldered hawk (*Buteo lineatus*), summer tanager (*Piranga rubra*), white-eyed vireo, yellow-billed cuckoo (*Coccyzus americanus*), and yellow-throated warbler (*Dendroica dominica*).

Evaluation of the study sampling effort in comparison to the number of species detected (species accumulation curve) indicated that the sample size adequately characterized bird diversity. Rank-abundance plots, frequency distributions, and other descriptive approaches were used to explore the abundance distributions and patterns in the dataset.

<u>Mammals</u>

The Southeast Coast Network I&M Program has taken steps to document the mammalian fauna of Ocmulgee National Monument by supporting a study by Webster (2010), which represents the first comprehensive survey of this important biological resource. In addition to gathering information from museums in intensive work, sampling in the monument was conducted in October 2003, for a total of seventeen days in the Main Unit (2,325 trap-nights of sampling effort) and two days in the Lamar Mounds Unit (Figure 37). Five major habitats were identified for mammals including creek edges, bottomland forest, upland hardwood forest, upland pine forest, and regularly maintained fields. Most field work (Sherman live traps, pitfall traps, and extensive groundtruthing for spoor) occurred in the main unit, which had adequate segments of each habitat. Trapping was not conducted at the Lamar Mounds unit due to the potential for flooding. Bats were not included in the survey.

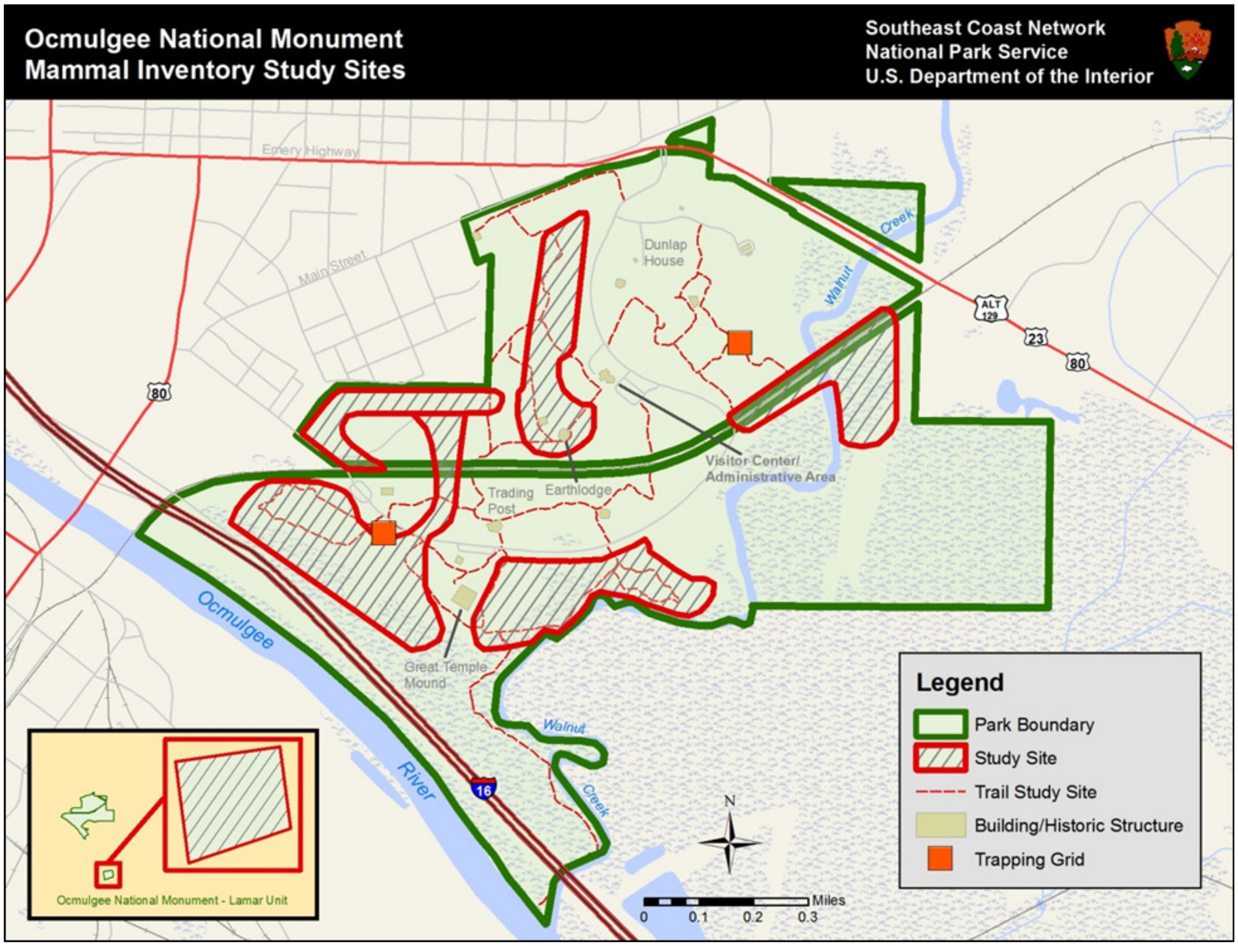


Figure 37. Mammal inventory study sites in the OCMU Main Unit in 2003. From Webster (2010).

A total of 23 species of terrestrial mammals were documented at Ocmulgee National Monument during the survey, including 21 species in the Main Unit (counting the domestic dog) and 11 in the Lamar Mounds Unit. Eleven species were added to this list that are widely distributed in the Southeast. These species were not encountered at the monument during the Webster (2010) survey, but were designated as probably present because they were expected to be there. Although the NPS Certified Species List (2013a) has 32 species (reported at some time from the monument) and Webster's (2010) list has 33 species (present or probably present), the two lists differ by much more than 1 species. In fact, the two lists have only 23 species in common. The NPS Certified Species List (2013a) has 32 mammalian species and includes 7 species of bats which, as mentioned, were not included in the Webster (2010) study; in addition, the oldfield mouse (*Peromyscus polionotus*) and the eastern chipmunk (*Tamias striatus*) are missing from Webster's (2010) list.

The white-tailed deer (*Odocoileus virginianus*) is the only large indigenous mammal presently in Ocmulgee National Monument and the surrounding area (GA DNR 2004; DeVivo et al. 2008). Beavers and other small mammals, including raccoons, opossums, flying squirrels, rabbits and numerous species of ground-dwelling rodents have been described as abundant within the monument (GA DNR 2004; DeVivo et al. 2008). The coyote is a mammalian species of special interest to monument staff, as it first was found at the monument around the turn of the twenty-first century (DeVivo et al. et al. 2008). Three mammalian species have apparently been extirpated (red wolf—*Canis rufus*, American black bear—*Ursus americanus*, and mountain lion—*Puma concolor*)—but note that Webster 2010 evaluated the black bear as "probably present," at least on a transient basis, in the Lamar Mounds unit.

In spring, summer, and fall of 2004–2005, Loeb (2005) surveyed for bats in five SECN parks, including Ocmulgee National Monument. Mist-netting for bats was conducted at four sites and acoustic sampling at 18 sites in the monument. A total of 16 bats within five species were captured in the mist nets, including the state SSC, Rafinesque's big-eared bat (*Corynorhinus rafinesquii*), big brown bat (*Eptesicus fuscus*), red bat (*Lasiurus borealis*), Seminole bat (*Lasiurus seminolus*), and evening bat (*Nycticeius humeralis*). Two more species, the eastern pipistrelle (*Pipistrellus subflavus*) and Brazilian free-tailed bat (*Tadarida brasiliensis*), were recorded by the bat detectors. Bat activity was detected at all of the sites sampled. Big brown bats were the most frequently found and occurred at 14 of the sites. Documentation of Rafinesque's big-eared bat was the first record for central Georgia. Other work has indicated that big brown bats, red bats, and Brazilian free-tailed bats have adjusted well to urban environments (Mager and Nelson 2001; Duchamp et al. 2004). The high diversity of bat species at Ocmulgee National Monument was also attributed to the location of the monument on the Fall Line, which allows for the presence of both Coastal Plain and Piedmont species. In addition, the monument offers habitat types ranging from pine forests to bottomland hardwoods, including large hollow trees for big-eared bats.

Exotic/Invasive Species

Invasive exotic species may fragment native ecosystems, displace native plants and animals, and alter ecosystem function. Invasive species are second only to habitat loss as threats to global biodiversity (Scott and Wilcove 1998). Such species negatively affect park resources and visitor enjoyment by altering landscapes and fire regimes, reducing native plant and animal habitat, and increasing trail maintenance needs (Young et al. 2007).

Exotic species are a foremost concern for national parks throughout the United States, including the Southeast and most certainly including Ocmulgee National Monument. As mentioned, there are 109 exotic/invasive vascular plant species presently known in the monument (Table 31, Appendix C); these include 69 terrestrial plant species (2 cultivated), 38 wetland plants (1 cultivated species), and 2 aquatic plants. Among fauna, there are an additional 3 birds and 9 mammals for a total number of 121 exotic/invasive species, excluding known exotic/invasive insects. Quantitative information and maps of present distribution/coverage are lacking even for the most high-impact of these species, although a map of the major plant communities/habitats of Ocmulgee National Monument was recently published (Zomlefer et al. 2013; Figure 33). It is important to note that nearly all of the exotic/invasive species that occur in the monument have been found in disturbed areas, as would be expected, although many of them occur in other habitats as well.

Flora

The National Park Service recently evaluated Ocmulgee National Monument as "heavily infested with exotic vegetation" (NPS 2014d). As examples, the Great Temple Mound was described as threatened by tree-of-heaven, and the Lamar Mound B (Spiral Mound) by Chinese privet. The state of Georgia has ranked the most noxious of the exotic plants in the state as the Top 10 (Miller et al. 2016). The monument has seven of the top ten, including four terrestrial plants: mimosa (*Albizia julibrissin*), golden bamboo (*Phyllostachys aurea*), kudzu (*Pueraria montana* var. *lobate*), and Chinese wisteria (*Wisteria sinensis*). It also includes three wetland plants: Chinese privet (*Ligustrum sinense*), Japanese honeysuckle (*Lonicera japonica*), and Nepalese browntop (*Microstegium vimineum*). These plants rapidly overgrow and shade out native, beneficial plant species, inhibiting their growth and displacing them in forests, fields, and/or wetlands. In addition, the berries produced by some of these species, such as Chinese privet, are less nutritious for wildlife than native species.

The Georgia Exotic Plant Pest Council (EPPC) also created a *Georgia List of Exotic and Invasive Plants*, wherein plants are ranked into categories with number one being the worst (GA EPPC 2015). The preface to the list notes that, as for the monument, detailed distribution information does not exist throughout the state for many of these species. Category one includes twenty species of exotic plants that cause "a serious problem in Georgia natural areas by extensively invading native plant communities and displacing native species." Ocmulgee has fourteen of the twenty Category one species (seven terrestrial species: *Ailanthus altissima*—tree of heaven, mimosa, English ivy, *Lespedeza cuneata*—sericea lespedeza, *Melia azedarach*—Chinaberry, kudzu, and wisteria; and seven wetland species: alligatorweed, Chinese privet, Japanese honeysuckle, *Lygodium japonicum*—Japanese climbing fern, Nepalese browntop, *Murdannia keisak*—marsh dewflower, and *Triadica sebifera*—Chinese tallow-tree). Interestingly, golden bamboo is ranked as a Category two species, despite the fact that it is on Georgia's top ten list of the most noxious invasive plants (Miller et al. 2016).

Finally, the National Park Service has a top-ten species list for the Southeast region (NPS 2015b). Ocmulgee National Monument has five of these species (tree of heaven, English ivy, kudzu, Chinese privet, Japanese honeysuckle).

Comparison of all three lists (Appendix C) reveals that four species—mimosa, Chinese wisteria, Nepalese browntop, and Chinese tallow-tree—are both category one species and members of the EPCC's Top Ten list. Two species, tree of heaven and English ivy, are both Category one species and members of the NPS Top Ten Species List. Three species, the most potentially damaging—Chinese privet, Japanese honeysuckle, and kudzu—are included on all three lists.

Overall, Ocmulgee National Monument has forty-one invasive vascular plant species indicated by rankings within categories one through four, including twenty terrestrial species (seven category 1, five category 2, four category 3, and three category 4); nineteen wetland species (seven category 1, three category 2, four category 3, and five category 4), and two aquatic species (one category 2, one category 4). The basis for this information is Zomlefer et al. (2013). Although that publication lists thirty-seven invasive vascular plants (Zomlefer et al. 2013), the table actually contains thirty-eight species; in addition, one species (bald brome, *Bromus racemosus*) was inadvertently omitted from the table although it was described in the text; and, Spanish needles (*Bidens bipinnata*), and spinyleaf naiad (*Najas minor*) were inadvertently omitted from that table. Inclusion of these species in the count would bring Zomlefer et al.'s (2013) tally into agreement with the forty-one invasive vascular plant taxa that we report here (Appendix C).

Combating such a large, formidable group of invasive taxa is a considerable challenge, especially with limited resources and financial support, and the monument does not have a guiding plan with a systematic approach to long-term management of exotic/invasive plants (NPS 2014d). Therefore, the management strategy has been to target certain species strategically. Park staff have established a list of 19 invasive plant species, and the list is being used for management control. As of 2013, 40 hectares (100 ac) of Ocmulgee National Monument had been successfully surveyed, treated, and managed for invasive plant species (G. LaChine, pers. comm., April 2013). For the past 10 years, park personnel have targeted the four most prevalent invasive species including tree of heaven, Chinese privet, Chinaberry, and kudzu. More recently a fifth species, Chinese tallow-tree (*Triadica sebifera*), has become widespread in the Walnut Creek wetlands area of the monument, and has also been found at the Lamar Mounds Unit (Zomlefer et al. 2013). Removal efforts have been undertaken for that species. Others, such as Japanese honeysuckle and English ivy, have been eradicated especially from sensitive areas (e.g.,with cultural resources) whenever possible (NPS 2012b). In some locations the wetland species alligatorweed and marsh dewflower, and the aquatic species parrotfeather (*Myriophyllum aquaticum*), are of increasing management concern (Burkholder et al. 2010).

Fauna

The NPS Species List for Ocmulgee National Monument includes only animals that people of the southeastern United States are mostly accustomed to—house finches, house sparrows, starlings, domestic dogs, domestic and feral cats, red foxes—the exception being the “unacceptable” Norway rat (Table 32). Feral hogs have become unusual at the monument main unit due to active control measures by park staff, but this invasive species continues to thrive at the Lamar Mounds unit where control measures are more difficult to implement (Chief Ranger Guy Lachine, pers. comm., April 2013; and see NPS 2014d). Overall, though, as mentioned, the worst exotic animal species affecting the monument are insects, a category of animals is not included in the NPS Certified Species List (2013a) because there is, as yet, no listing of the likely-thousands of insect species that occur in the monument. Two, in particular, merit mention here: Since the early 1990s, many pine trees in the monument have died from an infestation of the southern pine beetle (Meeker 2000). The southern pine beetle is considered the most destructive forest insect pest in the southeastern United States (Clarke 1995), and continues to be a potential threat to other internal stands in the monument and neighboring lands.

Table 32. Exotic/invasive vertebrate fauna in OCMU, based on the NPS Certified Species List (2013a) as modified considering information from recent surveys (2000–: Johnston 2006; Zomlefer et al. 2013).

Scientific Name	Common Name (s)
Branta canadensis	Canada goose
Passer domesticus	English sparrow, house sparrow
Sturnus vulgaris	European starling
Canis familiaris	domestic dog
Canis latrans	coyote
Dasypus novemcinctus	nine-banded armadillo
Felis catus	feral cat
Mus musculus	house mouse
Myocastor coypus	nutria
Rattus norvegicus	Norway rat
Sus scrofa	feral pig
Vulpes vulpes	red fox

The second insect emphasized here is the red fire ant (*Solenopsis invicta*). This species originated in South America and was introduced to the United States in the 1930s (Porter and Savignano 1990). Since its arrival, it has infested more than 1.2 million square kilometers (468,625 mi^2 [300 million ac]) across the southern United States, despite federal quarantine measures (Hawaii Ant Group 2007, DOW 2015). The red fire ant largely has displaced the two fire ant species native to the Southeast, the tropical fire ant (*Solenopsis geminata*) and the southern fire ant (*Solenopsis exloni*) (Porter and Savignano 1990). Red fire ants also threaten human health. In the United States, millions of people are stung each year and more than 80 have died from hypersensitivity to the ant venom. Red fire ants additionally threaten wildlife, significantly depress biodiversity, and damage crops, ornamental plants, and electrical equipment (Porter and Savignano 1990; Wojnik et al. 2001; Hawaii Ant Group 2007). According to Chief Ranger Guy Lachine, fire ants are thriving at Ocmulgee National Monument.

2.2.4. Overview of Issues Affecting OCMU Natural Resources

The present and potential stressors that are affecting or may affect Ocmulgee National Monument are summarized in Table 33. Overwhelmingly, the most pressing stress on the natural resources of the monument is from adjacent and upstream urbanization and its multitude of associated impacts.

Table 33. Present-day and potential stressors that are affecting or may affect OCMU [ND—no data or insufficient data to make judgment; NA—not applicable; NP—no problem; EP—existing problem; PP—pending problem; "–"—no data given].

Stressor	Surface Waters/ Wetlands	Groundwater	Airshed	Forest	Human Health
Encroaching Urbanization[a]	EP	ND (PP)	EP	EP	EP
Acidification	EP	ND	EP	EP	EP
Air Quality	PP	ND	EP	ND - PP	ND (PP)
Noxious Algal Blooms[b]	EP	NA	NA	NA	ND
Excessive Nutrients[c]	EP	ND	EP	ND	NP
Exotic / Invasive Species	EP	NA	ND	EP	ND
Habitat Disruption	EP	EP	NA	EP	EP
Hypoxia (streams)	EP	NA	NA	NA	NP
Light Pollution	EP	–	–	EP	PP
Metals Contamination[c]	EP	ND	ND	ND (PP)	EP
Other Toxic Substances	ND (PP)	NE (PP)	EP	ND	EP
Noise Pollution	ND	–	–	EP	EP
Sedimentation[c]	EP	ND	EP	NA	EP
Soil Erosion (including dust)	EP	ND	EP	EP	NP
Trash/Refuse Pollution	EP	ND	NA	EP	ND
Water Demand	PP	PP	NA	ND (PP)	PP
Water Quality	EP	PP	–	ND (PP)	EP

[a] Is adding more air pollution because of car exhausts; also will increase likelihood of collisions with deer.

[b] Natural phenomenon that can be greatly exacerbated by human activities.

[c] From car exhausts, pet wastes, etc.

Noise pollution and light pollution at night likely are adversely affecting monument biota; poor air quality remains a significant concern, although, as a hopeful sign, two major pollution sources have reduced their emissions over the past decade. The airshed is in violation of federal ozone and fine particulate standards that threaten the health of monument staff and frequent visitors, and the high ozone concentrations may be damaging terrestrial plant foliage. Ocmulgee National Monument also lies in an area that is prone to atmospheric acid deposition, and acidification, especially acid spates, likely is adversely affecting its surface waters. There is high potential that surface water quality and aquatic communities are sustaining impacts from air pollution including acidification, mercury and other heavy metals, and pesticides.

The hydrology of Ocmulgee National Monument, especially that of its largest stream, the Ocmulgee River, was dramatically altered by construction of the Macon Levee in 1950 and further modifications that raised the levee 0.9 meters (3 ft) 20 years later. The levee effectively channelized the river with attendant negative, sustained impacts on water quality and aquatic communities. The amount of stormwater runoff from urban areas has increased dramatically over the past 30 years in urbanizing areas (Georgia Department of Audits and Accounts 2005). Information is lacking about monument wetlands. Hydrologic data are available from a USGS gaging station for the Ocmulgee River adjacent to (short distance upstream from) the monument. Sparse water quality data, mostly collected only seasonally or less frequently, have shown that the two perennial streams flowing through the monument are both on the state's 303(d) list of impaired waters. In particular, unacceptably high levels of fecal coliforms and/or suspended sediments from nonpoint pollution sources have impaired the designated use of these waters. The surface waters of Ocmulgee National Monument are downstream from 303(d)-listed degraded waters outside NPS jurisdiction. The perennial and ephemeral streams in the monument all show obvious signs of degradation from sedimentation, bank erosion, and trash accumulation. The Ocmulgee River segment that flows through the park is also impaired for fish consumption because of high PCB content.

There are no operating wells for tracking groundwater quality or quantity, but a USGS well more than 70 kilometers (43.5 mi) west of the monument is being used by the National Park Service as a proxy for groundwater quantity conditions in the vicinity of the park, and has shown a statistically significant decline in water level over time. Groundwater quality is unknown but, because of pollution sources in the area surrounding the monument, groundwater quality is a concern identified by park staff. In addition, the increasing demands on water supplies from human population growth may pose a threat to surface and groundwater resources at Ocmulgee National Monument in the coming decades.

The aquatic flora and fauna of the monument are poorly known other than species lists. Progress in characterizing the diversity of amphibians and birds has been made through regular monitoring. The study suggests high diversity of birds in particular. In contrast, based on the available information, fish communities are very low in diversity and sensitive aquatic fauna have likely been locally extirpated. Diverse exotic/invasive plant and animal species occur in both terrestrial and aquatic/wetland habitats of Ocmulgee National Monument, and are a major concern. Adverse impacts on terrestrial ecosystems have been documented for some of these species, but attempts to control even the major noxious taxa are hampered by funding constraints and most of these species are poorly tracked. Despite the substantial progress that has been made by monument staff in combating exotic species, new invasions are a continuing issue and lasting progress depends heavily on regional project funding.

Various other stressors to the natural and historic resources of Ocmulgee National Monument are all related to encroaching urbanization, such as illicit dumping of trash and other refuse, erosion/washout of hiking trails that receive heavy use, potential adverse impacts from application of herbicides to maintain the CSX railroad bed, and spillover crime from the City of Macon. Chief Ranger Lachine (pers. comm., 30 April 2012) described the monument as the "stormwater outfall for the city of Macon—street litter flows into the park."

2.3. Indicators to Assess Natural Resource Condition

2.3.1. Management Directives and Planning Guidance

A General Management Plan (GMP) and Environmental Assessment/Impact statements for Ocmulgee National Monument were developed 30 years ago (NPS 1976, 1983) due to increasing concerns about protecting the monument from the impacts of surrounding urbanization. The NPS mission is to "preserve unimpaired the natural and cultural resources and values of the national park system for the enjoyment, education, and inspiration of this and future generations" (NPS 2015f).

Ocmulgee National Monument was listed on the National Register of Historic Places in 1996, and the National Park Service designated it a Traditional Cultural Property in 1997, the first such property east of the Mississippi River. The monument's specific mission statement has evolved over time; as previously explained, the present mission statement for the monument encompasses a dual conservation and education mission as mandated by the NPS Organic Act (1916) and the Historic Sites Act (1935):

> "The mission of the National Park Service at Ocmulgee National Monument is to protect and preserve lands known as the "Old Ocmulgee Fields," and promote understanding of and an appreciation for the 12,000-year continuum of American Indian-related cultural and natural resources."

Ocmulgee National Monument has a long-range interpretive plan, as of 2009 (see NPS 2009). However, the monument does not yet have a science-/scholarship-based Resource Stewardship Strategy (RSS), which is designed to help park staff achieve and maintain desired resource conditions as described in the GMP. This report will assist Ocmulgee National Monument in developing its RSS, by providing measurable science-/scholarship-based indicators to impartially assess monument natural resource conditions over time, and to establish target values that represent desired conditions.

In 1999, the National Park Service (NPS 1999) developed an action plan, the Natural Resources Challenge, for preserving the natural resources of the national parks (see Carter et al. 2007), and has been engaged in many efforts to carry out that plan. The NPS I&M Division has done considerable work to identify natural resources and indicators that are important from the perspective of the monument:

Three general properties were identified that broadly affect the integrity of ecosystems and natural resources in regional parks: (a) parks are generally surrounded by altered landscapes; (b) the ecosystems of the network are driven to a large extent by natural disturbance process such as hurricanes, flooding, and fire; and (c) the region is increasingly subject to human development, resulting in diverse anthropogenic effects on park resources (DeVivo et al. 2008).

The I&M Division developed a suite of conceptual models to support and guide development of a monitoring program for the parks, using a general ecosystem model as a template for specific models of the six dominant ecosystem types found in regional parks. Ocmulgee National Monument has three of these—Upland Forests, Bottomland Hardwoods (wetlands), and Streams. Each model includes a set of system drivers, local drivers, and park resources. The I&M Division also identified 25 vital signs, most of which were planned to be monitored as part of the I&M Program efforts (Table 34). The natural resource based vital signs span all categories of the ecological monitoring framework: Air & Climate, Geology & Soils, Water, Biological Integrity, Human Use, and Ecosystem Patterns and Processes. The I&M Program's work also covers ecosystem patterns (land use/land cover) cover) and various aspects of human use. Many of the measures were on the preliminary list of potential indicators for Ocmulgee National Monument. For many of these parameters, however, information for the monument is not yet available, underscoring the importance of the I&M program's work to establish present natural resource conditions in the monument and track them over time to assess the monument's health.

Table 34. Vital signs identified by the I&M Division for SECN inland parks including OCMU [1—Vital Sign for which the SECN will develop protocols and implement monitoring; 2—Vital Sign that is monitored by a network park, another NPS program, or another federal or state agency]. Modified from DeVivo et al. (2008).

Ecological Monitoring Framework Subcategories	Network Vital Sign	Measures	OCMU
Air Quality[1]	Ozone	Atmospheric ozone concentration, damage to sensitive vegetation	2
	Wet and Dry Deposition	Wet and dry sulfate and nitrate deposition	2
	Visibility and Particulate Matter	IMPROVE suite for visibility and fine particulates, particle size analyses: pm 10, pm 2.5, haze index	2
	Air Contaminants	Concentration of mercury, semi-volatile organic compounds, acidic (N,S) and nutrient (N) components of contaminants	2
Weather and Climate[2]	Weather and Climate	Air temperature, precipitation, relative humidity, tides, location and magnitude of extreme weather events	2
Geomorphology[3]	Stream/River Channel Characteristics	Percent cover of coarse woody debris, detritus, distribution and extent of geomorphic features (runs, riffles, pools); grain size distribution; distribution, extent and rate of change of erosion features	1
Hydrology[3]	Groundwater Dynamics	Water table levels	2
	Surface Water Dynamics	Discharge, magnitude and duration of flooding events	2
Water Quality[3]	Riverine Water Quality	pH, temperature, dissolved oxygen, specific conductance, turbidity, trace ions, nutrient concentrations	1
Invasive Species[4]	Invasive/Exotic Plants	Occurrence of invasive plant species	1
Focal Species or communities[4]	Amphibians	Species occurrence, diversity, percent area occupied, disease incidence.	1
	Birds	Species occurrence, diversity, relative abundance	1
	Plant Communities	Plant species occurrence, diversity; percent cover by herbaceous, shrub and overstory; rooting by feral hogs and armadillos; occurrence of disease, occurrence of insect outbreaks, occurrence of non-native species; NVCS class	1

[1] Air and Climate

[2] Geology and Soils

[3] Water monitoring

[4] Biological Integrity

3. Study Scoping and Design

3.1. Preliminary Scoping

Southeast Coast Network I&M program manager Joe DeVivo organized an initial workshop for this project in Atlanta, wherein we received guidance about the background and foundation of NPS National Resource Condition Assessments (NRCAs). We also received counsel about the best NPS specialists to contact about various aspects of the project, available NPS data, and NPS websites with important information. This meeting addressed all project objectives, especially (ii) Determine the subset of NPS-identified and PI-identified data and information sources that are most pertinent and useful for developing indicators and performance measures and (vi) Conduct a series of workshops to assist in project completion.

In recognition of the fact that park staff have, by far, the most advanced and detailed, comprehensive understanding about the natural resources of Ocmulgee National Monument, we then visited the monument and spent several hours with Chief Ranger Guy Lachine. We discussed each category of natural resources, and learned his knowledgeable views about issues for each category that would need to be considered in inventory and assessment efforts. His input was truly essential to enable us to select an optimal set of natural resource indicators that would be the most useful to the park staff both short-term and long-term. We also were given his guidance about which indicators should be emphasized as major priorities for the monument.

An extensive, continued effort over the entire span of the project was then conducted to obtain all manner of natural resource information pertinent to the monument—historic information, reports, books, peer-reviewed publications, management plans, GIS data, etc. All of this information was carefully considered in writing the final synthesis of the inventory and status of monument natural resources. The findings were presented within an ecosystem framework (Figure 38), that considered Ocmulgee National Monument as the ecosystem, following DeVivo et al. (2008). Using a hierarchical framework patterned after Unnasch et al.'s (2009) *Ecological Integrity Assessment Framework*, we first considered the overall goal(s) of the park staff for the desirable status, i.e., the ecological integrity, of each category of natural resources in the monument.

3.2. Study Design

3.2.1. Indicator Framework, Focal Study, Resources and Indicators

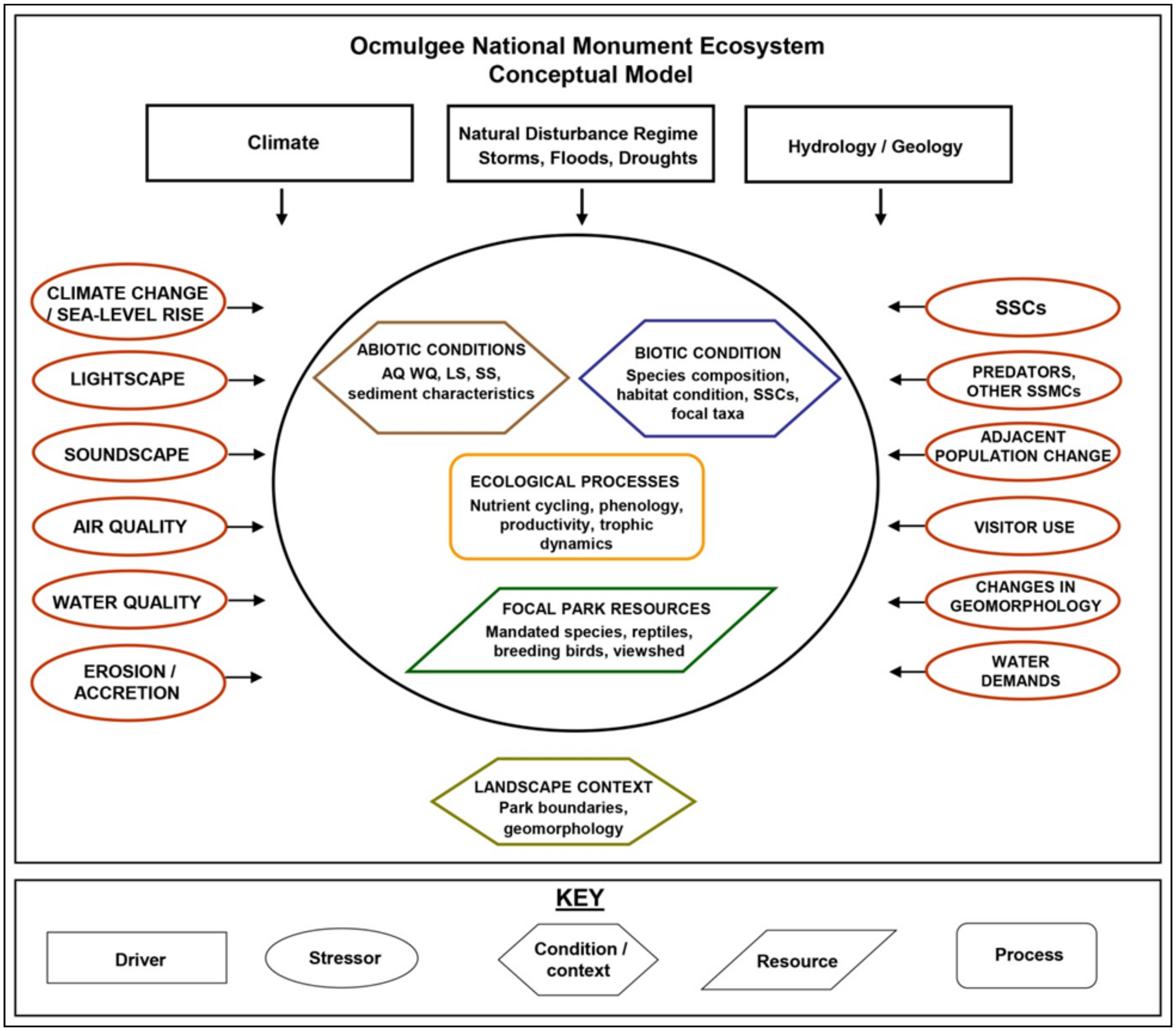


Figure 38. Conceptual model of the OCMU ecosystem, used as a general framework to select indicators of natural resource health for the monument. Adapted from information in DeVivo et al. (2008).

Ecological integrity is defined here as the ability of an ecological system to support and maintain a community of organisms with species composition, diversity, and functional organization comparable to those of the natural/historic habitats in the monument. We conducted a macroscale inventory of landscape patterns (land cover/land use) surrounding the monument; human population demographics in the area surrounding the monument and visitor statistics within the monument. We also examined air quality (airshed level), water quality (within the monument, but considering pollution sources near the monument), the soundscape, the lightscape, and stressors on the natural resources within the monument. This included a concerted effort to gather and organize existing databases for multiple GIS data layers describing monument natural resources. Next, we inventoried what is known about the vegetation, habitat structure, natural communities, SSCs, exotic/invasive species, and species of special interest for park managers. For each category of natural resources, we identified a suite of indicators and measures for tracking natural resource health at Ocmulgee National Monument. These indicators were selected to be scientifically sound while also providing a user friendly, straightforward, and easily accomplished method for evaluation.

Our intentions in meeting the latter requirement were two-fold: First, to provide, insofar as possible, a suite of indicators and the methods to assess them that park staff and the National Park Service in general will find clear, simple and rapid, and relatively inexpensive to conduct; and second, to provide an indicator system with powerful messages that are easy/fast to explain to policymakers who often have dramatic influence over our nation's national parks.

As noted by the South Florida Water Management District (Doren et al. 2008) in its *System-wide Indicators for Everglades Restoration 2008 Assessment*, "Any method of communicating complex scientific and findings to non-scientists [for Ocmulgee National Monument, the general citizenry, visitors to the park, and politicians who strongly influence critically needed funding for the park] must:

1. Be developed with consideration for the specific audience,
2. Be transparent as to how the science was used to generate the summary findings,
3. Have easy to follow, simplified results going back through the analyses and data to see a clear and unambiguous connection to the information used to roll-up the results,
4. Maintain credible scientific results without minimizing or distorting the science, and
5. Should not be, or appear to be, a judgment call (Norton 1988; Dale and Beyeler 2001; Niemi and McDonald 2004; Dennison et al. 2007).

The method must also be effective in quickly and accurately getting-the-point-across to the audience in order for the information to be used effectively (Rowan 1991; 1992; Dunwoody 1992; Weigold 2001; Thomas et al. 2006; Dennison et al. 2007).

Thus, here we use a "stoplight report card system" approach (Doren et al. 2009; NPS 2009a) of good (green), fair (yellow), and poor (red) to summarize our evaluation of present natural resource conditions at Ocmulgee National Monument (Table 35). This system has been used with great success to assess natural resource conditions systems such as Chesapeake Bay and its watershed (Williams et al. 2007), and the Florida Everglades ecosystem (Ferriter et al. 2007; Doren et al. 2008; Doren et al. 2009). As an additional feature, our assessment includes clear identification of conditions that are not possible for the National Park Service to control.

Table 35. The color-coded "stoplight report card" system used to succinctly convey the status of Ocmulgee NM natural resources.

Good	Fair	Poor
Green	Yellow	Red

We were instructed by the National Park Service to use indicators that were as quantifiable as possible, and supported by peer-reviewed science literature. We therefore clarify, with supporting scientific basis, any suggested indicators for which quantitative information for the monument was not available. Because this stipulation, while logical, greatly restricted the suite of indicators that could be proposed, in Chapter 6 we also include discussion of data gaps that we view as especially important to fill so that certain much-needed indicators can be developed. Finally, to ensure that the data used to develop the indicators and assessment were of acceptable quality, we restricted our inventory and this analysis to reliable sources (e.g., National Park Service, peer-reviewed literature, QA-QC'd water quality data, etc.), and to data collected by those sources within the past decade.

This indicator framework and suite of indicators for Ocmulgee National Monument support the identified goals of the National Park Service to "develop service-wide products that improve management of biological resources in parks, and maintain a broad ecosystem-based framework for park management (Unnasch et al. 2009)."

It should also be noted that the National Park Service (NPS 2014d) recently developed a State of the Park report for Ocmulgee National Monument. The report provides a summary of overall status and trends of six categories of park natural (and cultural) resources including air quality, lightscape (dark night sky), geologic features and processes, water quality, plant and wildlife communities, and protected species of concern. The report focused on NPS "priority resources," that is, fundamental and other important resources and values for Ocmulgee National Monument based on its purpose and significance within the National Park System, as documented in the general management plan. The information on natural resources in Ocmulgee National Monument was contributed toward improving monument priority-setting, and facilitating communication about resource status to the general public. The *State of the Park Report for Ocmulgee National Monument* (NPS 2014d) uses a similar stoplight system with additional information overlain about the trend in condition based on park staff's general knowledge, and about general confidence in the assessment. We considered the state of the park assessments in developing the suite of indicators presented in this report.

Available Data

Data Selection and Acquisition

Data files available through NPS GIS personnel were pared down to those relevant to natural resource management concerns. An FTP site was set up for file transfer from NPS personnel to the CAAE server. Data considered necessary for specific analytical or display purposes, but unavailable from NPS files, were obtained from external databases. The databases that provided statewide data for use in assessing Ocmulgee National Monument included:

- NLCD 2006 data (Fry et al. 2011), provided through the Multi-Resolution Land Characterization (MRLC) consortium (MRLC 2015);
- Georgia Land Use Trends 2005 and 2008 available from Georgia GIS Clearinghouse (2017; registration required for access).
- Statewide hydrology, elevation, geographic names and government unit file were obtained from the Geospatial Data Gateway (NRCS 2014);
- National Wetlands Inventory (NWI), Critical Habitat, National Wildlife Refuge Boundaries, and Wilderness Preserve Boundaries were obtained from the United States Fish and Wildlife Service (USFWS 2015);
- Landfill, Land Application Sites and 305(b) and 303(d) waterbody listings for 2010 were obtained from the GA DNR Environmental Protection Division (GA EPD 2017);
- 2010 U.S. Census Population Density data obtained from U.S. Census Bureau (USCB 2015b).

NPScape should also be mentioned. It is a landscape dynamics monitoring project of the National Park Service that produces and delivers to parks a suite of landscape-scale datasets, maps, reports, and other products to inform resource management and planning at local, regional, and national scales. Initial analyses include six major categories (population, housing, roads, land cover, pattern, and conservation status) that broadly address the environmental drivers, natural attributes, and conservation context of the parks. In aggregate, these measures contribute to assessments of current natural resource status, potential threats, and conservation vulnerability and opportunity. See NPScape (NPS 2014b) and the NPS Integrated Resource Management Applications (IRMA) portal (NPS 2015c).

Data Oversight and Database Management

Each file was reviewed for spatial reference and availability and correctness of metadata. Where necessary, files were copied and post-processed to marry into a cohesive database for across-the-board integration in map-making and analyses. Aerial imagery was examined in ArcMap and orthorectified where necessary.

Organizational efforts were made to maintain copies of NPS data in an “unadulterated” form digitally segregated from data that had been geoprocessed or created by the CAAE, while maintaining a logical directory structure. We separately maintained oversight of CAAE GIS systems (software and hardware), GIS computer hardware upkeep and maintenance, troubleshooting/updating of ArcGIS software, and, as needed, addressed any other database management requirements for spatial data amassed by CAAE staff. All of the GIS data we have gathered are listed in Appendix A.

Map Generation

Maps depicting various geographic themes were developed for Ocmulgee National Monument, including soils, geology, hydrology, wetlands, population density, impervious surfaces, urban encroachment and social trails, and land use coverage/change in the monument, sub-watershed, and/or overall river basin. We designed the maps to address points of interest specific to the monument, and to illustrate geographic positioning of known site localities and/or regional relationships.

4. Natural Resource Conditions

4.1. Watershed/Landscape Dynamics

4.1.1. Human Population in the Surrounding Area

Issue: Population size and rate of growth are linked to adverse ecosystem impacts. About two-thirds of the main unit perimeter borders urban and suburban development (Figures 5 and 6). While the population of the City of Macon has declined recently, the Atlanta area continues to expand at an average annual rate population increase of 2.4 to 2.9%—maintained since 1950 (Benfield et al. 1999, U.S. Census data from 2012).

The many stressors presently sustained by the natural resources of Ocmulgee National Monument (Table 33) are linked to urbanization of the watershed. Human-related land transformation is the primary driving force in the loss of biological diversity worldwide (Vitousek et al. 1997). The size, density, and rate of growth of the human population in a given area are linked to rapidly escalating environmental disruption (Ehrlich and Holdren 1971) and exotic plant species diversity and abundance (McKinney 2001). As noted by Meyer and Turner (1992), "population remains one of the few candidate driving forces that is readily measured and for which statistical associations have been found with ecosystem decline." The human population size, growth, and density surrounding national parks are unquestionably major influences on the park ecosystems. Thus, Rivard et al. (2000) found that species richness, extirpations, and alterations within other national parks are all related to characteristics of the lands surrounding the parks. In addition, species invasions and introductions were more frequent in parks that were subject to the most human influence.

Although the science literature is replete with reports about environmental degradation linked to increasing human population density, information is mostly lacking about the quantitative level of population density that acts as a threshold, triggering significant damage to the adjacent natural ecosystem. Luck (2007) summarized the issue as follows: "…clear and predictable links between human population dynamics and environmental change remain elusive largely because of the complexity of the human enterprise and its many and varied impacts on nature" (Figure 39). Viewed from a quantitative standpoint, impacts of high human population density can extend many kilometers beyond city boundaries (Myers 1994; Repetto 1994), but the effects can vary from minor to major in areas of lower human population density, largely depending on the major land uses (Luck 2007, and references therein). Context is important: For example, a marked increase in human population density near a wilderness reserve would be expected to have quite different impacts than if the increase occurred near a city park. Socioeconomics may exert influences on the degree of environmental impact.

Regardless of these complexities, we felt it important to represent human population density (HPD) and human population growth (HPG) as indicators of natural resource health in Ocmulgee NM, to account for the fact that human population impacts on adjacent natural resources are not fully captured by related indicators such as land use (Figure 40). In addition, it can be stated with confidence that human population growth results in land-use changes and increases exotic species introductions, and that land protected for conservation is often greatly reduced near human population centers (Luck 2007). The status of Ocmulgee NM as a relatively small "green island" adjacent to an urbanized area makes human population indicators important as well. As Luck (2007) wrote, “Protected areas close to human settlements suffer from ‘double jeopardy’ (Harcourt et al. 2001): they are small, which makes them susceptible to external impacts, and they are surrounded by high HPD, potentially undermining their capacity to afford adequate protection to their associated ecosystems.”

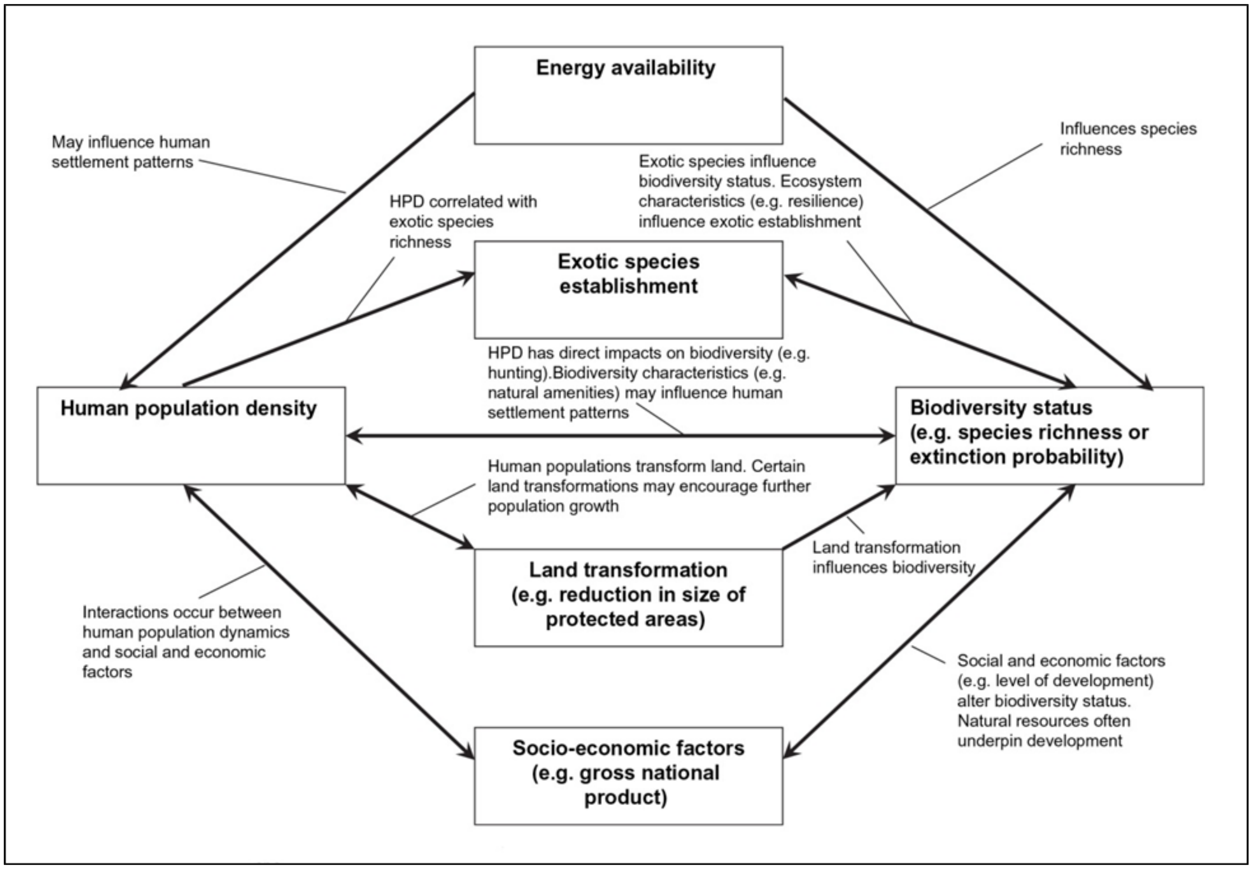


Figure 39. A schematic of possible relationships between human population density and biodiversity, especially focusing on the negative impacts of human population growth. The evidence for each of these relationships varies in the literature. The diagram includes biodiversity feedback loops, but not interconnections between energy availability, exotic species establishment, land transformation and socio-economic factors. From Luck (2007), with permission.

Our evaluation system for the two human population indicators considered the following information:

- Over the past decade (2001–2010), the national average was a 9.71% increase in HPG (1% per year), and the average HPD was 31.3 people per square kilometer (81.3 people per mi^2). The 1% per year value was used in developing the evaluation system for HPG; we centered the middle category, fair, around this value (0.8 to 1.2% per year).

- The state of Georgia had an overall population density of 65.7 people per square kilometer (170.2 people per mi^2 as of 2010; USCB 2016).

- As of 2010, the Atlanta metro area had 659 people per square kilometer (1,686 people per mi^2), and the population growth rate was 2.46% per year over the period from 2000 to 2010.

- With exception of the Atlanta area (population 5,443,532), the state of Georgia had an average population density of 85.6 people per square mile (33.0 people per km^2), within the category of > 17.8 to 48.3 people per square kilometer (> 46 to 125 people per mi^2; USCB 2016)

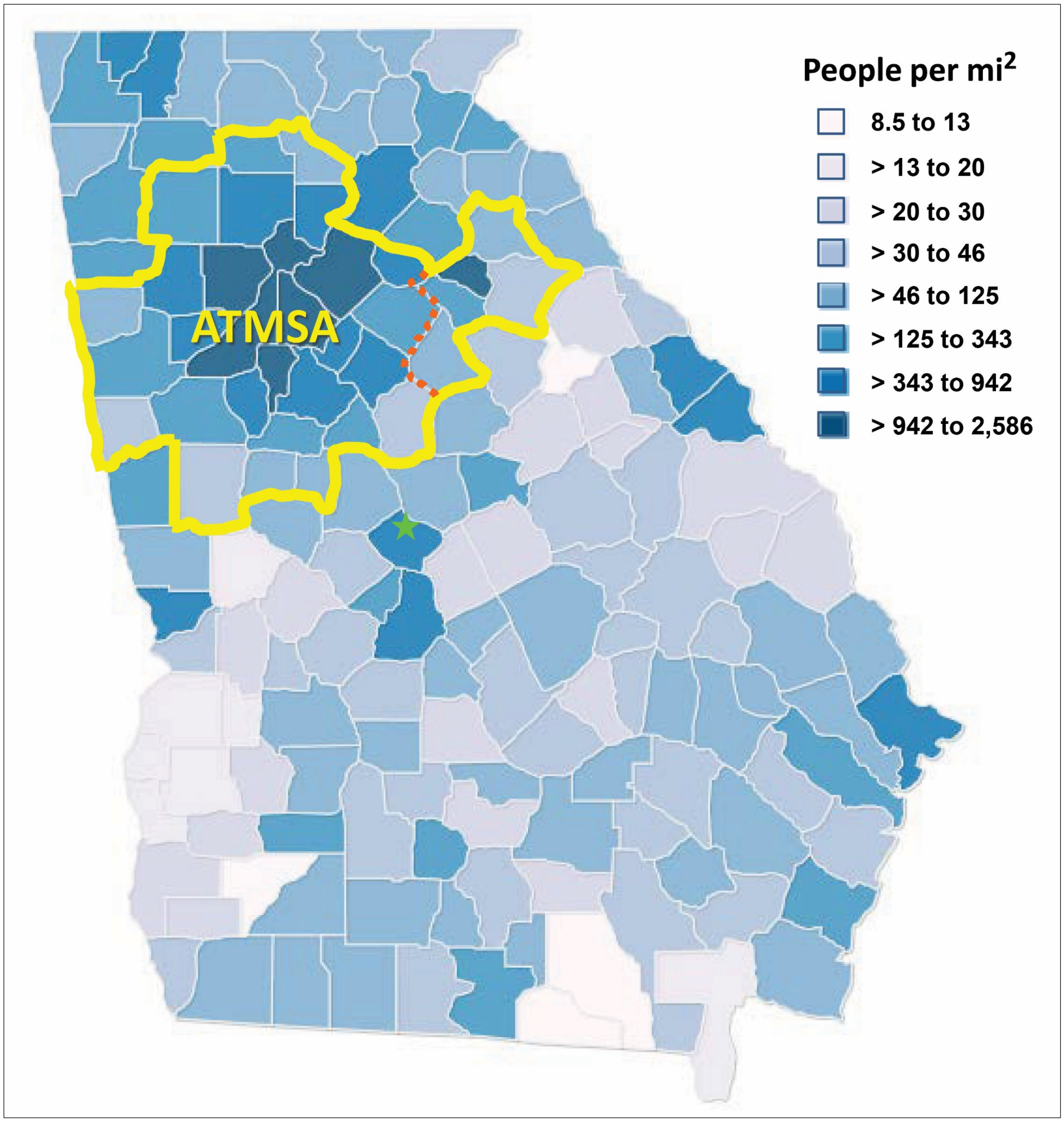


Figure 40. Map showing the Georgia population per square mile by county as of 2010, also showing the location of the park (green star), and the Atlanta Metro area (yellow boundary) including five counties that were added to the area in 2013 (to the right of the orange dotted line; UNC Charlotte 2013). Data source for the map: USCB, Census of Population and Housing; land area is based on information in the TIGER database, calculated for use with Census 2010 data. Map modified from Index Mundi 2017.

- As a historic "reference" condition, about 500 years ago the HPD of the area was 0.9 people per square kilometer (2.3 people per mi^2) (area of the southeast region from Burkett et al. 2001; number of American Indians there from Fagan 1995, Smith 2000).

- Analysis of 24 present-day wilderness areas revealed that all had population densities of ≤ 5 people per square kilometer (12.8 people per mi^2) (Mittermeier et al. 2003). We expect that present-day conditions, even in areas considered somewhat "remote," would have substantially higher human population density than did the southeastern United States about 500 years ago.

- We set the good category cutoff at ≤ 5 people per square kilometer (13 people per mi^2), comparable to present-day conditions near the wilderness areas described above. Fair was set near the low end of the range of the average for most areas of Georgia (20 people per square kilometer [50 people per mi^2]). The evaluation of three selected human population indicators in relation to Ocmulgee National Monument is shown in Tables 36a–36c.

Table 36a. The five indicators used to evaluate surrounding population condition and its impact on Ocmulgee. Note that for this index, good indicates minimal adverse impact, whereas poor indicates maximal adverse impact.

Indicator	Good	Fair	Poor
$HPG_{5\text{–}km}$ (human population growth within a 5-km [3.1-mile] radius)	≤ 0.8% per year	0.8 to 1.2% per year	> 1.2% per year
$HPG_{80\text{–}km}$ (human population growth within an .80-km (50-mile) radius)	≤ 0.8% per year	0.8 to 1.2% per year	> 1.2% per year
$HPD_{5\text{–}km}$ (human population density within a 5-km radius)	≤ 5 people/km^2 (13/$mile^2$)	5 to 20/km^2 (13 to 50/$mile^2$)	> 20 per km^2 (> 50/$mile^2$)
$HPD_{80\text{–}km}$ (human population density within ,an.80-km radius)	no change	no change	no change

Table 36b. The present surrounding population condition and its impact on Ocmulgee, evaluated by the indicators in Table 36a.

Indicator	Ocmulgee evaluation	Rating
$HPG_{5\text{–}km}$	8.6% decrease in Macon population (over the past decade). Bibb Co. projected to grow only 1% per year from 2010–2020.	good
$HPG_{80\text{–}km}$	2.5% increase in Macon population per year (Atlanta), northwest of Ocmulgee and sprawling closer over time.	poor
$HPD_{5\text{–}km}$	Macon: 633 people/km^2 (1,639 people/mi^2 as of 2010)	poor
$HPD_{80\text{–}km}$	Atlanta area: high population density 91 people/km^2, (236 people/mi^2); the southernmost edge of this ,high.density is now only 80 km (50 mi) from Ocmulgee.	poor

Table 36c. The overall evaluation of the surrounding population condition and its impact on Ocmulgee, based on the five indicators in Table 36b.

Rating	Criteria	Overall rating
Good	$HPG_{5\text{–km}}$, $HPD_{5\text{–km}}$ both good, ≤ 2 others good, ≤ 1 fair, 0 poor	poor
Fair	≥ 2 fair, ≤ 1 poor	
Poor	≥ 2 poor	

The National Park Service (NPS 2014d) *State of the Park Report for Ocmulgee National Monument* rated surrounding population condition an overall fair (moderate concern) rather than poor. Its analysis included a specific measure of human population for the indicator human population density and demographics within the overall category adjacent land cover and use. That evaluation noted that in the nearly 20 years between 1992 and 2010, human population actually decreased 8.7% in the watershed upstream from the monument, but increased 20.8% in the area surrounding the monument. Thus, the National Park Service (NPS 2014d) rated human population density and demographics near the monument as "warranting moderate concern, trend not changing, with medium confidence in the assessment."

4.1.2. Visitors—Human Population Within the Monument

Issue: Although the NPS mission is partly centered on excellence in service for park visitors, visitors have been shown to negatively impact another key portion of the agency's mission, to protect natural and cultural resources.

Visitors' impacts are identified by the National Park Service as among the top ten issues for National Parks (NatGeo 2015; also see Buckley 2003; Taylor and Knight 2003; Park et al. 2008). The two central portions of the NPS mission are in conflict especially when visitor pressure is high.

Park staff have not expressed concerns about parking, so ample parking to accommodate visitors is assumed. Our evaluation of visitation condition is based on three indicators:

- Visitor Number (VIS—annual total, peak season total, and trend over time);
- Visitor Number per Area ($VP\text{-}A_{SEASONAL}$—peak season from March–October, 245 days); and
- Visitor Pressure on Trails ($VP\text{-}T_{SEASONAL}$—peak season total—see Figure 41).

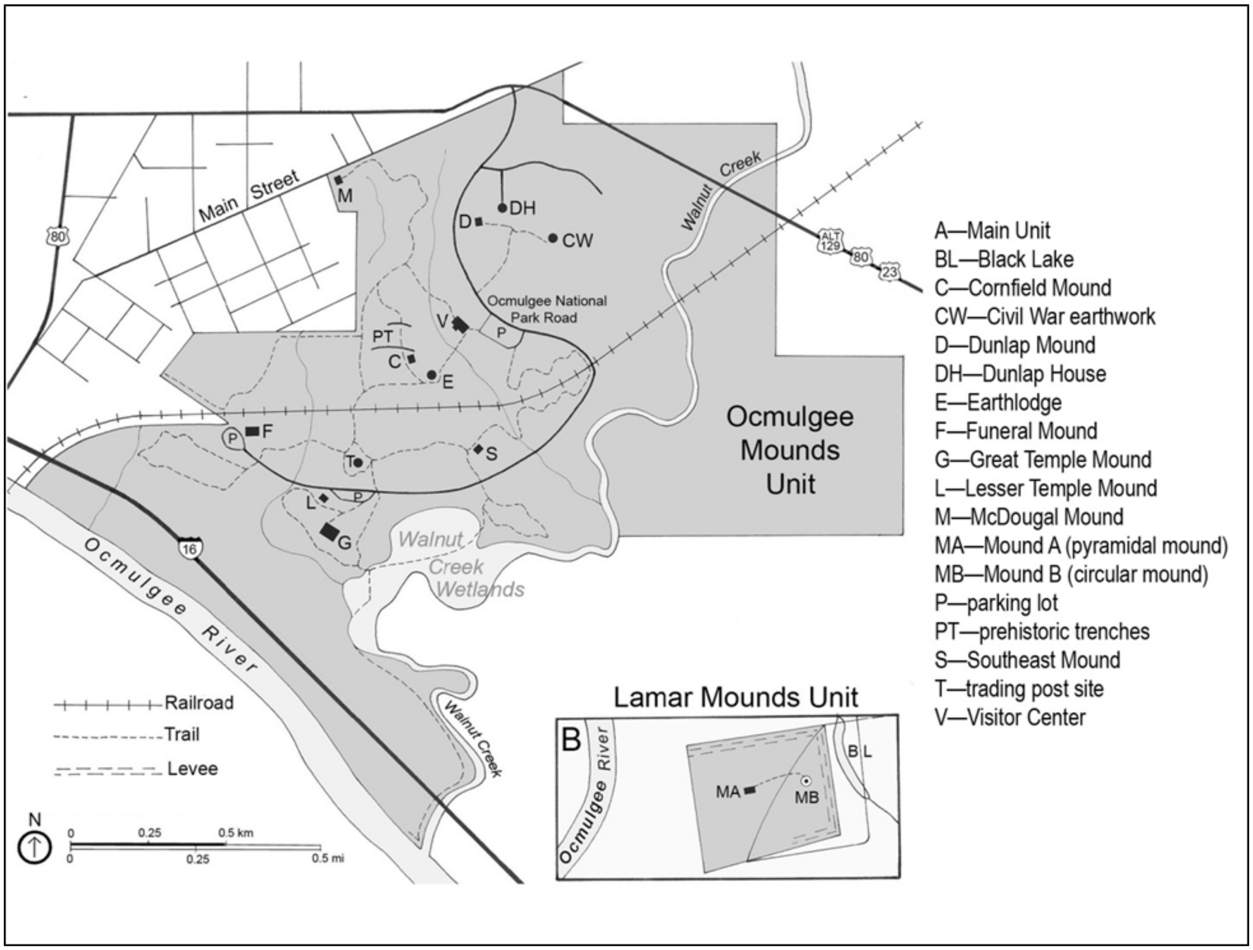


Figure 41. Map of Ocmulgee NM, showing trails and locations of major cultural features where most visitors would be expected (Zomlefer et al. 2013).

The annual visitor number per area was estimated by dividing the number of visitors by the total monument area. This approach assumes that visitors use all areas of the monument equally, and is unrealistic because many visitors concentrate in certain areas such as trails in areas with American Indian mounds. Therefore, the approach underestimates visitor pressure in the highly used areas, but enables a straight-forward calculation of visitor pressure for the monument. The growing season total was estimated based on the fact that according to NPS statistics for recreationist visitors, 80% of visitors come to the monument in March through October (see NPS 2015e). The final indicator, visitor pressure on trails, is more realistic than visitor number per area (because people do concentrate in trail areas). A similar approach was followed as for visitor number per area, using trail length rather than area. For these calculations, we conservatively assumed that one-third of the 70,000 visitors per year use the nature trails.

Evaluation of overall visitation condition in Ocmulgee National Monument is outlined in Tables 37a–37c. It should be noted that this visitation condition is intended to serve as a “place holder” until park staff can develop an RSS, including a targeted recreational carrying capacity for the monument. This target could be developed, for example, following Cole and Thomas (2010). It would also be helpful for park staff to collect data on trail damage and trash left in the monument to strengthen the visitation condition evaluation from the perspective of impacts on monument natural resources.

Table 37a. Indicators used to evaluate visitation condition at Ocmulgee.

Indicator	Good	Fair	Poor
VIS (number of visitors per year)	VIS trend stable or decreasing	VIS trend decreasing	VIS trend stable or increasing
VP-ASEASONAL (visitor pressure per unit area)	< 10 visitors/hectare/day	≥ 10 to 25 visitors/hectare/day	> 25 visitors/hectare/day
VP-TSEASONAL (visitor pressure on trails)	< 5 visitors/km of trail/day	≥ 5 to ≤ 15 visitors/km of trail/day	> 15 visitors/km of trail/day

Table 37b. The present visitation condition at Ocmulgee, evaluated by the indicators in Table 37a.

Indicator	Ocmulgee evaluation	Rating
VIS	8.6% decrease in Macon population (over the past decade). Bibb Co. projected to grow only 1% per year from 2010–2020.	poor
VP-ASEASONAL	2.5% increase in Metro Atlanta population per year, northwest of Ocmulgee and sprawling closer over time.	good
VP-TSEASONAL	Macon: 633 people/km^2 (1,639 people/mi^2)	poor

Table 37c. The overall evaluation of the visitation condition at Ocmulgee, based on the three indicators in Table 37b.

Rating	Criteria	Overall rating
Good	≥ 2 indicators good, 0 poor	poor
Fair	≥ 2 indicators fair or good, 1 poor	
Poor	≥ 2 indicators poor	

In its *State of the Park Report for Ocmulgee National Monument*, the National Park Service (NPS 2014d) evaluations exemplified the previously mentioned conflict in the two central portions of the NPS mission statement. Although increased use of this relatively small park by visitors is expected to increase stressors for monument natural resources such as sensitive biota, the fact that the number of visitors continues to increase appeared to have been considered "separately" or "apart" from impacts on natural resources. Based on the fact that the total of 120,025 visitors to the monument in 2012 was 7% higher than the five-year average (111,993 visitors) in 2007–2011, the number of visitors condition received an overall evaluation of "good condition and condition is unchanging, with medium confidence in the assessment."

4.1.3. Landscape Dynamics in the Surrounding Watershed

Issue: Watershed land use /land cover has been shown to strongly affect the habitat quality and integrity of terrestrial and aquatic communities. Ocmulgee National Monument already sustains substantial impacts from adjacent urban and suburban development.

Changes in the composition and configuration of different land cover types within and adjacent to national parks has been shown to greatly affect biological and physical processes within those parks, such as habitat availability, animal movements, potential for invasion by non-native plants, water quality, and in-stream habitat for fish and other aquatic life (NPS 2012b). Information about changes and trends in landscape-scale indicators in and around parks can help park managers anticipate, plan for, and manage associated effects to park resources.

According to Piekielek and Hansen (2012) "landscape dynamics refers to changes in natural land cover types and human land use." Many protected areas are incomplete "pieces" of larger surrounding ecosystems that are unprotected from human impacts (Hansen et al. 2011). The National Park Service has long recognized the need to create protective buffer areas around national parks, but private land rights issues since the 1980s have made this prospect untenable (Hansen et al. 2011). Thus, surrounding land use intensification increasingly threatens many protected areas, and landscape dynamics have been identified as a high-priority indicator for national parks (Piekielek and Hansen 2012, p.13):

Habitat destruction and fragmentation are the leading causes of species loss globally, and many protected areas are experiencing declines in biodiversity as a result of human activity on surrounding lands (Parks and Harcourt 2002; Sanchez-Azofeifa et al. 2003)… [R]ecent studies have documented rates of land use change around U.S. national parks that exceed national or regional averages (Radeloff et al. 2010).

Agriculture and Urbanization

Changes in land use/land cover over time, especially loss of "green" or natural categories through increase in two land use/land cover categories—urbanization and agriculture—are increasingly used as broad-scale predictors of watershed conditions and ecosystem health (King et al. 2005; Rothenberger et al. 2009).

Nonpoint source pollution—especially from urban/ suburban areas, croplands, and industrialized animal production—has been identified as the greatest threat to water quality in the United States (EPA 1994). Major changes resulting from conversion of natural lands to agricultural use include soil erosion, chemical contamination of those lands and receiving waters, and increased water demands. Chemical contaminants—including pesticides, fertilizers, and heavy metals from animal feeds—cause diverse acute and chronic impacts on water quality and quantity, soil quality, air quality, pollination by beneficial fauna, seed dispersal, biodiversity, and habitat loss (Pickett et al. 2001, and references therein). The confined swine and poultry operations of industrialized agriculture produce extremely high quantities of manure, which are applied to small land areas with shallow soil layers that cannot possibly accommodate the massive wastes (Burkholder et al. 2007, and references therein).

Although agricultural land use has been clearly related to environmental degradation, thresholds in the percent land use linked to significant change in ecosystem health are seldom reported, likely because adverse impacts occur at very low levels of natural land conversion to agriculture. Thus, Hagen et al. (2010) documented major impacts on streams at a level of "light" (percentage undefined) agricultural land use in cropland. Industrialized swine production agriculture can cause extreme impacts to sub-watershed airsheds, soils, surface waters, and groundwaters from only one operation (Mallin 2000; Burkholder et al. 2007, and references therein). As another example, Cuffney et al. (2005) assessed invertebrates and algae in stream sites across a gradient of agricultural land use. The data suggested a threshold response with precipitous declines in biological metrics at low levels of agricultural intensity.

Entire ecosystems, including all components from soil, air, and water to biota, have been "drastically modified" (Pickett et al. 2001) by watershed urbanization, in comparison to ecosystems in watersheds dominated by natural land cover or cropland cultivation (Paul and Meyer 2001). In the United States and other industrialized nations, conversion of land to urban/suburban development is growing more rapidly than the populations in urban areas, leading to increased urban sprawl and fragmentation of remaining green spaces (Makse et al. 1995). Urbanization severely degrades aquatic communities and terrestrial ecosystems (Garie and McIntosh 1986; Pickett et al. 2001; Zielinksi 2002). More specifically germane to Ocmulgee National Monument, in a study now more than 30 years old, of 21 watersheds in the Atlanta area, Benke et al. (1981) found a negative relationship between benthic macroinvertebrate species richness and the degree of watershed urbanization. Increased urbanization promotes an increase in avian biomass but a reduction in species richness, and selection for omnivorous, granivorous, and cavity-nesting species (Chace and Walsh 2006). Analogous findings have been reported for a wide array of aquatic and terrestrial biota.

Impervious Cover

The percentage of impervious cover (IC) in particular—roads, parking lots, building roofs, etc.—has been a reliable barometer for ecosystem health in urbanizing areas. Impervious cover blocks water and associated pollutants from being able to percolate through soil, resulting in rapid transport of much higher volumes and pollutant loads directly to receiving surface waters. As a typical example, the total volume of pollutant-laden runoff from a 0.4-hectare (1-ac) parking lot was 16-fold more than the runoff from an undeveloped meadow (Schueler 1994). Impervious cover thresholds have been developed for ecological damage, especially focusing on stream ecosystems. In fact, the term "urban stream syndrome" has been used to describe the state of ecological degradation common for "city streams" worldwide (Meyer et al. 2005). Key features are low species diversity, dominance of pollution-tolerant taxa, poor water quality, and degraded physical habitat (Schueler et al. 2009, and references therein). Schueler et al. (2009) developed an empirical impervious cover model (ICM; Figure 42—improved over Schueler 1994, which is much more often cited) based on data for many streams which indicated that detectable stream degradation generally occurs—sometimes described as "greatly depressed ecosystem health"—when the IC of a given watershed is 7 to 10% (overall range 2–15%) (e.g., Booth and Reinelt 1993; Shaver et al. 1994; Booth and Jackson 1997; Wang et al. 1997, Mallin 2000).

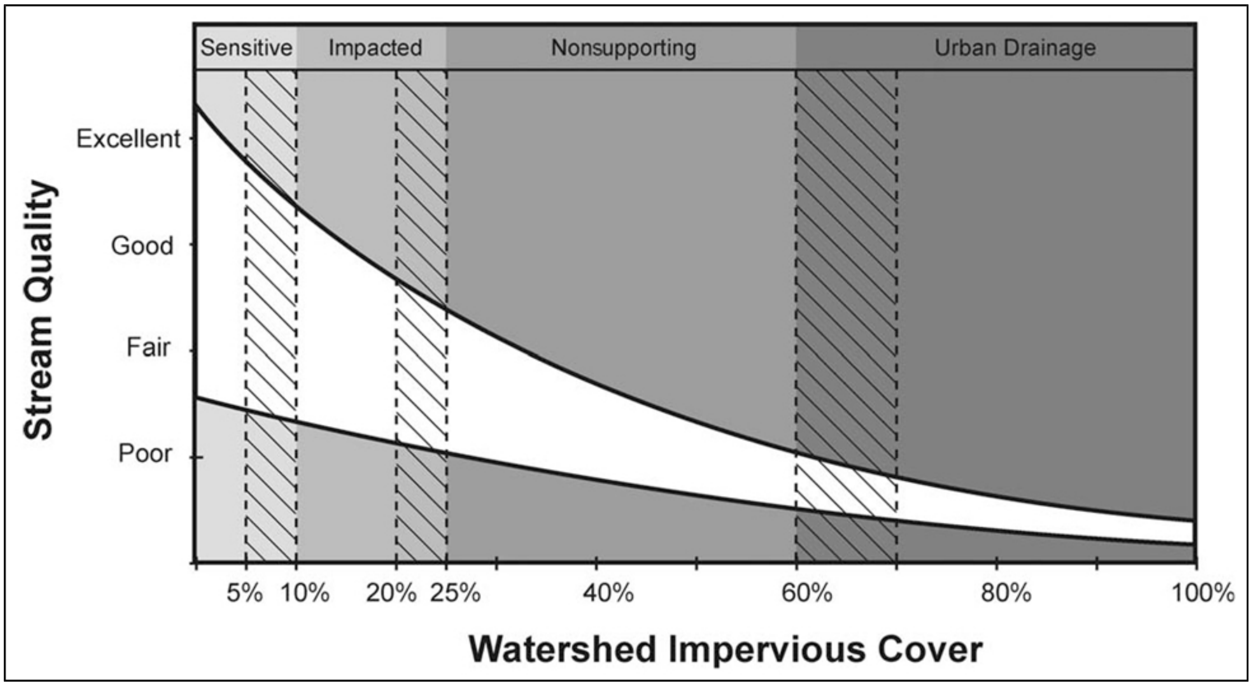


Figure 42. An impervious cover model (ICM) of stream quality and macroinvertebrate community response to urban development as the percentage of impervious cover in a given watershed or sub-watershed (Schueler et al. 2009).

The IC thresholds in these ICMs depended on the specific biological indicator, the ecoregion, and the history of watershed land use: Lower IC thresholds were found for streams in watersheds that had extensive forests or natural vegetation cover prior to urban development.

Higher IC thresholds characterized streams in watersheds that had extensive prior disturbance (e.g., croplands) prior to urbanization (Harding et al. 1998; Ourso and Frenzel 2003; Cuffney et al. 2005) because the macroinvertebrate communities had already lost sensitive species to stressors from the pre-urban agricultural land use (Coles et al. 2012).

An underlying, widely accepted assumption in efforts to determine the first threshold for decline of stream biota in response to urbanization is that the "biological communities are resistant to change at low levels of urban development. Then, as levels of urban development increase, a period of rapid degradation occurs in the community condition, ending in a period of exhaustion when no further change occurs" (Coles et al. 2012; Figure 43). However, a detailed recent analysis conducted by the USGS, involving multiple study regions across the nation, found no evidence of a resistance threshold nor an exhaustion threshold. Instead, beneficial macroinvertebrate communities declined in response to very low levels of urbanization; for example, in the Atlanta and Boston study regions, stream macroinvertebrates showed a linear rather than threshold response to urbanization (Figure 44; also documented elsewhere, e.g., Moore and Palmer 2005). The authors concluded that stream macroinvertebrate communities are much more sensitive to urbanization than previously thought (Coles et al. 2012). In fact, at 10% IC, the macroinvertebrate community composition had already decreased by 25%. The lack of an exhaustion threshold was interpreted as important because it indicates that stream rehabilitation efforts have a high probability of improving biological condition

(Coles et al. 2012). In other words, the data from this study indicate that, if given a chance, many streams can recover from “urban syndrome.”

This background information is included here because IC thresholds to protect ecosystem health have mostly been based on the ICM approach, using a first threshold of 10% IC as good, and a second threshold of 20–25% as fair. This approach recently was re-evaluated as insufficiently protective, both the formerly accepted 10% IC primary threshold and the 20–25% IC secondary threshold (Coles et al. 2012). Regarding the latter, 20–25% IC would protect only highly tolerant biota from stress, disease and death due to urbanization impacts (Weaver and Garman 1994). Stream biological metrics were described as consistently shifting to poor condition at 20–25% watershed IC (Wang et al. 1997; Collier and Clements 2011; Coles et al. 2012).

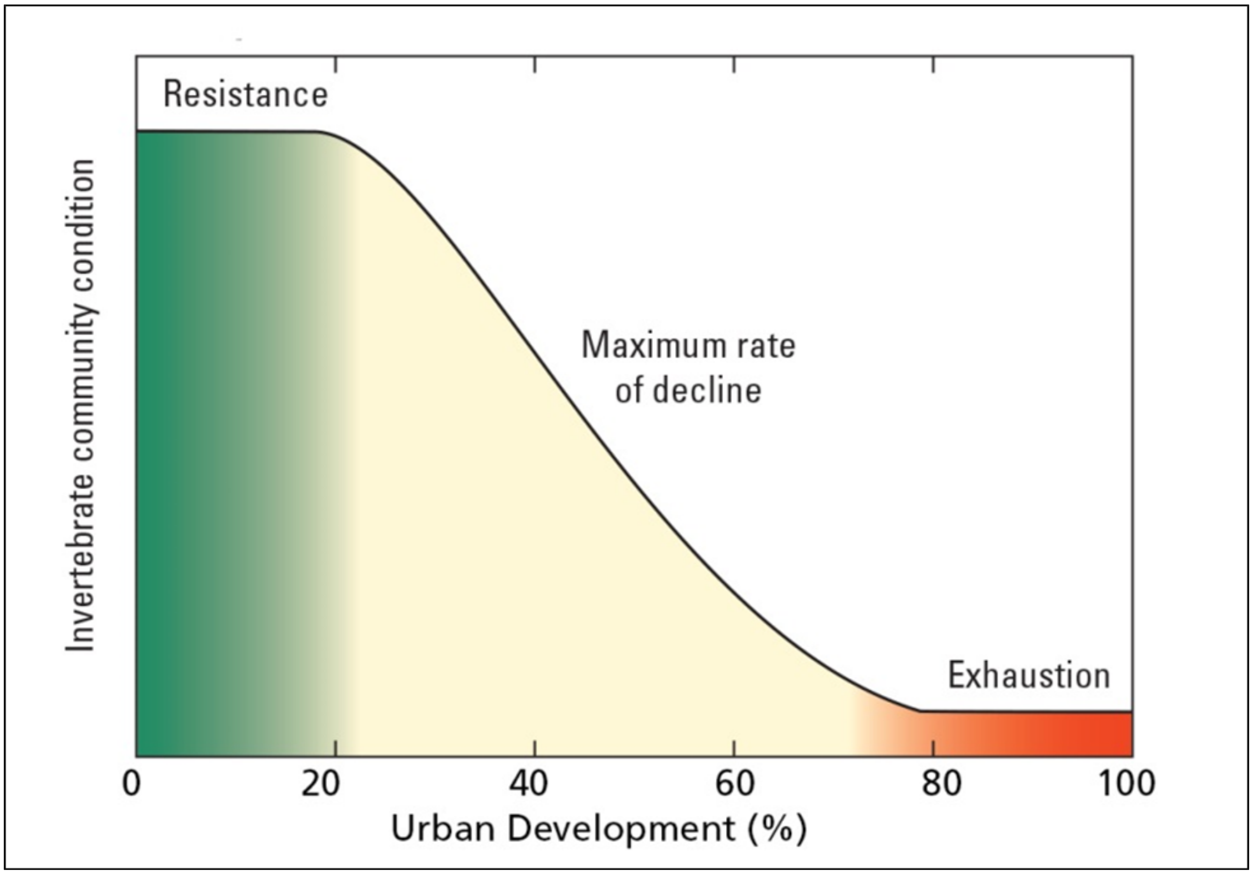


Figure 43. A previously widely accepted conceptual model of the response of stream biota to urban development that is now questioned. Modified from Coles et al. (2012).

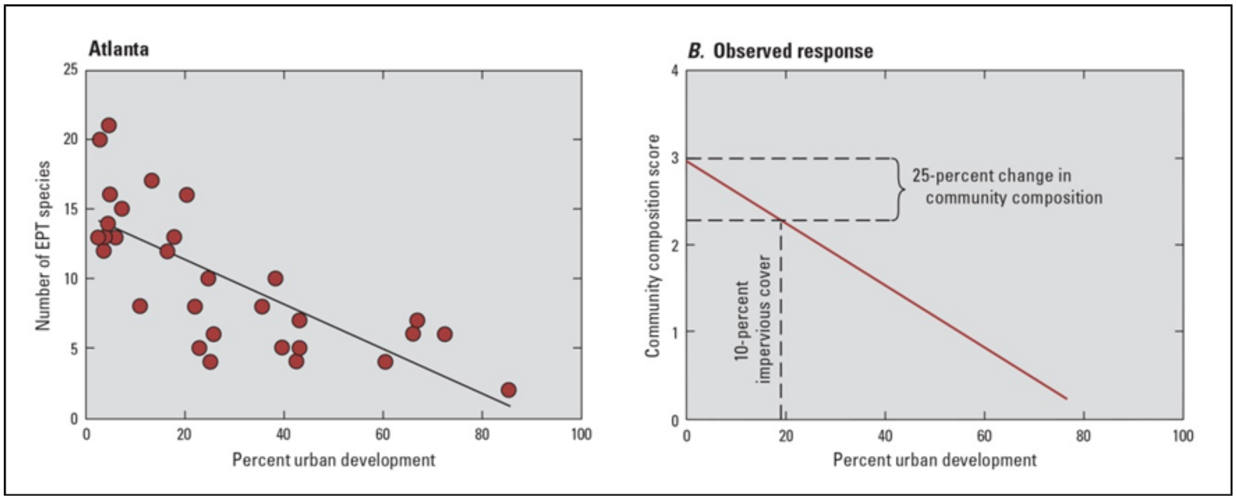


Figure 44. Invertebrate community response to urban development in the Atlanta and Boston areas. Left: Response of EPT species (*Ephemeroptera*—mayflies, *Plecoptera*—stoneflies, and *Trichoptera*—caddisflies) to urbanization in the Atlanta area. Many of these species are sensitive to contaminants, changes in stream flow, and other stressors caused by urbanization, and have been lost from streams in the Atlanta area. Right panel: Generalized schematic from the USGS (Coles et al. 2012) showing similar response of invertebrate communities to urban development in the Boston area. Note that at 10% impervious cover (less than 20% urban development), the community composition had declined by 25%. Modified from Coles et al. (2012)

Indicators for Land Use/Land Cover Influence

Ocmulgee National Monument, at present, has little agricultural influence; only 11% of the land use in the Ocmulgee River watershed, and less than 7% of lands in the Walnut Creek watershed, are in agriculture. Therefore, the following indicators and ratings were developed without consideration of agriculture except indirectly through the tacit assumption that loss of agricultural lands will continue to occur through urban/suburban development. It is recommended that the indicators should be tracked at ten-year intervals (or five-year intervals, if park staff consider that more desirable). The indicators describe conditions that are often economically difficult or impossible to reverse. Therefore, the good rankings are conservatively defined toward the goal of maximizing protection of the monument.

Impervious Cover (IC)

Viewed from a resource protection standpoint, as explained above, it is not scientifically supported to evaluate a 25% loss in stream macroinvertebrate community composition with 10% IC in a given watershed as good. Figure 42, a widely accepted ICM, suggests that at 10% IC, streams develop “detectable” to “greatly depressed” ecosystem health. Although the lower end of range of percentage IC at which ecosystem health is seriously impacted is broad (2–15%), it also seems reasonable to err on the side of caution to afford more protection for the nation’s national parks. Other studies have shown that wetlands exhibit signs of adverse impacts when watershed IC exceeds 2–4%, or about one house for every 3.2–4.0 hectares (8–10 ac) of watershed area (Reinelt and Horner 1991, Hicks and Larson 1997). The recent USGS analysis (Coles et al. 2012)—and the central conclusion that stream macroinvertebrate communities, commonly considered a major “barometer” of stream ecosystem health, are much more sensitive to urbanization that previously thought—also factored heavily in our considerations about the levels of percentage of impervious cover to be assigned to good, fair, and poor rankings. These rankings reflect the present status of what is known in the science literature about stream macroinvertebrate community response to urbanization.

Change in Green Space

The Greenspace Indicator (% GRN) tracks the change in the percentage of greenspace land over time, both within a five-kilometer (3-mi) radius of the monument, and in the Ocmulgee River watershed. The change is generally a loss. It has been demonstrated that only a 12% loss of forest cover in a watershed results in detectable adverse impacts on the macroinvertebrate communities of streams draining the area (Klein 1979). Conversion of a forest to homes on 0.10-hectare (0.25-ac) lots can increase the frequency and severity of flooding by 100-fold (basis—Soil Conservation Service 1986; see Zielinski 2002; and Klein 2015). When the land is converted to IC rather than open space, impacts are sustained at lower percentages of impervious surface (explained above).

The evaluation format used to assess the land use/land cover condition surrounding Ocmulgee National Monument is shown in Tables 38a–38c. Based on these indicators and this evaluation format, the present overall condition of land use/land cover surrounding the monument is good.

Table 38a. Indicators used to evaluate land use/land cover condition at Ocmulgee NM.

Indicator	Good	Fair	Poor
$\%IC_{5\text{–}km}$ (impervious cover, 5-km radius surrounding Ocmulgee, decadal basis)	IC ≤ 5%	IC > 5 to < 10%	IC ≥ 10%,
$\%GRN_{WAT}$ (total greenspace loss in Ocmulgee River watershed, past 5–10 years)	GRN loss < 1%	GRN loss ≥1 to < 5%	GRN loss ≥ 5%

Table 38b. The present land use/land cover condition at Ocmulgee NM, evaluated by the indicators in Table 38a.

Indicator	Ocmulgee evaluation	Rating
$\%IC_{5\text{–}km}$	Some of the land within a 5-km radius of the monument is urbanized by the City of Macon.	poor
$\%GRN_{WAT}$	The Ocmulgee River watershed had 15% developed land (urban/suburban) as of 2001. In the 5 years between 2001 and 2006, there was a 5% increase in developed land use/land cover.	poor

Table 38c. The overall evaluation of the land use/land cover condition at Ocmulgee NM, based on the two indicators in Table 38b.

Rating	Criteria	Overall rating
Good	IC ≤ 5%, and < 1% GRN Loss	poor
Fair	IC > 5 to < 10%, and ≥ 1 to < 5% GRN loss	
Poor	IC > 10%, and ≥ 5% GRN Loss	

The *State of the Park Report for Ocmulgee National Monument* (NPS 2014d) also included evaluation of the natural resources category 'adjacent land cover and use.' This included three specific measures: (i) agricultural land use, (ii) forested & wetland land use coverage, and (iii) developed land use coverage (non-open space); a fourth specific measure (iv) human population, was considered separately within the broad category (adjacent land cover and use—human population density and demographics), and was considered by our evaluation. Regarding measures (indicators) i–iii which specifically refer to land use/land cover, the National Park Service (NPS 2014d) evaluation noted that between 1992 and 2006, the percentage of lands surrounding Ocmulgee NM that are used for agriculture increased from 3.8% to 12%. In contrast, during the same 15-year period, forest and/or wetland areas decreased from 71.2% to 66%; and, as previously noted, human population density increased by 20.8% in the area surrounding the monument during 1992–2010. Thus, all three specific measures for adjacent land cover and use were rated by the National Park Service (NPS 2014d) as "warrants moderate concern and the trend in condition is unchanging, with high confidence in the assessment."

4.2. Air Quality

Issue: Air pollution is an ongoing serious problem for Ocmulgee National Monument because of the adjacent population center and because of the Atlanta Metropolitan area. Air pollution is causing an array of adverse impacts on the natural resources of the monument.

In general, animals are exposed to air pollutants by inhaling gases or small particles, ingesting particles suspended in food or water, or absorbing gases through the skin (soft-bodied invertebrates, amphibians with thin, moist skin etc.) (EPA 2016a). Ozone, SO2, and NOx mostly affect the respiratory system, and animals to with higher respiratory rates (e.g., many birds) are likely to be more adversely affected by gaseous pollutant injury. Metals such as mercury in air pollution can affect the circulatory, respiratory, gastrointestinal, and central nervous systems. Often organs such as the kidney, liver, and brain are targeted, and entire populations can be adversely affected with damage extending subsequent generations.

The array of impacts of acid deposition on terrestrial and freshwater ecosystems is the subject of exhaustive literature (Tomlinson and Tomlinson 1990; Charles and Christie 1991; Brimblecombe et al. 2007 and references therein). In terrestrial ecosystems, species such as pines are especially sensitive to the elevated nitrate enrichment that results in the soils, and their growth and survival are depressed (Aber 1992). Leaves affected by acid deposition are damaged, especially the chlorophyll pigment that is vital to photosynthesis. Like many other pollutants, acid deposition depresses terrestrial biodiversity as sensitive species are eliminated and more acid-tolerant species can survive. Acidification effects in freshwater streams depend on the surrounding geology and soils, which determine the capacity of the water to neutralize acids. Streams most susceptible to acidification occur in watersheds with granite or gneiss bedrock typical of some soils at Ocmulgee NM, where soils have insufficient base cations freely available to neutralize incoming H+ ions. The effects of decreasing pH on aquatic invertebrates and fish have been summarized in National Acid Precipitation Assessment Program (NAPAP) reports (e.g., NAPAP 1991, 2005) and similar documents from Scandinavia where acidification impacts have been extreme: In early stages of acidification, acid-sensitive species are replaced by acid-tolerant ones. As the pH continues to decline, toxic metals become more bioavailable, and more species are lost until even the microbial consortium of decomposers is adversely affected. The worst problems with acid deposition result from acid spates, wherein a “slug” or high amount of acidic water moves into a stream in the early phases of a storm. Larval stages of amphibians and fish are eliminated by acid spates over a short period (hours to a few days).

Considering the entire Southeast, the NPS Air Resources Division evaluates 10-year trends in air quality for parks with on-site or nearby monitoring. Maps in the most recently available progress report show trends in ozone, deposition, and visibility that can be used to discern regional trends (NPS 2007). For the period 1996–2005, ozone concentrations and nitrogen (N) and sulfur (S) deposition in the Southeast appear to be decreasing, while visibility is relatively unchanged.

More specific to Ocmulgee National Monument, the National Park Service (NPS 2011) has developed guidance for assessing the air-quality conditions within its parks, focusing on five key indicators among the myriad of air pollutants affecting the Atlanta area. These indicators are ozone (with two sub-indicators: human health, and Ocmulgee NM flora), N deposition, S deposition, visibility, and acidification (with five sub-indicators: ozone [human health], pollutant exposure, ecosystem sensitivity, park protection, and overall summary risk). For ozone, the National Park Service included consideration of vegetation sensitivity as well as human health, because science has shown that some plant species are more sensitive to ozone than humans. Thus, use of an ozone standard for humans would not be sufficiently protective of those species.

The National Park Service has developed management targets or “thresholds” for these five indicators, summarized in Tables 39a–39c. The information and supporting science are given in several agency reports, especially National Park Service (NPS 2011) and Sullivan et al. (2011) where the conditions in Ocmulgee National Monument are also described. All of the indicators are not possible for park staff to control. Following the NPS guidance and stoplight system, the present overall air-quality condition at Ocmulgee National Monument is rated as poor. This evaluation is similar to that suggested by the state of the park report (NPS 2014d) based on a smaller number of indicators—ozone, nitrogen and sulfur wet deposition levels, and average visibility in the park—for 2005–2009. Considering the fact that air quality, while poor, has been improving with respect to ozone concentrations in the Macon area, the National Park Service (NPS 2014d) gave an overall rating of “warrants significant concern; improving trend over time; and medium confidence in the assessment.”

Table 39a. Indicators used to evaluate air quality conditions in Ocmulgee National Monument. The main indicators are: Ozone, N Deposition, S Deposition, Visibility, and Acidification, and sub-categories of indicators are: Ozone—human health, plants; Acidification—pollutant exposure, ecosystem sensitivity, park protection, and overall summary risk.

Indicator	Good	Fair	Poor
OZONE (5 year impact on human health)	≤ 60 ppb	61–75 ppb	≥ 76
OZONE W126 (ozone impact on flora over the growing season)	< 7 ppm-hour	7–13 ppm-hour	> 12 ppm-hour
OZONE SUM06 (cumulative ozone impact on flora)	< 8 ppm-hour	8–15 ppm-hour	> 15 ppm-hour
N-DEP (nitrogen deposition)	< 1 kg/ha/year	1–3 kg/ha/year	≥ 3 kg/ha/year
S-DEP (sulfur deposition)	<1 kg/ha/year	1–3 kg/ha/year	≥ 3 kg/ha/year
VIS (visibility in deciviews)	< 2 dv	2–8 dv	> 8 dv
ACID (pollutant exposure)	rank <13	≥ 13 to 23	> 23 to 35
ACID (ecosystem sensitivity)	rank <15	≥ 15 to 20	> 20 to 35
ACID (park protection)	rank <15	≥ 15 to <23	≥ 23 to 35
ACID (summary risk index)	rank ≤2.5	> 2.5 to 3.4	> 3.4 to 5

Table 39b. Air-quality conditions in Ocmulgee, evaluated by the indicators in Table 39a.

Indicator	Ocmulgee NM evaluation	Rating
OZONE	79–82 ppb (11 days in 2012) for the 8-hour averaging time, 4th maximal value	poor
OZONE W126	> 13 ppm (2012)	poor
OZONE SUM06	> 15 ppm-hour (2012)	poor
N-DEP	> 3 kg/ha/year in 2005–2009; 10–15 kg/ha/yr in 2011–2012.	poor
S-DEP	> 3 kg/ha/year in 2005–2009; 10–20 kg/ha/yr.in 2011–2012	poor
VIS	> 8 dv in 2005–2009	poor
ACID (pollutant)	very high (rank > 23)	fair
ACID (ecosystem)	very low (rank < 15)	fair
ACID (protection)	moderate (rank > 15 to < 23)	fair
ACID (summary)	moderate (> 2.5 to 3.4)	fair

Table 39c. The overall evaluation of the air quality conditions in Ocmulgee NM, based on the ten indicators in Table 39b.

Rating	Criteria	Overall rating
Good	≥ 5 indicators good, none poor	Poor
Fair	≥ 3 indicators fair, ≤ 2 poor	
Poor	≥ 3 indicators poor	

4.3. Soundscape

Issue: Noise pollution is an ongoing, serious problem in the urbanized area surrounding Ocmulgee NM, and is adversely affecting the physiology, behavior, and survival of the monument's natural fauna.

As explained earlier, in the urbanized setting, the main unit of Ocmulgee NM has been described by Chief Ranger Guy Lachine (April 2013) as sustaining substantial road noise as well as noise from incoming/outgoing airplane flights. Interstate traffic volume near the monument is increasing and perimeter vegetation is dying, thus reducing its capacity as a sound barrier.

Three soundscape indicators were developed for Ocmulgee NM, and are outlined in Table 40a (See Table 40b for ratings on each indicator). In the overall evaluation, the $DATA/OBS_{SOUND}$ indicator is weighted more heavily than the other two indicators (Table 40c). However, the other two indicators can be used to evaluate the soundscape if data and/or reliable observations are not available.

Table 40a. Indicators used to evaluate soundscape conditions in Ocmulgee NM.

Indicator	Good	Fair	Poor
$SOUND_{POP}$ (proximity to population center)	closest population center with < 50,000 people is ≥ 20 kilometers (12.4 mi) away	closest population center has ≥ 50,000 to 100,000 people and is ≥ 8 to < 20 km (≥ 5 to < 12.4 mi) away	closest population center has > 100,000 people and is < 8 km (< 5 mi) distant; or closest population center has ≥ 50,000 to 100,000 people and is within an 8-km (5-mi) radius of the monument
$SOUND_{TRAV}$ (proximity to a major mode of travel)	nearest major road or railroad is >v8 km (5 mi) distant; no major airport or airplane flyway influence	1 major road and/or railroad is nearby, or 1 railroad, or a major airport/airplane flyway	≥ 1 major road and/or railroad and/or major airport nearby
$SOUND_{DATA/OBS}$ (data available for Ocmulgee or Ocmulgee staff observations)	outside noise ≤ 24 dB(A) during daytime when related (noise-generating) human activity is greatest; or park staff describe monument as quiet	outside noise > 24 to 55 dB(A) during daytime periods with greatest related human activity; or park staff describe monument as sometimes sustaining noticeable noise pollution	outside noise > 55 dB(A) during daytime periods with greatest related human activity; or park staff describe monument as sometimes sustaining substantial noise pollution

Table 40b. The present soundscape conditions in Ocmulgee, evaluated by the indicators in Table 40a.

Indicator	Ocmulgee evaluation	Rating
$SOUND_{POP}$	The main unit of the monument lies immediately adjacent to the City of Macon (population 91,351 as of 2012); in fact, part of the monument is within the city limits.	poor
$SOUND_{TRAV}$	Interstate Hwy. 16 runs through the entire south end of the main unit; the Norfolk Southern railroad traverses the entire mid-section of the main unit; and State Hwy. 50/23/129 crosses through a portion of the northern main unit.	poor
$SOUND_{DATA/OBS}$	Not available; park staff describe Ocmulgee as sometimes sustaining noticeable noise pollution.	fair

Table 40c. The overall evaluation of the present soundscape conditions in Ocmulgee, based on the three indicators in Table 40b.

Rating	Criteria	Overall rating
Good	$SOUND_{DATA/OBS}$ plus one other indicator good; third indicator good or fair; or no data but the other two indicators good	poor
Fair	All three indicators fair; or no data but park staff have observed sometimes-noticeable noise pollution and both other indicators fair	
Poor	$SOUND_{DATA/OBS}$ poor; or no data but park staff have observed sometimes-substantial noise pollution, and one or both other indicators poor	

4.4. Lightscape

Issue: Light pollution in urbanized or developing areas can adversely affect the physiology, behavior, and survival of naturally occurring, beneficial fauna.

The lightscape indicator for Ocmulgee NM uses the Bortle Dark-Sky Scale for assessing artificial light pollution, with evaluation rankings detailed in Table 41a. These rankings are based on potential impacts of sufficient light to reveal “ground objects,” meaning that sufficient light would be available to alter predator-prey interactions at least in some areas of the monument. The night sky for Ocmulgee National Monument is Class 5 (suburban sky—ground objects partly lit) or worse (Table 41b; see Table 41c for overall evaluation of lightscape).

Table 41a. Indicators used to evaluate lightscape conditions in Ocmulgee.

Indicator	Good	Fair	Poor
$LITE_{ARTIF}$ (Bortle Dark Sky Scale)	Classes 1 to 2 excellent, truly dark skies; or typical, truly dark skies.	Classes 3 to 4 rural sky: ground objects vaguely apparent; or rural/ suburban transition: sky noticeably brighter than the terrain, ground objects still fairly obscure.	≥ Class 5 suburban sky: ground objects partly lit, to inner city sky.
ALR (Average anthropogenic all-sky luminance/average natural all-sky luminance)	ALR < 0.33 (< 26 nL average anthropogenic light in the sky; low concern)	ALR ≥ 0.33 to 2.00 (26–156 nL average anthropogenic light; moderate concern)	ALR > 2.00 (> 156 nL average anthropogenic light; high concern)

Table 41b. The present lightscape conditions in Ocmulgee, evaluated by the indicators in Table 41a.

Indicator	Ocmulgee evaluation	Rating
$LITE_{ARTIF}$	Suburban development immediately adjacent; parts of Ocmulgee estimated to have artificial light equivalent to bright suburban sky, Class 6.	poor
ALR	The modeled ALR for Ocmulgee was 7.5, which is considered of significant (high) concern	poor

Table 41c. The overall evaluation of the present lightscape conditions in Ocmulgee, based on the two indicators in Table 41b.

Rating	Criteria	Overall rating
Good	Both indicators good	poor
Fair	Both indicators fair	
Poor	Both indicators poor	

The good, fair, and poor categories for modeled ALR (Tables 13 and 14 of this report) were applied as a second indicator of lightscape. The modeled ALR for Ocmulgee National Monument was 7.5, considered high or of significant concern. Thus, both lightscape indicators for the monument were rated as poor, for an overall evaluation of lightscape condition as poor in the monument. This evaluation is similar to that suggested by the state of the park report (NPS 2014d), wherein that overall rating was "warrants significant concern; deteriorating; medium confidence in the assessment." The National Park Service (NPS 2014d) noted that, while Macon sustained a slight population decreasing trend in population from 2001–2010, the nearby Atlanta area increased by 28% over that period; thus, a decreasing trend in night sky quality is expected.

4.5. Soils and Streambank Erosion

Issue: The soils in the monument area are moderately to highly erodible, increasing the potential for damage along streambanks as well as monument roads, trails, and other highly used areas. Based on obvious visual evidence, streambank erosion and sediment burial of stream bottom habitats are common and severe. The moderate acid deposition sustained by the monument could decrease the soil pH to conditions that impede the metabolism of beneficial microbial consortia while also enhancing solubility of porewater toxic metals (Bååth 1989).

There have been no studies of soils, soil erosion, or streambank erosion in Ocmulgee National Monument, but its soils would be expected to be similar to those in the region. Therefore, we developed a simple, straightforward index of soil condition for the monument as follows:

Soil erodibility of the soil types in Ocmulgee National Monument ($Soil_{EROD}$)—which has been assessed in the published literature based on the soil erodibility factor, K (Olson and Wischmeier 1963; and USDA Soil Conservation Service maps)—is detailed in Table 42a, along with visual evidence of soil erosion in the monument ($Soil_{VIS}$), visual evidence of streambank erosion in the monument ($Bank_{EROD}$), stream bottom habitat burial in the monument ($Soil_{HAB}$), and soil acidification potential based on air quality in areas such as Ocmulgee National Monument with poor buffering capacity of the mostly clay soils, due to the absence of limestone parent materials ($Soil_{ACID}$).

Soils indicators one and five ($Soil_{EROD}$ and $Soil_{ACID}$) are based on information already provided to the monument; indicators two through four are based on surveys that can be conducted within two hours along representative lengths of WalnutCreek and the Ocmulgee River in Ocmulgee NM. Assessment of these indicators can be conducted at intervals deemed appropriate by park staff (e.g., two-year or five-year) using a consistent, quantitative approach such as walking three 100-m (328-ft) segments along each stream (e.g., see Gordon et al. 2004) and including photographic documentation. The fourth indicator, $Soil_{HAB}$, could be quantitatively strengthened by assessing the area covered based on photography, and/or by measuring the depth of obvious sediment deposits in representative areas as in Walser and Bart (1999). That study involved measuring sediment depth (mm) at uniform distances along a transect of a 100-meter stream length by inserting a steel rod through the sediment layer until hard underlying substratum was reached. A "sedimentation index" was then calculated for that segment by dividing the mean sediment depth for all transect points by the mean water depth for all transect points. Other simple, rapid, straightforward approaches that could be used are described in Clapcott et al. (2011).

It should also be noted that the National Park Service is developing a visual technique using a consistent approach with photography over time to document streambank erosion in SECN parks, which will strengthen the $Bank_{EROD}$ indicator (former SECN program manager Joe DeVivo, pers. comm., April 2013).

To assess the overall soils and streambank erosion condition in the monument, we used the evaluation system detailed in Table 42c.

About 60% of the soil types found in Ocmulgee National Monument are erodible to highly erodible and/or flooded to severely flooded (Appendix D). Severe erosion is common along roadways and trails. Streambank erosion is common on the major stream segments, which are characterized by sediment deposits that cover much of the stream bottom. The soil acidification potential is moderate, based on the air quality described previously. Thus, four of the five soil and streambank erosion indicators are poor (Table 42b), and the overall evaluation of soil and streambank erosion condition in Ocmulgee National Monument is poor (Table 42c).

Table 42a. Indicators used to evaluate soil condition at Ocmulgee NM.

Indicator	Good	Fair	Poor
$SOIL_{EROD}$ (erodability of soil types).)	≤ 10% of the soil types are eroded to severely eroded	> 10% to 20% of the soil types are eroded to severely eroded, including 1 abundant soil	> 20% of the major soil types are eroded to severely eroded, including > 2 abundant soils
$SOIL_{VIS}$ (visual evidence of soil erosion)	little or no streambank erosion in Ocmulgee	a few areas along roadways and trails show signs of erosion	erosion is obvious and common along roadways and trails
$STREAMBANK_{EROD}$ (visual evidence of streambank erosion)	little or no streambank erosion is evident in Ocmulgee	occasional signs of streambank erosion after major rain events	severe erosion is evident and common along major stream segments in Ocmulgee
$SOIL_{HAB}$ (stream bottom habitat burial)	no visual evidence of sediment deposits (e.g.,mud or sand bars)	occasional areas with obvious sediment deposits, but sediment deposits are mostly absent	stream bottoms are generally covered by obvious sediment deposits in areas where flow allows accumulation
$SOIL_{ACID}$ (C)	low (basis: NPS air quality analysis)	moderate (basis: NPS air quality analysis)	high (basis: NPS air quality analysis)

Table 42b. The present soil condition at Ocmulgee NM, evaluated by the indicators in Table 42a.

Indicator	Ocmulgee evaluation	Rating
$SOIL_{EROD}$	60% of soil types in Ocmulgee are eroded to severely eroded.	poor
$SOIL_{VIS}$	Erosion is obvious and common along roadways and trails.	poor
$STREAMBANK_{EROD}$	Streambank erosion is common along major stream segments.	poor
$SOIL_{HAB}$	Sediment deposits cover much of the bottom area of the stream segments in locations where flow allows accumulation. Stream sedimentation is an identified management concern of park staff.	poor
$SOIL_{ACID}$	Moderate in Ocmulgee, based on air quality information and poor soil buffering capacity (limestone parent material absent).	fair

Table 42c. The overall evaluation of the soil condition at Ocmulgee NM, based on the five indicators in Table 42b.

Rating	Criteria	Overall rating
Good	≥ 3 indicators are good, ≤ 2 indicators are fair, no indicator is poor	
Fair	≥ 3 indicators are fair and ≤ 1 indicator is poor	poor
Poor	> 2 indicators are poor	

In the *State of the Park Report for Ocmulgee National Monument*, the National Park Service (NPS 2014d) considered these natural resources under the heading, "geology and soils." Four indicators of condition included (i) terrestrial soil erodibility (specific measures—soil class type, soil erodibility factor, and critical shear stress); (ii) riparian soil erodibility (specific measure—channel stability index); (iii) stream sedimentation (specific measure—percent bankside visual estimate of sediment cover); and (iv) soil acidity (specific measure—soil pH). In assessing terrestrial soil erodibility, the National Park Service (NPS 2014d) noted that soils in Ocmulgee NM are classified as Bibb-typic soils, fluvaquent (mostly lean dry with sand, moderate to high in erodibility and critical shear stress), very deep and poorly drained, hydric and flood-prone. In addition, the National Park Service described evidence of common, severe streambank erosion (CSI likely > 20); there is evidence of common, high, and extremely rapid sedimentation, with sediment deposits covering 60–80% of the stream bottom in many locations. The natural soil pH is 5.8–7.0, meaning that the streams are poorly buffered (Wetzel 2001); moreover, acid deposition in the area is high. Thus, the National Park Service (NPS 2014d) rated terrestrial soil erodibility and soil acidity as "warranting moderate concern," and riparian soil erodibility and stream sedimentation as "warranting significant concern," and the National Park Service overall evaluation of geology and soils was "warrants significant concern," with high confidence in the assessment" (note that trends in condition were not given). This rating is comparable to our evaluation.

4.6. Water Resources

<u>Issue</u>: Tracking hydrologic changes and ground- and surface-water quantity over time is important for natural resources in Ocmulgee NM. Increasing watershed development leads to higher demands on water supplies, which exacerbates the duration and severity of droughts. This problem is expected to be exacerbated by climate change (Richter et al. 1997; Kundzewicz et al. 2007; Brekke et al. 2009).

4.6.1. Water Quantity

<u>Surface Water</u>

The availability of Indicators of Hydrologic Alteration (IHA) software makes it possible to use the hydrologic data provided by the USGS to rapidly assess hydrologic changes affecting other Ocmulgee NM natural resources over time. As mentioned, IHA calculates environmental flow components (EFCs) and indicators of hydrologic alteration (IHA). About 20 years of daily data are recommended for estimating many of the parameters for analysis (The Nature Conservancy 2009). As mentioned, the USGS gaging station (022130002240) on the Ocmulgee River at Macon has collected discharge data since the 1890s, except for a 15-year gap in the early 1900s. There are ample data to enable the National Park Service to use the IHA to conduct a range of variability analysis (Richter 1997, Mathews and Richter 2007). Thresholds in biological response can be identified quickly within an adaptive framework. Once Ocmulgee National Monument has a RSS, park staff will document strategies for managing the monument's natural and cultural resources. That plan will include hydrologic indicators and targets.

Until the RSS and hydrologic targets have been developed for Ocmulgee National Monument, hydrologic indicators cannot be clearly identified. Comparison of discharge in the decade before vs. the decade after installation of the Macon levee (1950) reveals that there was a more regular annual cycle with more pronounced seasonal differences in the decade before the levee was added (Figure 45). This problem reflects the fact that the natural hydrology of Ocmulgee National Monument is still poorly understood (DeVivo et al. 2008), partly because:

1. In 1911 one of the oldest dams in Georgia, the Lloyd Shoals Dam at Lake Jackson, was constructed 42 kilometers (26 mi) upstream from Macon and the monument. Thus, Ocmulgee River flows have been substantially altered for more than 100 years, and for 40 years before the Macon levee was added.

2. The Macon levee extensively altered the hydrology of both monument units (see Burkholder et al. 2010).

3. The sandy ground behind the Macon levee is especially porous so that water "boils up" out of the ground.

4. The Macon levee is the only levee in Georgia that has been evaluated as unsafe and high risk because it is in poor condition (Vieira et al. 2007).

5. An unfinished levee was constructed in the late 1930s to protect the Lamar unit from flooding, and borders the northern, eastern, and part of the southeastern sides of that unit.

6. The previously described, massive flood in 1994 created the Wall Creek wetlands, a now-permanently-flooded area.

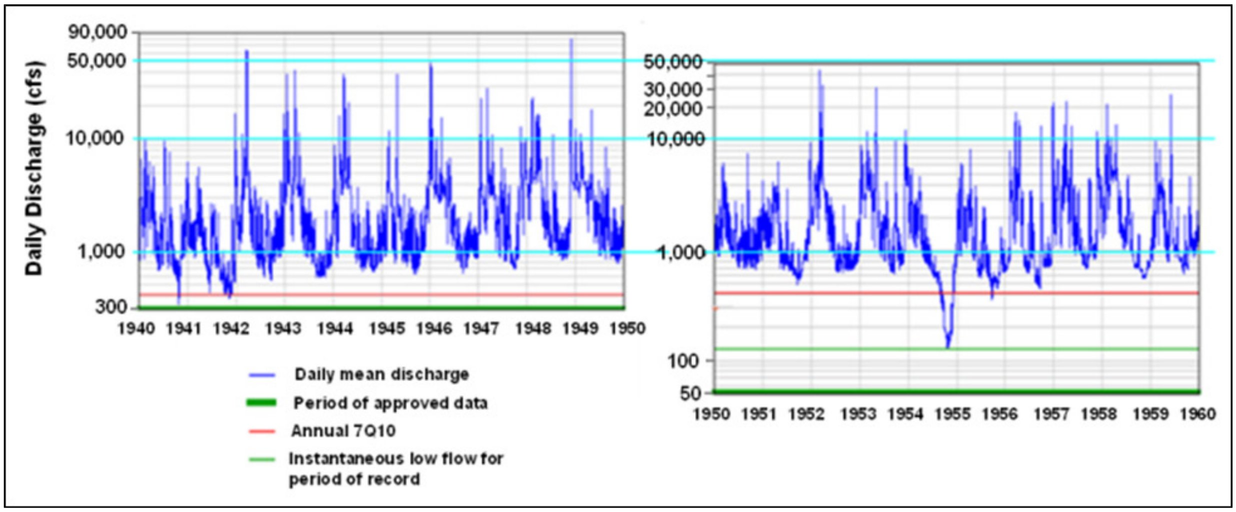


Figure 45. Flow at the USGS gaging station on the Ocmulgee River in Macon, 10 years before and 10 years after installation of the Macon levee in 1950 (left and right panels, respectively). Light blue lines at 1,000 cfs, 10,000 cfs, and 50,000 cfs were added to facilitate comparison. Note that prior to construction of the levee, the annual cycles were clearer and the flow maximum in each annual cycle was generally higher. From USGS 2015b.

The information in hand was insufficient, in our view, to assess hydrologic condition at Ocmulgee National Monument. In the interim until a RSS for the monument can be developed, including customized hydrologic indicators, we suggest use of an indicator for use of the Ocmulgee River for water supplies of the City of Atlanta. The Atlanta area presently includes 10 counties and 71 municipalities (ARC 2016). Four of those counties (DeKalb, Henry, Rockdale, and a portion of Clayton) form the north and northwest areas of the Ocmulgee River basin. The Metropolitan North Georgia Water Planning District (MNGWPD 2009) estimated that by 2009, Atlanta was taking an average of 50 mgd from the Ocmulgee River to augment its water supply, which is mainly from the Chattahoochee and Etowah/Coosa basins (also with a smaller amount taken from the Flint River basin). The data show a steady increase in Ocmulgee River water use by the Atlanta area over the period from 2000 through 2009 (MNGWPD 2011; Figure 46), which supports OCMU staff's concern that the monument eventually could be stressed for water because of upstream demands.

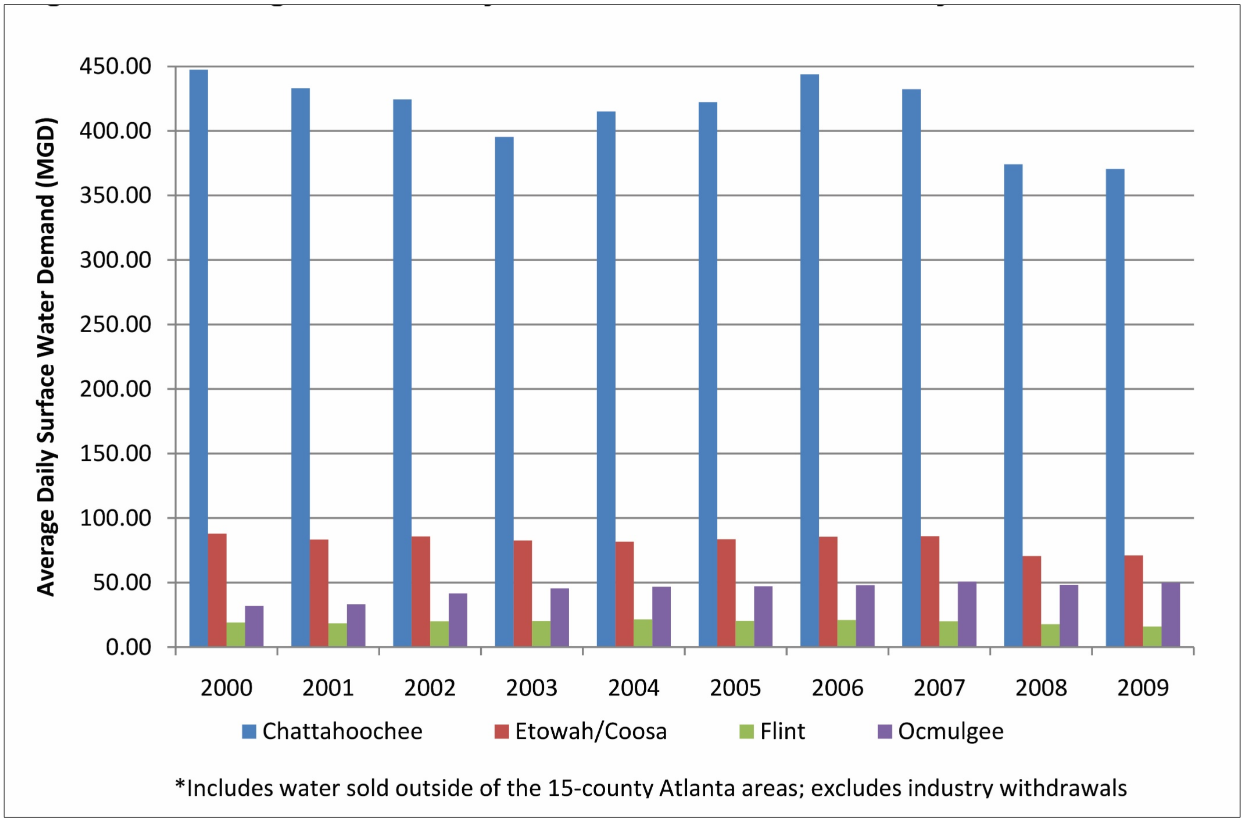


Figure 46. Average annual daily surface water withdrawals by basin made by Atlanta during 2000 through 2009. These amounts include water sold outside Atlanta but exclude industry withdrawals (MNGWPD 2011).

Water use from the Ocmulgee River by Atlanta, however, is only half of the impact from the Atlanta area that should be considered here; the rest of this story has to do with water return, and with the quality of the water returned. In part reflecting inter-basin transfers, while Atlanta withdrew 50 mgd from the Ocmulgee River by 2009, it returned 78 mgd; that is, 155% of the water withdrawn was "returned" (Figure 47). The "returned" water is sewage that, except for malfunction periods, is treated to some extent (that is, with secondary treatment or more advanced treatment) (MNGWPD 2011). Considering this information collectively, we developed two indicators for water quantity at Ocmulgee National Monument (Table 43a,b):

$Water_{AT\text{-}USE}$—the percentage of the water supply for the Atlanta metropolitan area that is the Ocmulgee River; and

$Water_{AT\text{-}RETURN}$—the percentage of the water quantity taken by the Atlanta area that is returned to the Ocmulgee River, and the source(s).

These surface water quantity indicators are based not only on the proportional reliance by Atlanta upon the Ocmulgee River for its water supply, but also on the balance between the amount withdrawn and the amount returned. In addition, the second indicator includes consideration of the quality of the water returned in comparison to the river water that was withdrawn.

As shown in Table 43a and 43b, assessment of surface water quantity using these two indicators leads to an overall evaluation of surface water quantity potentially affecting Ocmulgee National Monument as poor (Table 43c).

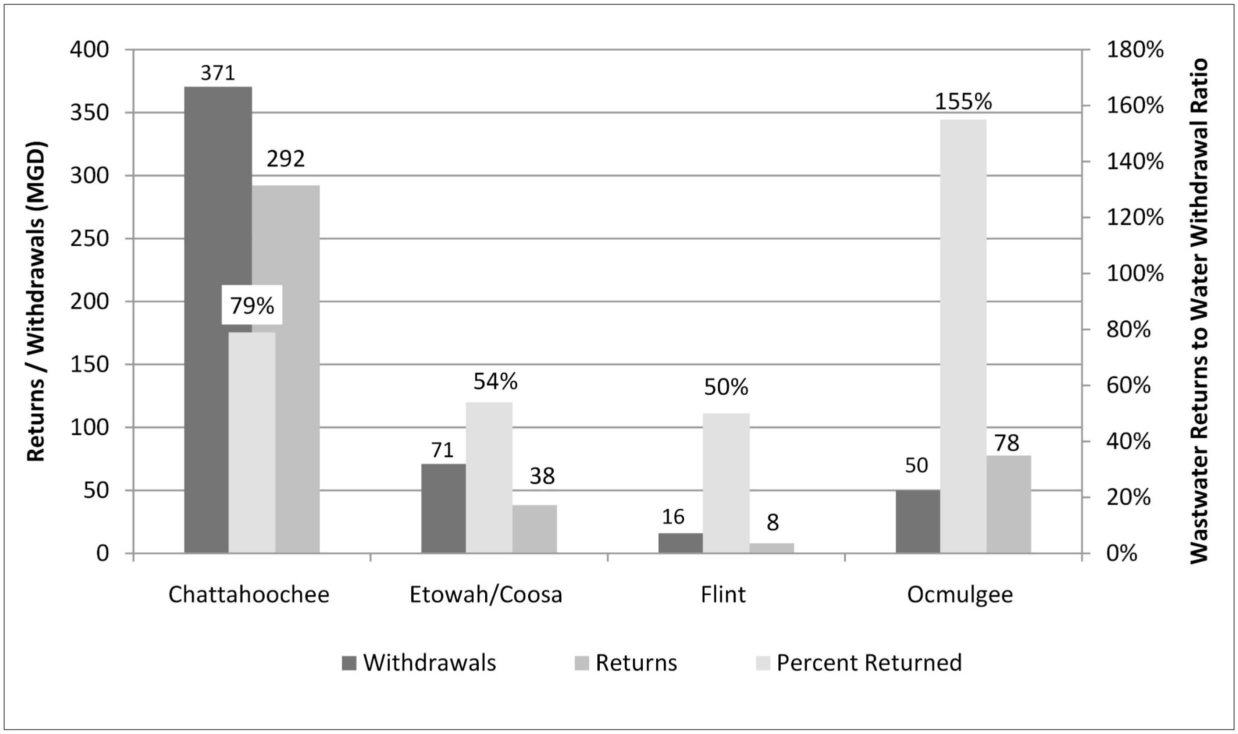


Figure 47. Water withdrawn and "returned" to the Ocmulgee River by the Atlanta area as of 2009. From MNGWPD (2011).

Table 43a. Indicators used to evaluate surface water quantity condition at Ocmulgee.

Indicator	Good	Fair	Poor
Water$_{AT\text{-}USE}$ (use of the Ocmulgee River by the Atlanta area; percentage of the Atlanta area water supply)	Water$_{AT\text{-}USE}$ < 2%; the Ocmulgee River is a minor portion (< 2%) of Atlanta area water supply. Projected to remain stable over the next decade. Balance is maintained	Water$_{AT\text{-}USE}$ is 2–5% of the AtMA's water supply. Projected to increase over the next decade.	Water$_{AT\text{-}USE}$ is > 5% of the Atlanta area water supply. Projected to increase over the next decade. Water withdrawn vs. returned is not balanced.
Water$_{AT\text{-}RETURN}$ (the percentage of water returned to.the.Ocmulgee River by the Atlanta area, and source(s))	WQuant$_{AT\text{-}RETURN}$ is within 10% of Water$_{AT\text{-}USE}$, and returned water of comparable quality.	WQuant$_{AT\text{-}RETURN}$ is within ± 10% of Water$_{AT\text{-}USE}$, and returned water of comparable quality.	WQuant$_{AT\text{-}RETURN}$ > 10% of Water$_{AT\text{-}USE}$, and returned water is worse in quality (e.g., has nutrient supplies that stimulate noxious algae).

Table 43b. The present surface water quantity condition at Ocmulgee, evaluated by the indicators in Table 43a.

Indicator	Ocmulgee evaluation	Rating
$Water_{AT\text{-}USE}$	The Atlanta area uses the Ocmulgee River for at least 8% of its water supply, and that percentage is projected to increase (2011 data).	poor
$Water_{AT\text{-}RETURN}$	155% of the volume withdrawn by the Atlanta area is returned to the Ocmulgee River as sewage that is treated to varying degrees (2009 data). Park staff concern: Most sewage treatment results in effluent that is much higher in pollutants of concern than the river water.	poor

Table 43c. The present surface water quantity condition at Ocmulgee, evaluated by the indicators in Table 43b.

Rating	Criteria	Overall Rating
Good	$Water_{AT\text{-}USE} < 2\%$; $Water_{AT\text{-}RETURN}$ within 10% of $Water_{AT\text{-}USE}$	poor
Fair	$Water_{AT\text{-}USE}$ is 2–5% and projected to increase; $Water_{AT\text{-}RETURN} \geq 10\%$ of $Water_{AT\text{-}USE}$ and returned water of comparable quality	
Poor	$Water_{AT\text{-}USE} > 5\%$ and projected to increase; $Water_{AT\text{-}RETURN} > 10\%$ of $Water_{AT\text{-}USE}$ and returned water is worse in quality (e.g.,,has high nutrients supplies that stimulate noxious algae).	

In its *State of the Park Report for Ocmulgee National Monument*, the National Park Service (NPS 2014d) included the indicator 'surface water dynamics' (specific measures—daily mean discharge, mean monthly flow, and the magnitude and duration of extreme high and low flow events) within the broad priority resource category 'water quantity and quality.' In attempting to evaluate hydrologic condition based on the available information, the National Park Service (NPS 2014d) noted that the frequency of extreme low flows was significantly higher in 2012, reflecting drought conditions based on an analysis of flows since 1960 in the Ocmulgee River using IHAs. Also considered was evidence for continued, ongoing, poor control of stormwater runoff upstream from Ocmulgee National Monument in tributaries to the Ocmulgee River (Gregory et al. 2012). The overall evaluation of surface water dynamics (hydrology) by the National Park Service (NPS 2014d) was "warrants moderate concern and the trend in the condition is unchanging, with medium confidence in the assessment." In our view, additional data evaluation over time beyond the 2012 dataset will enable the National Park Service to be in a strong position to use develop quantitative IHAs for Ocmulgee NM to track changes in hydrologic conditions and impacts.

<u>Groundwater</u>
An excellent dataset is available for a USGS monitoring well approximately 70 kilometers (43.5 mi) Ocmulgee National Monument that has been in operation since August 1953, within the SECP aquifer. These records document that there has been a statistically significant decrease over time for groundwater levels in the area ($p < 0.01$) (Wright 2012b; Figure 30). Moreover, groundwater use is projected to increase over the coming years from the burgeoning demands of the rapidly growing human population in the Metropolitan Atlanta area. Using a simple, straightforward approach, we

developed two indicators for groundwater supply based on these points of information (Tables 44a and 44b). Our overall evaluation of Groundwater Supply Condition in the monument is poor (Table 44c).

Table 44a. Indicators used to evaluate groundwater conditions in Ocmulgee NM.

Indicator	Good	Fair	Poor
GRW_{SUPPLY} (groundwater level)	Statistically significant increasing trend in groundwater level for 1 or both USGS monitoring wells nearest the monument over the period of record (decadal re-evaluation); if only for 1 well, the other has a stationary trend.	Stationary trend for both wells.	Statistically significant decreasing trend in groundwater level for 1 or both USGS monitoring wells nearest the monument over the period of record (decadal re-evaluation); if only for 1 well, the other has a stationary trend.
GRW_{USE} (expected groundwater use)	Groundwater use projected to decrease over the next decade.	Groundwater use projected to remain stationary over the next decade.	Groundwater use projected to increase over the next decade.

Table 44b. The present groundwater supply conditions in Ocmulgee, evaluated by the indicators in Table 44a.

Indicator	Ocmulgee evaluation	Rating
GRW_{SUPPLY}	Groundwater level has significantly decreased over the period of record in a USGS monitoring well near the monument, within the same aquifer.	poor
GRW_{USE}	Groundwater use is projected to increase significantly with the demands of the rapidly increasing human population in the watershed.	poor

Table 44c. The overall evaluation of the present groundwater supply conditions in Ocmulgee, based on the two indicators in Table 44b.

Rating	Criteria	Overall rating
Good	Both indicators good	poor
Fair	≥1 indicator fair	
Poor	≥1 indicator poor	

In its *State of the Park Report for Ocmulgee National Monument*, the National Park Service included a 'groundwater quantity' indicator (with specific measure—groundwater level) within the broad priority resource category 'water quantity and quality.' The National Park Service noted, as in this report, that groundwater level has significantly decreased at the one USGS well near the monument that has a period of record exceeding 10 years (Rasmussen et al. 2009). The overall evaluation of groundwater quantity by the National Park Service (NPS 2014d), based on groundwater, was "warrants moderate concern and the trend condition is deteriorating, with a high level of confidence in the assessment."

4.6.2. Water Quality

Issue: Water pollution is a serious problem for aquatic communities in Ocmulgee National Monument. Severe water quality degradation has been caused by the surrounding and upstream urbanization, which is adding nutrients from fertilizers, car exhausts, pet wastes, and airborne pollutants; suspended solids from land disturbance; and an array of toxic substances from various industries, sewage, and street runoff.

Information is not available about groundwater quality in or near the monument. Therefore, this section focuses on surface-water quality only. There is a wealth of peer-reviewed literature in support of widely accepted parameters indicating the status of surface water quality in freshwaters, and state standards and/or federal recommendations for use in interpreting acceptable levels of these parameters (Hynes 1970; Whitton 1975; Wetzel 2001; GA DNR 2008d, GA DNR 2016; EPA 2000, 2003a). These parameters are pH, DO, turbidity, nutrients (especially TP and inorganic N as nitrate and/or ammonium), suspended algal biomass as chlorophyll *a* concentration (chl*a*, corrected for pheopigments from freshly dead and/or decomposing algae), and various toxic chemical environmental contaminants (CECs). We selected the suite of indicators and the evaluation procedure shown in Tables 45a–45c to assess surface water-quality condition in the monument. A good evaluation was based on protecting, at least, most sensitive aquatic life and sensitive life history stages in monument waters.

Table 45a. Indicators used to evaluate surface water-quality conditions in Ocmulgee NM. Values are percentage of samples in each category that did not meet standards.

Indicator	Good	Fair	Poor
pH	≥ 90%	≥ 75 to < 90%	< 75%
DO (dissolved oxygen; mg/L)	≥ 90%	≥ 80 to < 90%	< 80%
BOD_5 (biochemical oxygen demand; mg/L)	≥ 90%	≥ 80 to < 90%	< 80%
Turbidity (NTU)	≥ 90%	≥ 75 to < 90%	< 75%
TSS (total suspended solids; mg/L)	≥ 90%	≥ 75 to < 90%	< 75%
TP (total phosphorus; µg/L)	≥ 90%	≥ 75 to < 90%	< 75%
NO_x-N (nitrate + nitrite; µg/L)	≥ 90%	≥ 75 to < 90%	< 75%
FECAL (fecal coliform bacteria; mpn/100 mL)	≥ 90%	≥ 80 to < 90%	< 80%

Table 45b. Criteria and overall evaluation of surface water-quality conditions in Ocmulgee NM, based on the eight indicators in Table 45a.

Indicator	NPS Management Target(s)	Ocmulgee NM evaluation	Rating
pH	Georgia standard: 6.0–8.5	100% compliance (297 of 297 samples)	good
DO	Georgia standard: Average 5.0 mg/L; minimum 4.0 mg/L	99% compliance (284 of 288)	good
BOD	Mallin et al. (2006) recommendation: ≤ 3 mg/L	95% met recommendation (39 of 41)	good
Turbidity	EPA recommendation: 5.7 NTU	22% met recommendation (59 of 263)	poor
TSS	EPA recommendation: < 10 mg/L (spike)	61% met recommendation (19 of 31)	poor
TP	EPA recommendation: 30 µg/L	65% met recommendation (28 of 43)	poor
NO_x-N	EPA recommendation: 177 µg/L	23% met recommendation (10 of 43)	poor
FECAL	Georgia standard: < 200 (May–Oct); < 1,000 (Nov–Apr) as GMs; or EPA: < 400 cfu/100 mL)	74% met recommendation (192 of 258)	poor

Table 45c. The overall evaluation of the present surface water-quality conditions at Ocmulgee NM based on the eight indicators in Table 45b.

Rating	Criteria	Overall rating
Good	5–7 parameters good; 0–2 parameters fair; 0 parameters poor	poor
Fair	≤ 2 groups poor	
Poor	≥ 3 groups poor	

In the *State of the Park Report for Ocmulgee National Monument*, the National Park Service (NPS 2014d) based its evaluation of the indicator water chemistry in the Ocmulgee River on six specific measures. These measures include temperature and pH considered together, DO and BOD considered together, nitrate+nitrite and TP considered together, total suspended solids, fecal coliform bacteria, and lead and zinc concentrations considered together. Based on the data analysis from Burkholder et al. (2010), [temperature and pH] and [DO and BOD] were rated as "good condition with high confidence in the assessment." The other four specific measures were all evaluated as "warrants significant concern, with high confidence in the assessment." Thus, four specific measures were color-coded red (poor) and two were green (good). With two-thirds of the specific measures red (poor), we would evaluate overall water quality condition in Ocmulgee National Monument as poor based on the analysis given in National Park Service (NPS 2014d). The National Park Service assessment agrees with the outcome of our analysis here.

4.7. Biological Resources

Issue: The biota of Ocmulgee National Monument is strongly influenced by urbanization from the City of Macon. The air quality, soundscape, lightscape, and water quality of the available habitats in the monument are degraded. High numbers of exotic/invasive taxa—including some of the most voracious invasive species in the Southeast—inhabit the monument, and have compromised the natural flora and fauna in both terrestrial and wetland environments. Exotic/invasive taxa are a primary concern of park staff, along with several species of special management concern.

This suite of indicators was especially challenging because there is no quantitative information available about species of interest among the biological resources of Ocmulgee National Monument, a situation common to various other parks in the network. The information available for important plant communities is restricted to species lists. As explained, that information was questionable because it was based on unvouchered and/or decades-old vouchered lists. A recent vouchered species list was compiled by Zomlefer et al. (2013), based on data collected in 2008–2012. It is a scientifically sound starting point from which to assess vascular plant species diversity in the monument. Even so, population abundance data even in representative habitats or areas of the monument, are lacking for all species of interest, from SSCs to exotic/invasive taxa to SSMCs. Zomlefer et al. (2013) did provide rough abundance information, from "rare" to "common," and their notes are the extent of the abundance information available. Thus, basic data on the numbers of plants of a certain species per unit surface area of the monument remain unavailable at present. That information is needed to calculate reliable basic diversity indices such as Shannon Weaver (Shannon-Wiener) (Shannon and Weaver 1949; MacArthur and MacArthur 1961; Peet 1974). Other indices that rely solely on species numbers were considered, but have major limitations: For example, classic incidence-based indices such as the Jaccard and Sørensen Index (J&SI) estimate similarity between two communities, focusing on richness and composition. The efficacy of the J&SI in providing a realistic measure of species diversity is in debate because the presence/absence data used are neither quantitative nor abundance-based; typically a significant under-sampling bias is involved; and there is no accounting for rare species or unseen shared species (Gotelli and Colwell 2001; Chao et al. 2006). Because of these significant limitations, the J&SI often has been found to yield variable results for the same dataset (Koleff et al. 2003).

In the *State of the Park Report for Ocmulgee National Monument*, the National Park Service (NPS 2014d) evaluated the status of the broad category 'flora and fauna.' The evaluation noted the high species richness and diversity of amphibians and birds in the monument, as well as the presence of 12 highly invasive, Category I plant species such as Chinese privet, kudzu, and Japanese honeysuckle. The overall rating was "resource is in good condition and the trend in condition is unchanging, with high confidence in the evaluation."

We used a somewhat different approach in evaluating the present status of Ocmulgee NM biota. The following biota indicators were developed within the major constraints imposed by the lack of abundance data for species in the monument. The suite of available indicators should be modified as more information becomes available, especially abundance data for selected species.

4.7.1. Vascular Plant Flora

Georgia ranks sixth in the nation for overall biological species richness; historically nearly 3,000 species of vascular plants were reported statewide (see GISTF 2015). However, little is known about the historic species richness or diversity of vascular plants in Ocmulgee National Monument. As mentioned, the "sight list" (NPS 2013a) compiled by park personnel over the past decade contains more than 900 unverified plant species names, considerably more than the 562 vouchered species reported by Zomlefer et al. (2013).

Lacking a verified historic, thorough survey and list of the vascular plant flora of Ocmulgee National Monument, we developed indicators for this large, important group considering terrestrial and wetland habitats separately. For each of the two general habitats, indicators were based on the proportion of exotic taxa and total number of exotic taxa as outlined in Table 46a, and on the proportion of invasive taxa. Thus, we considered vascular plant communities within the context of alteration by exotic plant species.

Exotic/invasive plants represent more than one-third (36%) of the terrestrial plant taxa in this monument, and 15% of the wetland flora (Appendix C). Their presence in terrestrial plant communities seems particularly serious; they include 7 of the 20 Category 1 species of most invasive exotic/invasive plants in the state, as well as 12 species that have been classified by the Georgia EPPC as Category 2 through Category 4 invasive taxa. Three of the highly invasive Category 1 terrestrial taxa (English ivy, *Sericea lespedeza*, kudzu) are common (most abundant status) in the monument. Wetland habitats of Ocmulgee NM have been colonized by a lower percentage of exotic/invasive taxa; nevertheless, three highly invasive taxa classified as Category 1 species are "common" in the monument (alligatorweed, occasional to common; Chinese privet; marsh dewflower; popcorn tree, infrequent to common). Parrotfeather (Category 2—infrequent to common), Florida hedgenettle (Category 3), and longbristle smartweed (Category 4) are also common in the monument. Monument wetland/aquatic habitats additionally have 14 other highly invasive taxa as well, although none of these are described as common by Zomlefer et al. (2013). Based on the indicators and evaluation schematic shown in Tables 46a–46c, the overall vascular flora condition in the monument is poor.

Table 46a. Indicators (two terrestrial and two wetland) used to evaluate vascular flora conditions in Ocmulgee NM.

Indicator	Good	Fair	Poor
$TERR_{EX\%}$ (proportion of exotic terrestrial taxa)	< 5% of the terrestrial taxa are exotic/invasive	> 5–15% are exotic/invasive	> 15% are exotic/invasive
$TERR_{EX\text{-}CAT}$ (number of highly invasive taxa)	no Category #1–#4 taxa	no Category #1 taxa common; some Category #2–#4 taxa common	some Category #1 taxa as well as some Category #2–#4 taxa common
$WET_{EX\%}$ (proportion of exotic wetland aquatic taxa)	< 5% of the wetland taxa are exotic/invasive	> 5–15% are exotic/invasive	> 15% are exotic/invasive
$WET_{EX\text{-}CAT}$ (number of highly invasive wetland/aquatic taxa)	no Category #1–#4 taxa	no Category #1 taxa common; some Category #2–#4 taxa common	several Category #1 taxa as well as some Category #2–#4 taxa common

Table 46b. The present vascular flora conditions in Ocmulgee NM, evaluated by the indicators in Table 46a.

Indicator	Ocmulgee evaluation	Rating
$TERR_{EX\%}$	As of 2012 (Zomlefer et al. 2013), 189 terrestrial vascular plant taxa in the monument, including 70 exotic/invasive taxa (2 cultivated), comprising 36% of the total.	poor
$TERR_{EX\text{-}CAT\%}$	7 (35%) of the 20 Category #1 species + 12 Category #2–#4 species; 7 common as well as highly invasive (3 Category #1 + 2 Category #2 + 2 Category #3).	poor
WET_{EX}	249 wetland/aquatic vascular plant taxa in the monument, including 40 exotic/invasive taxa (1 cultivated) comprising 15% of the total.	fair
$WET_{EX\text{-}CAT}$	7 Category #1 species + 13 Category #2–#4 species; 4 of the Category #1 species, 1 Category #2 species, 1 Category #3 species, and 1 Category #4 species are common in OCMU wetland/aquatic habitats.	poor

Table 46c. The overall evaluation of the present vascular flora conditions in Ocmulgee NM, based on the four indicators in Table 46b.

Rating	Criteria	Overall rating
Good	≥ 3 indicators good, ≤ 1 indicator fair	poor
Fair	≥ 2 indicator fair, ≤ 1 indicator poor	
Poor	≥ 2 indicators poor	

4.7.2. Fish

According to the Georgia Museum of Natural History (2009), there are more than 325 species of fish that occur in Georgia freshwaters, including more than 60 SSCs (8 federally listed, 57 state listed). About one-third of the freshwater fish fauna is imperiled and at least six species likely have been extirpated, especially from areas that have sustained dense human population growth. Gilbert (1969) reported 83 fish species in the central Chattahoochee River drainage. Considering the historically rich fish fauna that characterized the state and the region, a relatively small number of native warm water fish species—25, according to the NPS Certified Species List (2013b)—remain in the surface waters of Ocmulgee NM. That list is based in part on references, rather than recent surveys. As a troubling point, the most recent survey of fish in the monument documented only 11 species.

Many previous studies from various geographic regions, including the Southeast (Meador et al. 2005, and references therein), have reported that fish species richness in streams decreases over time with increasing watershed urbanization. For example, Scott and Helfman (2001) developed a conceptual model for the effects of urbanization-related habitat disturbance on fish communities in streams of the Southeast, showing loss of endemic species concomitant with native and exotic invasive species that “artificially inflate” species richness (Figure 48, lower panel). Long and Schorr (2005) reported a clear negative effect of urbanization on water quality, habitat, and fish assemblages in these small to mid-sized streams. All 21 of their sampling sites showed some level of impaired biotic integrity; none were rated as good or excellent.

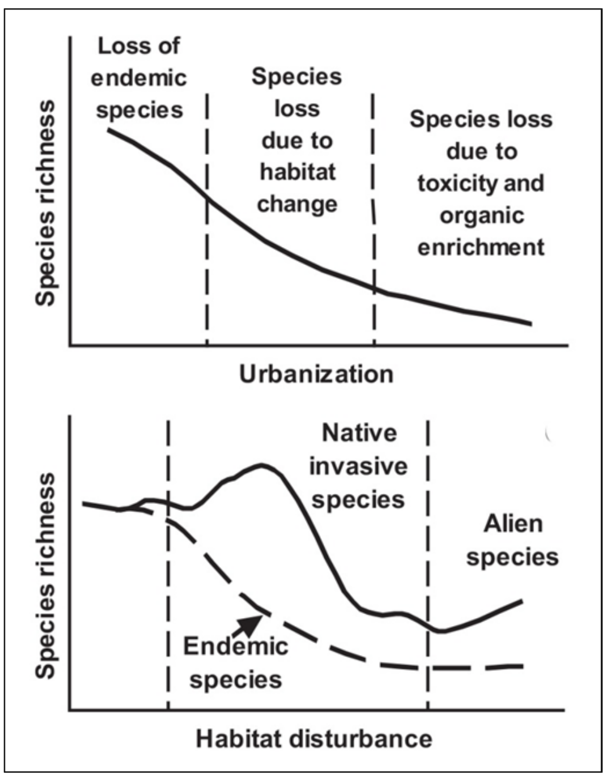


Figure 48. Two conceptual models of the influence of urbanization on species richness in streams (upper panel—Paul and Meyer 2001, based on streams in Ohio; lower panel—Scott and Helfman 2001, based on streams of the Southeast).

Yet, according to the most recent survey a decade ago (Johnston 2006; survey conducted in 2003), monument waters had only 25% as many fish species as the sites examined by Long and Schorr (2005). It should also be noted that two species characteristic of highly urbanized areas, bluegills and creek chubs, are included in the NPSpecies List (2013a) for fish species in the monument; and that the native fish species that can act as an invasive, the redbreast sunfish (*Lepomis auritus*—TISI 2014), was reported from both areas. Comparison with other studies similarly indicates that fish species numbers in the monument are depauperate. Six streams in the nearby mid-Chattahoochee River watershed that were predominantly influenced by agricultural land use contained from 27 to 46 species when sampled in 1995. That study spanned streams in both the Piedmont and Coastal Plain. Some of the most abundant taxa in the streams were also reported for streams in Ocmulgee National Monument (the bandfin shiner, *Luxilus zonistius*, in four streams; the blackbanded darter, *Percina nigrofasciata*, in three streams; and the creek chub, *Semotilus atromaculatus*, in two streams).

Based on this information, we developed a fish species richness indicator (FISH) and evaluated the fish condition in the monument as fair (Tables 47a–47b). We recommend that fish species in the monument be assessed at five-year intervals or more frequently.

Table 47a. Species richness as the indicator used to evaluate fish condition in Ocmulgee NM.

Indicator	Good	Fair	Poor
FISH (fish species richness)	15 native species	10–15 native species	≤ 9 native species

Table 47b. The present fish condition in Ocmulgee NM, evaluated by the indicators in Table 47a.

Indicator	Ocmulgee evaluation	Rating
FISH	11 native fish species have recently (past decade) been reported in Ocmulgee NM.	fair

4.7.3. Herpetofauna

Although the recent surveys of herpetofauna in the monument have yielded interesting and helpful information, abundance data for the species found are not yet available so that classic species diversity indices such as the Shannon Weaver cannot be developed (Peet 1974; Magurran 1988, 2004). There is little information on the historic species richness of herpetofauna in the monument until Tuberville et al. (2005). Considering the known high diversity of herpetofauna in this region together with the high habitat degradation/loss and other negative impacts from watershed development, herpetofauna diversity likely was substantially higher than the findings of Tuberville et al. (2005).

In its *State of the Park Report for Ocmulgee National Monument*, the National Park Service (NPS 2014d) described high amphibian diversity in the monument and noted that 25 species had been documented to occur there, likely in reference to the Tuberville et al. (2005) study. It should be noted, however, that that survey relied upon dated museum records equally as sightings. Considering that (i) the findings from that survey are now 12–14 years old, (ii) many museum records are substantially more dated, and (iii) during the past decade there have been increasing, major pressures on the natural resources of this monument from surrounding urbanization and air/water pollution, the present-day amphibian species richness may well be lower. The most recent NPS survey, conducted during March–May 2011, detected 14 amphibian species. As two indicators of herpetofauna condition, we suggest that trends in detection of vocal anurans and the data from VESs should be tracked over time, beginning with the 2011 baseline data, and setting that condition as good (Tables 48a–48c).

Table 48a. Indicators used to evaluate herpetofauna conditions at Ocmulgee NM.

Indicator	Good	Fair	Poor
$V\text{-}_{Anurans}$ (vocal anuran amphibian species detected with ARD; consistent procedure, same timing and sites)	≥ 14 vocal anuran amphibian species detected	10–13 detected (up to 25% fewer)	< 10 detected
$HERP_{VES}$ (# of species from VES, using consistent procedure, same timing and sites)	≥ 15 amphibian and reptile species detected	12–14 species detected (up to 20% fewer)	< 12 species detected

Table 48b. The present herpetofauna conditions at Ocmulgee NM, evaluated by the two indicators in Table 48a.

Indicator	Ocmulgee evaluation	Rating
$V\text{-}_{Anurans}$	March–May 2011:14 vocal amphibian anuran species (all native) detected at 21 established sites.	good
$HERP_{VES}$	May 2011: 15 amphibian and reptile species detected (same 21 sites), all native species.	good

Table 48c. The overall evaluation of the present herpetofauna conditions in Ocmulgee NM, based on the two indicators in Table 48b.

Rating	Criteria	Overall rating
Good	Both indicators good	good
Fair	≥ 1 indicator fair, no indicator poor	
Poor	≥ 1 indicator poor	

4.7.4. Birds

Abundance data are lacking for bird species in the monument, preventing calculation of Shannon Weaver or other widely accepted diversity indices for bird diversity. Therefore, at present we have based indicators for bird fauna condition in this monument on the North American Breeding Bird Survey (BBS), and on the baseline survey conducted by Byrne et al. (2011b).

The BBS was developed by the Fish and Wildlife Service in response to the need for a continental monitoring program following the widespread use of DDT (dichloro-diphenyl-trichloro-ethane) and other chlorinated hydrocarbon pesticides, and anecdotal reports about related increased mortality of songbirds (Robbins et al. 1986). The program presently represents a cooperative effort between the United States (USGS), Environment Canada—Canadian Wildlife Service, and the Comisión Nacionale para el Conocimiento Uso de la Biodiversidad (CONARIO). The BBS presently includes 3,400 randomly located permanent survey routes established along secondary roads. Each route is 39.4 kilometers (24.5 mi) long and consists of 50 stops spaced at 0.8-kilometer (0.5-mi) intervals. The routes are surveyed once each year during the peak of the breeding season. Volunteers experienced in identifying birds by sight and sound record all birds detected within 0.4 kilometers (0.25 mi) of each stop during a three-minute observation period (Robbins et al. 1986, Sauer et al. 2003). As a limitation, the annual surveys yield what might be more accurately described as a relative abundance index because they do not produce a complete counting of the breeding bird populations. In addition, differences in experience among volunteers can sometimes cause inconsistencies in the results. Nevertheless, these annual surveys have proven valuable in assessments of bird population trends (Link and Sauer 1998, Sauer et al. 2003).

BBS summaries of the data by year allow a rapid, user-friendly analysis of trends in the number of individuals and the number of species detected over time at a station of interest (see Pardieck et al. 2015). The data are also presented by individual species. For BBS Route 27035 (Macon, Ga.), the information since the turn of the century is somewhat provocative (Table 49). The first four years (2000–2003) are represented by only one year (2002), so it is not possible to determine whether that was a true "representative" year for the beginning of the century. The number of species (56) was comparable to the other nine years (2004–2012: range, 55–62), but the total abundance (number of individuals) fell from 702 individuals (2002) to an average of 639 individuals (2004–2007: range, 600–676 individuals), and then to 574 individuals (2008–2012; range, 520–658 individuals). Thus, from 2002 to 2012, the number of species remained comparable (56–58), but the number of individuals declined by nearly 20%.

Table 49. Breeding Bird Survey results for BBS Route 27035—Macon, Ga., the route closest to Ocmulgee NM.

Parameter	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
# Species	–	–	56	–	62	–	62	58	62	55	59	59	57
# Individuals	–	–	702	–	600	–	676	602	658	580	520	593	518

We suggest that the BBS data for the Macon Route can be used as secondary information, or as an alternate, to Byrne et al.'s (2011b) index for species richness ($BIRD_{OBS\ SPP}$, the observed number of species in the monument; Table 50a). It should be expected that BSS will differ from $BIRD_{OBS\ SPP}$ because of differences in methods, and because the monument offers much better habitat than the City of Macon in general. Thus, tracking both indicators over time may yield an interesting comparison. Other indicators developed from the Byrne et al. (2011b) study are total bird abundance ($BIRD_{ABUND}$, number of individuals), $BIRD_{DIST}$ (the six most widely distributed birds in the monument), and $BIRD_{SSC}$ which considers the three bird SSCs that were reported for the monument in the NPSpecies List (NPS 2013a; see Tables 50b-50c for present and overall conditions). Finally, the status of the NPSpecies List (2013a) for bird fauna in Ocmulgee National Monument merits mention. This valuable list should be verified at least on a decadal basis. Otherwise, there will be no way to track the total number of species that actually are present in Ocmulgee National Monument at some time during an annual cycle, or the percentage of neotropical migrants, or other important information. At present, the total number reported on the list is 172 native species. Considering the variation reported annually in the BBS, the following categories of native species numbers might be used for evaluation: good, ≥ 55; fair, 48–54; poor, ≤ 47. We did not suggest the total number of species on the NPS Certified Species List, tracked over time, as an indicator in consideration of the fact that extensive survey of the monument over an annual cycle would require a major, personnel- and time-intensive effort, but it is important nevertheless.

Table 50a. Indicators used to evaluate bird fauna conditions in Ocmulgee NM.

Indicator	Good	Fair	Poor
$BIRD_{BBS}$ (breeding birds; annual, routinely conducted by volunteers for the USGS)	≥ 55 native spp.	48–54 spp.	≤ 47 spp.
$BIRD_{OBS\ SPP}$ (assessed at 10-year intervals, same timing/sites as in 2009)	≥ 70 native spp.	63–69 native spp.	< 41 native spp.
$BIRD_{ABUND}$ (# individuals, same assessment)	> 625 individuals in total	550–625 individuals	< 550 individuals
$BIRD_{DIST}$ (most widely distributed, same)	same 8 spp.	6–7 of the 8 spp.	≤ 5 of the 8 spp.
$BIRD_{SSC}$ (assessed at 10-year intervals in "best" locations)	all 4(5) SSCs observed	3 of 4 (or 4 of 5) SSCs observed	≤ 2 SSCs (or ≤ 3 SSCs) observed

Table 50b. The present bird fauna conditions in Ocmulgee NM, evaluated by the indicators in Table 50a.

Indicator	Ocmulgee evaluation	Rating
$BIRD_{BBS}$	North American BBS near the monument (Macon): 2002: 56 spp., 702 individuals 2004–2007: 60 spp., 639 individuals 2008–2012 : 58 spp., 574 individuals The lowest # of species annually over the 2000–2012 period was 55 species in 2009.	good
$BIRD_{OBS\ SPP}$	April–June 2009: 71 native species detected at 20 established sites.	good
$BIRD_{ABUND}$	April–June 2009: 663 individuals detected at 20 established sites.	good
$BIRD_{DIST}$	April–June 2009: most widely distributed taxa: Carolina wren, northern cardinal, tufted titmouse, red-bellied woodpecker, Carolina chickadee, American crow, and white-eyed vireo.	good
$BIRD_{SSC}$	As of 2013 (NPS Certified Species List): 4(5) SSCs: cerulean warbler, golden-winged warbler, Wilson's plover, wood stork; 5th SSC according to the GA DNR (Chafin 2011) Swainson's warbler.	good

Table 50c. The overall evaluation of the present bird fauna conditions in Ocmulgee NM, based on the five indicators in Table 50b.

Rating	Criteria	Overall rating
Good	$BIRD_{BBS}$ or $BIRD_{OBS\ SPP}$ good, ≥ 2 other indicators good, ≤ 1 other indicator fair, no indicator poor	good
Fair	$BIRD_{BBS}$ or $BIRD_{OBS\ SPP}$ fair, ≤2 other indicators fair, ≤ 1 other indicator poor	
Poor	≥ 2 indicators poor	

4.7.5. Mammals

Lacking other helpful information, we based the present form of the mammalian species indicator on the proportion of exotic/invasive mammalian taxa relative to the total number of mammalian taxa inhabiting Ocmulgee National Monument (Tables 51a–51b). Webster (2010) described depauperate mammalian species for this monument, consisting of 22 documented native taxa. His final list included 11 other species that are widely distributed in the Southeast and probably inhabit the monument (see Appendix C), although the survey did not document those 11 species. We recommend that mammalian species should be assessed on a five- to ten-year basis, and that population-level studies should be conducted on mammalian species of special management concern (SSMC), to strengthen and improve the mammalian fauna indicator in the future.

Table 51a. The indicator used to evaluate mammalian fauna conditions in Ocmulgee NM, based on one indicator

Indicator	Good	Fair	Poor
MAM_{INV} (proportion of exotic/invasive species; assessed every 10 years)	< 5%, none common	5–10%	> 10%

Table 51b. The present mammalian fauna conditions in Ocmulgee NM, evaluated by the one indicator in Table 51a.

Indicator	Ocmulgee evaluation	Rating
MAM_{INV}	27% of the mammalian species in Ocmulgee (9 of 33) are exotic/invasive taxa, including feral cats which park staff describe as common. Recently invasive coyotes have become a concern for park staff.	poor

It should be noted that specific indicators for exotic/invasive species were not developed for two reasons: First, we have already factored exotic/ invasive species into the indicators for vascular flora and mammals in this monument. Second, as Ferriter et al. (2007) wrote, "The indicator[s] for invasive exotics is not similar in nature or context to other indicators because nonindigenous [species] in themselves do not make good indicators of ecological function, process, or structure…"

Based on their extensive experience combating exotic/invasive species in the Florida Everglades, Ferriter et al. (2007) suggested use of the following parameters to evaluate and report the status of invasive species:

- The number of different exotic/invasive species present;
- The number, abundance, and frequency of new exotic/invasive species in the ecosystem;
- The number and abundance of extant exotic/invasive species found in new locations;
- The location and density of invasive species, especially in relation to native communities;
- The rate of invasive species spread; and
- The effectiveness of control actions or programs for exotic/invasive species, generally measured as a decrease in the spatial extent of a (plant) species.

Unfortunately, very little of any of these types of information is available for Ocmulgee National Monument other than the total number of exotic/invasive taxa. As such data become available, indicators for specific exotic/invasive species should be added.

5. Climate and Climate Change

5.1. Climate

Climate is considered here as the short-term and long-term patterns and processes of weather events for a given location. Climate is among the most significant influences on natural resources anywhere on Earth: Weather and climate are key drivers for ecosystem patterns and processes, affecting both biotic and abiotic components alike. Understanding the role of climate as a forcing agent for other vital signs (e.g., plant and animal communities) is a critical component of NPS operations and SECN monitoring. Continuous weather monitoring provides key information when managers attempt to separate the effects of climate from the effects of human-induced disturbance on plant and animal community and population dynamics (Wright 2011). Summary climate data for Ocmulgee NM were presented in annual reports published by the network during 2009–2014, however these reports are no longer being published. Much of this same and more recent data are now easily available from online primary sources.

There are some indications that climate changes have been noted at the Ocmulgee National Monument in the summer season (June–August) during the decade through an increasing trend in mean temperature and a strongly decreasing trend in precipitation. That is, it has been hotter and drier in the summers of the past decade.

Ocmulgee National Monument is located in an area characterized by a warm and humid, temperate climate. Climate data are available from two stations near the monument (Table 52). The regional climate is moist and temperate (mean annual temperature 15.6°C [60°F]; average annual range 7.8–20.6°C [46–69°F]). Annual rainfall averages 129.5 centimeters (cm; or 51 inches, in) per year, with minimal snowfall (GA DNR 1997; Southeast Regional Climate Center 2007). Evaporation and transpiration account for approximately 76 cm (30 in) of rainfall, resulting in about 45.7 cm (18 in) annually available for streamflow and percolation to groundwater. The Ocmulgee area has a humid, subtropical temperature, often reaching the mid-30s (°C, or mid-90s [°F]) or higher in summer and decreasing to 6.5–7.5°C (mid-40s [°F]) during winter (GA DNR 2004). Precipitation generally is greatest in February–March and least in October. A dry season extends from mid-summer to late fall (GA DNR 2004).

Table 52. Weather stations in or near OCMU (dd—decimal degrees). From Wright (2012a).

Distance (km [miles])	Station Name	National Network	Station ID	Lat (dd)	Long (dd)	County	Elev. (ft)	Start Date
21.9 [13.6]	Brender Macon Middle	RAWS	BOLG1	33.0097	-83.7397	Jones	300	2/20/2003
16.9 [10.5]	Georgia Regional Airport	COOP	095443	32.6833	-83.65	Bibb	342.8	12/1/1948

5.1.1. Temperature

The analyses of climatic conditions for this report were completed in 2012–2013 and, thus, generally used data available through 2011 (storms) or 2012. Data from the National Weather Service (NWS) of the National Oceanic and Atmospheric Administration (NOAA) provide information on changes in temperature, precipitation, and drought conditions over time. Its historic record for the Climate Division 5 area, including Macon and Ocmulgee National Monument, covers the period from 1901 to the present; data were available through 2012 at the time this report was written, see NCEI 2015. The mean annual temperature across that period was 17.6°C (63.7°F), and it decreased by 0.05°C (0.1°F) over the 112-year record or considering the summer season (Figures 49 and 50).

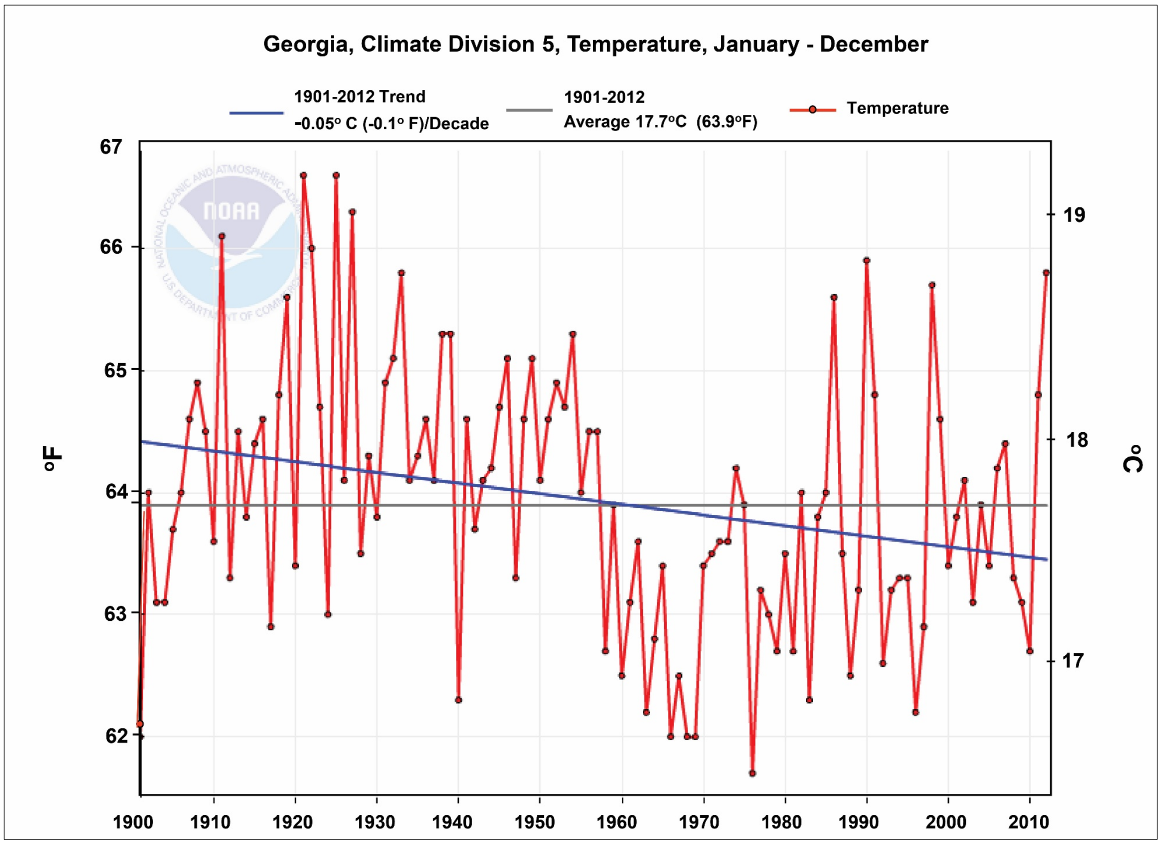


Figure 49. Mean annual temperature for the Climate Division 5 area, including OCMU (1901–2012), showing little change over time. From the NOAA National Weather Service (NCEI 2015), hereafter referred to as NOAA NWS.

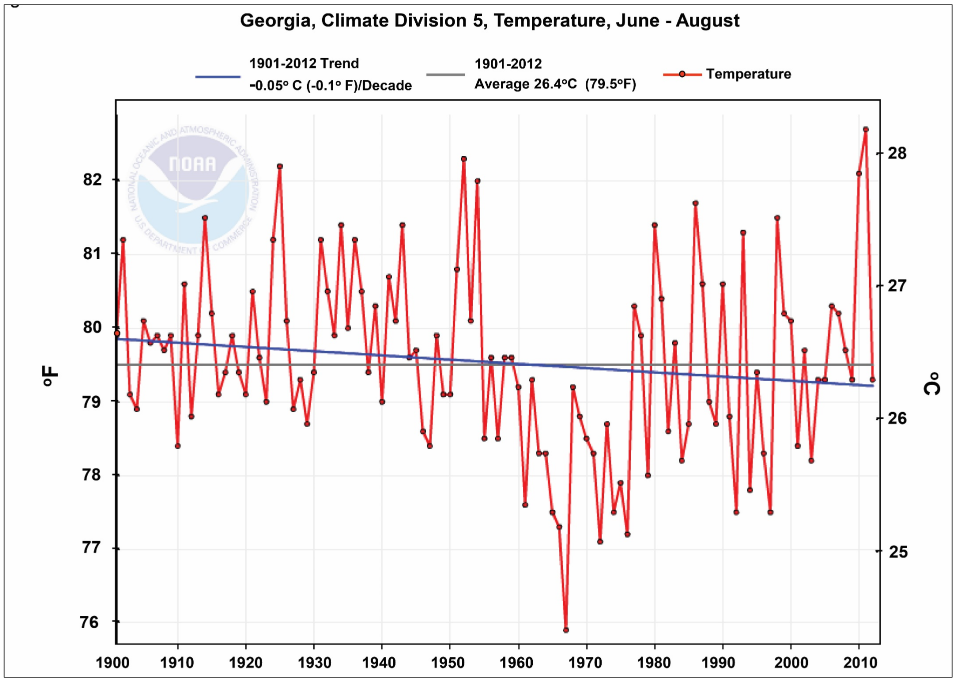


Figure 50. Mean summer temperature (June–August) in the Climate Division 5 area during 1901–2012, showing little change over time (though data suggest a downward trend that is not statistically significant). From NOAA NWS.

5.1.2. Precipitation

Similar analyses were conducted for precipitation in the Climate Division 5 area. Both average annual and average summer (June–August) precipitation from 1901 to 2012 varied greatly, but showed a slight decreasing trend (–0.25 cm [–0.1 in] per decade, and –0.33 cm [– 0.13 in] per decade, respectively; Figures 51 and 52).

Overall, then, annual and summer temperatures statistically have remained roughly constant, with the suggestion of a minor decrease long-term (1901–2012). The same finding is true of annual and summer precipitation.

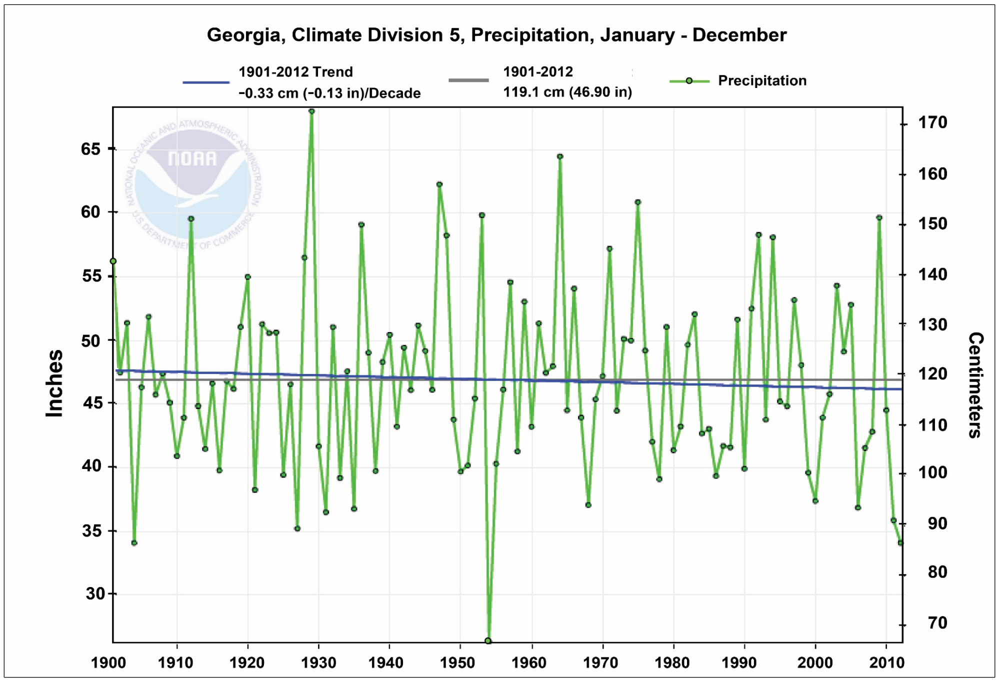


Figure 51. Mean annual precipitation in the Climate Division 5 area during 1901–2012, showing little change. The mean annual precipitation was 119.1 centimeters (46.90 in) over that period, with a decreasing trend of 0.33 centimeters (0.13 in) per decade. From NOAA NWS.

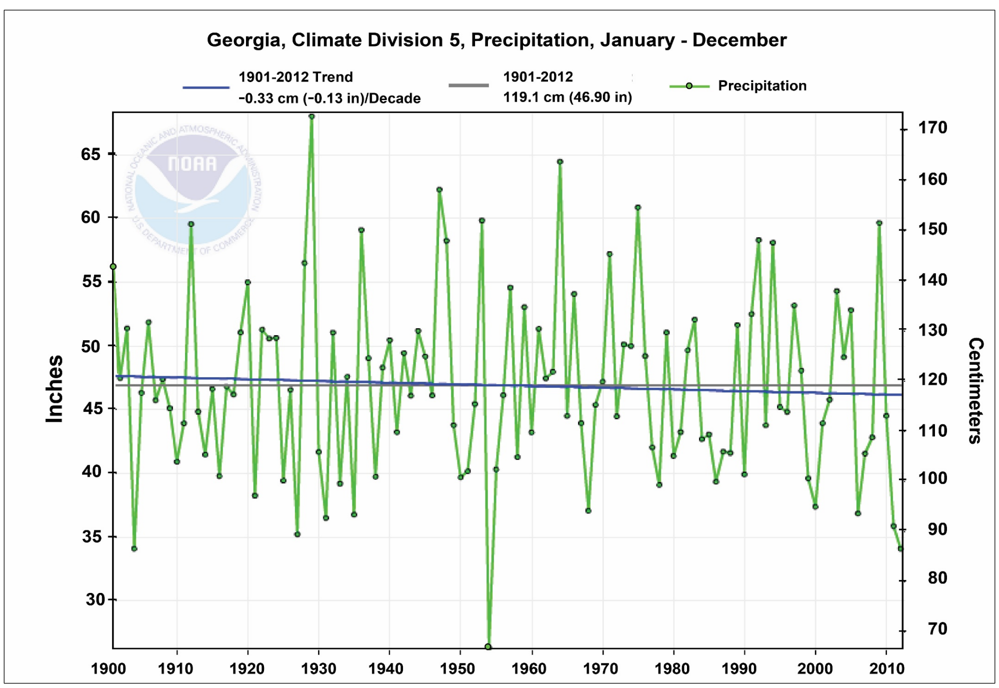


Figure 52. Mean summer precipitation for Climate Division 5 from 1901 to 2012, suggesting a slight decrease over time of –0.33 cm (–0.13 in) per decade. From NOAA NWS.

5.1.3. Moisture

Drought severity was assessed (1896 or 1920 through 2012) using the Palmer Drought Severity Index (PDSI, a scale ranging from -5 to +5), which assesses the duration and intensity of long-term drought-inducing circulation patterns (Dai et al. 2004; Dai 2011a,b). PDSI values rank the severity of a given drought (Table 53). Drought severity during the summer season (June–August) was highly variable over the period of record, but the data show a strong increase in the proportion of months that were in the abnormally dry, excessively dry, and severely dry classes since 1976 (Figures 53 and 54). Moreover, within the past decade (2002–2012) the PDSI has decreased substantially; thus, in the Ocmulgee NM area, droughts have recently worsened (Figure 55).

Table 53. The Palmer Drought Severity Index (PDSI) scale, which ranges from -5 to +5. From Dai et al. (2004).

Scale Interval	Class Description
-3 or less	Severely dry
-2 to less than -3	Excessively dry
-1 to less than -2	Abnormally dry
-1 to less than 1	Slightly dry / favorably moist
1 to less than 2	Abnormally wet
2 to less than 3	Wet
3 or greater	Excessively wet

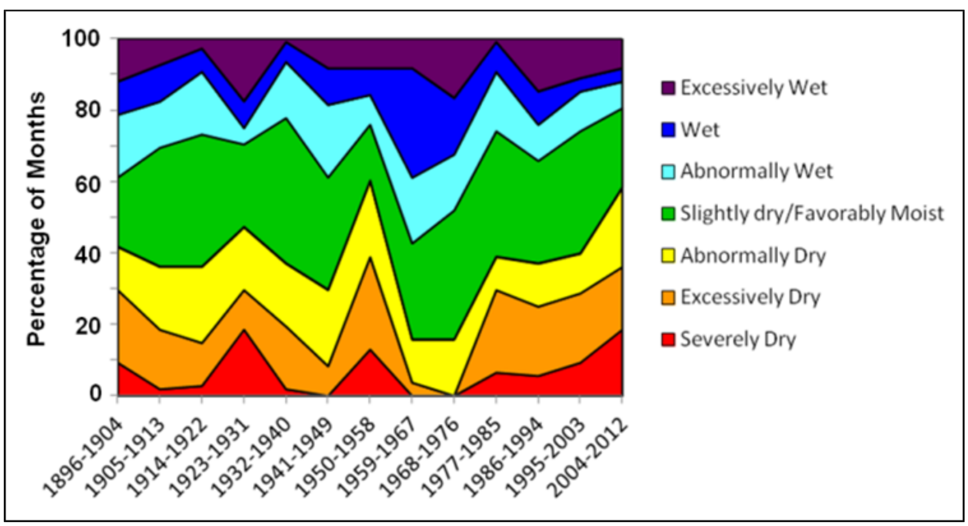


Figure 53. PDSI values for the Climate Division 5 area over 9-year periods from 1896 to 2012, showing a large percentage of months in the "excessively dry" class over the past four decades. Data from the Southeast Regional Climate Center (SERCC).

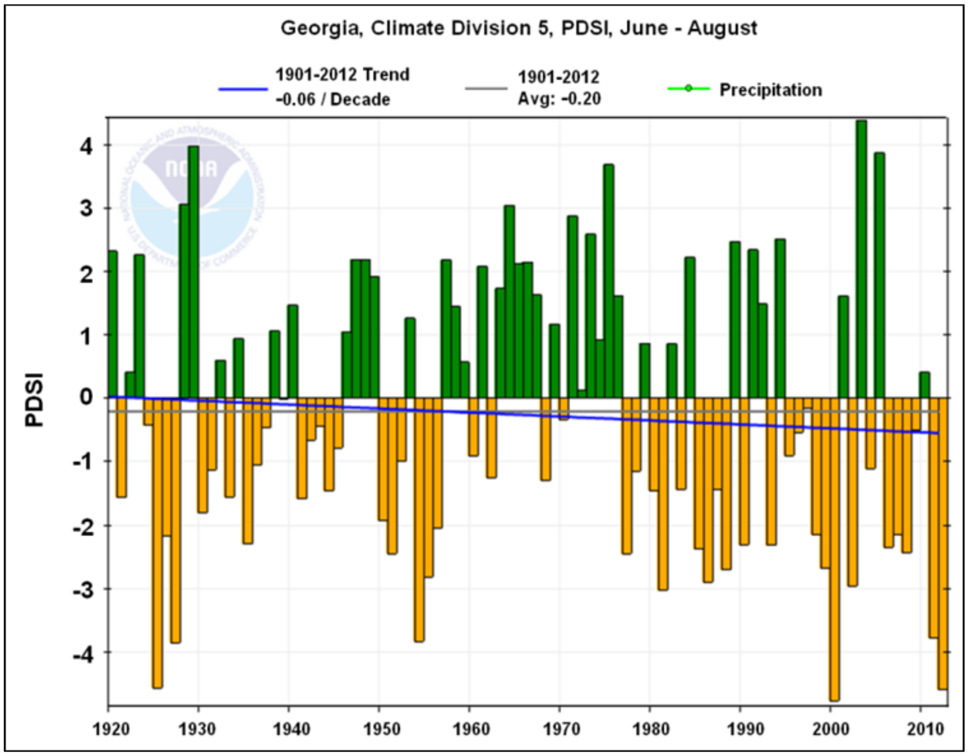


Figure 54. PDSI values for the Climate Division 5 area over the period of record (1920–2012; NCEI 2015).

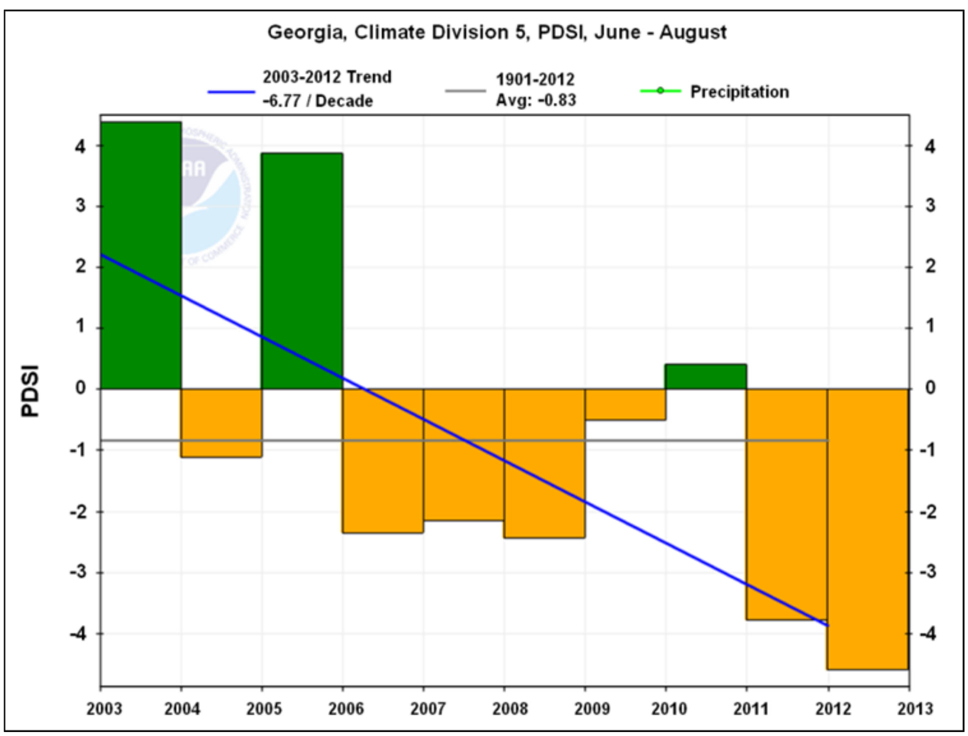


Figure 55. PDSI values over the past decade (2003–2012) in the Climate Division 5 area, showing a decrease. Data from NOAA NWS.

5.1.4. Phenology (Growing Degree Days)

Phenology is the study of the effects of changes in the seasonal variation of temperature and precipitation on biological processes, reflected in the timing of reproduction, flowering, and the length of the growing season (NOAA NWS). We assessed changes in phenology as growing degree days (GDDs), defined as the total amount of time in an annual cycle when the temperature is above 4.4°C (40°F), roughly equivalent to the growing season when non-evergreen plants are able to photosynthesize. The monthly mean temperature for Climate Division 5 over time (1930 to 2012) was used to estimate the approximate number of GDDs per month:

GDD = (Tm – 40) Dm

where Tm = monthly mean temperature, and Dm = number of days in month. The GDDs for each month were added to estimate the GDDs per year, and these values were plotted over time to assess long-term changes in the numbers of GDDs in the area (Figure 56). Using the approach of Dorr et al. (2009), we also considered phenology within the context of a calendar year by selecting an arbitrary GDD threshold of 1200 and then estimating the date at which that number of GDDs was reached. This would be similar to estimating the specific date of a phenologic event, such as cherry tree flowering in March or April. The total monthly accumulated GDD through March 31st was calculated by multiplying the mean daily temperature by the number of days in a month, and the difference from 1,200 was determined. The number of days required to reach the 1,200 GDD was estimated as the slope of the line for the approximate month. If the difference was positive, the exact date where 1200 was achieved was estimated as the slope of the line between the total GDD for March and the total for April. If the difference was negative, the same procedure was used between February and March. In this way, the calendar date when the 1200 GDD was achieved was calculated for each year. The annual GDD for the Climate Division 5 area has not appreciably changed over the period from 1930 to 2012, and also more recently from 2003 to 2012(Figure 56). Overall, this analysis suggests that the phenology in the Climate Division 5 area is static. There has been little change in the time to the date when 1200 GDD is reached (Figure 57).

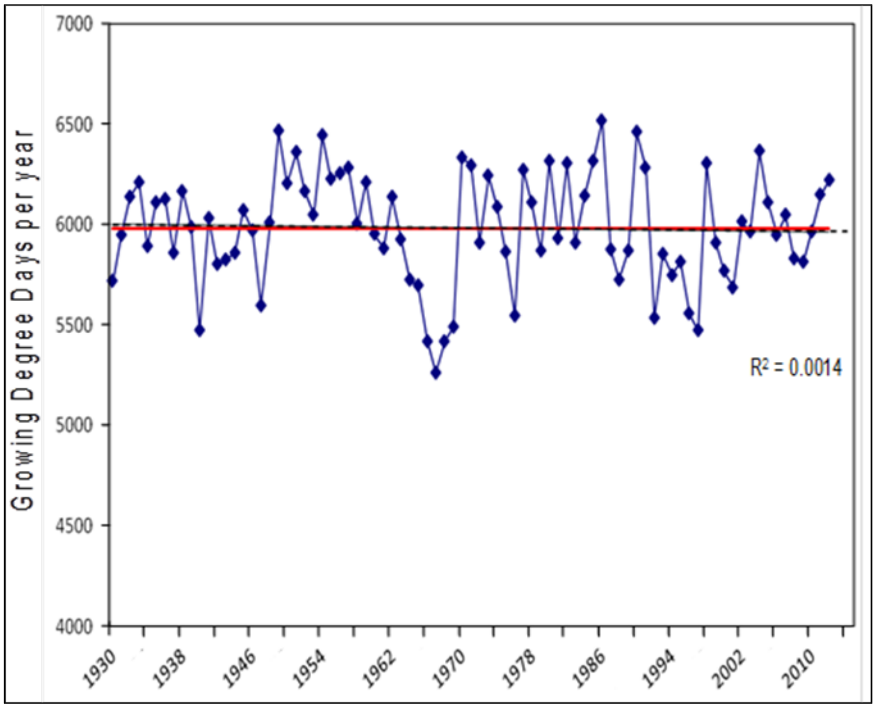


Figure 56. The GDDs per year for Climate Division 5 area from 1930 through 2012. The long-term mean annual number of GDDs is 5984 (dashed line). The red line indicates the trend and suggests little or no change over time. Data from the SERCC.

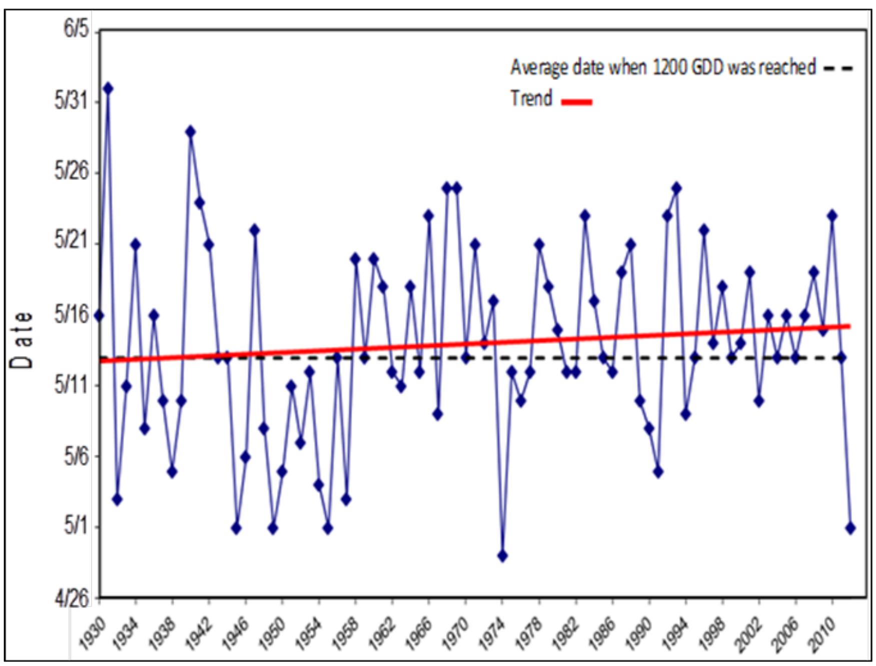


Figure 57. The approximate date when 1200 GDD was reached for each year in the Macon, Ga. area during the period from 1930 to 2012. The long-term mean approximate date when 1200 GDD was reached (5/12) is shown by the dashed line. There has been little change over time, as indicated by the red line. Data from the SERCC.

5.1.5. Extreme Weather Events

Storm tracks within a 161-kilometer (100-mi) radius of the City of Macon were acquired from 1930 to 2012 from the NOAA National Weather Service. Each storm was rated as a tropical depression (TD), a tropical storm (TS), and category 1–4 hurricanes. Storms categorized as tropical depressions have maximum sustained winds of 61 kilometers per hour (38 miles per hour [mph]) or less. Tropical storms have maximum sustained winds of 63 to 117 kilometers per hour (39 to 73 mph) (US DOC 2013). The Saffir/Simpson Hurricane Scale (SSHS; Table 54, Figure 58) rates and categorizes hurricanes on a scale of 1 to 5 based on wind speeds (Blake et al. 2007). Storms that occurred on successive days were combined into one storm event, and the event was assigned the most severe storm rating that it received. The data were considered by month and year (data from SCONC 2015).

Of the 52 storms in total from 1851 through 2012, most were tropical depressions and tropical storms; no hurricanes affected Macon throughout the entire period (Table 55). Most storms in the Macon area have occurred between during June and October, with maximal events in September (Figure 58). The total number of storms has increased from the mid-1980s to the present (Figure 60) to a level documented in the 1950s.

Table 54. The Saffir/Simpson Hurricane Scale (SSHS). From Blake et al. (2007).

Scale Number (Category)	Wind Speed (mph)	Millibars	Inches	Surge (ft)	Damage
1	74–95	> 979	> 28.91	4 to 5	Minimal
2	96–110	965–979	28.50–28.91	6 to 8	Moderate
3	111–130	945–964	27.91–28.47	9 to 12	Extensive
4	131–155	920–944	27.17–27.88	13 to 18	Extreme
5	> 155	< 920	< 27.17	> 18	Catastrophic

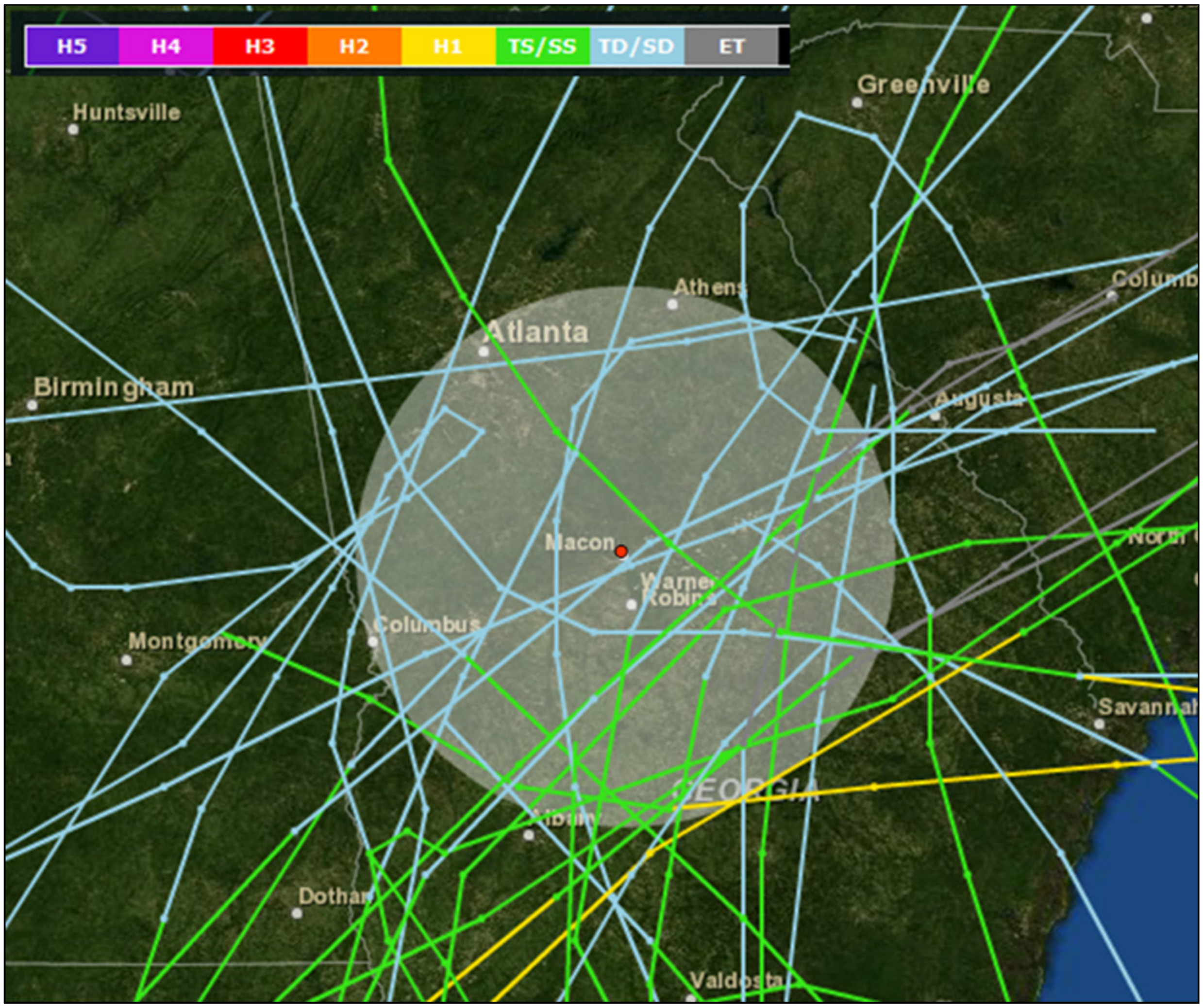


Figure 58. Tropical cyclones (1930–2011) within 161 km (100 mi) of Macon, Ga. From Bill Murphey at the GA DNR State of Georgia Climate Office; also see SCONC 2015 and NOAA 2017.

Table 55. The total numbers of lows, extratropical storms, tropical depressions, subtropical storms, and tropical storms that affected the area within a 161-km (100-mi) radius of Macon, Ga. during the period from 1851 through 2012. (SCONC 2015).

Classification	# of Storms	% of Storms
Category 2–5 Hurricanes	0	0.0%
Category 1 Hurricanes	2	2.4%
Tropical Storms	31	38.3%
Subtropical Storms	0	0.0%
Tropical Depressions	37	45.7%
Subtropical Depressions	2	2.4%
Extratropical Storms	8	10.0%
Lows	1	1.2%
Total	81	100%

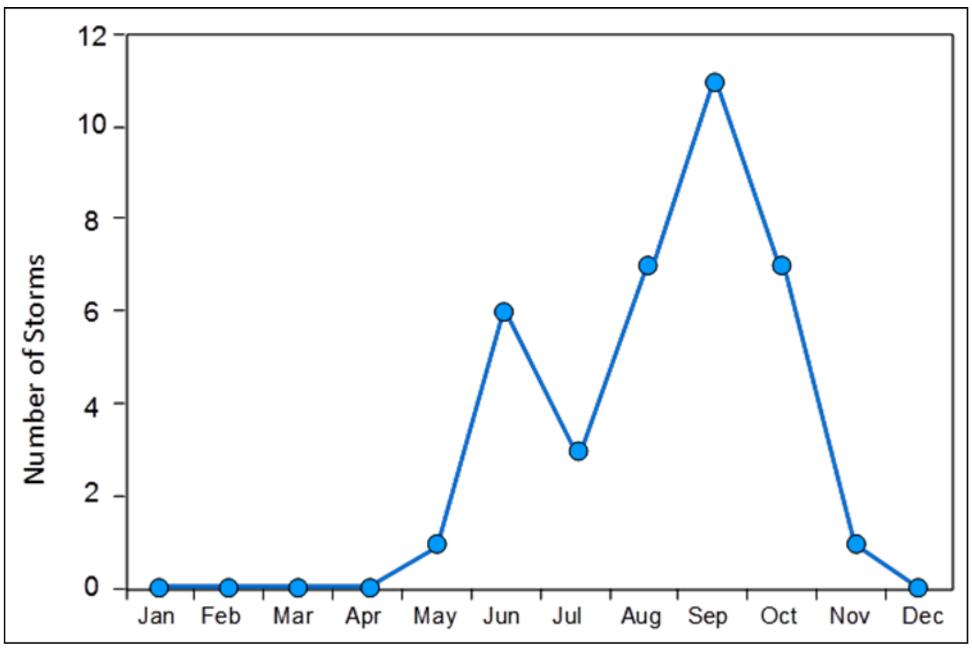


Figure 59. The total number of major and minor storms per month (1930–2012) that have occurred within 161 km (100 mi) of Macon, Ga. Data from the Georgia State Climate Office.

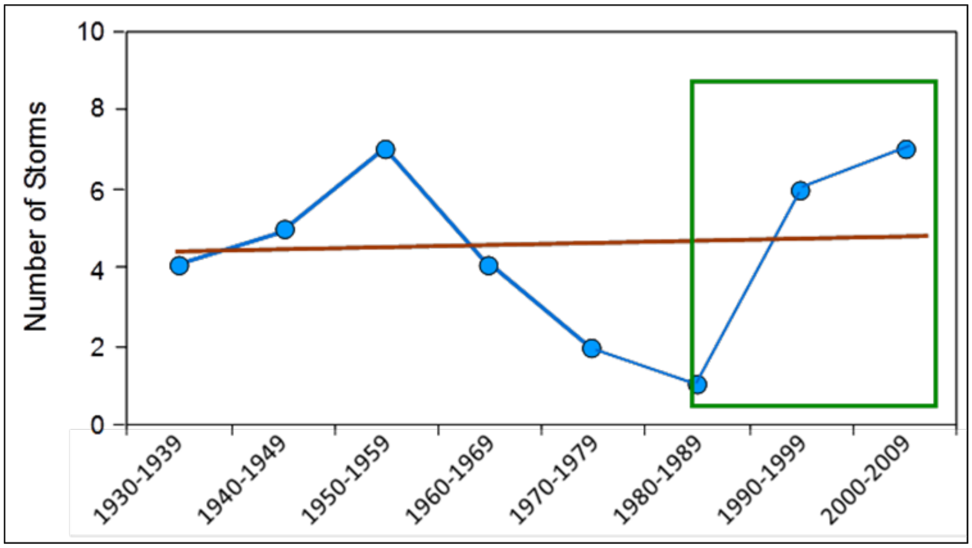


Figure 60. The total number of major and minor storms per decade (1930–2009, the latest year for which a complete decade of data were available) that occurred within 161 km (100 mi) of Macon, Ga. Storms have increased from the mid-1980s to the present (green box). Data from the Georgia State Climate Office.

5.2. Climate Change

Issue: Climate change is advancing in the Southeast, manifested through warming temperatures, altered patterns and amounts of precipitation (droughts, floods), and storm frequency. If current trends continue these changes may affect natural resources of Ocmulgee NM.

Species richness, extirpations, and introductions in the national parks of Canada have all been found to be strongly related to climate, more than to any other factor (Rivard et al. 2000). Baron et al. (2008, 2009) described climate change as already redefining U.S. national parks, and advised park managers to begin to include climate change considerations into all activities and plans. To increase resilience of the natural biota, Baron et al. (2008) recommended reducing habitat fragmentation and loss, invasive species, and pollution; protecting important ecosystem and physical features; restoring damaged systems and natural processes; and reducing the risks of catastrophic loss through establishing refugia, relocating valued species, replicating populations and habitats, and attempting to maintain representative examples of beneficial species populations. The extent to which any of this can be done for Ocmulgee National Monument is unclear, given the urbanization that is immediately adjacent to it.

The Intergovernmental Panel on Climate Change (IPCC) has projected that temperature in the Southeast will increase 2.2 to 5.0°C (4 to 9°F) by 2080 (Karl et al. 2009). Since 1970, average annual temperatures in the Southeast region, including the Macon, Georgia area, have increased by 1.1°C (2°F) (Karl et al. 2009, Fisichelli 2013, Kunkel et al. 2013; and see Figure 61). Winters in particular are warming: the average number of freezing days has declined by 4 to 7 days per year (Karl et al. 2009). Most areas are also becoming wetter especially in the autumn, whereas in spring–summer seasons, the area affected by moderate to severe droughts has increased (Karl et al. 2009). It is uncertain as to whether annual precipitation will increase or decrease, but models suggest that there will be heavier downpours interspersed with increased droughts between storm events (Karl et al. 2009; Carter et al. 2014).

Thus, both the risk of flooding and the risk of drought are expected to increase. Coastal areas are expected to sustain stronger hurricanes, accelerated sea level rise, and larger storm surges (Karl et al. 2009). The IPCC also has projected that flow seasonality will increase in rain-dominated regions such as the southeastern U.S., resulting in higher flows during the peak flow season and lower flows during low-flow seasons and/or longer dry periods (Kundzewicz et al. 2007). Future floods and droughts likely will not occur at previous rates because climate change is expected to be a major force controlling the frequency and timing of flow seasonality (Brekke et al. 2009). Projections about smaller-scale, regional and sub-regional impacts have high uncertainty, such that accurate assessment of climate change effects on flow and water supply will require long-term monitoring (Knowles et al. 2006; Brekke et al. 2009).

In the Ocmulgee area, summer temperatures over the past decade have been rising rapidly, likely exacerbated by a “city” or urbanization effect (Karl et al. 1988; Myer 1991). The region has also sustained a decreasing trend in precipitation and moisture concomitant with an increase in the proportion of “dry” months. These are undesirable conditions from the perspective of attempting to maintain, insofar as possible, a healthy ecosystem in the monument. Moreover, these trends are forecasted to continue and may accelerate.

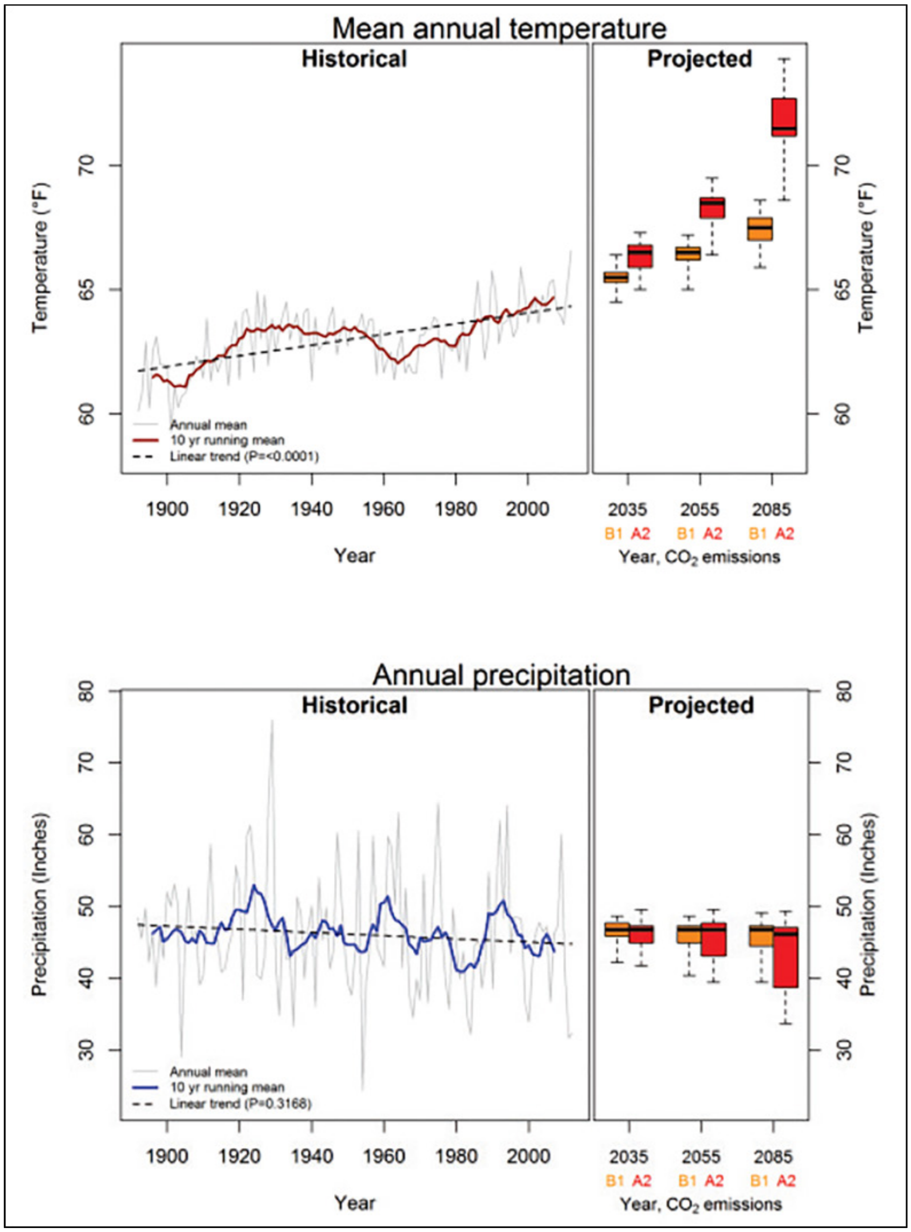


Figure 61. Historical and projected mean annual temperature and annual precipitation for OCMU. Historical data (1892–2012) from the Milledgeville, GA long-term weather station (CDIAC 2015). Projected climate change (30-year means) for the region including OCMU (data from Kunkel et al. 2013, see Tables 4, 6 and Figures 26, 37) are for three future time periods centered on 2035 (2021–2050), 2055 (2041–2070), and 2085 (2070–2099). The low (B1) and high (A2) greenhouse gas emissions scenarios are presented (IPCC 2007). Projected climate boxplots indicate the variability in future projections among 14–15 CMIP3 climate models. Values for the area including OCMU are based on projected changes from individual climate models averaged across the southeast region: the bold horizontal black line represents the mean among all models, the upper and lower bounds of the boxes indicate the 75th and 25th percentile model output values and the whiskers show the minimum and maximum change averaged across the region. From NPS (2014b).

6. Discussion

6.1. Summary of Natural Resource Conditions in Ocmulgee National Monument

This in-depth analysis of the natural resources of Ocmulgee National Monument considered available information for all natural resource categories ranging from climate to mammals (Tables 36—51). A total of 51 indicators were used to evaluate the 15 categories of natural resources for which sufficient information was available to allow assessment. The overall condition of 12 categories was rated as poor; one was assessed to be in fair condition and two were in good condition.

The overall Report Card of Natural Resource Conditions in Ocmulgee National Monument is cause for concern—more so because of the 15 categories of natural resources, most are not possible for the National Park Service to control (Tables 56–57). Only a few categories, all within the monument biota, can be even partly controlled by park staff. For example, park staff cannot control the introductions of more exotic/invasive taxa that have dramatically altered the natural communities, because these undesirable taxa can be carried into the monument by human visitors, birds, wind, water, etc.

Table 56. Overall Report Card of Natural Resource Conditions in OCMU.

NATURAL RESOURCE CATEGORY	Indicator(s)	OCMU
Human Population Surrounding the Monument	5	poor
Visitation—Human Population in the Monument	3	poor
Land Use/Land Cover	2	poor
Air Quality	7	poor
Soundscape	3	poor
Lightscape	2	poor
Soil and Streambank Erosion	5	poor
Surface Water Hydrology	2	poor
Groundwater Water Supply	2	poor
Surface Water Quality	8	poor
Vascular Flora	4	poor
Fish	1	fair
Herpetofauna	2	good
Birds	5	good
Mammals	1	poor

Table 57. Summary of Natural Resource Conditions in OCMU, including 15 separate categories that were evaluated using the 52 listed indicators.

Category	Indicators	Present status in Ocmulgee National Monument	Condition	Overall
Human population near park	$HPG_{5\text{-km}}$, $HPG_{80\text{-km}}$—human population growth (5- or 80-km radius)	population growth declined in the past decade (City of Macon); high population growth (over 2.5% per year) in nearby metro Atlanta	Poor	Poor
	$HPD_{5\text{-km}}$, $HPD_{80\text{-km}}$ —human population density (5- or 80-km radius)	High population density—633 people /km^2 in 5 km radius; 236 people / km^2 in 80 km radius.	Poor	
Visitation—human population in park	VIS— # visitors/year (trend)	*130,000 visitors (2012)—comparable the past few previous years; increased from 120,000 visitors a decade earlier. Most popular tourist destination in mid-Georgia	Poor	Poor
	VP-$A_{GR\text{-}SEAS}$–visitor pressure/park area (growing season)	*Average of 343 visitors / ha / growing season (April–October) or 2 visitors per ha / day.	Good	
	VP-$T_{GR\text{-}SEAS}$ –visitor pressure on trails (growing season)	*Avg. of 51 visitors/km of trail/year (83 visitors/mile of trail/day).	Poor	
Land use/ land cover	% $IC_{5\text{-km}}$ —impervious cover in 5-km radius around the battlefield	*The land within 5 km radius of the park is urbanized by the City of Macon.	Poor	Poor
	%GRNWAT—greenspace middle Tallapoosa watershed.	*Ocmulgee River watershed had 15% developed land as of 2001; in the 5 years between 2001 and 2006, there was a 5% increase in developed land use/land cover.	Poor	
Air quality	Ozone—ozone effects on humans	*2012: 79–82 ppb ozone (11 days, 8-hour avg. time, 4th max. value)	Poor	Poor
	W126, SUM06—ozone effects on plants	*2005–2009: W126: > 13 ppm	Poor	
		*2005–2009: SUM06: > 15 ppm-hour	Poor	
	N-DEP—nitrogen deposition	*2005–2009: N-DEP > 3 kg/ha/year	Poor	
	S-DEP — sulfur deposition	*2005–2009: S-DEP > 3 kg/ha/year	Poor	
	VIS— visibility	*2005–2009: VIS > 8 dv	Poor	
	ACID— acidification	*Pollutant exposure very high; ecosystem sensitivity very low; park protection moderate; overall, moderate risk from acidic pollution.	Fair	Fair

Table 57 (continued). Summary of Natural Resource Conditions in OCMU, including 15 separate categories that were evaluated using the 52 listed indicators.

Category	Indicators	Present status in Ocmulgee National Monument	Condition	Overall
Soundscape	POP_{SOUND}—proximity to population center	*Main unit adjacent to/in the City of Macon (91,351 people as of 2012.	Poor	Poor
	$SOURCE_{SOUND}$—proximity to major source (road, RR, etc.)	*Interstate Hwy 16 and State Hwy 50 cross northern and southern areas of the park; a railroad crosses the mid-section.	Poor	
	$DATA/OBS_{SOUND}$—noise pollution data available for the park	*Data not available for OCMU; staff describe as sometimes sustaining / noticeable noise pollution.	Fair	
Lightscape	Bortle Dark Sky Scale classes ($LITE_{ARTIF}$): 1–2 (truly dark skies) 3–4 (rural.skies) ≥ 5 (suburban sky, ground objects partly lit) to 9 (inner city sky)	*Suburban development is immediately adjacent. Parts of the park are estimated to have artificial light in the night sky equivalent to bright suburban sky Class 6	Poor	Poor
	ALR–anthropogenic light ratio	*Modeled ALR is 7.5 (> 1586nL in 50% or more of the park.		
Soil & streambank erosion	$Soil_{EROD}$—characteristic erodability of all soil types	*more than half of the soil types in the park are severely eroded.	Poor	Poor
	$Soil_{VIS}$—evidence of soil erosion	* Erosion obvious and common along roadways and trails	Poor	
	$Bank_{EROD}$—visual evidence of streambank erosion	* Streambank erosion common along major stream segments.	Poor	
	$Soil_{HAB}$—stream bottom habitat burial	*Sediment deposits cover much of stream bottom where flow allows accumulation; management concern	Poor	
	$Soil_{ACID}$–soil acidification potential	* Moderate soil acidification potential, based on air quality information and poor soil buffering capacity.	Fair	
Surface water quantity	$WATER_{AT\text{-}USE}$–proportional use of the Ocmulgee River for metro Atlanta water supply	*Metro Atlanta uses the Ocmulgee River for at least 8% of its water supply (2011 data) and is projected to increase.	Poor	Poor
	$WATER_{AT\text{-}RETURN}$–percentage of volume withdrawn that is returned and sources	* 155% of volume withdrawn is returned as sewage that is treated to varying degrees; the treated sewage is substantially higher in some pollutants of concern than the river water.	Poor	

Table 57 (continued). Summary of Natural Resource Conditions in OCMU, including 15 separate categories that were evaluated using the 52 listed indicators.

Category	Indicators	Present status at Ocmulgee National Monument	Condition	Overall
Ground-water supply	$GRW_{SU97PPLY}$—groundwater level	* Groundwater level has significantly decreased over period of record in two USGS monitoring wells near the park.	Poor	Poor
	GRW_{USE}—expected groundwater use	* Groundwater level has significantly decreased over period of record in two USGS monitoring wells near the park.	Poor	
Surface water quality	pH 6.0 to 8.5	* pH—100% compliance (297 samples)	Good	Poor
	DO ≥ 4 mg/L; avg. 5 mg/L	* DO— 99% compliance (284 of 288 samples)	Good	
	BOD5–biochemical oxygen demand; < 3 mg/L	* 95% met recommendation (39 of 41 samples)	Good	
	Turbidity ≤ 5.7 NTU	* Turbidity — 22 % met recommendation (59 of 263 samples)	Poor	
	TSS < 10 mg/L	* 61% met recommendation (19 of 31 samples)		
	TP–total phosphorus ≤ 30 µg/L	* 65% met recommendation (28 of 43 samples)	Poor	
	NO_x-N ≤ 177 µg/L	* NOx-N—23% met recommendation (10 of 43 samples)	Poor	
	FECAL-GA– < 200 cfu/100 mL (May–Oct); < 1000 (Nov- Apr) as GMs; or EPA < 400 cfu/100 mL	* FECAL—74% compliance (192 of 258)	Poor	
Vascular flora	$TERR_{EX}$— # Exotics / Total	As of 2012: 36% (70 of 180 spp.) of the total terrestrial taxa are exotic/invasive.	Poor	Poor
	$TERR_{CAT}$— # highly invasive taxa	*35% (7 of the 20 spp.) of Category #1 taxa; over 12 Category #2–#4 species; 7 highly invasive spp are common in the park (3 Category #1, 2 Category #2, 2 Category #3)	Poor	
	WET_{EX}— # Exotics / Total	*15% (40 of 244 spp.) of the total wetland/aquatic taxa are exotic / invasive. 15% (3 spp.) of Category #1 taxa are wetland an occur in the park	Poor	
	WET_{CAT}— # highly invasive taxa	* 7 Category #1 alert taxa and 13 Category #2–#4 species in OCMU. Four of Category #1 species and 3 Category #2–#4 species are common in the park.	Poor	

Table 57 (continued). Summary of Natural Resource Conditions in OCMU, including 15 separate categories that were evaluated using the 52 listed indicators.

Category	Indicators	Present status at Ocmulgee National Monument	Condition	Overall
Fish	$FISH_{SPP}$—fish species richness (#)	*11 native fish species recently (past decade) were verified via a survey in the park.	Fair	Fair
Herpetofauna	V-ANURANS– # of species detected	* March–May 2011:14 vocal anuran native spp detected.	Good	Good
	$HERP_{VES}$—# species detected	* May 2011: 15 amphibian and reptile taxa detected with VES.	Good	
Birds	BIRDBBS—# native spp./year	* 2002–2012: 56–60 spp.; lowest # was 56 spp. in 2002	Good	Good
	$BIRD_{OBS\ SPP}$—# native spp.	*April–May 2009: 71 native spp. (20 established sites in park)	Good	
	$BIRD_{ABUND}$ —# individuals	* April–May 2009: 693 individuals: Carolina wren, northern cardinal, tufted titmouse, red-bellied woodpecker, Carolina chickadee, American crow, white-eyed vireo.	Good	
	$BIRD_{DIS}$ –7 most widely distributed species (same as for BIRDABUND)	* the same 7 species as for $BIRD_{ABUND}$.	Good	
	$BIRD_{SSC}$—# SSCs observed	* NPS Certified Species lists 2013: American kestrel, solitary vireo, yellow warbler SSCs in OCMU.	Good	
Mammals	MAM_{INV}—# exotic spp./ total #	* At least 27% of the mammalian spp. in the park (9 of 33) are exotic/invasive, including recently invasive coyotes.	Poor	Poor

Nevertheless, this report card can function as a valuable resource for monument staff and the network by enabling rapid communication to concerned citizens, policymakers in local, state, and federal governments, industries etc. about the pressing need to improve protection of the natural (and cultural) resources in this valuable national park. The central reason for the mostly poor status of its natural resources, is the many pressures and impacts of the urbanized Macon area adjacent to the monument, and the "long shadow" of the expanding Atlanta area in the upper watershed. It is our hope that the many people who expect to enjoy the natural and cultural resources of Ocmulgee National Monument will respond to the report card by contributing more stewardship toward the goal of improving the natural resource conditions for visitors now and in the future.

6.2. Remaining Major Knowledge Gaps and Next Steps

Major knowledge gaps prevented or seriously restricted evaluation of the present condition of several natural resource categories. These gaps, and efforts needed to fill them, are summarized as follows:

- Air Quality—It would assist future assessments for the National Park Service to install an air-quality monitor at Ocmulgee National Monument to facilitate tracking air quality changes over time. In addition, 12 plant species at Ocmulgee National Monument have been identified as especially sensitive to ozone (Porter 2003): Redbud (Cercis canadensis), green ash (Fraxinus pennsylvanica), sweetgum (Liquidambar styraciflua), tulip tree (Liriodendron tulipifera), Virginia creeper (Parthenocissus quinquefolia), loblolly pine (Pinus taeda), American sycamore (Platanus occidentalis), black cherry (Prunus serotina), American elder (Sambucus canadensis), sassafras (Sassafras albidum), crownbeard (Verbesina occidentalis), and northern fox grape (Vitis labrusca). The National Park Service should consider tracking selected populations of a subset of these species over time as sentinels of potentially harmful ozone levels.

- Soundscape—A study of the Ocmulgee NM soundscape should be completed in areas of concern at five- to ten-year intervals, using simple equipment such as the digital audio field recorder, and the "soundscape gradient" approach (i.e., adjacent to and then moving away from roads, railroad tracks in use by a train, etc.) described in Kuehne et al. (2013).

- Surface Water Hydrology—The RSS that will be developed for this monument is expected to identify additional hydrologic targets, as was done in the RSS for the Chattahoochee River National Recreation Area. Hydrologic targets are needed for tracking conditions in Ocmulgee NM over time.

- Surface Water Quality—Water quality data for the Ocmulgee River and Walnut Creek in and near the monument mostly have been/continue to be collected, outside the monument, at a sporadic frequency. Data for the eight parameters selected as indicators should be collected at least monthly to enable reliable assessment of water quality conditions over time, and at least one station on each stream should be established in the monument if possible.

- Groundwater Quality—We could find no information on groundwater quality in or near the monument. Monthly sampling at least every other year is needed to characterize the pH and track concentrations of contaminants such as nitrate+nitrite, sulfide, and metals (e.g., iron, aluminum, manganese), following Donahue (1998).

- Stream Sediment Quality—Park staff expressed concern about the quality of stream sediments in Ocmulgee NM (metals, PCBs etc.), but information to enable assessment was lacking. Data are needed to enable assessment of this important component of the aquatic resources in the monument.

- Streambank Erosion—A study such as that by Heeren et al. (2012) would be valuable in developing a Channel Stability Index (CSI) for the Ocmulgee River and Walnut Creek in the monument. The CSI is a type of rapid geomorphic assessment that provides a quick, straightforward method for characterizing stream reaches in terms of stability (Simon and Downs 1995). The CSI would be applicable to Ocmulgee NM because this index was originally designed for areas that are highly sensitive to erosion. Required measurements include bank height, bank face length, river stage at baseflow, degree of constriction, and average diameter of streambed sediment, following guidance on a two-page sheet. The National Park Service (NPS 2014d), in fact, already applied the CSI concept to Ocmulgee National Monument with an estimate for the CSI, but actual data to confirm the estimate are lacking. Metrics for the CSI include representative river stage (water surface height, measured in the thalweg of the stream, avoiding local scour pools), river channel width at the cross-section and one-fourth of a meander length upstream, measured at the bankfull height; and degree of constriction (relative decrease in channel width from upstream to downstream). Scores from several metrics are summed to create an aggregate score, with a higher score indicating greater instability: ≤ 10—stable, 10–20—moderately unstable, and ≥ 20—highly unstable (Simon and Klimetz 2008). The simple approach recommended by Heeren et al. (2012), requiring about 30 minutes to complete, have been found to perform as well or better than indices that require three years of bank erosion pin data (e.g., see Harmel et al. 1999). The CSI could then be developed as an indicator to provide a quantitative evaluation of streambank erosion condition in the monument over time.

- Stream Macroinvertebrate Communities—Stream macroinvertebrate communities are commonly used to evaluate stream conditions, but data for these biota are lacking in or near the monument. Stream macroinvertebrates should be added as an important biological component, and should be sampled at five-year intervals to assess stream biological condition following well-established protocols (Barbour et al. 1999; Bowles et al. 2008).

- Ecological Studies—It was difficult to develop indicators for the biota because of the restrictive nature of available information about them. Quantitative abundance data and maps are needed for key species of interest in Ocmulgee NM. These especially include:
    - the dominant terrestrial and wetland vascular plants within each of the general habitat types found in the monument;

- the common Category I invasive vascular plants, or selected species within this group that are of most concern to park staff;
- exotic/invasive fauna of most concern to park staff, such as feral cats; and
- species of special management concern, such as coyotes and their impact on foxes, feral cats, and deer.

- Updated Biota Surveys—The most recent survey of mammals in Ocmulgee NM is already a decade old, and needs to be updated in order to track the condition of this important natural resource category over time. As another example, the NPSpecies List for vascular flora in the monument showed many troubling discrepancies when compared to the vouchered plant species list of Zomlefer et al. (2013). It would be very helpful to repeat that rigorous effort on a decadal basis if possible in order to track the natural resource condition of the vascular flora of Ocmulgee National Monument over time.

- Vascular Plant Communities—Concerted studies of the key vascular plant communities (terrestrial and wetland) would be valuable contributions toward strengthened understanding about the condition of the monument flora. In addition, supporting the recommendation of the National Park Service (NPS 2014d), next steps for Ocmulgee NM in managing the condition and health of its plant communities should be to develop a long-term management plan for invasive plant control.

- Analysis Over Time of the Cumulative and Synergistic Effects of Pressures from Climatic, Land Use, and Exotic/Invasive Species Changes—A recent nationwide analysis of selected national parks over the past century indicates that most park protected-area-centered ecosystems (PACEs)—that is, lands surrounding national parks—sustained a 740% average increase in housing density since 1940; an average of 13% of vascular flora in the parks are now non-native; and the average ambient temperature has increased by 1.8°C (3.2°F) since 1895 in 80% of PACEs (Hansen et al. 2014). This is a sobering statistic, considering that a change of 4–5°C (9–10.8°F) in the average global temperature is the difference between the most recent Ice Age and present-day conditions (Miller 1990). Furthermore, these trends are projected to continue at similar or increasingly greater rates: The rate of climate warming in this century is projected to be from 2.5- to 5.8-fold higher than the rate measured during the 1900s (Hansen et al. 2014, and references therein). Temperatures are expected to increase by 2.58°C to 4.58°C. Watershed development is expected to accelerate; for example, an average 255% increase in housing density is projected by 2100 in lands surrounding national parks throughout the nation. The Atlanta area, near the monument, is growing rapidly. Exotic/invasive species generally are favored by disturbances such as these (Ferriter et al. 2007). The cumulative, synergistic effects of such changes are predicted to dramatically impact ecosystem function and biodiversity in national parks (Hansen et al. 2014). In fact, it has been estimated that 30% of the parklands may lose their present biomes by as early as 2030 (Hansen et al. 2014).

We have recommended various additional efforts to be considered by the Southeast Coast Network which, together with the present and planned I&M Division works, will greatly strengthen understanding about how each of these pressures affects Ocmulgee NM natural resources. The resulting databases will make it possible for the network to consider climatic, land use, and exotic/invasive species changes more realistically—through integrative rather than separate analyses of cumulative/synergistic impacts over time. Ultimately, that approach offers the best hope of restoring and protecting the natural resources of Ocmulgee National Monument.

7. Literature Cited

Abelson, P. H. 1987. Ozone and acid rain. Science 235:141.

Aber, J. D. 1992. Nitrogen cycling and nitrogen saturation in temperate forest ecosystems. Trends in Ecology and Evolution 7: 220–224.

Adams, S. M., M. S. Bevelhimer, M. S. Greeley Jr., D. A. Levine, and S. J. Teh. 1999. Ecological risk assessment in a large river-reservoir: 6. Bioindicators of fish population health. Environmental Toxicology and Chemistry 18: 628-640.

AirNow. 2015. Air Quality Index (AQI) basics. AirNow, United States Environmental Protection Agency. Available at: http://www.airnow.gov/?action=aqibasics.aqi (last accessed May 2017).

Alley, W. M. 1993. General design consideration. In: Alley, W.M. (ed.), Regional groundwater quality. Van Nostrand Reinhold, New York, New York.

American Lung Association (ALA). 2013. Most polluted cities. State of the Air 2013, ALA. Available at: http://www.stateoftheair.org/2013/city-rankings/most-polluted-cities.html (last accessed May 2017).

Arcadis. 2003. Ocmulgee River Watershed Management Plan. GA063002/Rpt1556, prepared for Georgia Department of Community Affairs. Arcadis G&M, Inc. Atlanta, Georgia. Available at: http://www.georgiaplanning.com/ocmulgee/report/ORW%20Mgmt%20Plan%20Text.pdf (last accessed May 2017).

Atlanta Regional Commission (ARC). 2007. 2007 Atlanta region population. ARC, Atlanta, Georgia.

Atlanta Regional Commission (ARC). 2016 Atlanta Regional Commission website: About us. Available at: http://www.atlantaregional.com/about-us/the-region (last accessed May 2017).

Atlanta Regional Commission. 2017. The Atlanta Region's Plan—Transportation. Atlanta Regional Commission. Atlanta, Georgia. Available at: http://documents.atlantaregional.com/The-Atlanta-Region-s-Plan/rtp/trends.pdf (last accessed August 2017).

Bååth, E. B. 1989. Effects of heavy metals in soil on microbial processes and population (a review). Water Air Soil Pollution 47: 335-379.

Baker, J. P. and S. W. Christensen. 1992. Effects of acidification on biological communities, Chapter 4 in: D. F. Charles, editor. Acidic deposition and aquatic ecosystems—regional case studies. Springer-Verlag, New York, New York.

Barber, J. R., C. L. Burdett, S. E. Reed, K. R. Crooks, D. M. Theobald, and K. M. Fristrup. 2011. Anthropogenic noise exposure in protected natural areas: estimating the scale of ecological consequences. Landscape Ecology 26: 1281–1295.

Barber, J. R., K. M. Fristrup, C. L. Brown, A. R. Hardy, L. M. Angeloni, and K. R. Crooks. 2009. Conserving the wild life therein: Protecting park fauna from anthropogenic noise. Park Science 23: 26–31.

Barber, J. R., K. R. Crooks, and K. M. Fristrup. 2010. The costs of chronic noise exposure for terrestrial organisms. Trends in Ecology and Evolution 25: 180–189.

Barbour, M. T., K. J. Gerrisen, B. D. Snyder, and J. B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: benthic macroinvertebrates and fish, second edition. Report EPA 841-B-99-002. Office of Water, EPA, Washington, District of Columbia.

Baron, J. S., C. D. Allen, E. Fleishman, D. McKenzie, L. Meyerson, J. Oropeza, and N. Stephenson. 2008. National Parks. Chapter 4 in: Julius, S. H. and J. M. West, editors. Preliminary review of adaptation options for climate-sensitive ecosystems and resources. Final Report, Synthesis and Assessment Product SAP4.4. U.S. Climate Change Science Program and the Subcommittee on Global Change Research, Washington, District of Columbia.

Baron, J. S., L. Gunderson, C. D. Allen, E. Fleishman, D. H. McKenzie, L. A. Meyerson, J. Oropeza, and N. Stephenson. 2009. Options for national parks and reserves for adapting to climate change. Environmental Management 44: 1033–1042.

Barvenik, S., A. Chirigotis, D. Engelberg, L. Fuller, J. Hamann, and M. Reed. 2009. Evaluation report: EPA needs to accelerate adoption of numeric nutrient water quality standards. Report No. 09-P-0223, U.S. Office of Inspector General, Washington, District of Columbia. Available at: https://www.epa.gov/sites/production/files/2015-11/documents/20090826-09-p-0223.pdf (last accessed May 2017).

Bell, P. A., B. L. Mace, and J. A. Benfield. 2009. Aircraft overflights at national parks: Conflict and its potential resolution. Park Science 26: 65–67.

Benfield, F. K., M. D. Raimi, and D. D. T. Chen. 1999. Once there were greenfields: how urban sprawl is undermining American's environment, economy and social fabric. Natural Resources Defense Council, New York, New York.

Benke, A. C., G. E. Willeke, F. K. Parrish, and D. L. Stites. 1981. Effects of urbanization on stream ecosystem. Completion Report OWRT Project No. A-055-GA. Office of Water Research and Technology, USDI, Fort Collins, Colorado.

Blake, E. S., E. N. Rappaport, and C. W. Landsea. 2007. The deadliest, costliest, and most intense United States tropical cyclones from 1851 to 2006 (and other frequently requested hurricane facts). National Weather Service, National Hurricane Center, Miami, Florida. Available at: http://www.nhc.noaa.gov/pdf/NWS-TPC-5.pdf (last accessed May 2017).

Booth, D. and C. Jackson. 1997. Urbanization of aquatic systems: degradation thresholds, stormwater detection and the limits of mitigation. Journal of the American Water Resources Association 33: 1077–1089.

Booth, D. and L. Reinelt. 1993. Consequences of urbanization on aquatic systems: measured effects, degradation thresholds, and corrective strategies. Pages 545–550 in: Proceedings—Watershed '93—a national conference on watershed management, Alexandria, Virginia.

Bortle, J. E. 2001. Introducing the Bortle dark-sky scale. Sky and Telescope 101:126–129. Available at: https://www.nps.gov/subjects/nightskies/upload/BortleDarkSkyScale-2.pdf (last accessed May 2017).

Bortle, J. E. 2006. Light pollution and astronomy: The Bortle dark-sky scale. Sky and Telescope. Originally appeared as "Introducing the Bortle dark-sky scale" in February 2001 issue. Available at: http://www.skyandtelescope.com/astronomy-resources/light-pollution-and-astronomy-the-bortle-dark-sky-scale/ (last accessed May 2017).

Boyle, T. P., J. Sebaugh, and E. Robinson-Wilson. 1984. A hierarchical approach to the measurement of changes in community structure induced by environmental stress. Journal of Testing and Evaluation 12:241–245.

Bowles, D. E., M. H. Williams, H. R. Dodd, L. W. Morrison, J. A. Hinsey, C. E. Ciak, G. A. Rowell, M. D. DeBacker, and J. L. Haack. 2008. Monitoring Protocol for Aquatic Invertebrates of Small Streams in the Heartland Inventory & Monitoring Network. Natural Resource Report NPS/HTLN/NRR—2008/042. National Park Service, Fort Collins, Colorado.

Brekke, L. D., J. E. Kiang, J.R. Olsen, R. S. Pulwarty, D. A. Raff, D. P. Turnipseed, R. S. Webb, and K. D. White. 2009. Climate change and water resources management: a federal perspective. USGS Circular 1331. USGS, Reston, Virginia.

Brimblecombe, P., H. Hara, and D. Houle (editors). 2007. Acid rain—Deposition to recovery. Springer, Dordrecht, Netherlands.

Buckley, R. 2003. Ecological indicators of tourist impacts in parks. Journal of Ecotourism 2: 54–66.

Burkett, V., R. Ritschard, S. McNulty, J.J. O'Brien, R. Abt, J. Jones, U. Hatch, B. Murray, S. Jagtap, and J. Cruise. 2001. Potential consequences of climate variability and change for the southeastern United States. Pages 137–166 in: The Potential consequences of climate variability and change: foundation report. Report by the National Assessment Synthesis Team for the US Global Change Research Program, Cambridge University Press, Cambridge, United Kingdom. Available at: http://data.globalchange.gov/assets/e9/97/436129058f2107f4925aeec13ed8/nca-2000-foundation-report.pdf (last accessed May 2017).

Burkholder, J. M., B. Libra, P. Weyer, S. Heathcote, D. Kolpin, P. S. Thorne, and M. Wichman. 2007. Impacts of waste from concentrated animal feeding operations on water quality. Environmental Health Perspectives 115: 308–312.

Burkholder, J. M., E. H. Allen, and C. A. Kinder. 2010. Assessment of water resources and watershed conditions in Ocmulgee National Monument, Georgia. Natural Resource Report NPS/SECN/NRR—2010/276. National Park Service, Fort Collins, Colorado.

Butcher, G. S., D. K. Niven, A. O. Panjabi, D. N. Pashley, and K. V. Rosenberg. 2007. The 2007 watch list for American birds. Available at: http://www.audubon.org/sites/default/files/documents/watchlist2007-technicalreport.pdf (last accessed May 2017).

Byrne, M. W. 2004. Appendix 8: Water resources in the Southeast Coast Network. In: Vital signs monitoring in the Southeast Coast Inventory and Monitoring Network - phase III (draft) report. National Park Service, Southeast Coast Network, Atlanta, Georgia.

Byrne, M. W., B. D. Smrekar, M. N. Moore, and C. S. Harris. 2011a. Summary of vocal anuran monitoring at Ocmulgee National Monument, 2009. Natural Resource Data Series NPS/SECN/NRDS—2011/157. National Park Service, Fort Collins, Colorado.

Byrne, M. W., J. C. DeVivo, J. R. Asper, and B. A. Blankley. 2011b. Landbird monitoring at Ocmulgee National Monument, 2009. Natural Resource Data Series National Park Service/SECN/NRDS—2011/305. National Park Service, Fort Collins, Colorado.

Byrne, M. W. and M. N. Moore. 2011. Incidence of chytrid fungus, *Batrachochytrium dendrobatidis*, in Southeast Coast Network Parks. Natural Resource Technical Report NPS/SECN/NRTR—2011/477. National Park Service, Fort Collins, Colorado.

Byrne, M. W., J. C. DeVivo, B. D. Smrekar, L. M. Elston, C. J. Wright, and E. Thompson. 2013. Protocol for monitoring vocal anuran communities in Southeast Coast Network parks. Natural Resource Report NPS/SECN/NRR—2013/720. National Park Service, Fort Collins, Colorado.

Carbon Dioxide Information Analysis Center (CDIAC). 2015. Home page for CDIAC. U.S. Department of Energy Office of Science and Oak Ridge National Laboratory. Available at: http://cdiac.ornl.gov/ (last accessed May 2017).

Carlson, C. L., and D. C. Adriano. 1993. Environmental impacts of coal combustion residues. Journal of Environmental Quality 22: 227–247. Available at: https://dl.sciencesocieties.org/publications/jeq/abstracts/22/2/JEQ0220020227 (last accessed August 2017).

Carter, L. M., J. W. Jones, L. Berry, V. Burkett, J. F. Murley, J. Obeysekera, P. J. Schramm, and D. Wear. 2014. Ch. 17: Southeast and the Caribbean. Pages 396–417 *in* Melillo, J.M., T. C. Richmond, and G. W. Yohe, editors. Climate change impacts in the United States: the third national climate assessment. U.S. Global Change Research Program. Available at: http://s3.amazonaws.com/nca2014/low/NCA3_Full_Report_17_Southeast_LowRes.pdf?download=1 (last accessed August 2017).

Carter, R., C. T. Bryson, and S. J. Darbyshire. 2007. Preparation and use of voucher specimens for documenting research in weed science. Weed Technology 21: 1101–1108.

Center for Global Development. 2007. CO_2 emissions from power plant worldwide. Press release. Available at: https://www.cgdev.org/sites/default/files/14846_file_CARMAPR.pdf (last accessed August 2017).

Chace, J. F., and J. J. Walsh. 2006. Urban effects on native avifauna: a review. Landscape and Urban Planning 74: 46-69.

Chafin, L. G. 2007. Field guide to the rare plants of Georgia. The University of Georgia, Athens, Georgia.

Chafin, L. G. 2011. Georgia's natural communities and associated rare plant and animal species: thumbnail accounts. Georgia Nongame Conservation Section, Wildlife Resources Division, Georgia Department of Natural Resources, Atlanta, Georgia. Available at: http://georgiawildlife.com/sites/default/files/wrd/pdf/rare-data/natural_communities_thumbnail_accounts.pdf (last accessed August 2017).

Chao, A. R. L. Chazdon, R. K. Colwell, T. Shen. 2006. Abundance-based similarity indices and their estimation when there are unseen species in samples. Biometrics 62: 361–371.

Charles, D. F. and S. Christie. 1991. Acidic deposition and aquatic ecosystems: regional case studies. Springer-Verlag, New York, New York.

Cinzano, P., F. Falchi, and C. D. Elvidge. 2001. The first world atlas of the artificial night sky brightness. Monthly Notices of the Royal Astronomical Society 328, 689–707.

Clapcott, J.E., Young, R.G., Harding, J.S., Matthaei, C.D., Quinn, J.M. and Death, R.G. (2011) Sediment Assessment Methods: Protocols and guidelines for assessing the effects of deposited fine sediment on in-stream values. Cawthron Institute, Nelson, New Zealand.

Clarke, J. S. and Pierce, R. R. 1984. Ground-water resources of Georgia: The Georgia Operator 21: 4.

Clarke, S. R. 1995. Impacts of southern pine beetles in special management areas. Pages 93–98 in: Eskew, L. G., editor. Forest health through silvaculture, proceedings of the 1995 National Silvacultural Workshop. General Technical Report RM-GTR-267. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Clean Air Task Force. 2010. The toll from coal. Clean Air Task Force, Boston, Massachusetts. Available at http://www.catf.us/resources/publications/files/The_Toll_from_Coal.pdf (last accessed August 2017).

Cole, D., and C. Thomas. 2010. Numerical visitor capacity: a guide to its use in wilderness. Gen. Tech. Rep. RMRS-GTR-247. USDA—Forest Service, Rocky Mountain Research Station Fort Collins, Colorado. Available at: http://www.fs.fed.us/rm/pubs/rmrs_gtr247.pdf (last accessed August 2017).

Coles, J. F., G. McMahon, A. H. Bell, L. R. Brown, F. A. Fitzpatrick, B. C. S. Eikenberry, M. D. Woodside, T. F. Cuffney, W. L. Bryant, K. Cappiella, L. Fraley-McNeal, and W. P. Stack. 2012. Effects of urban development on stream ecosystems in nine metropolitan study areas across the United States. USGS Circular #1373, Reston, Virginia. Available at: http://pubs.usgs.gov/circ/1373/ (last accessed May 2017).

Collier, K. J. and B. L. Clements. 2011. Influences of catchment and corridor imperviousness on urban stream macroinvertebrate communities at multiple scales. Hydrobiologia 664: 35–50.

Colwell, R. K. and D. C. Lees. 2000. The mid-domain effect: Geometric constraints on the geography of species richness. Trends in Ecology and Evolution 15: 70–76.

Cosner, O. J. 1973. Stratigraphy of an archeological site, Ocmulgee Flood Plain, Macon, Georgia. Water-resources investigations volumes 54–73. United States Geological Survey. 27 p.

Cowardin, L. M., Carter, V., Golet, F. C. and La Roe, E. T. 1979. Classification of wetlands and deepwater habitats in the United States. U.S. Dept. Interior, Fish & Wildlife Service, FWS/OBS-79/31.

Crocker, M. J. 1997. Encyclopedia of acoustics. John Wiley and Sons, New York, New York.

Cuffney, T. F., H. Zappia, E. M. P. Giddings, and J. F. Coles. 2005. Effects of urbanization on benthic macroinvertebrate assemblages in contrasting environmental settings: Boston, Massachusetts, Birmingham, Alabama, and Salt Lake City, Utah. Proceedings of Symposium 47: Effects of Urbanization on Stream Ecosystems, pp. 361–407.

Dai, A., K. E. Trenberth, and T. Qian. 2004. A global data set of Palmer Drought Severity Index for 1870–2002: Relationship with soil moisture and effects of surface warming. Journal of hydrometeorology 5: 1117–1130.

Dai, A. 2011a. Characteristics and trends in various forms of the Palmer Drought Severity Index (PDSI) during 1900–2008. Journal of Geophysical Research 116, D12115. Doi: 10.1029/2010JD015541.

Dai, A. 2011b. Drought under global warming: A review. Wiley Interdisciplinary Reviews: Climate Change 2: 45–65. DOI: 10.1002/wcc.81.

Dale, V. H. and S. C. Beyeler. 2001. Challenges in the development and use of ecological indicators. Ecological Indicators 1: 3-10.

David, J. 2012. Ocmulgee National Monument. Old Fields boundary study and environmental assessment [brochure]. Ocmulgee National Monument, National Park Service, Macon, Georgia. Available at: http://www.nps.gov/ocmu/learn/management/upload/ocmu-brochure_lr_regular.pdf (last accessed May 2017).

Defenders of Wildlife (DOW). 2015. Invasive species in North Carolina. Available at: http://www.defenders.org/publications/north_carolina.pdf (last accessed May 2017).

Dennison, W. C., T. R. Lookingbill, T. J. B. Carruthers, J. M. Hawkey, and S. L. Carter. 2007. An eye-opening approach to developing and communicating integrated environmental assessments. Frontiers in Ecological Environments 5: 307–314.

DeVivo, J. C., C. J. Wright, M. W. Byrne, E. DiDonato, and T. Curtis. 2008. Vital signs monitoring in the Southeast Coast Inventory & Monitoring Network. Natural Resource Report NPS/SECN/NRR—2008/061. National Park Service, Fort Collins, Colorado.

Donahue, J. C. 1998. Groundwater quality in Georgia for 1996-1997. Circular 12M. Georgia Department of Natural Resources, Environmental Protection Division, and Georgia Geological Survey, Atlanta, Georgia.

Doren, R. F., J. C. Trexler, M. Harwell, G. R. and Best (editors). 2008. System-wide indicators for Everglades restoration 2008 Assessment. Unpublished Technical Report. South Florida Water Management District, West Palm Beach, Florida.

Doren, R. F., J. C. Volin, and J. H. Richards. 2009. Invasive exotic plant indicators for ecosystem restoration: an example from the Everglades restoration program. Ecological Indicators 9S: S29-S36.

Dorr, J. L., S. D. Klopfer, K. M. Convery, R. M. Schneider, L. C. Marr, and J. M. Galbraith. 2009. Natural resource condition assessment with addendum, Fort Pulaski National Monument, Georgia. Natural Resource Report NPS/NRPC/WRD/NRR—2009/103. National Park Service, Fort Collins, Colorado.

Dowd, J. F. 2011. Program Flow. The University of Georgia, Athens, Georgia.

Duchamp, J. E., D. W. Sparks, and J. O. Whitaker Jr. 2004. Foraging-habitat selection by bats at an urban-rural interface: comparison between a successful and a less successful species. Canadian Journal of Zoology 82: 1157–1164.

Dunwoody, S. 1992. The media and public perceptions of risk: How journalists frame risk stories. Pages 75-100 in: Bromley, D. W. and K. Segerson, editors. The social response to environmental risk—policy formulation in an age of uncertainty. Kluwer Academic Publishers, Boston, Massachusetts.

Ehrlich, P. R. and J. P. Holdren. 1971. Impact of population growth. Science 171: 1212–1217.

Ellis, J. C., and C. F. Gilbert. 1980. How to handle 'less-than' data when forming summaries. Water Research Centre Enquiry Report ER 764. Water Research Centre, Medmenham, United Kingdom.

Encyclopaedia Britannica. 2015. Fall line. Encyclopaedia Britannica Online, Encyclopaedia Britannica Inc., 2013. Available at: http://www.britannica.com/science/fall-line (last accessed May 2017).

The Environmental Integrity Project and Earthjustice. 2009. Coming clean: What the EPA knows about the dangers of coal ash. A summary of the U.S. EPA's 2007 Human and Ecological Risk Assessment of Coal Combustion Wastes. Available at: default/files/library/reports/final-coming-clean-ejeip-report-20090507.pdf (last accessed August 2017).

Environmental Systems Research Institute (ESRI). 2005. ArcGIS desktop software, version 9.1.

Evans, J. W. 1991. A fisheries and recreational use survey of the Upper Ocmulgee River. Final Report, Federal Aid Project F-33. Game and Fish Division, Georgia Department of Natural Resources, Atlanta, Georgia.

Fagan, B. 1995. Ancient North America, 2nd edition. Thomas and Hudson, New York, New York.

Fancy, S. G., J. E. Gross, and S. L. Carter. 2009. Monitoring the condition of natural resources in US national parks. Environmental Monitoring and Assessment 151: 161–174.

Ferriter, B. Doren, D. Thayer, B. Miller, T. Pernas, S. Hardin, J. Lane, M. Kobza, D. Schmitz, M. Bodle, L. Toth, L. Rodgers, P. Pratts, S. Snow, and C. Goodyear. 2007. Chapter 9: The status of nonindigenous species in the South Florida environment. In: 2007 South Florida Environmental Report (SFER). South Florida Water Management District, West Palm Beach, FL.

Fisichelli, N. 2013. Climate change trends for the State of the Park Report, Ocmulgee National Monument, Georgia. National Park Service Climate Change Response Program. National Park Service, Fort Collins, Colorado. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2195834 (last accessed May 2017).

Froeschauer, P. 1989. A vegetation history of Ocmulgee National Monument, Macon, Georgia. CPSU Technical Report No. 51. National Park Service Cooperative Unit, Institute of Ecology, University of Georgia, Athens, Georgia.

Fry, J., G. Xian, S. Jin, J. Dewitz, C. Homer, L. Yang, C. Barnes, N. Herold, and J. Wickham. 2011. Completion of the 2006 National Land Cover Database for the conterminous United States, PE&RS, Vol. 77(9):858-864. Available at: http://www.mrlc.gov/nlcd2006.php (last accessed May 2017).

Fuller, R. A., P. H. Warren, and K. J. Gaston. 2007. Daytime noise predicts nocturnal singing in urban robins. Biology Letters 3: 368–370.

Gaddy, L. L. and J. B. Nelson. 2004. Vascular plant inventory of the Ocmulgee National Monument, Bibb County, Georgia. Unpublished report. National Park Service, SECN, Athens, Georgia.

Garie, H. L. and A. McIntosh. 1986. Distribution of benthic macroinvertebrates in a stream exposed to urban runoff. Water Resources Bulletin 22: 447–455.

Georgia Department of Audits and Accounts. 2005. Georgia's water-related activities. Report 05-12, Atlanta, GA.

Georgia Department of Natural Resources (GA DNR). 1994. Information about the air quality index (AQI). GA DNR Environmental Protection Division, Air Protection Branch. Condensed from Measuring Air Quality: The pollutant standards index, EPA Office of Air Quality Planning and Standards. Available at: http://www.georgiaair.org/information/aqi.html (last accessed May 2017).

Georgia Department of Natural Resources (GA DNR). 2001. Georgia stormwater management manual, Volume 1. GA DNR, Atlanta, Georgia.

Georgia Department of Natural Resources (GA DNR). 2003. Total maximum daily load evaluation for seventy-nine stream segments in the Chattahoochee River basin for fecal coliform. GA DNR, Atlanta, Georgia.

Georgia Department of Natural Resources (GA DNR). 2004. Ocmulgee River basin management plan 2003. GA DNR EPD, Atlanta, Georgia. Available at: http://epd.georgia.gov/sites/epd.georgia.gov/files/related_files/site_page/Ocmulgee-Contents.pdf (last accessed May 2017).

Georgia Department of Natural Resources (GA DNR). 2007a. Total maximum daily load evaluation for seventy stream segments in the Ocmulgee River basin for sediment (biota impacted). GA DNR EPD, Atlanta, Georgia. Available at: https://epd.georgia.gov/sites/epd.georgia.gov/files/related_files/site_page/EPD_Final_Ocmulgee_PCB_TMDL_2007.pdf (last accessed May 2017).

Georgia Department of Natural Resources (GA DNR). 2007b. Total maximum daily load evaluation for three stream segments of the Ocmulgee River for PCBs in fish tissue. GA DNR EPD, Atlanta, Georgia.

Georgia Department of Natural Resources (GA DNR). 2007c. Total maximum daily load evaluation for seventy-four stream segments in the Ocmulgee River basin for fecal coliform. GA DNR EPD, Atlanta, Georgia.

Georgia Department of Natural Resources (GA DNR). 2007d. Ambient air surveillance report—2005–2006 risk assessment discussion. Toxic Network. EPD, Air Protection Branch, GA DNR, Atlanta, GA, 125 pp.

Georgia Department of Natural Resources (GA DNR). 2008a. Total maximum daily load evaluation for twenty-five stream segments in the Chattahoochee River basin for sediment (biota-impacted). GA DNR—EPD, Atlanta, Georgia.

Georgia Department of Natural Resources (GA DNR). 2008b. Protected plant species in Georgia. Available at: http://www.georgiawildlife.org/node/1371 (last accessed in June 2015).

Georgia Department of Natural Resources (GA DNR). 2008c. Georgia 2008 305(b)/303(d) Report. GA DNR—Environmental Protection Division (EPD), Atlanta, Georgia.

Georgia Department of Natural Resources (GA DNR). 2008d. Water Quality in Georgia 2006–2007. Appendix A: Waters assessed for compliance with designated use. Narrative including the 2008 listing assessment methodology and code key for abbreviations: 2008 Rivers and Streams [303(d) List]. GA DNR, Atlanta, Georgia. Available at: http://epd.georgia.gov/sites/epd.georgia.gov/files/related_files/site_page/Y2008_Cover-Chapter3_305b.pdf (last accessed May 2017).

Georgia Department of Natural Resources (GA DNR). 2012. 2011 ambient air surveillance report. Environmental Protection Division—Air Protection Branch Ambient Monitoring Program, GA DNR, Atlanta, Georgia. Available at: http://amp.georgiaair.org/docs/report11.pdf (last accessed May 2017).

Georgia Department of Natural Resources (GA DNR). 2016. Georgia's 2016 305(b)/303(d) Listing Assessment Methodology. GA DNR, Atlanta, GA.

Georgia Environmental Protection Division (GA EPD). 2013. Georgia's plan for the adoption of water quality standards for nutrients: Revision 2.0. Georgia Department of Natural Resources Environmental Protection Division Atlanta, Georgia.

Georgia Environmental Protection Division (GA EPD). 2017. Geographic information systems GIS databases and documentation. Available at: https://epd.georgia.gov/geographic-information-systems-gis-databases-and-documentation (last accessed May 2017).

Georgia Exotic Pest Plant Council (GA-EPPC). 2015. Georgia list of exotic and invasive plants. Available at: https://www.gaeppc.org/list/ (last accessed May 2017).

Georgia GIS Clearinghouse. 2017. Map data and aerial photography. Available at: https://data.georgiaspatial.org/ (last accessed May 2017).

Georgia Invasive Species Task Force (GISTF). 2015. Introduction to invasive species. Available at: http://gainvasives.org/what-is/introduction-to-invasive-species/ (last accessed August 2015).

Georgia Museum of Natural History. 2009. Fishes of Georgia (website). Available at: http://fishesofgeorgia.uga.edu/index.php?page=home (last accessed May 2017).

Georgia's Forest Legacy Program. 1990. Forest Legacy Program for Assessment of Needs for the State of Georgia.

Gilbert, R. J. 1969. The distribution of fishes in the central Chattahoochee River drainage. Master of Science thesis, Auburn University, Auburn, Alabama.

Godfrey, R. K. and J. W. Wooten. 1979. Aquatic and wetland plants of the southeastern United States - monocotyledons. University of Georgia Press, Athens, Georgia.

Godfrey, R. K. and J. W. Wooten. 1981. Aquatic and wetland plants of the southeastern United States—dicotyledons. University of Georgia Press, Athens, Georgia.

Goodell, J. 2006. Big coal: The dirty secret behind America's energy future. Houghton Mifflin Company, New York, New York.

Google. 2015. Google Earth website. Available at: http://www.google.com/earth/index.html (last accessed May 2017).

Gordon, N. D., T. A. McMahon, B. L. Finlayson, C. J. Gippel, and R. J. Nathan. 2004. Stream hydrology: an introduction for ecologists. John Wiley & Sons, Ltd., West Sussex, United Kingdom.

Gosselink, J. G., L. C. Lee, and T. A. Muir. 1990. Ecological processes and cumulative impacts: illustrated by bottomland hardwood wetland ecosystems. CRC Press, Boca Raton, Florida.

Gotelli, N. J. and R. K. Colwell. 2001. Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. Ecology Letters 4: 379–391.

Gregory, M. B., C. Wright, C. D. Jones, J. F. Dowd, and J. C. DeVivo. 2012. Summary of stream flow conditions at five riverine parks in the Southeast Coast Network, 2010. Natural Resource Report NPS/SECN/NRDS—2012/313. National Park Service, Fort Collins, Colorado.

Haas, G. and T. Wakefield. 1998. National parks and the American public: a national public opinion survey on the national park system. National Parks and Conservation Association and Colorado State University, Washington, D.C. and Fort Collins, Colorado.

Hadley, R. F. and E. D. Ongley, editors. 1989. Sediment and the environment. Proceedings of a Symposium. Publication No. 184. International Association of Hydrological Sciences, Washington, District of Columbia.

Haedrick, R. 1975. Diversity and overlap as measures of environmental quality. Water Research 9: 945–949.

Hagen, E. M., M. E. McTammany, J. R. Webster, and E. F. Benfield. 2010. Shifts in allochthonous input and autochthonous production in streams along an agricultural land-use gradient. Hydrobiologia 655: 61–77.

Haines, T. A. 1981. Acidic precipitation and its consequences for aquatic ecosystems: a review. Transactions of the American Fisheries Society 110: 669–707.

Hansen, A. J., C. R. Davis, N. Piekielek, J. Gross, D. M. Theobald, S. Goetz, F. Melton, and R. DeFries. 2011. Delineating the ecosystems containing protected areas for monitoring and management. BioScience 61: 363–373. Available at: https://watermark.silverchair.com/api/watermark (last accessed September 2017).

Hansen, A. J., N. Piekielek, C. Davis, J. Haas, D. M. Theobald, J. E. Gross, W. B. Monahan, T. Olliff, and S. W. Running. 2014. Exposure of U.S. national parks to land use and climate change 1900–2100. Ecological Applications 24: 484–502.

Harcourt, A. H., S. A. Parks, and R. Woodroffe. 2001. Human density as an influence on species/area relationships: double jeopardy for small African reserves? Biodiversity and Conservation 10: 1011–1026.

Harding, J. S., E. E. Benfield, P. V. Bolstad, G. S. Helfman, and E. B. Jones. 1998. Stream biodiversity: the ghost of land use past. Proceedings of the National Academy of Science (U.S.A.) 95: 14843–14847.

Harmel, R. D., C. T. Haan, and R. C. Dutnell. 1999. Evaluation of Rosgen's streambank erosion potential assessment in northeast Oklahoma. Journal of the American Water Resources Association 35: 113–121.

Hawaii Ant Group. 2007. A plan for prevention of establishment of new ant species in Hawaii, with special attention to the red imported fire ant (Solenopsis invicta). Interagency group consisting of representatives from the Hawaii Department of Agriculture, Bishop Museum, the University of Hawaii, the USGS, the USDA, and the U.S. FWS. Available at: http://www.invasive.org/gist/moredocs/solinv03.pdf (last accessed May 2017)

Heck, W. and E. B. Cowling. 1997. The need for a long-term cumulative secondary ozone standard—an ecological perspective. Environmental Manager 3: 23–33.

Heeren, D. M., A. R. Mittelstet, G. A. Fox, D. E. Storm, A. T. Al-Madhhachi, T. L. Midgley, A. F. Stringer, K. B. Stunkel, and R. D. Tejral. 2012. Using rapid geomorphic assessments to assess streambank stability in Oklahoma Ozark streams. Transactions of the American Society of Agricultural and Biological Engineers 55: 957–968.

Herlihy, A. T., P. R. Kaufmann, and M. E. Mitch. 1991. Stream chemistry in the eastern United States. 2. Current sources of acidity in acidic and low acid-neutralizing capacity streams. Water Resources Research 27: 629–642.

Hetrick, J. H. and M. S. Friddell. 1990. A geologic atlas of the Central Georgia Kaolin District: NA Geologic Atlas GA-6, Environmental Protection Division, GA DNR.

Hicks, A. L. and J. S. Larson. 1997. Aquatic invertebrates as an index for estimating the impacts of urbanization on freshwater wetlands. The Environmental Institute, University of Amherst, Massachusetts. Report submitted to EPA, Corvallis, Oregon.

Homer, C. G., Dewitz, J. A., Yang, L., Jin, S., Danielson, P., Xian, G., Coulston, J., Herold, N. D., Wickham, J. D., and Megown, K., 2015. Completion of the 2011 National Land Cover Database for the conterminous United States—Representing a decade of land cover change information. Photogrammetric Engineering and Remote Sensing, v. 81, no. 5, p. 345-354. Available at: http://www.mrlc.gov/nlcd2011.php (last accessed May 2017).

Hynes, H. B. N. 1970. The ecology of running waters. University of Toronto Press, Toronto, Canada.

Index Mundi. 2017. Georgia population per square mile, 2010, by county. Available at: https://www.indexmundi.com/facts/united-states/quick-facts/georgia/population-density#map (last accessed September 2017).

Integrated Taxonomic Information System online database (ITIS). 2012. Available at: www.itis.gov/ (last accessed May 2017).

Intergovernmental Panel on Climate Change (IPCC). 2007. Climate Change 2007—The Physical Science Basis: Summary for Policy Makers. Cambridge University Press, Cambridge, United Kingdom.

Johnston, C. E., M. Castro, L. Casten, A. Henderson, and A. Kennon. 2006. Fish inventories at Southeast Coast Network Parks (draft final report). Auburn University, Auburn, Alabama.

Jones, C. D. and M. B. Gregory. 2013. Summary of stream flow conditions at five riverine parks in the Southeast Coast Network, 2012. Natural Resource Data Series NPS/SECN/NRDS—2013/505. National Park Service, Fort Collins, Colorado.

Karl, T. R., H. Diaz, and G. Kukla. 1988. Urbanization: its detection in the U. S. climate record. Journal of Climatology 1: 1099–1123.

Karl, T. R., J. M. Melillo, and T.C. Peterson (eds.). 2009. Global climate change impacts in the United States. U.S. Global Change Research Program. Cambridge University Press, New York.

Karr, J. R., and E. W. Chu. 1995. Ecological integrity: Reclaiming lost connections. Pages 34–48 in: Westra, L., and J. Lemons, editors. Perspective on ecological integrity. Kluwer Academic Publishing, The Netherlands.

KellerLynn, K. 2013. Geologic resources inventory scoping summary: Ocmulgee National Monument, Georgia. Geologic Resources Division, National Park Service, Fort Collins, Colorado. Available at: http://www.nature.nps.gov/geology/inventory/publications/s_summaries/OCMU_GRI_scoping_summary_2013-0306.pdf (last accessed May 2017).

King, R. S., M. E. Baker, D. F. Whigham, D. E. Weller, T. E. Jordan, P. F. Kazyak, and M. K. Hurd. 2005. Spatial considerations for linking watershed land cover to ecological indicators in streams. Ecological Applications 15: 137–153.

Klein, R. D. 1979. Urbanization and stream impairment. Water Resources Bulletin 15: 948-963.

Klein, R. D. 2015. Aquatic resources. Chapter 5 in How to win land development issues. Community and Environmental Defense Services, Owings Mills, Maryland. Originally published in 2003 revised in 2015. Available at: http://ceds.org/pdfdocs/Chapter5.pdf (last accessed May 2017).

Knowles, Noah, M. D. Dettinger, and D. R. Cayan. 2006. Trends in snowfall versus rainfall in the western United States: Journal of Climatology 19: 4545–4559.

Koleff, P., K. J. Gaston, J. J. Lennon. 2003. Measuring beta diversity for presence-absence data. Journal of Animal Ecology 72: 367–382.

Kuehne, L. M., B. L. Padgham, and J. D. Olden. 2013. The soundscapes of lakes across an urbanization gradient. PLOS ONE 8(2): e55661. doi:10.1371/journal.pone.0055661.

Kundzewicz, Z. W., L. J. Mata, N. W. Arnell, P. Döll, P. Kabat, B. Jiménez, K. A. Miller, T. Oki, Z. Sen, and I. A. Shiklomanov. 2007. Freshwater resources and their management. Pages 173–210 in: Parry, M. L., O. F. Canziani, J. P. Palutikof, P. J. van der Linden, and C. E. Hanson, editors. Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom.

Kunkel, K. E., L. E. Stevens, S. E. Stevens, L. Sun, E. Janssen, D. Wuebbles, M. C. Konrad II, C. E., Fuhrman, B. D. Keim, M. C. Kruk, A. Billet, H. Needham, M. Schafer, and J. G. Dobson. 2013. Regional climate trends and scenarios for the U.S. National Climate Assessment: Part 2. Climate of the Southeast U.S. NOAA Technical Report NESDIS 142–2. NOAA, Silver Spring, Maryland.

Larson, J. S., M. S. Bedinger, C. F. Bryan, S. Brown, R. T. Huffman, E. L. Miller, D. G. Rhodes and B. A. Touchet. 1981. Transition from wetlands to uplands in southeastern bottomland hardwood wetlands. Pages 225–273 in: J. R. Clarke and J. Benforado, eds. Wetlands of the bottomland hardwood forests: proceedings of a workshop on bottomland hardwood forest wetlands of the southeastern United States. Elsevier Scientific Publishing, Amsterdam, Netherlands.

Lawton, D. E., F. J. Moye, J. B. Murray, B. J. O'Connor, H. M. Penley, G. S. Sandrock, W. E. Marsalis, M. S. Friddell, J. H. Hetrick, P. F. Huddlestun, R. E. Hunter, W. R. Mann, B. F. Martin, S. M. Pickering, F. J. Schneeberger, and J. D. Wilson. 1976. Geologic map of Georgia (scale 1:500,000). Environmental Protection Division, Georgia Department of Natural Resources, Atlanta, Georgia.

Leeth, D. C., J. S. Clarke, C. J. Wipperfurth and S. D. Craig. 2005. Ground-water conditions and studies in Georgia, 2002–03. United States Geologic Survey, Scientific Investigations Report 2005–5065, 2005.

LeGrand, H. E. 1962. Geology and ground-water resources of the Macon area, Georgia: Georgia Geological Survey Bulletin 72.

Lichvar, R. W. 2013. The National Wetland Plant List: 2013 wetland ratings. Phytoneuron 2013-49: 1-241. Available at: http://www.phytoneuron.net/2013Phytoneuron/49PhytoN-2013NWPL.pdf (last accessed in May 2017).

Link, W. A. and J. R. Sauer. 1998. Estimating population change from count data: application to the North American Breeding Bird Survey. Ecological Applications 8: 258–268.

Loeb, S. 2005. Bat inventories of Chattahoochee River National Recreation Area, Congaree National Park, Fort Pulaski National Monument, Fort Sumter National Monument, and Ocmulgee National Monument. National Park Service SECN, Atlanta, Georgia.

Long, J. and M. S. Schorr. 2005. Effects of watershed urban land use on environmental conditions and fish assemblages in Chattanooga area streams (Tennessee-Georgia). Journal of Freshwater Ecology 20: 527–537.

Luck, G. W. 2007. A review of the relationships between human population density and biodiversity. Biological Reviews 82: 607–645.

Lynch, E., D. Joyce, and K. Fristrup. 2011. An assessment of noise audibility and sound levels in U.S. national parks. Landscape Ecology 26: 1297–1309.

MacArthur, R., and J. MacArthur. 1961. On bird species diversity. Ecology 42:594–98.

Macon-Bibb County Planning & Zoning Commission. 2006. 2030 Planning Smart Choices—Comprehensive Plan, Community Assessment.

Mager, K. J. and T. A. Nelson. 2001. Roost-site selection by eastern red bats (Lasiurus borealis). American Midland Naturalist 145: 120–126.

Magurran, A. E. 1988. Ecological diversity and its measurement. Cambridge University Press, Cambridge, United Kingdom.

Magurran, A. E. 2004. Measuring biological diversity. Blackwell Publishing, Oxford, United Kingdom.

Makse, H. A., S. Havlin, and H. E. Stanley. 1995. Modelling urban growth patterns. Nature 377: 608–612.

Mallin, M. A. 2000. Impacts of industrial-scale swine and poultry production on rivers and estuaries. American Scientist 88: 26–37.

Mallin, M. A. V. L. Johnson, S. H. Ensign, and T. A. MacPherson. 2006. Factors contributing to hypoxia in rivers, lakes, and streams. Limnology and Oceanography 51:690–701.

Mathews, R., and B. D. Richter. 2007. Application of the Indicators of Hydrologic Alteration software in environmental flow setting. JAWRA Journal of the American Water Resources Association 43: 1400-1413.

Mayer, J. J., and I. L. Brisbin, Jr. 1991. Wild pigs of the United States. University of Georgia Press, Athens.

McIntosh, R. I. 1967. An index of diversity and the relation of certain concepts to diversity. Ecology 48: 392–404.

McKinney, M. L. 2001. Effects of human population, area, and time on non-native plant and fish diversity in the United States. Biological Conservation 100: 243–252.

McNaughton, S. J. 1977. Diversity and stability of ecological communities: a comment on the role of empiricism in ecology. American Naturalist 111: 515–525.

Meador, M. R., J. F. Coles, and H. Zappia. 2005. Fish assemblage responses to urban intensity gradients in contrasting metropolitan areas: Birmingham, Alabama and Boston, Massachusetts. American Fisheries Society Symposium 47: 409–423.

Meeker, J. R., W. N. Dixon, J. L. Foltz, and T. R. Fasulo. 2000. Featured creatures—southern pine beetle. University of Florida publication number EENY-176. Available at: http://entnemdept.ufl.edu/creatures/trees/southern_pine_beetle.htm (last accessed August 2017).

Metropolitan North Georgia Water Management District (MNGWMD). 2009. Water supply and water conservation plan. Section two. Available at: http://northgeorgiawater.org/wp-content/uploads/2015/05/Sec2_ExistingFacilities_WSWC_May2009.pdf (last accessed May 2017).

Metropolitan North Georgia Water Management District (MNGWMD). 2011.Metropolitan North Georgia Water Planning District water metrics report. Prepared by the Atlanta Regional Commission. MNGWMD, Atlanta, Georgia. Available from: http://documents.northgeorgiawater.org/2010_Water_Metrics_Report_FINAL%281%29.pdf (last accessed August 2017).

Meyer, J. L., M. J. Paul, and W. K. Taulbee. 2005. Stream ecosystem function in urbanizing landscapes. Journal of the North American Benthological Society 24: 602–612.

Meyer, W. B. and B. L. Turner II. 1992. Human population growth and global land-use/ cover change. Annual Review of Ecology and Systematics 23: 39–61.

Miller, J. A. 1990. Ground water atlas of the United States: Segment 6—Alabama, Florida, Georgia, and South Carolina. Hydrologic Investigations Atlas 730-G. U.S. Geological Survey, Reston, Virginia.

Miller, J. H., E. B. Chambliss, and C. T. Bargeron. 2016. Invasive plants of the thirteen southern states. Joint project of the Bugwood Network, the USDA Forest Service, the USDA Animal and Plant Health Inspection Service - Plant Protection and Quarantine program, the University of Georgia - Warnell School of Forest Resources, and the University of Georgia - College of Agricultural and Environmental Sciences - Department of Entomology. Available at: https://www.invasive.org/south/seweeds.cfm?sort=14 (last accessed August 2017).

Mittermeier, R. A., C. G. Mittermeier, T. M. Books, J. D. Pilgrim, W. R. Konstant, G. A. B. Da Fonseca, and C. Kormos. 2003. Wilderness and biodiversity conservation. Proceedings of the National Academy of Sciences U.S.A. 100: 10309–10313.

Monroe, M., P. Newman, E. Pilcher, R. Manning, and D. Stack. 2007. Now hear this. Legacy Magazine 18: 19–25.

Montoya, J. M., and D. Raffaelli. 2010. Climate change, biotic interactions and ecosystem services. Philosophical Transactions of the Royal Society B 365: 2013–2018.

Moore, A. A. and M. A. Palmer. 2005. Invertebrate biodiversity in agricultural and urban headwater streams: implications for conservation and management. Ecological Applications 15: 1169–1177.

Moore, C., F. Turina, and J. White. 2013. Recommended indicators and thresholds of night sky quality for NPS State of the Park reports. Interim guidance. Natural Sounds & Night Skies Division, NPS.

Multi-resolution Land Characteristics Consortium (MRLC). 2015. National Land Cover Database (NLCD). MRLC, United States Geologic Survey. Available at: http://www.mrlc.gov/index.php (last accessed May 2017).

Myer, W. B., 1991. Urban heat island and urban health: early American perspective. Professional Geographer 43: 38–48.

Myers, N. 1994. Population and biodiversity. Pages 117–136 in: Graham-Smith, F., editor. Population—the complex reality. Royal Society, London, United Kingdom.

National Acid Precipitation Assessment Program (NAPAP). 1991. National Acid Precipitation Assessment Program report to Congress—1990 integrated assessment report. Office of the Director, NAPAP, Washington, District of Columbia.

National Acid Precipitation Assessment Program (NAPAP). 2005. National Acid Precipitation Assessment Program report to Congress - an integrated assessment. Office of the Director, NAPAP, Washington, District of Columbia.

National Aeronautics and Space Administration (NASA). 2015. Aerial image of the United States at night. Available at: https://www.nasa.gov/sites/default/files/images/712129main_8247975848_88635d38a1_o.jpg (last accessed May 2017).

National Atmospheric Deposition Program (NADP). 2006. Hydrogen ion concentration as pH from measurements made at the Central Analytical Laboratory, 2006. Available at: http://nadp.sws.uiuc.edu/maplib/pdf/2006/pH_06.pdf (last accessed September 2017).

National Atmospheric Deposition Program (NADP). 2015. Hydrogen ion concentration as pH from measurements made at the Central Analytical Laboratory, 2015. Available at: http://nadp.sws.uiuc.edu/maplib/pdf/2015/pH_2015.pdf (last accessed September 2017).

National Centers for Environmental Information (NCEI). 2015. Climate at a glance: Time series plots. NCEI, National Oceanic and Atmospheric Administration, U.S. Department of Commerce. Available at: http://www.ncdc.noaa.gov/cag/time-series (last accessed May 2017).

National Geographic (NatGeo). 2015. Top 10 issues facing national parks. NationalGeographic.com. Available at: http://travel.nationalgeographic.com/travel/top-10/national-parks-issues/ (last accessed May 2017).

National Oceanic and Atmospheric Association (NOAA). 2017. Historic storm tracks. Available at: https://coast.noaa.gov/hurricanes/?redirect=301ocm#/app=1834&3e3d-selectedIndex=0 (last accessed August 2017).

National Park Service (NPS). 1976. Ocmulgee National Monument, statement for management (B1); and General Management Plan and environmental assessment (B2). National Park Service, OCMU, Macon, Georgia.

National Park Service (NPS). 1983. Annual statement for interpretation and visitor services, and environmental impact statement.

National Park Service (NPS). 1999. Natural resource challenge: the National Park Service's action plan for preserving natural resources. NPS, Washington, District of Columbia. Available at: https://www.nps.gov/nature/challenge.htm (last accessed May 2017).

National Park Service (NPS). 2002. Baseline water quality data inventory and analysis: Ocmulgee National Monument. Technical Report NPS/NRWRD/NRTR-2001/288. Water Resources Division, National Park Service, Fort Collins, Colorado.

National Park Service (NPS). 2006. Management policies. U.S. Department of the Interior. Available at: https://www.nps.gov/policy/mp2006.pdf (last accessed May 2017).

National Park Service (NPS). 2007. Interim outdoor lighting guidelines (draft). National Park Service Night Sky Team, Version 1.0. National Park Service, Fort Collins, Colorado.

National Park Service (NPS). 2009a. Ocmulgee National Monument: Long range interpretive plan. Available at: https://www.nps.gov/hfc/pdf/ip/ocmu-lrip-2009.pdf (last accessed August 2017).

National Park Service (NPS). 2009b. 2005–2009 5-year average air quality conditions. Air Resources Division, National Park Service, Fort Collins, Colorado. Available at: http://www.nature.nps.gov/air/Pubs/pdf/gpra/AQConditions_NPS_0509_table.pdf (last accessed August 2017).

National Park Service (NPS). 2011. Rating air quality conditions. Air Resources Division, National Park Service, Natural Resource Program Center, Denver, Colorado. Available at: http://nature.nps.gov/air/Planning/docs/20111122_Rating-AQ-Conditions.pdf (last accessed May 2017).

National Park Service (NPS). 2012a. Geologic resources inventory project for Ocmulgee National Monument. Available at: https://irma.nps.gov/App/Reference/Profile/2188759/ (last accessed May 2017).

National Park Service (NPS). 2012b. Inventory & monitoring program status report, 2012: Ocmulgee National Monument. National Park Service, SECN, Athens, Georgia. Available at: http://www.nps.gov/ocmu/learn/nature/upload/OCMU_Program_Summary_2012-2.pdf (last accessed May 2017).

National Park Service (NPS). 2012c. Measuring lightscapes. Natural Sounds and Night Skies Division, National Park Service. Available at: http://www.nature.nps.gov/night/measure.cfm (last accessed May 2017).

National Park Service (NPS). 2013a. NPSpecies. The National Park Service biodiversity database. Secure online version of certified organisms. Available at: https://irma.nps.gov/NPSpecies/ (last accessed May 2017).

National Park Service (NPS). 2013b. Ocmulgee National Monument Resource brief: amphibian community monitoring, 2011. Inventory & Monitoring Program, National Resource Program Center, Denver, Colorado.

National Park Service (NPS). 2014a. National Park Service GRI geology-GIS data model documents. Inventory and Monitoring, National Park Service. Available at: http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm (last accessed May 2017).

National Park Service (NPS). 2014b. NPScape. Inventory and Monitoring, National Park Service. Available at: http://science.nature.nps.gov/im/monitor/npscape/ (last accessed May 2017).

National Park Service (NPS). 2014c. Science of sound. Natural Sounds and Night Skies Division, National Park Service. Available at: http://www.nature.nps.gov/sound/science.cfm/ (last accessed May 2017).

National Park Service (NPS). 2014d. State of the park report for Ocmulgee National Monument. State of the Park Series No. 11. National Park Service, Washington D.C. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2227387 (last accessed May 2017).

National Park Service (NPS). 2014e. Ocmulgee old fields boundary study & environmental assessment. National Park Service, Macon, Georgia. Available at: https://parkplanning.nps.gov/document.cfm?parkID=399&projectID=38186&documentID=57618 (last accessed in August 2017).

National Park Service (NPS). 2015a. Effects of noise. Natural Sounds and Night Skies Division, National Park Service. Available at: http://www.nature.nps.gov/sound/effects.cfm (last accessed May 2017).

National Park Service (NPS). 2015b. Exotic plants and management in parks of the Southeast. Presentation. Biological Resource Management Division, National Park Service. Available at: http://www.nature.nps.gov/biology/invasivespecies/Documents/SE_EPMT%5B1%5D.pdf (last accessed May 2017).

National Park Service (NPS). 2015c. Integrated Resource Management Applications (IRMA) portal. Available at: https://irma.nps.gov/App/Portal/Home (last accessed May 2017).

National Park Service (NPS). 2015d. Ocmulgee National Monument, Georgia home page. Available at: http://www.nps.gov/ocmu/index.htm (last accessed May 2017).

National Park Service (NPS). 2015e. Ocmulgee National Monument: Summary of visitor use by month and year, for 2014. Available at: https://irma.nps.gov/Stats/SSRSReports/Park%20Specific%20Reports/Summary%20of%20Visitor%20Use%20By%20Month%20and%20Year%20%281979%20-%20Last%20Calendar%20Year%29?Park=OCMU (last accessed May 2017).

National Park Service (NPS). 2015f. What we do: Our mission. Available at: http://www.nps.gov/aboutus/index.htm (last accessed May 2017).

National Park Service (NPS). 2016. NPS Stats. National Park Service visitor use statistics. Available at: https://irma.nps.gov/Stats/Reports/Park (last accessed May 2017).

National Park Service Geologic Resources Inventory Program (NPS GRI). 2012a. Unpublished digital geologic map of the Eastern portion of Ocmulgee National Monument, Georgia (NPS, GRD, GRI, OCMU, OCME digital map) adapted from a Georgia Department of Natural Resources map by Hetrick and Friddell (1990). Geospatial dataset. Available at: https://irma.nps.gov/App/Reference/Profile/2189081 (last accessed May 2017).

National Park Service Geologic Resources Inventory Program (NPS GRI). 2012b. Unpublished digital geologic map of the Western portion of Ocmulgee National Monument, Georgia (NPS, GRD, GRI, OCMU, OCMW digital map) adapted from a Georgia Department of Natural Resources map by LeGrand (1962). Geospatial dataset. Available at: https://irma.nps.gov/App/Reference/Profile/2189083 (last accessed May 2017).

National Parks Conservation Association (NPCA). 2017. Diamond in the rough - an economic analysis of the proposed Ocmulgee National Park and Preserve. Available at: https://www.npca.org/resources/3189-diamond-in-the-rough (last accessed August 2017).

National Research Council. 2000. Clean coastal waters—understanding and reducing the effects of nutrient pollution. National Academy Press, Washington, District of Columbia.

Natural Resources Conservation Service (NRCS). 2013. Web Soil Survey home page. NRCS, United States Department of Agriculture. Available at: http://websoilsurvey.nrcs.usda.gov/app/ (last accessed May 2017).

Natural Resources Conservation Service (NRCS). 2014. Geospatial data gateway. Version 5.10. NRCS, United States Department of Agriculture. Available at: https://gdg.sc.egov.usda.gov/GDGHome.aspx (last accessed May 2017).

Natural Resources Conservation Service (NRCS). 2015. Plants database. NRCS, U.S. Department of Agriculture. Available at: http:/plants.usda.gov/java/ (last accessed May 2017).

Natural Resources Defense Council (NRDC). 2011. Toxic power—how power plants contaminate our air and states. NRDC, New York, New York.

Navarro, H. R. 2004. Flume measurements of erosion characteristics of soils at bridge foundations in Georgia. Master of Science thesis in Civil Engineering, Georgia Institute of Technology, Atlanta, Georgia.

Niemi, G. J. and M. E. McDonald. 2004. Ecological indicators. Annual Review of Ecology, Evolution, and Systematics 35: 89-111.

Norton, B. G. 1998. Improving ecological communication: the role of ecologists in environmental policy formation. Ecological Applications 8: 350-364.

Obey, C. D. 2002. Congressional Testimony submitted to the Senate Committee on Indian Affairs, Department of Interior Oversight Hearing on the Protection of Native American Sacred Places. August 2, 2003, Washington, District of Columbia.

Ocmulgee National Park & Preserve Initiative. 2017. Economic impact. Ocmulgee National Park & Preserve Initiative, Macon, GA. Available at: http://www.ocmulgeepark.org/economic-impact/ (last accessed August 2017).

Olsen, L. A. 1984. Effects of contaminated sediment on fish and wildlife: review and annotated bibliography. Report FWS/OBS-82/66. U.S. Fish and Wildlife Service, Washington, District of Columbia.

Olson, T. C., and W. H. Wischmeier. 1963. Soil-Erodibility Evaluations for Soils on the Runoff and Erosion Stations1. Soil Sci. Soc. Am. J. 27:590-592. doi:10.2136/sssaj1963.03615995002700050035x

Ourso, R., and A. Frenzel. 2003. Identification of linear and threshold responses in streams along a gradient of urbanization in Anchorage, Alaska. Hydrobiologia 501: 117-131.

Pardieck, K. L., D. J. Ziolkowski Jr., M.-A.R. Hudson. 2015. North American Breeding Bird Survey Dataset 1966–2014, version 2014.0. U.S. Geological Survey, Patuxent Wildlife Research Center. Available at: https://www.pwrc.usgs.gov/BBS/RawData/ (last accessed May 2017).

Park, L. O., R. E. Manning, J. L. Marion, S. R. Lawson, and C. Jacobi. 2008. Managing visitor impacts in parks: a multi-method study of the effectiveness of alternative management practices. Journal of Park and Recreation Administration 26: 97-121.

Parks, S. A. and A. H. Harcourt. 2002. Reserve size, local human density, and mammalian extinctions in the U.S. protected areas. Conservation Biology 16: 800–808.

Parris, K. M., M. Velik-Lord, and J. M. A. North. 2009. Frogs call at a higher pitch in traffic noise. Ecology and Society, 14: 25. Available at: http://www.ecologyandsociety.org/vol14/iss1/art25/ (last accessed July 2016).

Paul, M. J. and J. L. Meyer. 2001. Streams in the urban landscape. Annual Review of Ecology and Systematics 32: 333–365.

Peet, R. K. 1974. The measurement of species diversity. Annual Review of Ecology and Systematics 5:285–307.

Piekielek, N. B., and A. J. Hansen. 2012. Extent of fragmentation of coarse-scale habitats in and around U.S. national parks. Biological Conservation 155: 13–22. Available at: http://www.montana.edu/hansenlab/documents/downloadables/piekielekhansen2012.pdf (last accessed September 2017).

Pickett, S. T. A., M. L. Cadenasso, J. M. Grove, C. H. Nilon, R. V. Pouyat, W. C. Zipperer, and R. Costanza. 2001. Urban ecological systems: linking terrestrial ecological, physical, and socioeconomic components of metropolitan areas. Annual Review of Ecology and Systematics 32: 127–157.

Porter, S. D., and D. A. Savignano. 1990. Invasion of polygyne fire ants decimates native ants and disrupts arthropod community. Ecology 71: 2095–2106.

Porter, E. 2003. Southeast Coast Network air quality report. Air Resources Division, National Park Service, Denver, Colorado.

Puckett, D. L. 1997. Ocmulgee National Monument. A survey of natural resources. Unpublished report. Governor's Intern Program, Ocmulgee National Monument, National Park Service, Macon, Georgia.

Radeloff, V.C., S. I. Stewart, T. J. Hawbaker, U. Gimmi, A. M. Pidgeon, C. H. Flather, R. B. Hammer, and D. P. Helmers. 2010. Housing growth in and near United States protected areas limits their conservation value. Proceedings of the National Academy of Science (USA) 107: 940–945.

Rasmussen, T. C., J. F. Dowd, R. J. McKinnon, B. M. Price, and R. D. Sherrell. 2009. Southeast Coast Network groundwater monitoring: Protocol development and analysis of existing data. Natural Resource Report NPS/SECN/NRR–2009/126. National Park Service, Fort Collins, Colorado.

Reinelt, L. E. and R. R. Horner. 1991. Urban storm water impacts on the hydrology and water quality of palustrine wetlands in the Puget Sound region. In: Puget Sound research '91 proceedings, Puget Sound Water Quality Authority 1: 33–42.

Renken, R. A. 1996. Hydrogeology of the Southeastern Coastal Plain Aquifer System in Mississippi, Alabama, Georgia, and South Carolina. Regional Aquifer-System Analysis—Southeastern Coastal Plain. U.S. Geological Survey Professional Paper 1410-B. U.S. Government Printing Office, Washington, District of Columbia.

Repetto, R. 1994. The ''second India'' revisited: population, poverty, and environmental stress over two decades. World Resources Institute, Washington, District of Columbia.

Rich, C. and T. Longcore. 2006. Ecological consequences of artificial night lighting. Island Press, Washington, District of Columbia.

Richter, B., J. Baumgartner, R. Wigington, and D. Braun. 1997. How much water does a river need? Freshwater Biology 37: 231–249.

Rivard, D. H., J. Poitevin, D. Plasse, M. Carleton, and D. J. Currie. 2000. Changing species richness and composition in Canadian national parks. Conservation Biology 14: 1099–1109.

Robbins, C. S., D. Bystrak, and P. H. Geissler. 1986. The Breeding Bird Survey: its first fifteen years, 1965–1979. Resource Publication 157. U.S. Fish and Wildlife Service, Washington, District of Columbia.

Rothenberger, M., J. M. Burkholder, and C. Brownie. 2009. Long-term effects of changing land use practices on surface water quality in a coastal river and lagoonal estuary. Environmental Management 44: 505–523.

Rowan, K. E. 1991. When simple language fails: Presenting difficult science to the public. Journal of Technical Writing and Communication 21: 369–382.

Rowan, K. E. 1992. Strategies for enhancing comprehension of science. Pages 131-143 in: Lewenstein, B. V., editor. When science meets the public. American Association for the Advancement of Science, Washington, District of Columbia.

Sanchez-Azofeifa, G., G. C. Daily, A. S. Pfaff, and C. Busch. 2003. Integrity and isolation of Costa Rica's national parks and biological reserves: examining the dynamics of land-cover change. Biological Conservation 109: 123–135.

Sauer, J. R., J. E. Fallon, and R. Johnson. 2003. Use of North American Breeding Bird Survey data to estimate population change for bird conservation regions. The Journal of Wildlife Management 67: 372–389.

Schneider, J. and J. Boggs. 2013. America's dirtiest power plants. Penn Environment Research & Policy Center, Philadelphia, PA. Available at: http://environmentamericacenter.org/sites/environment/files/reports/Dirty%20Power%20Plants.pdf (last accessed September 2017).

Schueler, T. R. 1994.The importance of imperviousness. Watershed Protection Techniques 1: 100–111.

Schueler, T. R., L. Fraley-McNeal and K. Cappiella. 2009. Is impervious cover still important? Review of recent research. Journal of Hydrologic Engineering 14: 309–315.

Schwela, D. 2000. Air pollution and health in urban areas. Reviews in Environmental Health 15: 13–42.

Scott, M. C. and G. S. Helfman. 2001. Native invasions, homogenization, and the mismeasure of integrity of fish assemblages. Fisheries 26: 6–15.

Scott, J. M. and D. S. Wilcove. 1998. Improving the future for endangered species. BioScience 48: 579–580.

Sengpiel Audio. 2016. Sound Measuring. Available at: http://www.sengpielaudio.com/calculator-dba-spl.htm (last accessed May 2017).

Seong, J. C., T. H. Park, J. H. Ko, S. I. Chang, M. Kim, J. B. Hold, and M. R. Mehdi. 2011. Modeling of road traffic noise and estimated human exposure in Fulton County, Georgia, USA. Environment International 37: 1336-1341.

Shannon, C. E. W. and W. Weaver. 1949. The mathematical theory of communication. The University of Illinois Press, Urbana, Illinois.

Shannon, G., M. F. McKenna, L. M. Angeloni, K. R. Crooks, K. M. Fristrup, E. Brown, K. A. Warner, M. D. Nelson, C. White, J. Briggs, S. McFarland, and G. Wittemyer. 2016. A synthesis of two decades of research documenting the effects of noise on wildlife. Biological Reviews 91: 982–1005.

Shaver, E., J. Maxted, G. Curtis, and D. Carter. 1994. Watershed protection using an integrated approach. Department of Natural Resources and Environmental Control, Dover, Delaware.

Simon, A. and L. Klimetz. 2008. Magnitude, frequency, and duration relations for suspended sediment in stable ("reference") southeastern streams. Journal of the American Water Resources Association 44: 1270–1283.

Simon, A., and P. W. Downs. 1995. An interdisciplinary approach to evaluation of potential instability in alluvial channels. Geomorphology 12: 215–232.

Smith, C. R. 2000. The native people of North America - Southeast Culture Area. Available at: http://www.cabrillo.edu/~crsmith/noamer_soeast.html (last accessed May 2017).

Soil Conservation Service (SCS). 1986. Urban hydrology for small watersheds. Technical Release #55. U.S. SCS, Washington, District of Columbia.

Southeast Regional Climate Center (SERCC). 2007. University of North Carolina, Chapel Hill, home page for the SERCC. Available at: http://www.sercc.com/ (last accessed May 2017).

State Climate Office of North Carolina (SCONC). 2015. Hurricanes database. SCONC, North Carolina State University. Available at: http://www.nc-climate.ncsu.edu/climate/hurricanes/search.php?page=3&stype=4 (last accessed May 2017).

State of Georgia Office of Planning and Budget. 2010. Georgia 2030 population projections. Available at: http://www.georgiawaterplanning.org/documents/162904242georgiapopulationprojections-march2010_001.pdf (last accessed May 2017).

Sullivan, T. J., G. T. McPherson, T. C. McDonnell, S. D. Mackey, and D. Moore. 2011. Evaluation of the sensitivity of inventory and monitoring national parks to acidification effects from atmospheric sulfur and nitrogen deposition: Southeast Coast Network (SECN). Natural Resource Report NPS/NRPC/ARD/NRR—2011/375. National Park Service, Denver, Colorado.

Taylor, A. R. and R. L. Knight. 2003. Wildlife responses to recreation and associated visitor perceptions. Ecological Applications 13: 951-963.

Taylor, C. J. and W. M. Alley. 2001. Ground-water level monitoring and the importance of long-term water-level data. USGS Circular 1217. USGS, Reston, Virginia.

Texas Invasive Species Institute (TISI). 2014. Redbreast sunfish: Lepomis auritus. TISI, Texas State University System. Available at: http://www.stoppinginvasives.org/home/database/lepomis-auritus (last accessed May 2017).

The Nature Conservancy. 2009. Indicators of hydrologic alteration Version 7.1 User's Manual. The Nature Conservancy, Arlington, Virginia. Available at: http://www.conservationgateway.org/ConservationPractices/Freshwater/EnvironmentalFlows/MethodsandTools/IndicatorsofHydrologicAlteration/Pages/IHA-Software-Download.aspx (last accessed July 2016).

Thomas, J. E., T. A Saxby, T. J. B. Carruthers, E.G. Abal, and W.C. Dennison. 2006. Communicating science effectively. IWA Publishing, London, United Kingdom.

Tomlinson, G. H. and F. L. Tomlinson. 1990. Effects of acid deposition on the forests of Europe and North America. CRC Press, Boca Raton, Florida.

Tuberville, T. D., J. D. Wilson, M. E. Dorcas, and J. W. Gibbons. 2005. Herpetofaunal species richness of southeastern National Parks. Southeastern Naturalist 4: 537–569.

Tweet, J. S., V. L. Santucci, and J. P. Kenworthy. 2009. Ocmulgee National Monument. Pages 179–189 in Paleontological resource inventory and monitoring Southeast Coast Network. Natural resource technical report NPS/NRPC/NRTR—2009/197. National Park Service, Fort Collins, Colorado.

Tyson, A.W. 1993. Georgia's ground water resources, Bulletin 1096. University of Georgia Cooperative Extension Service.

United States Army Corps of Engineers (USACE). 2015. National Wetland Plant List (NWPL), version 32. Available at: http://rsgisias.crrel.usace.army.mil/NWPL/ (last accessed May 2017).

United States Census Bureau (USCB). 2015a. Home page. USCB, U.S. Department of Commerce. Available at: http://www.census.gov/ (last accessed May 2017).

United States Census Bureau (USCB). 2015b. TIGER/Line® with selected demographic and economic data. Available at: http://www.census.gov/geo/maps-data/data/tiger-data.html (last accessed May 2017).

United States Census Bureau (USCB). 2016. Quick Facts. Available from: https://www.census.gov/quickfacts/GA (last accessed August 2017).

United States Department of Commerce (US DOC). 2013. Tropical cyclone definitions. National Weather Service Instruction 10-604. Operations and Services Tropical Cyclone Weather Service Program, NWSPD 10-6. NOAA NWS. Available at: http://www.nws.noaa.gov/directives/sym/pd01006004curr.pdf (last accessed May 2017).

United States Environmental Protection Agency (EPA). 1994. The quality of our nation's water: 1992. Report No. EPA/841/F-94/002. Office of Water, EPA, Washington, District of Columbia.

United States Environmental Protection Agency (EPA). 2000. Ambient water quality criteria recommendations, information supporting the development of state and tribal nutrient criteria: rivers and streams in Nutrient Ecoregion IX. Report EPA 822-B-00-011. EPA, Washington, District of Columbia.

United States Environmental Protection Agency (EPA). 2002a. 2002 National Emissions Inventory booklet. EPA, Washington, District of Columbia. Available at: https://www.epa.gov/sites/production/files/2015-07/documents/2002_nei_booklet_0.pdf (last accessed August 2017).

United States Environmental Protection Agency (EPA). 2002b. National recommended water quality criteria: 2002. Report EPA-822-R-02-047. EPA, Washington, District of Columbia.

United States Environmental Protection Agency (EPA). 2003a. Bacterial water quality standards for recreational waters (freshwater and marine waters): status report. Report EPA-823-R-03-008. EPA, Washington, District of Columbia.

United States Environmental Protection Agency (EPA). 2003b. Guidance for estimating natural visibility conditions under the regional haze program. Report EPA-454/B-03-005. EPA, Washington, District of Columbia. Available at: https://www3.epa.gov/ttn/naaqs/aqmguide/collection/cp2/20030901_oaqps_epa-454_b-03-005_estimating_natural%20_visibility_regional_haze.pdf (last accessed May 2017).

United States Environmental Protection Agency (EPA). 2004. 305(b) Lists/assessment unit information year 2004. Office of Water, EPA, Washington, District of Columbia.

United States Environmental Protection Agency (EPA). 2007. Review of the national ambient air quality standards for ozone: Policy assessment of scientific and technical information. OAQPS staff paper. Report No. EPA-452/R-07-007. EPA, Washington, District of Columbia. Available at: https://www.regulations.gov/document?D=EPA-HQ-OAR-2008-0699-0251 (last accessed May 2017).

United States Environmental Protection Agency (EPA). 2016a. National Ambient Air Quality Standards (NAAQS). EPA, Washington, District of Columbia. Available at: https://www.epa.gov/criteria-air-pollutants/naaqs-table (last accessed May 2017).

United States Environmental Protection Agency (EPA). 2016b. What are the six common air pollutants? Available at: http://www.epa.gov/criteria-air-pollutants (last accessed May 2017).

United States Fish and Wildlife Service (USFWS). 2015. USFWS national GIS data. Geospatial Services, USFWS. Available at: http://www.fws.gov/gis/data/national/index.html (last accessed May 2017).

United States Geological Survey (USGS). 2008. Georgia's ground-water resources and monitoring network, 2008. Fact Sheet 2008-3072. USGS, Reston, Virginia. Available at: http://pubs.usgs.gov/fs/2008/3072/pdf/fs2008-3072.pdf (last accessed May 2017).

United States Geological Survey (USGS). 2015a. National Map viewer and download platform. Available at: http://nationalmap.gov/viewer.html (last accessed May 2017).

United States Geological Service (USGS). 2015b. USGS 02213000 Ocmulgee River at Macon, Ga. National Water Information System, USGS. Available at: http://waterdata.usgs.gov/usa/nwis/uv?site_no=02213000 (last accessed May 2017).

Unnasch, R. S., D. P. Braun, P. J. Comer, and G. E. Eckert. 2009. The Ecological Integrity Assessment Framework: a framework for assessing the ecological integrity of biological and ecological resources of the National Park System. Version 1.0, January 2009. For the National Park Service. Available at: http://www.natureserve.org/sites/default/files/publications/files/nps_ecological_integrity_framework.pdf (last accessed May 2017).

Vieira, M., Y. Jung, K. Kuyu, and M. Taylor. 2007. Levee certification and map modernization. Presentation at Georgia Association of Floodplain Management conference. Map Modernization Program, Federal Emergency Management Agency, U.S. Department of Homeland Security. Available at: http://www.gafloods.org/pdf/2006_2007/Levee_Certification_Watershed%20Concepts.pdf (last accessed May 2017).

Vigil, J. F., R. J. Pike, and D. G. Howell. 2000. A tapestry of time and terrain. Pamphlet to accompany Geologic Investigations Series I-2720. USGS Information Services, Denver, Coloroado. Available at: https://pubs.usgs.gov/imap/i2720/ (last accessed August 2017).

Vitousek, P. M., H. A. Mooney, J. Lubchenco, and J. M. Melillo. 1997. Human domination of Earth’s ecosystems. Science 277: 494–499.

Walser, C.A. and Bart, H.L. Jr. 1999. Influence of agriculture on in-stream habitat and fish community structure in Piedmont watersheds of the Chattahoochee River System. Ecology of Freshwater Fish. 8: 237–246.

Wang, L., J. Lyons, P. Kanehl, and R. Gatti. 1997. Influences of watershed land use on habitat quality and biotic integrity in Wisconsin streams. Fisheries 22: 6–12.

Watson, C., and K. Malloy. 2006. The South Atlantic migratory bird initiative implementation plan: An integrated approach to conservation of all birds across all habitats, version 3.1. Atlantic Coast Joint Venture. Available at: http://www.acjv.org/documents/SAMBI_Plan3.2.pdf (last accessed May 2017).

Watson, J. K. 2005. Avian Conservation Implementation Plan—Ocmulgee National Monument. Final draft. National Park Service Southeast Region in cooperation with the U.S. Fish and Wildlife Service and Bird Conservation Partners, Atlanta, Georgia. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2176899 (last accessed May 2017).

Weaver, L. A. and G. C. Garman. 1994. Urbanization of a watershed and historical changes in a stream fish assemblage. Transactions of the American Fisheries Society 123: 162–172.

Webster, W. D. 2010. Mammalian diversity in nineteen Southeast Coast Network Parks. Natural Resource Report NPS/SECN/NRR—2010/263. National Park Service, Fort Collins, Colorado.

Weigold, M. F. 2001. Communicating science: a review of the literature. Science Communication 23: 164–193.

Wetzel, R. G. 2001. Limnology, third edition. Academic Press, New York, New York.

Wheeler, B. J. 2007. Ocmulgee National Monument. Cultural landscape report. National Park Service, Southeast Regional Office, Cultural Resources Division, National Park Service, Atlanta, Georgia.

Whittaker, R.H. 1972. Evolution and measurement of species diversity. Taxon 21: 231–251.

Whitton, B. A. (editor). 1975. River ecology. Studies in Ecology, Volume 2. University of California Press, Berkeley, California.

Williams, M., B. Longstaff, C. Buchanan, R. Llansó, and P. Bergstrom. 2007. Development of an integrated and spatially explicit index of Chesapeake Bay health (Bay Habitat Health Index - BHHI). Draft—Technical Documentation (v 1.5). Joint initiative of the Chesapeake Bay Program's Tidal Monitoring and Analysis Workgroup (TMAW) and Living Resources and Analysis Workgroup. Chesapeake Bay Program, Annapolis, Maryland.

Wisniewski, J. M., G. Krakow, and B. Albanese. 2005. Current status of endemic mussels in the lower Ocmulgee and Altamaha Rivers. In: Hatcher, K. J., editor. Proceedings of the 2005 Georgia Water Resources Conference, held April 25-27, 2005, at The University of Georgia. Institute of Ecology. University of Georgia, Athens, Georgia.

Wojnik, D. P., C. R. Allen, R. J. Brenner, E. A. Forys, D. P. Jouvenaz and R. S. Lutz. 2001. Red imported fire ants: impact on biodiversity. American Entomologist 47:16–23.

World Health Organization (WHO). 2009. Night noise guidelines for Europe. WHO Regional Office for Europe, UN City, Marmorvej 51, DK-2100 Copenhagen Ø, Denmark.

Wright, C. J., E. Thompson, B. A. Blankley, M. W. Byrne, T. Curtis, and M. B. Gregory. 2011. Summary of weather and climate monitoring in Southeast Coast Network parks, 2010. Natural Resource Data Series NPS/SECN/NRDS—2011/309. National Park Service, Fort Collins, Colorado.

Wright, C. J. 2012a. Summary of weather and climate monitoring in Southeast Coast Network parks, 2011. Natural Resource Data Series NPS/SECN/NRDS—2012/365. National Park Service, Fort Collins, Colorado.

Wright, C. J. 2012b. Groundwater conditions in Southeast Coast Network Parks, 2011. Natural Resource Data Series NPS/SECN/NRDS—2012/326. National Park Service, Fort Collins, Colorado.

Young, C. C., J. L. Haack, L.W. Morrison, and M. D. DeBacker. 2007. Invasive Exotic Plant Monitoring Protocol for the Heartland Network Inventory and Monitoring Program. Natural Resource Report NPS/HTLN/NRR-2007/018. National Park Service, Fort Collins, Colorado.

Zielinski, J. 2002. Watershed Vulnerability Analysis. Center for Watershed Protection, Ellicott City, Maryland. Available at: http://www.riversimulator.org/Resources/farcountry/WatershedTools/Watershed_Vulnerability_Analysis_-_CWP.pdf (last accessed September 2017).

Zirschky, J., G. P. Keary, R. O. Gilbert, and E. J. Middlebrooks. 1985. Spatial estimation of hazardous waste site data. Journal of Environmental Engineering 111: 777–789.

Zomlefer, W. B., D. E. Giannasi, J. B. Nelson, and L. L. Gladdy. 2013. A baseline vascular plant survey for Ocmulgee National Monument, Bibb County, Macon, Georgia. Journal of the Botanical Research Institute of Texas 7: 453–473. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2203347 (last accessed May 2017).

Appendix A. Automated Program for Computing Growing Degree Day and Drought Severity Statistics

These two programs were written with assistance from the NCSU Statistics Department (Dr. Consuelo Arellano). Both programs use data requested and received from the Southeast Regional Climate Center (SERCC) located in Chapel Hill, NC (Mr. William Schmitz, Service Climatologist/Meteorologist).

The first program uses data called Growing Degree Days (GDD) and calculates the date where the 1200 GDD threshold is reached. The computation involves finding the calendar date when the 1200 GDD threshold is reached for each year in the dataset. This requires summing the monthly values until the sum is greater than 1200 and then calculating the slope of the line between that month and the month preceding to determine the exact date on which the 1200 would be achieved. Typically the value 1200 is achieved between April and May, but occasionally between March and April, or May and June, depending on temperature.

The second program uses Palmer Drought Severity Index data and ranks the severity of drought over seven classes ranging from severely dry to excessively wet. The computation involves calculating the proportion of the number of monthly observations in each drought class for every nine-year period.

In these programs for OCMU and the SECN, the reference city has been set equal to Atlanta.

Appendix B. Available Water Quality Data

Table B-1. Description of surface water quality monitoring locations in the OCMU area (sources: GA DNR-EPD via STORET, MWA, and City of Macon).

Proximity to OCMU	Location	Description	Lat	Long	Source
Walnut Creek, OCMU	GEPD 5011251	Walnut Creek, NE boundary of OCMU	32.8461	-83.5956	GA DNR
Upstream from OCMU—Walnut Creek	JVR—Walnut Creek Bridge	Jeffersonville Rd. (0.4 mi upstream)	32.8521	-83.5934	MWA
	Walnut Creek	at Jeffersonville Rd. (0.4 mi upstream)	–	–	City of Macon
	GEPD 503160403	Walnut Creek, NE boundary of OCMU	32.85215	-83.593	GA DNR
Ocmulgee River near OCMU	MLK Jr. Blvd. Bridge	adjacent to OCMU	32.8387	-83.6205	MWA
Upstream from OCMU—Ocmulgee River	GEPD 5010001	3.2 mi upstream—Ocmulgee River	32.8697	-83.6542	GA DNR

Table B-2. Recent available data (since 1999) for surface water quality in the OCMU area (UC—unacceptable conditions; nd—not detectable; sv—single value; SRP—soluble reactive phosphorus; sources: GA DNR-EPD via STORET, MWA, and City of Macon).[a, b, c, d]

Site of monitoring	Parameter	Date	n	Mean (range) or single value (sv)	Median	# of UCs
GEPD 5011251	Temperature (°C)	Jan 99–Mar 00	22	18.1 (7.5–29.3)	17.1	–
	Discharge (cfs)	Jan 99–Mar 00	21	143.4 (0.2–300)	200	–
	Stream stage height (ft)	Jan 99–Mar 00	22	1.35 (0.52–3.4)	1.26	–
	Turbidity (NTU)	Jan 99–Jan 00	12	14.4[g] (3–40[g])	9[g]	8[g]
	Spec. cond. (µmhos/cm, field)	Jan 99–Mar 00	22	116.8 (73–150)	120.5	–
	DO (mg/L)	Jan 99–Mar 00	21	8.6 (6.1–11.1)	8.5	–
	pH	Jan 99–Mar 00	23	7.3 (6.9–7.8)	7.3	–
	$NO_3^-N + NO_2^-N$ (µg/L)	Jan 99–Jan 00	12	202 (40–340)	205	8
	NH_4^+N (µg/L)	Jan 99–Dec 00	12	56 (30–130)	40.5	–
	TP (µg/L)	Jan 99–Jan 00	12	29 (20–50[f])	26	4[f]
	TOC (µg/L)	Jan 99–Jan 00	12	2.0 (1.2–4.4)	2	–
	BOD_5 (mg/L)	Jan 99–Jan 00	12	2.1 (2–3.3[g])	2	1[g]

[a] For computing means and medians, all values reported by the data source as less than the level of detection or the reporting limit were replaced with half the value of the method detection limit, following Ellis and Gilbert (1980) and Zirschky et al. (1985).

[b] Values for toxic metals (cadmium, copper, lead, zinc) were reported as "less than" a range of values that include the CCC; or, for chromium, the species was not designated.

[c] Selected parameters included those most commonly considered in water quality assessment; most of those that were not included here also had been sampled infrequently (1 or a few dates).

[d] More than 50% of the samples were below detection or below the reporting limit with the analytical technique used; thus, statistical interpretation was not attempted

[e] Underlined—in violation of state standard (GA DNR 2008d), except for fecal coliforms. This table considers all fecal coliform and *Escherichia coli* data collectively, whereas Appendix 2 considers data amenable to calculation of GMs. Since only a portion of the bacterial data were collected with sufficient frequency to enable calculation of GMs—which are used for the state standards—these data were evaluated here as follows: Fecal coliforms > 400 mpn/100 mL level, which is the criterion recommended by the EPA (2003) for data collected too infrequently for calculation of GMs by the state's criterion (at least 4 samples collected within a 30-day period) and *E. coli* > 235 mpn/100 mL (single sample).

[f] Blue—exceeds the EPA (2000) recommendation for acceptable water quality; or exceeds recommended values to protect aquatic life (BOD_5—see Mallin 2006).

[g] Red—exceeds EPA (2000) recommendation for acceptable water quality (for TSS, <10 mg/L increase (spike); for metals (Al, Cu, Hg, Pb, Ni, Zn), see p.68 of this report). For pH, EPA (2002b) recommends that data should be within the range 6.5–9. However, this report follows Georgia regulations (pH > 6.0).

Table B-2 (continued). Recent available data (since 1999) for surface water quality in the OCMU area (UC—unacceptable conditions; nd—not detectable; sv—single value; SRP—soluble reactive phosphorus; sources: GA DNR-EPD via STORET, MWA, and City of Macon).a, b, c, d

Site of monitoring	Parameter	Date	n	Mean (range) or single value (sv)	Median	# of UCs
GEPD 5011251 (cont.)	Alkalinity, carbonate as $CaCO_3$ (mg/L)	Jan 99–Nov 99	11	42 (31–51)	43	–
	Fecal coliforms (mpn/100 mL)	Jan 99–Oct 00	16	7,168 [e] (20–92,000 [e])	945	10
JVR—Walnut Creek Bridge	Temperature (°C)	Jun 07–Feb 10	33	16.0 (2.7–26.5)	16	–
	Turbidity (NTU)	Nov 05–Jan 10	52	18.2[g] (1.6–250[g])	9.8[g]	37[g]
	Spec. cond. (µmhos/cm, field)	May 07–Feb 10	38	147.3 (53.2–488)	119.5	–
	DO (mg/L)	May 07–Feb 10	34	8.5 (3.8–13.6)	8.6	3
	pH	Apr 07–Feb 10	36	7.1 (6.3–7.8)	7.2	–
	$NO_3^-N + NO_2^-N$ (µg/L)	Jun 09–Jan 10	4	111 (brl–210[f])	105	1[f]
	NH_4^+N (µg/L)	Jun 09–Jan 10	4	all < 0.1[d]	–	–
	TKN (µg/L)	Jun 09–Jan 10	4	260[f] (brl–330[f])	305[f]	3[f]
	TP (µg/L)	Jun 09–Jan 10	4	brl–110[d]	–	1

[a] For computing means and medians, all values reported by the data source as less than the level of detection or the reporting limit were replaced with half the value of the method detection limit, following Ellis and Gilbert (1980) and Zirschky et al. (1985).

[b] Values for toxic metals (cadmium, copper, lead, zinc) were reported as "less than" a range of values that include the CCC; or, for chromium, the species was not designated.

[c] Selected parameters included those most commonly considered in water quality assessment; most of those that were not included here also had been sampled infrequently (1 or a few dates).

[d] More than 50% of the samples were below detection or below the reporting limit with the analytical technique used; thus, statistical interpretation was not attempted

[e] Underlined—in violation of state standard (GA DNR 2008d), except for fecal coliforms. This table considers all fecal coliform and *Escherichia coli* data collectively, whereas Appendix 2 considers data amenable to calculation of GMs. Since only a portion of the bacterial data were collected with sufficient frequency to enable calculation of GMs—which are used for the state standards—these data were evaluated here as follows: Fecal coliforms > 400 mpn/100 mL level, which is the criterion recommended by the EPA (2003) for data collected too infrequently for calculation of GMs by the state's criterion (at least 4 samples collected within a 30-day period) and *E. coli* > 235 mpn/100 mL (single sample).

[f] Blue—exceeds the EPA (2000) recommendation for acceptable water quality; or exceeds recommended values to protect aquatic life (BOD_5—see Mallin 2006).

[g] Red—exceeds EPA (2000) recommendation for acceptable water quality (for TSS, <10 mg/L increase (spike); for metals (Al, Cu, Hg, Pb, Ni, Zn), see p.68 of this report). For pH, EPA (2002b) recommends that data should be within the range 6.5–9. However, this report follows Georgia regulations (pH > 6.0).

Table B-2 (continued). Recent available data (since 1999) for surface water quality in the OCMU area (UC—unacceptable conditions; nd—not detectable; sv—single value; SRP—soluble reactive phosphorus; sources: GA DNR-EPD via STORET, MWA, and City of Macon).[a, b, c, d]

Site of monitoring	Parameter	Date	n	Mean (range) or single value (sv)	Median	# of UCs
JVR—Walnut Creek Bridge (cont.)	SRP (µg/L)	Jun 09–Jan 10	4	brl–70[d]	–	–
	Color	Nov 05–Aug 08	33	89.4 (15–1,200)	30	–
	BOD_5 (mg/L)	Jun 09–Jan 10	4	all < 2.0[d]	–	–
	TSS (mg/L)	Jun 09–Jan 10	4	10.5[g] (4–18[g])	10	2[g]
	Hardness, Ca+Mg (mg/L)	Jun 09–Jan 10	4	32 (30–33)	32	–
	Fecal coliforms (mpn/100 mL)	Jun 09–Aug 09	9	787 [e] (56–4,800 [e])	212	4
	Escherichia coli (mpn/100 mL)	Jun 09–Feb 10	10	368 [e] (0–2,187 [e])	174	3
	Cadmium, total (µg/L)	Jun 09–Jan 10	4	all < 5[e]	–	uncertain[c]
	Copper, total (µg/L)	Jun 09–Jan 10	4	all < 20[e]	–	uncertain[c]
	Lead, total (µg/L)	Jun 09–Jan 10	4	all < 5[e]	–	uncertain[c]
	Zinc, total (µg/L)	Jun 09–Jan 10	4	all < 20[e]	–	–
	Cadmium, dissolved (µg/L)	Jun 09–Jan 10	4	all < 5[e]	–	uncertain[c]

[a] For computing means and medians, all values reported by the data source as less than the level of detection or the reporting limit were replaced with half the value of the method detection limit, following Ellis and Gilbert (1980) and Zirschky et al. (1985).

[b] Values for toxic metals (cadmium, copper, lead, zinc) were reported as "less than" a range of values that include the CCC; or, for chromium, the species was not designated.

[c] Selected parameters included those most commonly considered in water quality assessment; most of those that were not included here also had been sampled infrequently (1 or a few dates).

[d] More than 50% of the samples were below detection or below the reporting limit with the analytical technique used; thus, statistical interpretation was not attempted

[e] Underlined—in violation of state standard (GA DNR 2008d), except for fecal coliforms. This table considers all fecal coliform and *Escherichia coli* data collectively, whereas Appendix 2 considers data amenable to calculation of GMs. Since only a portion of the bacterial data were collected with sufficient frequency to enable calculation of GMs—which are used for the state standards—these data were evaluated here as follows: Fecal coliforms > 400 mpn/100 mL level, which is the criterion recommended by the EPA (2003) for data collected too infrequently for calculation of GMs by the state's criterion (at least 4 samples collected within a 30-day period) and *E. coli* > 235 mpn/100 mL (single sample).

[f] Blue—exceeds the EPA (2000) recommendation for acceptable water quality; or exceeds recommended values to protect aquatic life (BOD_5—see Mallin 2006).

[g] Red—exceeds EPA (2000) recommendation for acceptable water quality (for TSS, <10 mg/L increase (spike); for metals (Al, Cu, Hg, Pb, Ni, Zn), see p.68 of this report). For pH, EPA (2002b) recommends that data should be within the range 6.5–9. However, this report follows Georgia regulations (pH > 6.0).

Table B-2 (continued). Recent available data (since 1999) for surface water quality in the OCMU area (UC—unacceptable conditions; nd—not detectable; sv—single value; SRP—soluble reactive phosphorus; sources: GA DNR-EPD via STORET, MWA, and City of Macon).[a, b, c, d]

Site of monitoring	Parameter	Date	n	Mean (range) or single value (sv)	Median	# of UCs
JVR—Walnut Creek Bridge (cont.)	Copper, dissolved (µg/L)	Jun 09–Jan 10	4	all < 20[e]	–	uncertain[c]
	Lead, dissolved (µg/L)	Jun 09–Jan 10	4	all < 5[e]	–	uncertain[c]
	Zinc, dissolved (µg/L)	Jun 09–Jan 10	4	all < 20[e]	–	uncertain[c]
GEPD 503160403	Temperature (°C)	Mar 04–Dec 04	11	19.5 (11.2–24.8)	21.1	–
	Spec. cond. (µmhos/cm, field)	Mar 04–Dec 04	11	111.9 (51–140)	118	–
	DO (mg/L)	Mar 04–Dec 04	11	8.4 (6.7–10.4)	8.5	–
	pH	Mar 04–Dec 04	11	7.2 (6.7–7.7)	7.3	–
	Fecal coliforms (mpn/100 mL)	Mar 04–Dec 04	11	1,971 [e] (nd–16,000 [e])	500 [e]	6 [e]
MLK Jr. Blvd. Bridge	Temperature (°C)	Dec 07–Dec 10	178	17.3 (3.3–30.9)	16.8	–
	Turbidity (NTU)	Oct 05–Dec 10	199	29.4[g] (1.2–203[g])	18[g]	159[g]

[a] For computing means and medians, all values reported by the data source as less than the level of detection or the reporting limit were replaced with half the value of the method detection limit, following Ellis and Gilbert (1980) and Zirschky et al. (1985).

[b] Values for toxic metals (cadmium, copper, lead, zinc) were reported as "less than" a range of values that include the CCC; or, for chromium, the species was not designated.

[c] Selected parameters included those most commonly considered in water quality assessment; most of those that were not included here also had been sampled infrequently (1 or a few dates).

[d] More than 50% of the samples were below detection or below the reporting limit with the analytical technique used; thus, statistical interpretation was not attempted

[e] Underlined—in violation of state standard (GA DNR 2008d), except for fecal coliforms. This table considers all fecal coliform and *Escherichia coli* data collectively, whereas Appendix 2 considers data amenable to calculation of GMs. Since only a portion of the bacterial data were collected with sufficient frequency to enable calculation of GMs—which are used for the state standards—these data were evaluated here as follows: Fecal coliforms > 400 mpn/100 mL level, which is the criterion recommended by the EPA (2003) for data collected too infrequently for calculation of GMs by the state's criterion (at least 4 samples collected within a 30-day period) and *E. coli* > 235 mpn/100 mL (single sample).

[f] Blue—exceeds the EPA (2000) recommendation for acceptable water quality; or exceeds recommended values to protect aquatic life (BOD_5—see Mallin 2006).

[g] Red—exceeds EPA (2000) recommendation for acceptable water quality (for TSS, <10 mg/L increase (spike); for metals (Al, Cu, Hg, Pb, Ni, Zn), see p.68 of this report). For pH, EPA (2002b) recommends that data should be within the range 6.5–9. However, this report follows Georgia regulations (pH > 6.0).

Table B-2 (continued). Recent available data (since 1999) for surface water quality in the OCMU area (UC—unacceptable conditions; nd—not detectable; sv—single value; SRP—soluble reactive phosphorus; sources: GA DNR-EPD via STORET, MWA, and City of Macon).[a, b, c, d]

Site of monitoring	Parameter	Date	n	Mean (range) or single value (sv)	Median	# of UCs
MLK Jr. Blvd. Bridge (cont.)	Spec. cond. (μmhos/cm, field)	May 07–Dec 10	92	127.5 (23–337)	118	–
	DO (mg/L)	May 07–Dec 10	180	9.3 (5.3–21.7[e])	8.9	1[g]
	pH	Apr 07–Dec 10	181	7.4 (6.4–8.0)	7.4	–
	Color	Oct 05–Aug 08	34	45.1 (10–150)	30	–
	Alkalinity, carbonate as $CaCO_3$ (mg/L)	Dec 09–May 10	20	18.3 (7–24)	18.6	–
	Hardness, Ca+Mg (mg/L)	Dec 09–May 10	22	22 (16–29)	21	–
	Fecal coliforms (mpn/100 mL)	May 07–Dec 10	203	462[e] (0–24,000[e])	81	42[e]
	Escherichia coli (mpn/100 mL)	Dec 09–May 10	23	108.5 (0–547.5[e])	51	3[e]

[a] For computing means and medians, all values reported by the data source as less than the level of detection or the reporting limit were replaced with half the value of the method detection limit, following Ellis and Gilbert (1980) and Zirschky et al. (1985).

[b] Values for toxic metals (cadmium, copper, lead, zinc) were reported as "less than" a range of values that include the CCC; or, for chromium, the species was not designated.

[c] Selected parameters included those most commonly considered in water quality assessment; most of those that were not included here also had been sampled infrequently (1 or a few dates).

[d] More than 50% of the samples were below detection or below the reporting limit with the analytical technique used; thus, statistical interpretation was not attempted

[e] Underlined—in violation of state standard (GA DNR 2008d), except for fecal coliforms. This table considers all fecal coliform and *Escherichia coli* data collectively, whereas Appendix 2 considers data amenable to calculation of GMs. Since only a portion of the bacterial data were collected with sufficient frequency to enable calculation of GMs—which are used for the state standards—these data were evaluated here as follows: Fecal coliforms > 400 mpn/100 mL level, which is the criterion recommended by the EPA (2003) for data collected too infrequently for calculation of GMs by the state's criterion (at least 4 samples collected within a 30-day period) and *E. coli* > 235 mpn/100 mL (single sample).

[f] Blue—exceeds the EPA (2000) recommendation for acceptable water quality; or exceeds recommended values to protect aquatic life (BOD_5—see Mallin 2006).

[g] Red—exceeds EPA (2000) recommendation for acceptable water quality (for TSS, <10 mg/L increase (spike); for metals (Al, Cu, Hg, Pb, Ni, Zn), see p.68 of this report). For pH, EPA (2002b) recommends that data should be within the range 6.5–9. However, this report follows Georgia regulations (pH > 6.0).

Table B-2 (continued). Recent available data (since 1999) for surface water quality in the OCMU area (UC—unacceptable conditions; nd—not detectable; sv—single value; SRP—soluble reactive phosphorus; sources: GA DNR-EPD via STORET, MWA, and City of Macon).[a, b, c, d]

Site of monitoring	Parameter	Date	n	Mean (range) or single value (sv)	Median	# of UCs
GEPD 5010001	Temperature (°C)	Jan 99–Dec 00	43	20.4 (5–34.5[e])	20.5	4[e]
	Discharge (cfs)	Jan 99–Dec 00	45	1,329 (264–9,060)	850	–
	Stream stage height (ft)	Jan 99–Dec 00	45	6.9 (4.97–15.75)	6.25	–
	Turbidity (NTU)	Jan 99–Dec 00	24	7.8[g] (1–34[g])	5.5	12[g]
	Spec. cond. (µmhos/cm, field)	Jan 99–Dec 00	45	127 (81–173)	126	–
	DO (mg/L)	Jan 99–Dec 00	42	8.8 (6.8–12.6)	8.05	–
	pH	Jan 99–Dec 00	43	7.4 (6.7–8.0)	7.4	–
	$NO_3^-N + NO_2^-N$ (µg/L)	Jan 99–Dec 00	24	480[f] (20–840[f])	460[f]	23[f]
	NH_4+N (µg/L)	Jan 99–Dec 00	24	40 (30–130)	30	–
	TKN (µg/L)	Jan 99–Dec 00	24	1,055[f] (180–19,000[f])	270[f]	13[f]
	TP (µg/L)	Jan 99–Dec 00	24	28 (20–60)	22	7
	BOD_5 (mg/L)	Jan 99–Dec 00	24	2 (2–2)	2	–

[a] For computing means and medians, all values reported by the data source as less than the level of detection or the reporting limit were replaced with half the value of the method detection limit, following Ellis and Gilbert (1980) and Zirschky et al. (1985).

[b] Values for toxic metals (cadmium, copper, lead, zinc) were reported as "less than" a range of values that include the CCC; or, for chromium, the species was not designated.

[c] Selected parameters included those most commonly considered in water quality assessment; most of those that were not included here also had been sampled infrequently (1 or a few dates).

[d] More than 50% of the samples were below detection or below the reporting limit with the analytical technique used; thus, statistical interpretation was not attempted

[e] Underlined—in violation of state standard (GA DNR 2008d), except for fecal coliforms. This table considers all fecal coliform and *Escherichia coli* data collectively, whereas Appendix 2 considers data amenable to calculation of GMs. Since only a portion of the bacterial data were collected with sufficient frequency to enable calculation of GMs—which are used for the state standards—these data were evaluated here as follows: Fecal coliforms > 400 mpn/100 mL level, which is the criterion recommended by the EPA (2003) for data collected too infrequently for calculation of GMs by the state's criterion (at least 4 samples collected within a 30-day period) and *E. coli* > 235 mpn/100 mL (single sample).

[f] Blue—exceeds the EPA (2000) recommendation for acceptable water quality; or exceeds recommended values to protect aquatic life (BOD_5—see Mallin 2006).

[g] Red—exceeds EPA (2000) recommendation for acceptable water quality (for TSS, <10 mg/L increase (spike); for metals (Al, Cu, Hg, Pb, Ni, Zn), see p.68 of this report). For pH, EPA (2002b) recommends that data should be within the range 6.5–9. However, this report follows Georgia regulations (pH > 6.0).

Table B-2 (continued). Recent available data (since 1999) for surface water quality in the OCMU area (UC—unacceptable conditions; nd—not detectable; sv—single value; SRP—soluble reactive phosphorus; sources: GA DNR-EPD via STORET, MWA, and City of Macon).[a, b, c, d]

Site of monitoring	Parameter	Date	n	Mean (range) or single value (sv)	Median	# of UCs
GEPD 5010001 (continued)	TSS (mg/L)	Jan 99–Dec 00	24	10.1 [g] (2–42) [g]	7	7
	Alkalinity, carbonate as $CaCO_3$ (mg/L)	Jan 99–Dec 00	24	31 (17–72)	30.5	–
	Fecal coliforms (mpn/100 mL)	Jan 99–Oct 99	24	170 (nd–700 [e])	50	2 [e]

[a] For computing means and medians, all values reported by the data source as less than the level of detection or the reporting limit were replaced with half the value of the method detection limit, following Ellis and Gilbert (1980) and Zirschky et al. (1985).

[b] Values for toxic metals (cadmium, copper, lead, zinc) were reported as "less than" a range of values that include the CCC; or, for chromium, the species was not designated.

[c] Selected parameters included those most commonly considered in water quality assessment; most of those that were not included here also had been sampled infrequently (1 or a few dates).

[d] More than 50% of the samples were below detection or below the reporting limit with the analytical technique used; thus, statistical interpretation was not attempted

[e] Underlined—in violation of state standard (GA DNR 2008d), except for fecal coliforms. This table considers all fecal coliform and *Escherichia coli* data collectively, whereas Appendix 2 considers data amenable to calculation of GMs. Since only a portion of the bacterial data were collected with sufficient frequency to enable calculation of GMs—which are used for the state standards—these data were evaluated here as follows: Fecal coliforms > 400 mpn/100 mL level, which is the criterion recommended by the EPA (2003) for data collected too infrequently for calculation of GMs by the state's criterion (at least 4 samples collected within a 30-day period) and *E. coli* > 235 mpn/100 mL (single sample).

[f] Blue—exceeds the EPA (2000) recommendation for acceptable water quality; or exceeds recommended values to protect aquatic life (BOD_5—see Mallin 2006).

[g] Red—exceeds EPA (2000) recommendation for acceptable water quality (for TSS, <10 mg/L increase (spike); for metals (Al, Cu, Hg, Pb, Ni, Zn), see p.68 of this report). For pH, EPA (2002b) recommends that data should be within the range 6.5–9. However, this report follows Georgia regulations (pH > 6.0).

Table B-3. Recent available data (since 1999) for surface water quality (toxic concentrations) at two locations in the OCMU area (sources: GA DNR- via STORET, MWA, and City of Macon)[a] [Sb=Antimony; As=Arsenic; Cd=Cadmium; Ca=Calcium; Cr=Chromium; Cu=Copper; Pb=Lead; Mg=Magnesium; Hg=Mercury; Ni=Nickel; Se=Selenium; Tl=Thallium; and Zn=Zinc].

Proximity to OCMU/ Site	Date	Sb (µg/L)	As (µg/L)	Cd (µg/Lc)	Ca (µg/L)	Cr (µg/L)	Cu (µg/L)	Pb (µg/L)	Mg (µg/L)	Hg (µg/L)	Ni (µg/L)	Se (µg/L)	Tl (µg/L)	Zn (µg/L)
Walnut Creek, OCMU/ GA DNR 5011251	16 Sep 1999	1	2	0.5	11,000	1	1	2	4,200	0.1	1	2	2	5
	8 Mar 2000	1	2	0.5	7,800	1	1	1	3,300	0.1	1	2	2	6
Upstream from OCMU— Ocmulgee River/ GA DNR 5010001	1 Feb 2000	1	2	0.5	6,100	6	7	**6**[b]	2,800	0.1	3	2	2	25
	16 Sep 1999	1	2	0.5	12,000	1	1	1	2,700	0.1	1	2	2	3
	8 Mar 2000	1	1	0.5	7,100	1	1	1	2,000	0.1	1	2	2	1
	13 Jun 2000	1	3	0.5	10,000	3	1	2	2,500	0.1	2	2	2	7
	14 Nov 2000	1	4	0.5	11,000	1	2	2	2,400	0.1	1	4	2	15

[a]All values reported by the data source as less than the level of detection or the reporting limit were replaced with ½ the value, following Ellis and Gilbert (1980) and Zirschky et al. (1985).

[b].(Red) Exceeds EPA (2000) recommendation for acceptable water quality (for TSS, <10 mg/L increase (spike); for metals (Pb, Zn) see Table 24.

Table B-4. Recent available data (since 1999) for surface water quality parameters (n=1) at Walnut Creek (at Jeffersonville Rd.), upstream from OCMU [brl—below reporting limits; sv—single value; source: City of Macon]. Selected parameters included those most commonly considered in water quality assessment; most of those that were not included here also had been sampled infrequently (one or a few dates).

Water Quality (n = 1)	**15 Nov 07**	**11 Jan 08**	**20 Mar 08**
pH	sv 6.94	sv 6.38	sv 7.13
BOD_5 (mg/L)	brl	brl	sv 22.8
COD (mg/L)	sv 22	sv 20	sv 43
TP (µg/L)	sv 82	sv 112	sv 103
TSS (mg/L)	sv 108	sv 87	sv 70
TDS (mg/L)	sv 91	sv 91	sv 61
TKN (µg/L)	brl	brl	sv 60
NO_x (µg/L)	sv 97	sv 344	sv 171
Fecal coliforms (mpn/100 mL)	sv 150	sv 7,000	sv 4,500
Total coliforms, *Escherichia coli* (mpn/100 mL)	sv 11,000	sv > 24,196	sv 16,000
Lead (µg/L)	sv 3.27	sv 10.7	sv 5.15
Zinc (µg/L)	sv 105	sv 104	sv 74
Tetrachoroethane (volatile organic, µg/L)	sv 8.8	brl	brl

Appendix C. List of All Exotic Species of Vascular Plants in Ocmulgee.

Table C-1. Terrestrial vascular plant taxa in OCMU, modified from the NPS Certified Species List (NPS 2013a) following Zomlefer et al. (2013). Notes on habitat and abundance are from Zomlefer et al. (2013). From Zomlefer et al. (2013). (Hab.—habitat; Abund.—abundance; DA—disturbed area; FP—floodplain swamp; LM—Lamar Unit; PM—pond or marsh with open water; UF—upland forest; c—common; i—infrequent; o—occasional; r—rare).

Scientific Name	Common Name	Notes on Hab./Abund.
Acer floridanum[a]	Southern sugar maple, Florida maple, hammock maple	UF; i
Aesculus pavia	Red buckeye	FP, UF
Agalinis fasciculata[b]	Beach false foxglove	DA; i-c
Agrimonia pubescens[b]	Downy agrimony	LM Unit: DA, FP; o
Ailanthus altissima[f]	Tree-of-heaven, tree of heaven, ailanthus, copal tree	DA; o
Albizia julibrissin[f]	Silktree, mimosa, mimosa tree, powderpuff tree	DA, UF
Amaranthus viridis[b,f]	Slender amaranth	DA
Ambrosia artemisiifolia	Ragweed, annual ragweed, common ragweed, low ragweed	DA; c
Andropogon glomeratus[b]	Bushy bluestem	DA; o
Andropogon ternarius var. *ternarius*[b]	Splitbeard bluestem	DA; o

[a] Following Zomlefer et al. (2013), synonyms in the NPS Certified Species List are as follows:

Acer floridanum—synonym is *Acer barbatum*
Aphanes australis—synonym is *Aphanes microcarpa*
Brickellia eupatorioides—synonym is *Kuhnia eupatorioides*
Carex albicans var. *australis*—synonym is *Carex albicans*
Carya tomentosa—synonym is *Carya alba*
Dysphania ambrosioides—synonym is *Chenopodium abrosioides*
Cynodon dactylon var. *dactylon*—synonym is *Cynodon dactylon*
Erigeron strigosus var. *strigosus*—synonym is *Erigeron strigosus*
Galium sherardia—synonym is *Sherardia arvensis*
Lolium perenne var. *aristatum*—synonym is *Lolium perenne*
Passiflora lutea var. *lutea*—synonym is *Passiflora lutea*
Pleopeltis polypodioides var. *michauxiana*—synonym is *Polypodium polypodioides*
Polygonatum biflorum var. *biflorum*—synonym is *Polygonatum biflorum*
Potentilla indica—synonym is *Duchesnea indica*
Prunus angustifolia var. *angustifolia*—synonym is *Prunus angustifolia*
Prunus serotina var. *serotine*—synonym is *Prunus serotine*
Pueraria montana var. *lobate*—synonym is *Pueraria lobate*
Rhus copallinum—synonym is *Rhus copallina*

[b] Not previously included in the NPS Certified Species List for OCMU.

[c] *Bidens bipinnata* is listed by the GA EPPC as a Category #4 exotic / invasive species, but it is a native species (Weakley 2008, ITIS 2012).

[d] *Bromus racemosus* is described in the text of Zomlefer et al. (2013) as common in disturbed areas, but is missing from the Annotated Checklist.

[e] *Crataegus flava* (USDA Plants Database) is given in Zomlefer et al. (2013) as *Crataegus aprica*.

[f] Exotic/invasive taxa.

Table C-1 (continued). Terrestrial vascular plant taxa in OCMU, modified from the NPS Certified Species List (NPS 2013a) following Zomlefer et al. (2013). Notes on habitat and abundance are from Zomlefer et al. (2013). From Zomlefer et al. (2013). (Hab.—habitat; Abund.—abundance; DA—disturbed area; FP—floodplain swamp; LM—Lamar Unit; PM—pond or marsh with open water; UF—upland forest; c—common; i—infrequent; o—occasional; r—rare).

Scientific Name	Common Name	Notes on Hab./Abund.
Aphanes australis[a,f]	Parsley-piert, slender parsley piert	DA; o
Arabidopsis thaliana[f]	Mouse-ear cress, mouseear cress	DA
Aristida purpurascens[b]	Arrowfeather	DA; i-c
Asparagus officinalis[f]	Asparagus, garden asparagus, garden-asparagus	DA; i
Asplenium platyneuron	Ebony spleenwort	ferns and allies DA, UF; i-o
Bidens bipinnata[c]	Spanish needles, spanish-needles	–
Brickellia eupatorioides[a]	False boneset	UF
Bromus catharticus var. *catharticus*[b,f]	Rescue grass	DA; o-c
Bromus commutatus[b]	Hairy chess	DA; c
Bromus racemosus[d,f]	Bald brome	–
Callicarpa americana	Beautyberry, American beautyberry	UF; i

[a] Following Zomlefer et al. (2013), synonyms in the NPS Certified Species List are as follows:

Acer floridanum—synonym is *Acer barbatum*
Aphanes australis—synonym is *Aphanes microcarpa*
Brickellia eupatorioides—synonym is *Kuhnia eupatorioides*
Carex albicans var. *australis*—synonym is *Carex albicans*
Carya tomentosa—synonym is *Carya alba*
Dysphania ambrosioides—synonym is *Chenopodium abrosioides*
Cynodon dactylon var. *dactylon*—synonym is *Cynodon dactylon*
Erigeron strigosus var. *strigosus*—synonym is *Erigeron strigosus*
Galium sherardia—synonym is *Sherardia arvensis*
Lolium perenne var. *aristatum*—synonym is *Lolium perenne*
Passiflora lutea var. *lutea*—synonym is *Passiflora lutea*
Pleopeltis polypodioides var. *michauxiana*—synonym is *Polypodium polypodioides*
Polygonatum biflorum var. *biflorum*—synonym is *Polygonatum biflorum*
Potentilla indica—synonym is *Duchesnea indica*
Prunus angustifolia var. *angustifolia*—synonym is *Prunus angustifolia*
Prunus serotina var. *serotine*—synonym is *Prunus serotine*
Pueraria montana var. *lobate*—synonym is *Pueraria lobate*
Rhus copallinum—synonym is *Rhus copallina*

[b] Not previously included in the NPS Certified Species List for OCMU.

[c] *Bidens bipinnata* is listed by the GA EPPC as a Category #4 exotic / invasive species, but it is a native species (Weakley 2008, ITIS 2012).

[d] *Bromus racemosus* is described in the text of Zomlefer et al. (2013) as common in disturbed areas, but is missing from the Annotated Checklist.

[e] *Crataegus flava* (USDA Plants Database) is given in Zomlefer et al. (2013) as *Crataegus aprica*.

[f] Exotic/invasive taxa.

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Scientific Name	Common Name	Notes on Hab./Abund.
Capsella bursa-pastoris[f]	Common shepherd's purse, shepardspurse, shepherd's purse	DA; o
Carex albicans var. *australis*[a]	Stellate sedge, whitetinge sedge	UF; o
Carex blanda	Eastern woodland sedge	UF; i
Carex cephalophora[b]	Oval-leaf sedge	DA; i
Carex digitalis var. *floridana*[b]	Slender woodland sedge	DA
Carex laxiflora[b]	Broad looseflower sedge	UF; i
Carex leavenworthii[b]	Leavenworth's sedge	DA
Carex muehlenbergii var. *muehlenbergii*[b]	Muehlenberg's sedge	DA
Carex retroflexa	Reflexed sedge	DA; i-o
Carex striatula[b]	Lined sedge	UF; i
Carya ovata[b]	Common shagbark hickory	UF; o-c
Carya pallida	Sand hickory	UF
Carya tomentosa[a]	Mockernut hickory	UF

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Acer floridanum—synonym is *Acer barbatum*
Aphanes australis—synonym is *Aphanes microcarpa*
Brickellia eupatorioides—synonym is *Kuhnia eupatorioides*
Carex albicans var. *australis*—synonym is *Carex albicans*
Carya tomentosa—synonym is *Carya alba*
Dysphania ambrosioides—synonym is *Chenopodium abrosioides*
Cynodon dactylon var. *dactylon*—synonym is *Cynodon dactylon*
Erigeron strigosus var. *strigosus*—synonym is *Erigeron strigosus*
Galium sherardia—synonym is *Sherardia arvensis*
Lolium perenne var. *aristatum*—synonym is *Lolium perenne*
Passiflora lutea var. *lutea*—synonym is *Passiflora lutea*
Pleopeltis polypodioides var. *michauxiana*—synonym is *Polypodium polypodioides*
Polygonatum biflorum var. *biflorum*—synonym is *Polygonatum biflorum*
Potentilla indica—synonym is *Duchesnea indica*
Prunus angustifolia var. *angustifolia*—synonym is *Prunus angustifolia*
Prunus serotina var. *serotine*—synonym is *Prunus serotine*
Pueraria montana var. *lobate*—synonym is *Pueraria lobate*
Rhus copallinum—synonym is *Rhus copallina*

[b] Not previously included in the NPS Certified Species List for OCMU.

[c] *Bidens bipinnata* is listed by the GA EPPC as a Category #4 exotic / invasive species, but it is a native species (Weakley 2008, ITIS 2012).

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Castanea pumila	Allegeny chinkapin, allegheny chinkapin, chinkapin	UF
Centrosema virginianum	Spurred butterfly-pea, butterflypea	DA; i
Cerastium glomeratum	Sticky mouse-ear, sticky chickweed	DA; i
Cercis canadensis	Eastern redbud, redbud	DA/UF; o-c
Cnidoscolus stimulosus	Spurge-nettle, finger rot	DA; i
Cocculus carolinus	Coralbeeds	–
Cornus florida	Flowering dogwood	UF
Crataegus aprica[b]	Sunny hawthorn, yellowleaf hawthorn	DA; o
Crataegus dispar[b]	Aiken hawthorn	UF; r
Crataegus uniflora	Oneflower hawthorn, dwarf hawthorn	UF
Croton capitatus[f]	Woolly croton, doveweed, hogweed, hogwort	DA
Cynodon dactylon var. *dactylon*[a,f]	Bermuda grass, chiendent pied-de-poule, common bermudagrass	DA; c
Dactylis glomerata[b,f]	Orchard grass	DA; c

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Pueraria montana var. *lobate*—synonym is *Pueraria lobate*
Rhus copallinum—synonym is *Rhus copallina*

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Scientific Name	Common Name	Notes on Hab./Abund.
Danthonia spicata	Poverty danthonia, poverty oatgrass, poverty wild oat grass	DA; o
Desmodium ciliare[b]	Hairy small-leaf ticktrefoil	DA; i
Desmodium paniculatum var. *paniculatum*	Panicled tick-trefoil	DA
Dichanthelium aciculare	Witch grass, needleleaf rosette grass	DA; o
Dichanthelium commutatum var. *commutatum*[b]	Variable witch grass	UF?
Dichanthelium scoparium	Velvet witch grass, velvet panicum	DA
Digitaria ciliaris[b,f]	Southern crab grass	DA
Dysphania ambrosioides[a,f]	Mexican tea, Mexican-tea	DA; i
Elaeagnus pungens[a,f]	Thorny-olive	UF
Elephantopus carolinianus[b]	Leafy elephant's-foot	DA, UF; o
Eragrostis curvula[b,f]	Weeping lovegrass	DA; c

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Prunus serotina var. *serotine*—synonym is *Prunus serotine*
Pueraria montana var. *lobate*—synonym is *Pueraria lobate*
Rhus copallinum—synonym is *Rhus copallina*

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Scientific Name	Common Name	Notes on Hab./Abund.
Erechtites hieraciifolius[b]	Fireweed	PM; c
Erigeron strigosus var. *strigosus*[a]	Common rough fleabane, daisy fleabane, prairie fleabane, rough fleabane	DA; o-c
Erythronium umbilicatum[b]	Trout lily	UF; i
Eupatorium hyssopifolium[b]	Hyssopleaf eupatorium	DA; c
Euphorbia cyathophora[b]	Painted leaf	DA; i
Euphorbia hyssopifolia	Hyssopleaf sandmat	DA; i
Facelis retusa[b,f]	Trampweed, annual trampweed	DA; i
Fagus grandifolia	American beech	UF; i
Festuca subverticillata[b]	Nodding fescue	DA; c
Galium sherardia[a,f]	Field-madder, blue field-madder	DA; o
Galium triflorum[b]	Sweet-scented bedstraw	PM; r
Gamochaeta pensylvanica[b]	Pennsylvania everlasting	DA; o

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Scientific Name	Common Name	Notes on Hab./Abund.
Gamochaeta purpurea[b]	Spoonleaf purple everlasting	DA; i
Geranium carolinianum	Carolina crane's-bill, Carolina geranium	DA; i
Geranium molle[b,f]	Dove's-foot crane's-bill	DA
Glandularia pulchella[f]	Moss vervain, South American mock vervain	DA; o-c
Gomphrena serrata	Arrasa con todo	DA
Halesia carolina	Little silverbell, Carolina silverbell, silverbell	UF; i
Hedera helix[f]	English ivy	UF; c
Helenium amarum[f]	Bitterweed, bitter sneezeweed	–
Heterotheca latifolia var. *latifolia*[b,f]	Common camphorweed	DA; i
Hexastylis arifolia	Little brown jug, littlebrownjug	UF; i
Houstonia pusilla[b]	Tiny bluet	DA; c
Hydrangea quercifolia	Oakleaf hydrangea	UF
Hypericum gentianoides	Pineweed, orangegrass, pinweed st. johnswort	DA; o

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Hypochaeris radicata[f]	Spotted cat's-ear, common cat's-ear, false dandelion, frogbit	DA
Ilex ambigua	Carolina holly	UF
Ilex cornuta[f]	Chinese holly	–
Juniperus virginiana	Southern (eastern) red cedar	UF, i
Koelreuteria paniculata[f]	Golden rain tree	DA; i
Krigia virginica	Virginia dwarf-dandelion	DA; o
Lamium amplexicaule[f]	Henbit, common henbit, giraffehead	DA; o
Lamium purpureum[f]	Purple dead-nettle, dead nettle	DA
Lechea mucronata	Hairy pinweed	DA; r
Lechea racemulosa	Illinois pinweed	DA; i
Lepidium virginicum ssp. *virginicum*[b]	Poor man's pepper	DA; i
Lespedeza cuneata[b,f]	Sericea lespedeza	DA; c
Lespedeza stuevei[b]	Velvety lespedeza	DA; o

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Ligustrum japonicum[f]	Japanese privet	DA; o
Liriope spicata[b,f]	Creeping lilyturf	UF; i
Lolium perenne var. *aristatum*[f]	Italian ryegrass, winter rye grass	–
Lonicera fragrantissima[f]	Sweet breath of spring	DA; i
Lunaria annua[f]	Annual honesty	DA; i
Luzula bulbosa[b]	Bulbous woodsedge	DA; i
Malus angustifolia	Wild crabapple, southern crabapple	DA, UF
Melia azedarach[f]	Chinaberry, Chinaberry tree, Chinaberrytree	DA
Melica mutica	Two-flower melic, melic grass	DA, UF; i
Mirabilis jalapa[b,f]	Garden four-o'clock	DA; o
Monarda punctata	Eastern horse-mint, spotted beebalm	DA
Morella cerifera	Common wax-myrtle, wax myrtle, waxmyrtle	DA
Morus alba[f]	White mulberry, mulberry	DA; r-c
Nandina domestica[f]	Sacred-bamboo, nandina	DA, UF

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Scientific Name	Common Name	Notes on Hab./Abund.
Nemophila aphylla	Smallflower baby blue eyes	DA; o-c
Nuttallanthus canadensis	Common toadflax, Canada toadflax, oldfield toadflax, oldfield-toadflax	DA; i
Oenothera laciniata[b]	Cutleaf evening-primrose	DA
Oplismenus hirtellus	Woods-grass, bristle basketgrass	DA, FP, UF; c
Opuntia humifusa[b]	Southern prickly-pear	DA; i-c
Ostrya virginiana	American hop-hornbeam, eastern hophornbeam, hophornbeam	FP, UF; i-o
Oxalis articulata[b,f]	Windowbox wood-sorrel	DA; o
Oxalis dillenii[b]	Southern yellow wood-sorrel	DA; i
Passiflora incarnata	Maypops; purple passionflower	DA; o
Passiflora lutea var. lutea[a]	Eastern yellow passionflower, yellow passion-plant	UF
Perilla frutescens[f]	Beefsteak plant, beefsteakplant, beefsteak, beefsteak mint, purple perilla, purple mint	LM Unit: DA; c
Phoradendron serotinum ssp. *serotinum*	American mistletow	DA; o

[a] Following Zomlefer et al. (2013), synonyms in the NPS Certified Species List are as follows:

Acer floridanum—synonym is *Acer barbatum*
Aphanes australis—synonym is *Aphanes microcarpa*
Brickellia eupatorioides—synonym is *Kuhnia eupatorioides*
Carex albicans var. *australis*—synonym is *Carex albicans*
Carya tomentosa—synonym is *Carya alba*
Dysphania ambrosioides—synonym is *Chenopodium abrosioides*
Cynodon dactylon var. *dactylon*—synonym is *Cynodon dactylon*
Erigeron strigosus var. *strigosus*—synonym is *Erigeron strigosus*
Galium sherardia—synonym is *Sherardia arvensis*
Lolium perenne var. *aristatum*—synonym is *Lolium perenne*
Passiflora lutea var. *lutea*—synonym is *Passiflora lutea*
Pleopeltis polypodioides var. *michauxiana*—synonym is *Polypodium polypodioides*
Polygonatum biflorum var. *biflorum*—synonym is *Polygonatum biflorum*
Potentilla indica—synonym is *Duchesnea indica*
Prunus angustifolia var. *angustifolia*—synonym is *Prunus angustifolia*
Prunus serotina var. *serotine*—synonym is *Prunus serotine*
Pueraria montana var. *lobate*—synonym is *Pueraria lobate*
Rhus copallinum—synonym is *Rhus copallina*

[b] Not previously included in the NPS Certified Species List for OCMU.

[c] *Bidens bipinnata* is listed by the GA EPPC as a Category #4 exotic / invasive species, but it is a native species (Weakley 2008, ITIS 2012).

[d] *Bromus racemosus* is described in the text of Zomlefer et al. (2013) as common in disturbed areas, but is missing from the Annotated Checklist.

[e] *Crataegus flava* (USDA Plants Database) is given in Zomlefer et al. (2013) as *Crataegus aprica*.

[f] Exotic/invasive taxa.

Table C-1 (continued). Terrestrial vascular plant taxa in OCMU, modified from the NPS Certified Species List (NPS 2013a) following Zomlefer et al. (2013). Notes on habitat and abundance are from Zomlefer et al. (2013). From Zomlefer et al. (2013). (Hab.—habitat; Abund.—abundance; DA—disturbed area; FP—floodplain swamp; LM—Lamar Unit; PM—pond or marsh with open water; UF—upland forest; c—common; i—infrequent; o—occasional; r—rare).

Scientific Name	Common Name	Notes on Hab./Abund.
Phyllostachys aurea[f]	Golden bamboo, bamboo	DA; c
Pinus palustris	Longleaf pine	not in Zomlefer et al. (2013)
Pinus taeda	Loblolly pine	DA, UF, i
Piptochaetium avenaceum	Eastern needlegrass, blackseeded needlegrass	DA; o-c
Pityopsis graminifolia var. *graminifolia*	Narrowleaf silkgrass, narrow-leaved silkgrass	DA
Plantago aristata[f]	Buckthorn plantain	DA; o
Plantago lanceolata[b,f]	English plantain	DA; o
Plantago rugellii [b]	American plantain	LM Unit: DA; o
Plantago wrightiana[b]	Wright's plantain	DA; o
Pleopeltis polypodioides var. *michauxiana*[a]	Resurrection fern	ferns & allies UF; c
Poa compressa[b,f]	Canada bluegrass	DA; i

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Acer floridanum—synonym is *Acer barbatum*
Aphanes australis—synonym is *Aphanes microcarpa*
Brickellia eupatorioides—synonym is *Kuhnia eupatorioides*
Carex albicans var. *australis*—synonym is *Carex albicans*
Carya tomentosa—synonym is *Carya alba*
Dysphania ambrosioides—synonym is *Chenopodium abrosioides*
Cynodon dactylon var. *dactylon*—synonym is *Cynodon dactylon*
Erigeron strigosus var. *strigosus*—synonym is *Erigeron strigosus*
Galium sherardia—synonym is *Sherardia arvensis*
Lolium perenne var. *aristatum*—synonym is *Lolium perenne*
Passiflora lutea var. *lutea*—synonym is *Passiflora lutea*
Pleopeltis polypodioides var. *michauxiana*—synonym is *Polypodium polypodioides*
Polygonatum biflorum var. *biflorum*—synonym is *Polygonatum biflorum*
Potentilla indica—synonym is *Duchesnea indica*
Prunus angustifolia var. *angustifolia*—synonym is *Prunus angustifolia*
Prunus serotina var. *serotine*—synonym is *Prunus serotine*
Pueraria montana var. *lobate*—synonym is *Pueraria lobate*
Rhus copallinum—synonym is *Rhus copallina*

[b] Not previously included in the NPS Certified Species List for OCMU.

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[d] *Bromus racemosus* is described in the text of Zomlefer et al. (2013) as common in disturbed areas, but is missing from the Annotated Checklist.

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[f] Exotic/invasive taxa.

Table C-1 (continued). Terrestrial vascular plant taxa in OCMU, modified from the NPS Certified Species List (NPS 2013a) following Zomlefer et al. (2013). Notes on habitat and abundance are from Zomlefer et al. (2013). From Zomlefer et al. (2013). (Hab.—habitat; Abund.—abundance; DA—disturbed area; FP—floodplain swamp; LM—Lamar Unit; PM—pond or marsh with open water; UF—upland forest; c—common; i—infrequent; o—occasional; r—rare).

Scientific Name	Common Name	Notes on Hab./Abund.
Podophyllum peltatum	May-apple, May apple, mayapple	UF; o
Polygonatum biflorum var. *biflorum*[a]	Small Solomon's-seal, King Solomon's seal, King Solomon's-seal, smooth Solomon's seal	UF; i
Polystichum acrostichoides	Christmas fern	ferns & allies
Potentilla indica[a,f]	Indian-strawberry	DA
Prunus angustifolia var. angustifolia[a]	Chickasaw plum	DA
Prunus caroliniana	Carolina laurel cherry	DA, UF; c
Prunus serotina var. *serotina*[a]	Black cherry, black chokecherry	DA, UF; o
Ptelea trifoliata	Hop-tree, hoptree, common hoptree	UF; o
Pteridium aquilinum	Bracken, bracken fern, brackenfern	ferns & allies UF; O
Pueraria montana var. *lobata*[a,f]	Kudzu, kudzu vine	DA; c
Quercus coccinea[b]	Scarlet oak	LM Unit: DA, FP; i
Quercus falcata	Spanish oak, southern red oak	UF

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Carex albicans var. *australis*—synonym is *Carex albicans*
Carya tomentosa—synonym is *Carya alba*
Dysphania ambrosioides—synonym is *Chenopodium abrosioides*
Cynodon dactylon var. *dactylon*—synonym is *Cynodon dactylon*
Erigeron strigosus var. *strigosus*—synonym is *Erigeron strigosus*
Galium sherardia—synonym is *Sherardia arvensis*
Lolium perenne var. *aristatum*—synonym is *Lolium perenne*
Passiflora lutea var. *lutea*—synonym is *Passiflora lutea*
Pleopeltis polypodioides var. *michauxiana*—synonym is *Polypodium polypodioides*
Polygonatum biflorum var. *biflorum*—synonym is *Polygonatum biflorum*
Potentilla indica—synonym is *Duchesnea indica*
Prunus angustifolia var. *angustifolia*—synonym is *Prunus angustifolia*
Prunus serotina var. *serotine*—synonym is *Prunus serotine*
Pueraria montana var. *lobate*—synonym is *Pueraria lobate*
Rhus copallinum—synonym is *Rhus copallina*

[b] Not previously included in the NPS Certified Species List for OCMU.

[c] *Bidens bipinnata* is listed by the GA EPPC as a Category #4 exotic / invasive species, but it is a native species (Weakley 2008, ITIS 2012).

[d] *Bromus racemosus* is described in the text of Zomlefer et al. (2013) as common in disturbed areas, but is missing from the Annotated Checklist.

[e] *Crataegus flava* (USDA Plants Database) is given in Zomlefer et al. (2013) as *Crataegus aprica*.

[f] Exotic/invasive taxa.

Table C-1 (continued). Terrestrial vascular plant taxa in OCMU, modified from the NPS Certified Species List (NPS 2013a) following Zomlefer et al. (2013). Notes on habitat and abundance are from Zomlefer et al. (2013). From Zomlefer et al. (2013). (Hab.—habitat; Abund.—abundance; DA—disturbed area; FP—floodplain swamp; LM—Lamar Unit; PM—pond or marsh with open water; UF—upland forest; c—common; i—infrequent; o—occasional; r—rare).

Scientific Name	Common Name	Notes on Hab./Abund.
Quercus velutina	Black oak	UF; LM Unit: DA, FP; i
Rhus copallinum[a]	Winged sumac	–
Richardia brasiliensis[f]	Tropical Mexican-clover	DA?
Ruellia caroliniensis	Wild petunia, Carolina wild petunia	DA; o
Rumex hastatulus[b]	Wild dock	DA; c
Saccharum giganteum	Sugarcane plume grass	DA
Salpichroa origanifolia[b,f]	Lily-of-the-valley vine	DA; o
Salvia lyrata	Lyreleaf sage	DA
Sassafras albidum	Sassafras	–
Schedonorus arundinaceus[b,f]	Tall fescue	DA; i-c
Senna obtusifolia[f]	Sicklepod; Java-bean	DA; o
Sida rhombifolia[f]	Arrowleaf sida, cuban jute, Cuban-jute	DA
Sideroxylon lanuginosum[b]	Gum bumelia	UF; r-i
Sideroxylon lycioides	Buckthorn bumelia, silky buckthorn	DA, PM; r-i
Solidago altissima var. *altissima*[b]	Tall goldenrod	DA; i-c

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Lolium perenne var. *aristatum*—synonym is *Lolium perenne*
Passiflora lutea var. *lutea*—synonym is *Passiflora lutea*
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Prunus serotina var. *serotine*—synonym is *Prunus serotine*
Pueraria montana var. *lobate*—synonym is *Pueraria lobate*
Rhus copallinum—synonym is *Rhus copallina*

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[f] Exotic/invasive taxa.

Table C-1 (continued). Terrestrial vascular plant taxa in OCMU, modified from the NPS Certified Species List (NPS 2013a) following Zomlefer et al. (2013). Notes on habitat and abundance are from Zomlefer et al. (2013). From Zomlefer et al. (2013). (Hab.—habitat; Abund.—abundance; DA—disturbed area; FP—floodplain swamp; LM—Lamar Unit; PM—pond or marsh with open water; UF—upland forest; c—common; i—infrequent; o—occasional; r—rare).

Scientific Name	Common Name	Notes on Hab./Abund.
Sorghum bicolor[b,f]	Sorghum	DA; i
Spiraea cantoniensis[e,f]	Reeve's meadowsweet	UF? Cultivated?
Spiraea thunbergii[e,f]	Thunberg's meadowsweet	UF? Cultivated?
Stellaria media[f]	Chickweed, common chickweed, nodding chickweed	DA; i
Tephrosia spicata[b]	Spiked hoarypea	DA; i
Tillandsia usneoides	Spanish-moss, Spanish moss	FP; o
Tipularia discolor	Cranefly orchid, crippled cranefly	UF; r
Trichostema dichotomum	Common blue curles, blue curls, forked bluecurls	DA, UF
Tridens flavus	Redtop, purpletop, purpletop tridens	DA
Trifolium arvense[b,f]	Rabbitfoot clover	DA; c
Trifolium dubium[f]	Low hop clover, hop clover, smallhop clover, suckling clover	DA; i
Triodanis biflora	Small Venus' looking-glass	DA; I [can hybridize with *T. perfoliata*]
Vaccinium arboreum	Sparkleberry, tree sparkleberry, tree-huckelberry	unknown

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Passiflora lutea var. *lutea*—synonym is *Passiflora lutea*
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Pueraria montana var. *lobate*—synonym is *Pueraria lobate*
Rhus copallinum—synonym is *Rhus copallina*

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Scientific Name	Common Name	Notes on Hab./Abund.
Vaccinium corymbosum	Smooth highbush blueberry, highbush blueberry	DA
Verbascum thapsus[f]	Woolly mullein, big taper, common mullein, flannel mullein	DA; r
Verbena rigida[f]	Tuberous vervain	DA; o
Veronica arvensis	Corn speedwell, common speedwell	DA
Vicia hirsuta[b,f]	Tiny vetch	DA
Vicia lathyroides[b,f]	Spring vetch	DA
Vicia sativa ssp. *nigra*[f]	Narrowleaf vetch, garden vetch	DA
Vicia tetrasperma[b,f]	Slender vetch	DA
Viola arvensis[b,f]	European field-pansy	DA; o
Vitis aestivalis var. *bicolor*[b]	Silverleaf grape	FP, PM
Vulpia myuros[b,f]	Rat-tail fescue	DA; c
Wahlenbergia marginata[f]	Southern rockbell	DA, UF; o
Wisteria sinensis[f]	Chinese wisteria	DA
Xanthium strumarium[b]	Cocklebur	DA, FP; c
Youngia japonica[f]	Asiatic hawk's-beard, oriental false hawksbeard	DA

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Passiflora lutea var. *lutea*—synonym is *Passiflora lutea*
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Prunus serotina var. *serotine*—synonym is *Prunus serotine*
Pueraria montana var. *lobate*—synonym is *Pueraria lobate*
Rhus copallinum—synonym is *Rhus copallina*

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[e] *Crataegus flava* (USDA Plants Database) is given in Zomlefer et al. (2013) as *Crataegus aprica*.

[f] Exotic/invasive taxa.

Table C-1 (continued). Terrestrial vascular plant taxa in OCMU, modified from the NPS Certified Species List (NPS 2013a) following Zomlefer et al. (2013). Notes on habitat and abundance are from Zomlefer et al. (2013). From Zomlefer et al. (2013). (Hab.—habitat; Abund.—abundance; DA—disturbed area; FP—floodplain swamp; LM—Lamar Unit; PM—pond or marsh with open water; UF—upland forest; c—common; i—infrequent; o—occasional; r—rare).

Scientific Name	Common Name	Notes on Hab./Abund.
Yucca filamentosa	Curlyleaf yucca, Adam's needle	DA, UF; i
Yucca gloriosa	Mound lily yucca, moundlily yucca, glorious yucca	DA

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Aphanes australis—synonym is *Aphanes microcarpa*
Brickellia eupatorioides—synonym is *Kuhnia eupatorioides*
Carex albicans var. *australis*—synonym is *Carex albicans*
Carya tomentosa—synonym is *Carya alba*
Dysphania ambrosioides—synonym is *Chenopodium abrosioides*
Cynodon dactylon var. *dactylon*—synonym is *Cynodon dactylon*
Erigeron strigosus var. *strigosus*—synonym is *Erigeron strigosus*
Galium sherardia—synonym is *Sherardia arvensis*
Lolium perenne var. *aristatum*—synonym is *Lolium perenne*
Passiflora lutea var. *lutea*—synonym is *Passiflora lutea*
Pleopeltis polypodioides var. *michauxiana*—synonym is *Polypodium polypodioides*
Polygonatum biflorum var. *biflorum*—synonym is *Polygonatum biflorum*
Potentilla indica—synonym is *Duchesnea indica*
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Prunus serotina var. *serotine*—synonym is *Prunus serotine*
Pueraria montana var. *lobate*—synonym is *Pueraria lobate*
Rhus copallinum—synonym is *Rhus copallina*

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[f] Exotic/invasive taxa.

Table C-2. Terrestrial plants on the NPS Certified Species List (2013a), omitted above following Zomlefer et al. (2013) (except not the longleaf pine).

Scientific Name	Common Name
Acalypha gracilens	Slender copperleaf, slender threeseed mercury
Amaranthus hybridus	Green pigweed, slim amaranth, smooth amaranth
Anemone berlandieri	Tenpetal thimbleweed
Aquilegia canadensis	Red columbine
Botrychium lunarioides	Winter grapefern
Cedrus deodara	Deodar cedar
Cenchrus tribuloides	Sanddune sandbur
Chamaecrista fasciculata	Partridge pea, Showy partridgepea, sleepingplant
Chimaphila maculata	Striped prince's pine, striped prince's-pine
Chrysogonum virginianum	Green and gold
Dichanthelium boscii	Bosc's panicgrass
Dioscorea floridana	Florida wild yam
Elaeagnus commutata	Silverberry
Erythrina herbacea	Eastern coralbean, redcardinal
Erythronium americanum	Dogtooth violet
Fragaria virginiana	Virginia strawberry
Geranium maculatum	Spotted crane's-bill, spotted geranium, wild crane's-bill
Heterotheca subaxillaris	Camphorweed, golden aster
Impatiens capensis	Jewelweed, spotted touch-me-not
Ipomoea nil[a]	Whiteedge morningglory, whiteedge morning-glory
Iris cristata	Dwarf crested iris
Juglans nigra	Black walnut
Leptoloma cognatum	Witch grass
Liriope muscari[a]	Monkey grass; liriope
Lolium pratense	Common fescue
Maclura pomifera	Bois d'arc, osage orange, osageorange
Maianthemum racemosum ssp. *racemosum [Smilacina racemosa]*	Feathery false lily of the valley
Matelea carolinensis	Maroon Carolina milkvine
Oenothera fruticosa	Narrowleaf evening-primrose
Oenothera speciosa	Pinkladies, showy evening primrose, showy eveningprimrose
Opuntia ficus-indica	Common yellow oxalis, erect woodsorrel, sheep sorrel
Oxalis stricta	Purple woodsorrel, violet woodsorrel, violet wood-sorrel

[a] The variety, *Gnaphalium obtusifolium* var. *obtusifolium*, included in the NPS Certified Species List, is not found in the USDA Plants Database, and likely should have been given as *Gnaphalium obtusifolium* ssp. *obtusifolium*. The latter taxon, in turn, is a synonym of *Pseudoghnaphalium obtusifolium* ssp. *obtusifolium*.

Table C-2 (continued). Terrestrial plants on the NPS Certified Species List (2013a), omitted above following Zomlefer et al. (2013) (except not the longleaf pine).

Scientific Name	Common Name
Oxalis violacea	Purple woodsorrel, violet woodsorrel, violet wood-sorrel
Packera anonyma	Small's ragwort
Parthenocissus quinquefolia	Virginia creeper
Pennisetum glaucum	Pearl millet, pearl-millet, yellow bristlegrass
Penstemon australis	Eustis Lake beardtongue
Phacelia maculata	Spotted phacelia
Phoradendron leucarpum	Oak mistletoe
Pinus echinata	Arkansas pine, shortleaf pine, shortleaf yellow pine
Pinus glabra	Spruce pine; Walter's pine
Potentilla canadensis	Dwarf cinquefoil
Pseudognaphalium obtusifolium ssp. *obtusifolium*[a]	Rabbit-tobacco
Pyrrhopappus carolinianus	Carolina desert chicory, Carolina desert-chicory, Carolina false dandelion
Quercus alba	White oak
Rosa carolina	Carolina rose
Rubus canadensis	Smooth blackberry
Rudbeckia hirta	Blackeyed Susan, black-eyed Susan
Sanguinaria canadensis	Bloodroot
Sanicula marilandica	Snakeroot
Sideroxylon tenax	Tough bully; tough buckthorn
Solanum carolinense	Apple of Sodom, bull nettle, Carolina horsenettle
Solidago canadensis var. *scabra*	Tall goldenrod
Solidago odora	Anise-scented goldenrod, fragrant goldenrod
Spiraea arguta	Baby's-breath spirea
Sporobolus indicus var. *indicus*	Smut grass
Taraxacum officinale	Dandelion
Tephrosia virginiana	Virginia tephrosia
Tradescantia virginiana	Virginia spiderwort
Trillium decipiens	Deceptive trillium
Triodanis perfoliata	Clasping bellwort, clasping Venus' lookingglass, clasping Venus' looking-glass
Vaccinium stamineum	Deerberry
Vernonia acaulis	Stemless ironweed

[a] The variety, *Gnaphalium obtusifolium* var. *obtusifolium*, included in the NPS Certified Species List, is not found in the USDA Plants Database, and likely should have been given as *Gnaphalium obtusifolium* ssp. *obtusifolium*. The latter taxon, in turn, is a synonym of *Pseudoghnaphalium obtusifolium* ssp. *obtusifolium*.

Table C-3a. Wetland vascular plant taxa in OCMU, modified from the NPS Certified Species List (NPS 2013a) following Zomlefer et al. (2013). Notes on habitat(s) and relative abundance are from Zomlefer et al. (2013): DA—disturbed area, FP—floodplain swamp, LM—Lamar Unit, PM—pond or marsh with open water, UF—upland forest; c—common, i—infrequent, o—occasional, r—rare.

Scientific Name	Common Name	Notes on Hab./Abund.
Acalypha rhomboidea[a]	Rhombic copperleaf	DA; i
Acer negundo	Box elder, ashleaf maple	FP, UF; o
Acer rubrum	Red maple	UF; o
Acer saccharinum	Silver maple	UF
Acmella repens[a]	Creeping spotflower	LM Unit: DA, FP; r
Aesculus sylvatica[a]	Painted buckeye	UF
Allium canadense var. *canadense*[a]	Wild onion	DA; c
Allium vineale[a,d]	Field garlic	DA; i
Alternanthera philoxeroides[d]	Alligator weed, alligatorweed, pig weed	PM; o-c
Ampelopsis arborea	Peppervine	DA
Anthriscus caucalis[a,d]	Bur chervil	DA; i
Aralia spinosa	Devil's-walking-stick, Angelicatree, devils walkingstick	DA
Arisaema dracontium	Green dragon, greendragon	PM

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[b] Following Zomlefer et al. (2013), synonyms in the NPS Certified Species List are as follows: 21 changes

Athyrium asplenioides—synonym is *Athyrium filix-femina*
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[d] Exotic/invasive taxa.

Table C-3a (continued). Wetland vascular plant taxa in OCMU, modified from the NPS Certified Species List (NPS 2013a) following Zomlefer et al. (2013). Notes on habitat(s) and relative abundance are from Zomlefer et al. (2013): DA—disturbed area, FP—floodplain swamp, LM—Lamar Unit, PM—pond or marsh with open water, UF—upland forest; c—common, i—infrequent, o—occasional, r—rare.

Scientific Name	Common Name	Notes on Hab./Abund.
Arisaema triphyllum	Jack-in-the-pulpit, Indian jack in the pulpit, Jack in the pulpit	LM unit: FP
Arundinaria gigantea	Giant cane	DA; o
Asimina parviflora[a]	Small-flowered pawpaw	FP, UF; r-o
Asimina triloba	Common pawpaw, pawpaw	UF; i
Athyrium asplenioides[b]	Southern ladyfern, common ladyfern, lady fern, ladyfern	fern DA, PM, UF; i
Axonopus compressus	Southern carpetgrass, broadleaf carpetgrass	PM
Berchemia scandens	Supplejack, Alabama supplejack	DA, FP, PM; i-o
Betula nigra	River birch	FP; o
Bidens discoidea	Few-bracted beggar-ticks	FP
Bidens frondosa	Devil's beggar-ticks	PM; i
Bignonia capreolata	Cross-vine, crossvine	DA; c
Boehmeria cylindrica	False-nettle, smallspike false nettle	DA; i
Briza minor[d]	Lesser quaking grass, little quakinggrass	DA; o

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Table C-3a (continued). Wetland vascular plant taxa in OCMU, modified from the NPS Certified Species List (NPS 2013a) following Zomlefer et al. (2013). Notes on habitat(s) and relative abundance are from Zomlefer et al. (2013): DA—disturbed area, FP—floodplain swamp, LM—Lamar Unit, PM—pond or marsh with open water, UF—upland forest; c—common, i—infrequent, o—occasional, r—rare.

Scientific Name	Common Name	Notes on Hab./Abund.
Brunnichia ovata	Buckwheat-vine, American buckwheat vine, redvine	PM; o-c
Calycanthus floridus var. *floridus*[b]	Sweet-shrub, eastern sweetshrub	UF; i-o [note: new survey—terrestrial]
Calycocarpum lyonii [a]	Cupseed	PM
Campsis radicans	Trumpet-creeper, common trumpetcreeper, cow-itch	PM
Cardamine hirsuta[d]	Hairy bittercress	DA
Cardamine pensylvanica	Quaker bittercress	DA
Carex abscondita	Thicket sedge	UF; i
Carex amphibola	Amphibious sedge, eastern narrowleaf sedge	DA; i
Carex crebriflora[b]	Coastal plain sedge	UF; i
Carex crinita	Fringed sedge	DA; o
Carex debilis	White-edge sedge, white edge sedge	UF; i
Carex flaccosperma	Thinfruit sedge	LM Unit
Carex frankii [a]	Frank's sedge	LM UNIT: DA, FP; o

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Scientific Name	Common Name	Notes on Hab./Abund.
Carex joorii	Joor'sedge	FP; i
Carex louisianica	Louisiana sedge	PM; i
Carex lupulina	Hopsedge, hop sedge	PM; o
Carex lurida	Shallow sedge	DA, UF
Carex oxylepis	Sharpscale sedge	PM
Carex seorsa[a]	Weak stellate sedge	PM; i
Carex texensis[a]	Texas sedge	Fac PM
Carex typhina[a]	Cattail sedge	PM, UF i
Carex vulpinoidea[a]	Fox sedge	DA, PM
Carpinus caroliniana	American hornbeam	UF; o
Carya cordiformis	Bitternut hickory	UF; i
Carya glabra	Sweet pignut hickory, pignut hickory	UF
Carya illinoinensis[d]	Pecan	DA

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[d] Exotic/invasive taxa.

Table C-3a (continued). Wetland vascular plant taxa in OCMU, modified from the NPS Certified Species List (NPS 2013a) following Zomlefer et al. (2013). Notes on habitat(s) and relative abundance are from Zomlefer et al. (2013): DA—disturbed area, FP—floodplain swamp, LM—Lamar Unit, PM—pond or marsh with open water, UF—upland forest; c—common, i—infrequent, o—occasional, r—rare.

Scientific Name	Common Name	Notes on Hab./Abund.
Cayaponia quinqueloba	Fivelobe melonleaf, fivelobe cucumber	SOC PM; LM Unit: DA; r-o
Celtis laevigata	Southern hackberry, sugar berry, sugar hackberry, sugarberry	DA, UF; r
Cephalanthus occidentalis	Buttonbush, common buttonbush	PM; o
Chaerophyllum tainturieri	Southern chervil, chervil, hairyfruit chervil, hairy-fruit chervil	DA; o
Chamaecrista nictitans var. *nictitans*[a]	Common sensitive-plant	DA
Chasmanthium latifolium	River oats, roadleaf uniola, Indian woodoats, Indian wood-oats	UF; c
Chasmanthium laxum[a]	Slender spikegrass	DA; i
Chenopodium album[a]	Lamb's-quarters	DA; r
Cirsium horridulum var. *horridulum*[b]	Purple thistle, yellow thistle	DA
Commelina virginica	Virginia dayflower	FP

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Table C-3a (continued). Wetland vascular plant taxa in OCMU, modified from the NPS Certified Species List (NPS 2013a) following Zomlefer et al. (2013). Notes on habitat(s) and relative abundance are from Zomlefer et al. (2013): DA—disturbed area, FP—floodplain swamp, LM—Lamar Unit, PM—pond or marsh with open water, UF—upland forest; c—common, i—infrequent, o—occasional, r—rare.

Scientific Name	Common Name	Notes on Hab./Abund.
Conoclinium coelestinum	Mistflower, blue mistflower	UF
Conyza canadensis var. *canadensis*[a]	Common horseweed	
Cornus stricta[b]	Southern swamp dogwood, stiff dogwood	PM, UF; o
Crataegus marshallii[a]	Parsley haw, parsley hawthorn	DA
Crataegus spathulata	Littlehip hawthorn	DA, UF; o
Crataegus viridis	Green hawthorn	UF LM Unit: DA, FP; i
Cuscuta gronovii	Common dodder, scaldweed	FP; i
Cyperus echinatus	Globe flatsedge	DA; c
Cyperus erythrorhizos	Redroot flatsedge, red-root flat sedge, redroot nutgrass	FP, PM; c
Cyperus iria[a,d]	Ricefield flatsedge	DA; i
Cyperus retrorsus	Pinebarren flatsedge, pine barren flatsedge	DA, PM; o
Cyperus strigosus	False nutsedge, stawcolored flatsedge, strawcolor flatsedge, strawcolor nutgrass	DA
Cyperus virens	Green flatsedge	FP, PM; o

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Scientific Name	Common Name	Notes on Hab./Abund.
Dichanthelium dichotomum var. *dichotomum*[a]	Cypress witch grass	DA; c
Dichondra carolinensis	Carolina ponyfoot, Carolina ponysfoot, grass ponyfoot	DA; o
Dicliptera brachiata	Branched foldwing	UF LM Unit: DA, FP; o
Digitaria sanguinalis[d]	Northern crab grass, crabgrass, hairy crab grass, hairy crabgrass	DA; c
Digitaria serotina	Dwarf crab grass	DA; o
Diodia teres	Poor joe, poorjoe, rough buttonweed	DA; o
Diodia virginiana	Virginia buttonweed	DA
Dioscorea polystachya[a,d]	Cinnamon vine	PM
Diospyros virginiana	American persimmon, common persimmon, eastern persimmon, persimmon	DA, UF
Echinochloa crusgalli var. *crusgalli*[d]	Barnyard-grass, barnyard grass, barnyardgrass, cockspur	DA, FP; i-c
Elymus virginicus var. *virginicus*[b]	Common eastern wild-rye, Virginia wild rye, Virginia wildrye	PM; i

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Scientific Name	Common Name	Notes on Hab./Abund.
Eragrostis cilianensis[a,d]	Stinkgrass	DA
Eragrostis spectabilis	Purple lovegrass, petticoat-climber	DA, FP; i
Erigeron philadelphicus var. *philadelphicus*[a]	Philadelphia-daisy	DA; i
Euonymus americanus	Strawberry-bush, bursting-heart	Fac DA, UF; i
Eupatorium serotinum[a]	Late eupatorium	LM unit: DA; c
Forestiera acuminata	Swamp privet, eastern swampprivet, Texas forestiera	PM; o
Fraxinus caroliniana	Water ash, Carolina ash	FP; i
Fraxinus pennsylvanica	Green ash	FP
Galactia volubilis var. *volubilis*[a]	Eastern milkpea	DA; o
Galium aparine	Bedstraw, catchweed bedstraw, cleavers	DA; o
Gamochaeta coarctata[a,d]	American everlasting	DA; i
Gelsemium sempervirens	Carolina jessamine, evening trumpetflower	UF
Gonolobus suberosus[b]	Anglepid, angle-pod milkweed vine, angular-fruited milkvine	DA, PM, UF; c-o

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[b] Following Zomlefer et al. (2013), synonyms in the NPS Certified Species List are as follows: 21 changes

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Scientific Name	Common Name	Notes on Hab./Abund.
Hamamelis virginiana	Witch-hazel	UF; i
Halesia tetraptera[a]	Common silverbell	UF
Heliotropium amplexicaule[a,d]	Wild heliotrope	DA; o
Heliotropium indicum[d]	Indian heliotrope	FP; r
Hibiscus laevis	Smooth rose-mallow, halberdleaf rosemallow, scarlet rosemallow	PM; i-o
Hydrocotyle verticillata	Whorled marsh pennywort, whorled marshpennywort, whorled pennyroyal	PM; i
Hydrolea quadrivalvis	Waterpod, water-pod	PM
Hypericum hypericoides	St. Andrew's cross, St. Andrews cross	UF
Hypericum mutilum	Dwarf St.-John's-wort, dwarf St. Johnswort	DA; I LM Unit: DA, FP; i
Hypericum walteri[b]	Walter's marsh St.-John's-wort, greater marsh St. Johnswort	PM; o
Ilex decidua	Possum-haw, possumhaw	DA, UF; o-c

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Scientific Name	Common Name	Notes on Hab./Abund.
Ilex opaca	American holly	UF; i
Ilex vomitoria	Yaupon	DA, UF
Ipomoea coccinea	Scarlet creeper, Mexican morningglory, red morningglory, redstar	DA
Ipomoea cordatotriloba var. *cordatotriloba*[a]	Coastal morning-glory	DA; o
Ipomoea hederacea[a]	Ivyleaf morning-glory	DA; o
Ipomoea pandurata	Wild sweet potato, bigroot morningglory, bigroot morninglory, man of the earth	DA
Iris hexagona[a]	Anglepod blue flag	PM; i
Itea virginica	Virginia sweetspire, Virginia willow	FP; o
Iva annua[a,d]	Sumpweed	DA; C
Jacquemontia tamnifolia[d]	Clustervine, hairy clustervine, smallflower morningglory	DA
Juncus coriaceus	Leathery rush; tough rush	FP

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Scientific Name	Common Name	Notes on Hab./Abund.
Juncus dichotomus[a]	Forked rush	PM, UF; i-o [moved from terrestrial list]
Justicia ovata var. *ovata*[a]	Coastal plain water-willow	LM unit: DA, FP; i
Lactuca floridana	Woodland lettuce	DA, PM; i
Laportea canadensis[a]	Wood-nettle	LM Unit: DA, FP; o
Leersia lenticularis[a]	Catchfly cutgrass	LM Unit: FP; i
Leersia oryzoides[a]	Rice cutgrass	FP, PM; i
Leersia virginica	White cutgrass, whitegrass	PM; o
Ligustrum sinense[d]	Chinese privet, common chinese privet	FP, UF; c
Lindera benzoin	Northern spicebush, spicebush	–
Lindernia dubia var. *dubia*[b]	Moistbank false pimpernel, moistbank pimpernel	FP, PM; c
Liquidambar styraciflua	Sweet gum, sweetgum	UF; o
Liriodendron tulipifera	Tulip-tree, tuliptree, tulip poplar, yellow poplar	UF; o
Lobelia cardinalis	Cardinal flower, cardinalflower	FP

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Scientific Name	Common Name	Notes on Hab./Abund.
Lobelia elongata[a]	Longleaf lobelia	PM; i
Lonicera japonica[d]	Chinese honeysuckle, Japanese honeysuckle	UF; o
Ludwigia decurrens	Wingstem water-primrose, wingleaf primrose-willow, wingleaf waterprimrose	PM; o
Ludwigia glandulosa	Small-flowered seedbox, creeping seedbox, cylindricfruit primrose-willow	PM; o
Ludwigia leptocarpa	Water-willow, anglestem primrose-willow, anglestem waterprimrose	FP
Ludwigia palustris[a]	Common water-purslane	DA
Ludwigia peploides var. *glabrescens*[a]	Floating primrosewillow	PM; r
Ludwigia repens	Creeping seedbox, creeping waterprimrose	–
Luzula echinata	Spreading wood-rush, hedgehog woodrush	UF; i-o
Lycopus rubellus[a]	Stalked bugleweed	DA, FP; r-i
Lygodium japonicum[d]	Japanese climbing fern	Exotic CAT 1

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Scientific Name	Common Name	Notes on Hab./Abund.
Lyonia lucida	Shining fetterbush, fetterbush lyonia, fetterbush	FP; o
Macrothelypteris torresiana[a,d]	Mariana maiden fern	UF; i; LM UNIT: da, fp; o
Magnolia grandiflora	Southern magnolia	UF; r
Magnolia virginiana	Sweetbay	DA; i
Melothria pendula	Creeping cucumber, climbing cucumber	DA
Menispermum canadense	Canada moonseed	–
Mikania scandens	Climbing hempweed, climbing hempvine	FM, PM; c
Mimulus alatus	Winged monkey-flower	PM; LM Unit: DA, FP; o
Mitchella repens	Partridge-berry	UF
Modiola caroliniana	Bristly-mallow, Carolina bristle-mallow	DA
Morus rubra	Red mulberry	UF; LM Unit: DA, FP; i-o

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Scientific Name	Common Name	Notes on Hab./Abund.
Murdannia keisak[a,d]	Marsh dewflower, aneilima, Asian spiderwort, watermoving herb	DA, FP, PM; c
Myosotis macrosperma	Bigseed forget-me-not, large-seeded foreget-me-not	DA, UF
Nothoscordum bivalve[a]	False garlic	DA
Nyssa biflora	Swamp tupelo	FP
Nyssa ogeche[a]	Ogeechee lime	FP; i
Onoclea sensibilis var. *sensibilis*[b]	Sensitive fern	ferns PM; i
Osmundastrum cinnamomeum[b]	Cinnamon fern	ferns DA; i
Osmunda spectabilis[b]	American royal fern	ferns UF; i
Packera glabella	Butterweed	FM, PM; o
Panicum anceps	Beaked panicum, beaked panicgrass	DA, FP, PM; o
Panicum rigidulum[a]	Redtop panicum	PM; o
Panicum virgatum	Switchgrass, old switch panic grass	DA, UF
Paspalum dilatatum ssp. *Dilatatum*[b,d]	Dallis grass, Dallas grass, dallisgrass	DA; c

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Scientific Name	Common Name	Notes on Hab./Abund.
Paspalum floridanum[a]	Florida paspalum	DA; o
Paspalum notatum var. *saurae*[a,d]	Bahia grass	DA; o
Paspalum urvillei[d]	Vasey grass, vaseygrass, Vasey's grass	DA; o
Persea palustris	Swamp bay; swamp red bay	FP; i
Persicaria hydropiperoides[b]	Swamp smartweed	PM; c
Persicaria longiseta[a,d]	Longbristle smartweed, arrowleaf knotweed, arrowleaf tearthumb	LM Unit: DA, FP; c
Persicaria sagittata[b]	Arrowleaf tearthumb, Arrowleaf knotweed	FP
Persicaria virginiana[b]	Jumpseed, Virginia smartweed	PM, UF; i-o LM Unit: DA, FP; i
Phacelia dubia[a]	Smallflower phacelia	DA; r-c
Phanopyrum gymnocarpon	Swamp phanopryum, giant panic grass, Savannah panic grass	FP, PM; o-c
Pilea pumila	Greenfruit clearweed, Canada (Canadian) clearweed	FP; o
Planera aquatica	Planer-tree, planertree, water elm, water-elm	FP; I

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Table C-3a (continued). Wetland vascular plant taxa in OCMU, modified from the NPS Certified Species List (NPS 2013a) following Zomlefer et al. (2013). Notes on habitat(s) and relative abundance are from Zomlefer et al. (2013): DA—disturbed area, FP—floodplain swamp, LM—Lamar Unit, PM—pond or marsh with open water, UF—upland forest; c—common, i—infrequent, o—occasional, r—rare.

Scientific Name	Common Name	Notes on Hab./Abund.
Platanus occidentalis	American sycamore, sycamore	PM, UF; i-c
Poa annua[d]	Annual blue grass	DA; o
Poa autumnalis[a]	Autumn bluegrass	PM; i
Polypremum procumbens	Rustweed, juniper leaf	DA; c
Pyracantha koidzumii [a,d]	Formosan firethorn	Cultivated
Quercus laurifolia	Laurel oak	FP
Quercus lyrata	Overcup oak	FP
Quercus michauxii	Basket oak, swamp chestnut oak	DA
Quercus nigra	Water oak	DA, FP; o
Quercus phellos	Willow oak	UF
Quercus shumardii	Shumard oak	UF
Ranunculus abortivus	Kidney-leaf buttercup, early woodbuttercup, littleleaf buttercup	DA; i
Rhododendron canescens	Sweet, Piedmont azalea, mountain azalea, piedmont azalea	UF

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[b] Following Zomlefer et al. (2013), synonyms in the NPS Certified Species List are as follows: 21 changes

Athyrium asplenioides—synonym is *Athyrium filix-femina*
Calycanthus floridus var. *floridus*—synonym is *Calycanthus floridus*
Cirsium horridulum var. *horridulum*—synonym is *Cirsium horridulum*
Cornus stricta—synonym is *Cornus foemina*
Echinochloa crusgalli var. *crusgalli*—synonym is *Echinochloa crus-galli*
Elymus virginicus var. *virginicus*—synonym is *Elymus virginicus*
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Persicaria hydropiperoides—synonym is *Polygonum hydropiperoides*
Persicaria sagittata—synonym is *Polygonum sagittatum*
Persicaria virginica—synonym is *Polygonum virginianum*
Rubus pensilvanicus—synonym is *Rubus argutus*
Smilax hispida—synonym is *Smilax tamnoides*
Viburnum nudum var *nudum*—synonym is *Viburnum nudum*
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Scientific Name	Common Name	Notes on Hab./Abund.
Rhynchospora globularis var. *globularis*[a]	Globe beaksedge	FP, PM
Rubus pensilvanicus[b]	Pennsylvania blackberry, birch-leaved blackberry, prickly Florida blackberry	DA, PM
Rubus trivialis[a]	Southern dewberry	DA; c
Rumex acetosella[d]	Red dock; sorrel; sourweed	DA
Rumex crispus[d]	Curley dock, curly dock, narrowleaf dock	PM
Sabal minor	Dwarfed palmetto	PM; i
Sagittaria latifolia	Broadleaf arrowhead, common arrowhead, duck-potato	PM; i
Sambucus canadensis	Common elderberry, American elder	FP, PM; c
Sanicula canadensis[a]	Canadian black snakeroot	DA; i
Saururus cernuus	Lizard's-tail	PM; I LM Unit: DA, FP; o
Scirpus cyperinus	Woolgrass bulrush	FP, PM; o-c
Scutellaria lateriflora	Mad dog skullcap, blue skullcap	FP; i

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Scientific Name	Common Name	Notes on Hab./Abund.
Sesbania punicea[a,d]	Rattlebox	PM; o
Sesbania vesicaria[b]	Bladderpod, bagpod	FP; c
Setaria parviflora[a]	Knotroot bristlegrass	DA; i
Sisyrinchium atlanticum	Atlantic blue-eyed grass, eastern blueeyed grass, eastern blue-eyed grass	UF
Smilax bona-nox	Saw greenbrier; cat-brier	DA, PM; o-c
Smilax glauca	Whiteleaf greenbrier, cat greenbrier	PM; c
Smilax laurifolia	Bamboo vine, bamboo-brier, laurel greenbrier	LM Unit: DA, FP; o
Smilax rotundifolia	Common greenbrier, bullbriar, common catbriar	LM Unit: DA, FP; o
Smilax hispida[b]	Bristly greenbrier	DA
Smilax smallii[a]	Jackson-brier	UF; o
Sonchus oleraceus [a,d]	Common sow-thistle	DA; r
Sorghastrum nutans[a]	Yellow Indiangrass	DA; o
Sorghum halepense[d]	Johnson grass, aleppo milletgrass, herbe de Cuba	DA; o

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Scientific Name	Common Name	Notes on Hab./Abund.
Stachys floridana[d]	Florida betony; Florida hedgenettle	DA; c
Symphyotrichum lanceolatum[a]	White panicle aster	FP; i
Symphyotrichum pilosum	White oldfield aster, hairy white oldfield aster	UF
Symplocos tinctoria[a]	Sweetleaf	UF; i
Toxicodendron radicans ssp. *radicans*	Eastern poison ivy	DA
Trachelospermum difforme	Climbing dogbane	FP
Tradescantia ohiensis[a]	Smooth spiderwort	UF; i
Triadica sebifera[d]	Chinese tallow-tree, tallow tree, popcorn tree	FP, PM; i-c
Trillium maculatum[a]	Mottled trillium	PM?
Typha latifolia[a]	Common cattail	FP, PM; i
Ulmus alata	Winged elm	FP, UF; i
Ulmus americana	American elm	DA, FP; i-c
Ulmus rubra	Slippery elm	FP; o

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Scientific Name	Common Name	Notes on Hab./Abund.
Valerianella radiata[a]	Beaked cornsalad	DA; c
Verbena bonariensis[d]	Purpletop vervain, tall vervain	DA
Verbesina occidentalis	Southern crownbeard, yellow crownbeard	FP
Vernonia gigantea[a]	Giant ironweed	FP, PM; i
Viburnum nudum var. *nudum*[b]	Southern wild raisin, black haw	FP
Viola bicolor	Wild pansy, field pansy	DA
Viola primulifolia[b]	Primrose-leaf violet, primrose violet, violet	DA
Viola sororia[c]	Common blue violet, hooded blue violet	DA, UF; i-o
Vitis cinerea var. *floridana*	Florida grape	DA; o
Vitis rotundifolia	Muscadine, muscadine grape	DA, UF; c
Vitis vulpina[a]	Frost grape	DA, UF; o-c
Woodwardia areolata	Netted chainfern, chainfern	fern FP, PM, UF; o
Zephyranthes atamasca	Common atamasco-lily, atamasco lily	PM, UF; i

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[d] Exotic/invasive taxa.

Table C-3b. Wetland plants on the NPS Certified Species List (2013a), omitted above following Zomlefer et al. (2013).

Scientific Name	Common Name
Agalinis obtusifolia	Tenlobe false foxglove
Agalinis purpurea	Purple false foxglove
Alnus serrulata	Alder, brook-side alder, hazel alder
Amorpha fruticosa	Desert false indigo, desert indigobush, dullleaf indigo B329
Amsonia tabernaemontana	Eastern bluestar, willow slimpod
Andropogon virginicus	Broomsedge, broomsedge bluestem, yellow bluestem
Baccharis halimifolia	Eastern baccharis
Bidens aristosa	Bearded beggarticks, long-bracted beggar-ticks, tickseed sunflower
Carya aquatica	Water hickory
Carex atlantica	Prickly bog sedge
Carex gigantea	Giant sedge
Carex intumescens	Greater bladder sedge
Carex scoparia	Broom sedge, pointed broom sedge
Carex styloflexa	Bent sedge
Carex venusta	Darkgreen sedge
Chamaesyce maculata	Large spurge, spotted sandmat, spotted spurge
Clematis virginiana	Devil's darning needles, devil's-darning-needles, Virginia bower
Equisetum hyemale	Scouringrush horsetail
Erechtites hieracifolia	Burnweed
Eupatorium capillifolium	Dogfennel
Helianthus angustifolius	Swamp sneezeweed, swamp sunflower
Helianthus annuus	Common sunflower, annual sunflower, sunflower
Houstonia caerulea	Azure bluet
Ipomoea lacunosa	Pitted morningglory, white morningglory
Iris virginica	Virginia iris
Juncus effusus	Common rush, lamp rush, soft rush
Krigia caespitosa	Weedy dwarfdandelion
Mazus pumilus[a]	Japanese hedgehyssop, Japanese mazus
Microstegium vimineum[a]	Japanese shade grass, Vietnam grass
Nyssa sylvatica	Black gum, black tupelo, blackgum

[a] Exotic/invasive taxa.

Table C-3b (continued). Wetland plants on the NPS Certified Species List (2013a), omitted above following Zomlefer et al. (2013).

Scientific Name	Common Name
Phytolacca americana	American pokeweed, common pokeweed, inkberry
Pluchea camphorata	Camphor pluchea, camphor weed
Poa chapmaniana	Chapman's blue grass
Polygonum hirsutum	Hairy smartweed
Polygonum lapathifolium	Curltop ladysthumb, curlytop knotweed, curlytop smartweed
Polygonum punctatum	Dotted knotweed
Populus deltoides	Eastern cottonwood, common cottonwood, cottonwood
Ptilimnium capillaceum	Narrow-leaved mock bishopweed
Quercus pagoda	Cherrybark oak
Salix nigra	Black willow
Schizachyrium scoparium	Little bluestem
Smilax walteri	Coral greenbrier
Strophostyles helvola	Amberique-bean, trailing fuzzybean, trailing wild-bean, trailing wildbean
Symphyotrichum puniceum var. *puniceum*	Purple-stemmed aster
Verbena brasiliensis[a]	Brazilian verbena, tall verbena
Vernonia noveboracensis	Ironweed
Viola affinis	Floodplain violet, LeConte's violet, sand violet

[a] Exotic/invasive taxa.

Table C-3c. Wetland vascular plant taxa in OCMU, modified from the NPS Certified Species List (NPS 2013a) following Zomlefer et al. (2013).

Scientific Name	Common Name	Notes
Myriophyllum aquaticum[a]	Parrot-feather, Brazilian watermilfoil	–
Najas minor[a]	Spinyleaf naiad	–

[a] Exotic/invasive taxa.

Table C-3d. Omitted wetland vascular plant taxa in OCMU, following Zomlefer et al. (2013).

Scientific Name	Common Name	Notes
Najas filifolia	Needle-leaved waternymph	Endangered-State

Table C-4. List of all exotic (non-native) species of vascular plants in OCMU as documented through an intensive survey in the 2008-2012 growing seasons by Zomlefer et al. (2013). The GA EPPC's evaluaton of invasive plant status is indicated (GA-EPPC 2015; CAT—Category): Category 1—serious invasive; Category 2—moderately invasive; Category 3—minor invasive, or potential threat not yet known; and Category 4—naturalized in Georgia; additional data needed. Note that 50 species have an invasive status as indicated by Category designations (given as 37 by Zomlefer et al. 2013). Also indicated is the EPPC Top Ten Status, and the NPS Top Ten Species List for national parks in the Southeast region (NPS 2015b). Habitat information is included as DA—disturbed areas, OH—oak-hickory forest, RS—rocky slope, WE—wetland (stream, sewer overflow, swamp, water-filled ditches). "New Report" indicates whether the species was absent from the most recent NPS Certified Species List (NPS 2013a). Abundance is indicated (where reported by Zomlefer et al. 2013) as common (c), occasional (o—locally common and/or several individuals distributed within a given habitat), infrequent (i—sporadic occurrence of a small number of individuals), or rare (r—with very few individuals).

Type	Scientific Name	Common Name	New Report	Habitat	Abundance	Invasive Status EPPC	Invasive Status NPS Top 10
Terrestrial	Ailanthus altissima	Tree-of-heaven, tree of heaven, ailanthus, copal tree	–	DA	occasional	CAT 1	X
	Albizia julibrissin	Silktree, mimosa, mimosa tree, powderpuff tree	–	DA, UF	–	CAT 1, Top 10	–
	Amaranthus viridis	Slender amaranth	X	DA	–	–	–
	Aphanes australis	Parsley-piert, slender parsley piert	–	DA	occasional	–	–
	Arabidopsis thaliana	Mouse-ear cress, mouseear cress	–	DA	–	–	–
	Asparagus officinalis	Asparagus, garden asparagus, garden-asparagus	–	DA	infrequent	–	–
	Bromus catharticus var. catharticus	Rescue grass	X	DA	occasional to common	–	–
	Bromus commutatus	Hairy Chess	X	DA	common	–	–
	Bromus racemosus	Bald brome	X	DA	–	–	–
	Capsella bursa-pastoris	Common shepherd’s purse, shepardspurse, shepherd's purse	–	DA	occasional	–	–
	Croton capitatus	Woolly croton, doveweed, hogweed, hogwort	–	DA	–	–	–
	Cynodon dactylon var. dactylon	Bermuda grass, chiendent pied-de-poule, common bermudagrass	–	DA	common	CAT 2	–
	Dactylis glomerata	Orchard grass	X	DA	common	–	–
	Digitaria ciliaris	Southern crabgrass	X		–	–	–
	Dysphania ambrosioides	Mexican tea, Mexican-tea	–	DA	infrequent	–	–

Type	Scientific Name	Common Name	New Report	Habitat	Abundance	Invasive Status EPPC	Invasive Status NPS Top 10
	Elaeagnus pungens	Thorny-olive	X	UF	–	CAT 2	–
	Eragrostis curvula	Weeping lovegrass	X	DA	common	CAT 3	–
	Facelis retusa	Trampweed, annual trampweed	X	DA	infrequent	–	–
	Galium sherardia	Field-madder, blue field-madder	–	DA	occasional	–	–
	Geranium molle	Dove's-foot crane's-bill	X	DA	–	–	–
	Glandularia pulchella	Moss vervain, South American mock vervain	–	DA	occasional - common	–	–
	Hedera helix	English ivy	–	UF	common	CAT 1	–
	Helenium amarum	Bitterweed, bitter sneezeweed	–	–	–	–	–
	Heterotheca latifolia var. latifolia	Common camphorweed	X	DA	infrequent	–	–
	Hypochaeris radicata	Spotted cat's-ear, common cat's-ear, false dandelion, frogbit	–	DA	–	–	–
	Ilex cornuta	Chinese holly	–	–	–	CAT 4	–
	Koelreuteria paniculata	Golden rain tree	–	DA	infrequent	–	–
	Lamium amplexicaule	Henbit, common henbit, giraffehead	–	DA	occasional	–	–
	Lamium purpureum	Purple dead-nettle, dead nettle	–	DA	–	–	–
	Lespedeza cuneata	Sericea lespedeza	X	DA	common	CAT 1	–
	Ligustrum japonicum	Chinese privet	–	DA	occasional	CAT 2	–
	Liriope spicata	Creeping lilyturf	X	UF	infrequent	CAT 4	–
	Lolium perenne var. aristatum	Italian ryegrass, winter rye grass	–	–	–	–	–
	Lonicera fragrantissima	Sweet breath of spring	–	DA	infrequent	CAT 3	–
	Lunaria annua	Annual honesty	–	DA	infrequent	–	–
	Melia azedarach	Chinaberry, Chinaberry tree, Chinaberrytree	–	DA	–	CAT 1	–
	Mirabilis jalapa	Garden four-o'clock	X	DA	occasional	–	–
	Morus alba	White mulberry, mulberry	–	DA	rare to common	CAT 3	–
	Nandina domestica	Sacred-bamboo, nandina	–	DA, UF	–	CAT 2	–
	Oxalis articulata	Windowbox wood-sorrel	X	DA	occasional	–	–

Type	Scientific Name	Common Name	New Report	Habitat	Abundance	Invasive Status EPPC	Invasive Status NPS Top 10
	Perilla frutescens	Beefsteak plant, beefsteak, beefsteak mint, purple perilla, purple mint	–	LM Unit - DA	common	–	–
	Phyllostachys aurea	Golden bamboo, bamboo	–	DA	common	CAT2, Top 10	–
	Plantago aristata	Buckthorn plantain	X	DA	occasional	–	–
	Plantago lanceolata	English plantain	X	DA	occasional	–	–
	Poa compressa	Canada bluegrass	X	DA	infrequent	–	–
	Potentilla indica	Indian-strawberry	–	DA	–	–	–
	Pueraria montana var. lobata	Kudzu, kudzu vine	–	DA	common	CAT1, Top 10	X
	Richardia brasiliensis	Tropical Mexican-clover	–	DA?	–	–	–
	Salpichroa origanifolia	Lily-of-the-valley vine	X	DA	occasional	–	–
	Schedonorus arundinaceus	Tall fescue	X	DA	infrequent to common	CAT 3	–
	Senna obtusifolia	Sicklepod; Java-bean	–	DA	occasional	–	–
	Sida rhombifolia	Arrowleaf sida, cuban jute, Cuban-jute	–	DA		–	–
	Sorghum bicolor	Sorghum	X	DA	infrequent	–	–
	Spiraea cantoniensis	Reeve’s meadowsweet	new cult	UF? Cultivated?	–	–	–
	Spiraea thunbergii	Thunberg's meadowsweet	new cult	UF? Cultivated?	–	–	–
	Stellaria media	Chickweed, common chickweed, nodding chickweed	–	DA	infrequent	–	–
	Trifolium arvense	Rabbitfoot clover	X	DA	common	–	–
	Trifolium dubium	Low hop clover, hop clover, smallhop clover, suckling clover	–	DA	infrequent	–	–
	Verbascum thapsus	Woolly mullein, big taper, common mullein, flannel mullein	–	DA	rare	CAT 4	–
	Verbena rigida	Tuberous vervain	–	DA	occasional	–	–
	Vicia hirsuta	Tiny vetch	X	DA	–	–	–

Type	Scientific Name	Common Name	New Report	Habitat	Abundance	Invasive Status EPPC	Invasive Status NPS Top 10
	Vicia lathyroides	Spring vetch	X	DA	–	–	–
	Vicia sativa ssp. nigra	Narrowleaf vetch, garden vetch	–	DA	–	–	–
	Vicia tetrasperma	Slender vetch	X	DA	–	–	–
	Viola arvensis	European field-pansy	X	DA	occasional	–	–
	Vulpia myuros	Rat-tail fescue	X	DA	common	–	–
	Wahlenbergia marginata	Southern rockbell	–	DA, UF	occasional	–	–
	Wisteria sinensis	Chinese wisteria	–	DA	–	CAT 1, Top 10	–
	Youngia japonica	Asiatic hawk's-beard, oriental false hawksbeard	–	DA	–		–
Wetland	Allium vineale	Field garlic	X	DA	infrequent	CAT 4	–
	Alternanthera philoxeroides	Alligator weed, alligatorweed, pig weed	–	PM	occasional to common	CAT 1	–
	Anthriscus caucalis	Bur chervil	X	DA	infrequent	–	–
	Briza minor	Lesser quaking grass, little quakinggrass	–	DA	occasional	–	–
	Cardamine hirsuta	Hairy bittercress	–	DA	–	–	–
	Carya illinoinensis	Pecan	–	DA	–	–	–
	Cyperus iria	Ricefield flatsedge	X	DA	infrequent	–	–
	Digitaria sanguinalis	Northern crab grass, crabgrass, hairy crab grass, hairy crabgrass	–	DA	common	–	–
	Dioscorea polystachya	Cinnamon vine	X	PM	–	CAT 2	–
	Echinochloa crusgalli var. crusgalli	Barnyard-grass, barnyard grass, barnyardgrass, cockspur+B140	–	DA, FP	infrequent to common	–	–
	Eragrostis cilianensis	Stinkgrass	X	DA	–	–	–
	Gamochaeta coarctata	American everlasting	X	DA	infrequent	–	–
	Gomphrena serrata	Arrasa con todo	–	DA	–	–	–
	Heliotropium indicum	Indian heliotrope	–	FP	rare	–	–
	Iva annua	Sumpweed	X	DA	common	–	–
	Jacquemontia tamnifolia	Clustervine, hairy clustervine, smallflower morningglory	–	DA	–	CAT 4	–

Type	Scientific Name	Common Name	New Report	Habitat	Abundance	Invasive Status EPPC	Invasive Status NPS Top 10
	Ligustrum sinense	Chinese privet, common chinese privet	–	FP, UF	common	CAT 1, Top 10	X
	Lonicera japonica	Japanese honeysuckle, Chinese honeysuckle	–	UF	occasional	CAT 1, Top 10	X
	Lygodium japonicum	Japanese climbing fern	–	–	–	CAT 1	–
	Macrothelypteris torresiana	Mariana maiden fern	X	UF; LM Unit - DA, FP	infrequent; LM Unit - occasional	–	–
	Mazus pumilus	Japanese hedgehyssop, Japanese mazus	–	–	–	–	–
	Microstegium vimineum	Nepalese browntop, Japanese shade grass, Vietnam grass	–	–	–	CAT 1, Top 10	–
	Murdannia keisak	Marsh dewflower, aneilima, Asian spiderwort, watermoving herb	–	DA, FP, PM	common	CAT 1	–
	Paspalum dilatatum ssp. dilatatum	Dallis grass, Dallas grass, dallisgrass	–	DA	common	–	–
	Paspalum notatum var. saurae	Bahia grass	X	DA	occasional	CAT 2	–
	Paspalum urvillei	Vasey grass, vaseygrass, Vasey's grass	–	DA	occasional	CAT 3	–
	Persicaria longiseta	Longbristle smartweed, arrowleaf knotweed, arrowleaf tearthumb	X	LM Unit - DA, FP	common	CAT 4	–
	Poa annua	Annual blue grass	–	DA	occasional	CAT 3	–
	Pyracantha koidzumii	Formosan firethorn	new cultivated	–	–	–	–
	Rumex acetosella	Red dock; sorrel; sourweed	–	DA	–	–	–
	Rumex crispus	Curley dock, curly dock, narrowleaf dock	–	PM	–	–	–
	Sesbania punicea	Rattlebox	X	PM	occasional	CAT 2	–
	Sonchus oleraceus	Common sow-thistle	X	DA	rare	CAT 4	–
	Sorghum halepense	Johnson grass, aleppo milletgrass, herbe de Cuba	–	DA	occasional	CAT 3	–
	Stachys floridana	Florida betony; Florida hedgenettle	–	DA	common	CAT 3	–
	Triadica sebifera	Chinese tallow-tree, tallow tree, popcorn tree	–	FP, PM	infrequent to common	CAT 1, Top 10	–

Type	Scientific Name	Common Name	New Report	Habitat	Abundance	Invasive Status EPPC	Invasive Status NPS Top 10
	Verbena bonariensis	Purpletop vervain, tall vervain	–	DA	–	–	–
	Verbena brasiliensis	Brazilian verbena, tall verbena	–	–	–	–	–
Aquatic	Myriophyllum aquaticum	Parrot-feather, Brazilian watermilfoil	–	PM	infrequent to common	CAT 2	–
	Najas minor	Spinyleaf naiad	X	PM	–	CAT 4	–

Table C-5. Fish species reported to occur in OCMU, from the NPS Certified Species List (NPS 2013a).

Scientific Name	Common Name	Notes
Amia calva	Bowfin	–
Anguilla rostrata	American eel	–
Centrarchus macropterus	Flier, peacock sunfish, round sunfish	–
Cyprinella callisema	Ocmulgee shiner	–
Cyprinus carpio	Common carp, European carp	Exotic
Elassoma okefenokee	Okefenokee pygmy sunfish	–
Enneacanthus gloriosus	Bluespotted sunfish	–
Enneacanthus obesus	Banded sunfish, diamond sunfish, little sunfish	–
Esox americanus	Grass pickerel, redfin or grass pickerel, redfin pickerel	–
Esox niger	Chain pickerel	–
Gambusia holbrooki	Eastern mosquitofish	–
Ictalurus punctatus	Channel catfish, graceful catfish	–
Labidesthes sicculus	Brook silverside	–
Lepomis auritus	Redbreast sunfish	Found in recent survey
Lepomis gulosus	Warmouth	–
Lepomis macrochirus	Bluegill	Found in recent survey
Lepomis megalotis	Longear sunfish	–
Lepomis microlophus	Redear sunfish	–
Lepomis punctatus	Spotted sunfish	Found in recent survey
Micropterus cataractae	Shoal bass	SSC—not found in recent survey
Micropterus salmoides	Largemouth bass	–
Minytrema melanops	Spotted sucker	–
Mugil cephalus	Black mullet, gray mullet, striped mullet	–
Notemigonus crysoleucas	Golden shiner	–
Notropis hudsonius	Spottail shiner	–
Notropis maculatus	Taillight shiner	–
Notropis petersoni	Coastal shiner	–
Percina nigrofasciata	Blackbanded darter	Found in recent survey
Pomoxis annularis	White crappie	–
Pomoxis nigromaculatus	Black crappie	–
Pylodictis olivaris	Flathead catfish	–

Table C-6. Amphibian taxa reported to occur in OCMU, from the NPS Certified Species List (NPS 2013a).

Scientific Name	Common Name
Acris crepitans	Northern cricket frog
Acris gryllus	Southern cricket frog
Ambystoma opacum	Marbled salamander
Amphiuma means	Two-toed amphiuma
Bufo americanus	American toad
Bufo fowleri	Fowler's toad
Bufo terrestris	Southern toad
Desmognathus auriculatus	Southern dusky salamander
Desmognathus fuscus	Dusky salamander
Eurycea cirrigera	Southern two-lined salamander
Eurycea guttolineata	Three-lined salamander
Gastrophryne carolinensis	Eastern narrowmouth toad
Hyla avivoca	Bird-voiced treefrog
Hyla chrysoscelis	Cope's gray treefrog
Hyla cinerea	Green treefrog
Hyla squirella	Squirrel treefrog
Necturus punctatus	Dwarf waterdog
Plethodon ocmulgee	Ocmulgee slimy salamander
Pseudacris crucifer	Spring peeper
Pseudacris feriarum	Southeastern (upland) chorus frog
Pseudacris nigrita	Southern chorus frog
Pseudacris ornata	Ornate chorus frog
Pseudotriton ruber	Red salamander
Rana catesbeiana	Bullfrog
Rana clamitans	Green frog
Rana sphenocephala	Southern leopard frog

Table C-7. Reptilian taxa reported to occur in OCMU, from the NPS Certified Species List (NPS 2013a).

Scientific Name	Common Name
Agkistrodon contortrix	Copperhead
Agkistrodon piscivorus	Cottonmouth
Alligator mississippiensis	American alligator
Anolis carolinensis	Green anole
Carphophis amoenus	Worm snake
Chelydra serpentina	Snapping turtle
Chrysemys picta	Painted turtle
Cnemidophorus sexlineatus	Six-lined racerunner
Coluber constrictor	Racer
Crotalus horridus	Timber rattlesnake
Diadophis punctatus	Ringneck snake
Elaphe guttata	Corn snake, cornsnake
Elaphe obsoleta	Rat snake
Elaphe obsoleta spiloides	Gray rat snake
Eumeces fasciatus	Five-lined skink
Eumeces inexpectatus	Southeastern five-lined skink
Eumeces laticeps	Broadhead skink
Heterodon platirhinos	Eastern hog-nosed snake
Kinosternon subrubrum	Eastern mud turtle
Lampropeltis getula	Common kingsnake
Nerodia erythrogaster	Plainbelly water snake
Nerodia fasciata	Southern water snake
Nerodia sipedon	Northern water snake
Nerodia taxispilota	Brown water snake
Opheodrys aestivus	Rough green snake
Pseudemys concinna	River cooter
Sceloporus undulatus	Fence/prairie/plateau lizard
Scincella lateralis	Ground skink
Sternotherus odoratus	Common musk turtle
Storeria dekayi	Brown snake, Dekay's brown snake, DeKay's brownsnake
Terrapene carolina	Eastern box turtle
Thamnophis sauritus	Eastern ribbon snake
Thamnophis sirtalis	Common garter snake
Trachemys scripta	Slider
Virginia valeriae	Smooth earth snake

Table C-8. Bird taxa reported from OCMU, based on the NPS Certified Species List (NPS 2013a).

Scientific Name	Common Name	Notes
Accipiter cooperii	Cooper's hawk	–
Accipiter striatus	Sharp-shinned hawk	–
Actitis macularia[a]	Spotted sandpiper[a]	–
Agelaius phoeniceus[a]	Red-winged blackbird[a]	–
Aix sponsa[a]	Wood duck[a]	–
Anas americana[a]	American wigeon[a]	–
Anas clypeata[a]	Northern shoveler[a]	–
Anas crecca[a]	Green-winged teal[a]	–
Anas discors[a]	Blue-winged teal[a]	–
Anas platyrhynchos[a]	Mallard[a]	–
Anas strepera[a]	Gadwall[a]	–
Anhinga anhinga[a]	Anhinga[a]	–
Archilochus colubris	Ruby-throated hummingbird	–
Ardea alba[a]	Great egret[a]	–
Ardea herodias[a]	Great blue heron[a]	–
Aythya collaris[a]	Ring-necked duck[a]	–
Baeolophus bicolor	Tufted titmouse	–
Bombycilla cedrorum	Cedar waxwing	–
Branta canadensis	Canada goose	Exotic
Bubo virginianus	Great horned owl	–
Bubulcus ibis	Cattle egret	–
Buteo jamaicensis	Red-tailed hawk	–
Buteo lineatus	Red-shouldered hawk	–
Buteo platypterus	Broad-winged hawk	–
Butorides virescens[a]	Green heron[a]	–
Calidris minutilla[a]	Least sandpiper[a]	–
Calidris pusilla[a]	Semipalmated sandpiper[a]	–
Caprimulgus carolinensis	Chuck-will's-widow	–
Caprimulgus vociferus	Whip-poor-will	–
Cardinalis cardinalis	Northern cardinal	–
Carduelis pinus	Pine siskin	–
Carduelis tristis	American goldfinch	–
Carpodacus mexicanus	House finch	–
Carpodacus purpureus	Purple finch	–
Cathartes aura	Turkey vulture	–
Catharus fuscescens	Veery	–
Catharus guttatus	Hermit thrush	–
Catharus minimus	Gray-cheeked thrush	–
Catharus ustulatus	Swainson's thrush	–

[a]Blue designates taxa associated with wetland/aquatic habitats.

Table C-8 (continued). Bird taxa reported from OCMU, based on the NPS Certified Species List (NPS 2013a).

Scientific Name	Common Name	Notes
Certhia americana	Brown creeper	–
Chaetura pelagica	Chimney swift	–
Charadrius vociferus	Killdeer	–
Charadrius wilsonia[a]	Wilson's plover[a]	Threatened-State; None-Fed
Chordeiles minor	Common nighthawk	–
Circus cyaneus	Northern harrier	-
Coccothraustes vespertinus	Evening grosbeak	–
Coccyzus americanus	Yellow-billed cuckoo	–
Colaptes auratus	Northern flicker	–
Colinus virginianus	Northern bobwhite	–
Columba livia	Rock dove	–
Columbina passerina	Common ground-dove	–
Contopus virens	Eastern wood-pewee	–
Coragyps atratus	Black vulture	–
Corvus brachyrhynchos	American Crow	–
Corvus ossifragus[a]	Fish crow[a]	–
Cyanocitta cristata	Blue jay	–
Dendroica caerulescens	Black-throated blue warbler	–
Dendroica castanea	Bay-breasted warbler	–
Dendroica cerulea	Cerulean warbler	Rare-State; None-Fed
Dendroica coronata	Yellow-rumped warbler	–
Dendroica discolor	Prairie warbler	–
Dendroica dominica	Yellow-throated warbler	–
Dendroica fusca	Blackburnian warbler	–
Dendroica magnolia	Magnolia warbler	–
Dendroica palmarum	Palm warbler	–
Dendroica pensylvanica	Chestnut-sided warbler	–
Dendroica petechia	Yellow warbler	–
Dendroica pinus	Pine warbler	–
Dendroica striata	Blackpoll warbler	–
Dendroica tigrina	Cape May warbler	–
Dendroica virens	Black-throated green warbler	–
Dryocopus pileatus	Peleated woodpecker	–
Dumetella carolinensis	Gray catbird	–
Egretta caerulea[a]	Little blue heron[a]	–
Egretta thula[a]	Snowy egret[a]	–
Empidonax flaviventris	Yellow-bellied flycatcher	–
Empidonax virescens	Acadian flycatcher	–

[a]Blue designates taxa associated with wetland/aquatic habitats.

Table C-8 (continued). Bird taxa reported from OCMU, based on the NPS Certified Species List (NPS 2013a).

Scientific Name	Common Name	Notes
Eudocimus albus[a]	White ibis[a]	–
Euphagus carolinus	Rusty blackbird	–
Falco columbarius	Merlin	–
Falco sparverius	American kestrel	–
Fulica americana[a]	American coot[a]	–
Gallinago gallinago[a]	Common snipe[a]	–
Geothlypis trichas	Common yellowthroat	–
Grus canadensis	Sandhill crane	–
Guiraca caerulea	Blue grosbeak	–
Helmitheros vermivorus	Worm-eating warbler	–
Hirundo rustica	Barn swallow	–
Hylocichla mustelina	Wood thrush	–
Icteria virens	Yellow-breasted chat	–
Icterus galbula	Baltimore oriole, Northern oriole	–
Icterus spurius	Orchard oriole	–
Ictinia mississippiensis[a]	Mississippi kite[a]	–
Junco hyemalis	Dark-eyed junco	–
Lanius ludovicianus	Loggerhead shrike	–
Larus delawarensis[a]	Ring-billed gull[a]	–
Limnothlypis swainsonii	Swainson's warbler	SSC (Chafin 2011)
Megaceryle alcyon	Belted kingfisher	–
Megascops asio	Eastern screech owl	–
Melanerpes carolinus	Red-bellied woodpecker	–
Melanerpes erythrocephalus	Red-headed woodpecker	–
Meleagris gallopavo	Wild turkey	–
Melospiza georgiana[a]	Swamp sparrow[a]	–
Melospiza melodia	Song sparrow	–
Mimus polyglottos	Northern mockingbird	–
Mniotilta varia	Black-and-white warbler	–
Molothrus ater	Brown-headed cowbird	–
Mycteria americana	Wood stork[a]	Endangered-State; Endangered-Fed
Myiarchus crinitus	Great crested flycatcher	–
Oporornis formosus	Kentucky warbler	–
Pandion haliaetus[a]	Osprey[a]	–
Parula americana	Northern parula	–
Passer domesticus	House sparrow, English sparrow	Exotic
Passerculus sandwichensis	Savannah sparrow	–
Passerella iliaca	Fox sparrow	–

[a]Blue designates taxa associated with wetland/aquatic habitats.

Table C-8 (continued). Bird taxa reported from OCMU, based on the NPS Certified Species List (NPS 2013a).

Scientific Name	Common Name	Notes
Passerina cyanea	Indigo bunting	–
Phalacrocorax auritus[a]	Double-crested cormorant[a]	–
Pheucticus ludovicianus	Rose-breasted grosbeak	–
Picoides pubescens	Downy woodpecker	–
Picoides villosus	Hairy woodpecker	–
Pipilo erythrophthalmus	Eastern towhee, rufous-sided towhee	–
Piranga olivacea	Scarlet tanager	–
Piranga rubra	Summer tanager	–
Plegadis falcinellus[a]	Glossy ibis[a]	–
Podilymbus podiceps[a]	Pied-billed grebe[a]	–
Poecile carolinensis	Carolina chickadee	–
Polioptila caerulea	Blue-gray gnatcatcher	–
Progne subis	Purple martin	–
Protonotaria citrea	Prothonotary warbler	–
Quiscalus quiscula	Common grackle	–
Regulus calendula	Ruby-crowned kinglet	–
Regulus satrapa	Golden-crowned kinglet	–
Riparia riparia[a]	Bank swallow[a]	–
Sayornis phoebe	Eastern phoebe	–
Seiurus aurocapillus	Ovenbird	–
Seiurus motacilla[a]	Louisiana waterthrush[a]	–
Seiurus noveboracensis[a]	Northern waterthrush[a]	–
Setophaga ruticilla	American redstart	–
Sialia sialis	Eastern bluebird	–
Sitta canadensis	Red-breasted nuthatch	–
Sitta carolinensis	White-breasted nuthatch	–
Sitta pusilla	Brown-headed nuthatch	–
Sphyrapicus varius	Yellow-bellied sapsucker	–
Spizella passerina	Chipping sparrow	–
Spizella pusilla	Field sparrow	–
Stelgidopteryx serripennis	Northern rough-winged swallow	–
Strix varia	Barred owl	–
Sturnella magna	Eastern meadowlark	–
Sturnus vulgaris	European starling	Exotic
Thryothorus ludovicianus	Carolina wren	–
Toxostoma rufum	Brown thrasher	–
Tringa flavipes[a]	Lesser yellowlegs[a]	–
Tringa melanoleuca[a]	Greater yellowlegs[a]	–

[a]Blue designates taxa associated with wetland/aquatic habitats.

Table C-8 (continued). Bird taxa reported from OCMU, based on the NPS Certified Species List (NPS 2013a).

Scientific Name	Common Name	Notes
Tringa solitaria[a]	Solitary sandpiper[a]	–
Troglodytes aedon	House wren	–
Troglodytes troglodytes	Winter wren	–
Turdus migratorius	American robin	–
Tyrannus tyrannus	Eastern kingbird	–
Vermivora celata	Orange-crowned warbler	–
Vermivora chrysoptera	Golden-winged warbler	Endangered-State; None-Fed
Vermivora peregrina	Tennessee warbler	–
Vermivora pinus	Blue-winged warbler	-
Vireo flavifrons	Yellow-throated vireo	–
Vireo griseus	White-eyed vireo	–
Vireo olivaceus	Red-eyed vireo	–
Vireo philadelphicus	Philadelphia vireo	–
Vireo solitarius	Blue-headed vireo, solitary vireo	–
Wilsonia canadensis	Canada warbler	–
Wilsonia citrina	Hooded warbler	–
Zenaida macroura	Mourning dove	–
Zonotrichia albicollis	White-throated sparrow	–
Zonotrichia leucophrys	White-crowned sparrow	–

[a]Blue designates taxa associated with wetland/aquatic habitats.

Table C-9. Species of mammals reported to occur in Ocmulgee NM, based on the NPSpecies List (NPS 2013a).

Scientific Name	Common Name	Notes
Blarina carolinensis	Southern short-tailed shrew	–
Canis familiaris	Feral dog	Exotic
Canis latrans	Coyote	Invasive
Castor canadensis	American beaver	–
Corynorhinus rafinesquii	Rafinesque's big-eared bat, eastern big-eared bat, easter long-eared bat, eastern lump-nosed bat	Rare—State
Dasypus novemcinctus	Nine-banded armadillo	Invasive—JB added
Didelphis virginiana	Virginia opossum	–
Eptesicus fuscus	Big brown bat	–
Felis catus	Feral cat	Exotic
Lasiurus borealis	Eastern red bat, red bat	–
Lasiurus seminolus	Seminole bat	–
Lontra canadensis	North American river otter, northern river otter, river otter	–
Lynx rufus	Bobcat	–
Microtus pinetorum	Woodland vole	–
Mus musculus	House mouse	Exotic
Myocastor coypus	Nutria	Exotic
Neotoma floridana	Eastern woodrat	–
Nycticeius humeralis	Evening bat	–
Odocoileus virginianus	White-tailed deer	–
Ondatra zibethicus	Muskrat	–
Peromyscus polionotus	Oldfield mouse	–
Pipistrellus subflavus	Eastern pipistrelle	–
Procyon lotor	Common raccoon	–
Rattus norvegicus	Norway rat	Exotic
Scalopus aquaticus	Eastern mole	–
Sciurus carolinensis	Eastern gray squirrel	–
Sigmodon hispidus	Hispid cotton rat	–
Sus scrofa	Feral hog	Exotic
Sylvilagus floridanus	Eastern Cottontail	–
Tadarida brasiliensis	Brazilian free-tailed bat	–
Tamias striatus	Eastern chipmunk	–
Urocyon cinereoargenteus	Common gray fox	–
Vulpes vulpes	Red fox	Exotic

Appendix D. Geospatial File Information

Table D-1. Geospatial data gathered for Ocmulgee National Monument.

File_name	Layer_name	Category	Description	Source	Scale/ resolution	Project -ion	Datum	Meta data
basemaps (directory)	None—OCMU Basemap Layers	Park Data	This directory contains a number of basemap/basedata layers that cover roads, trails, buildings, streams, features, utilities and many more areas. The source is unknown and there is no metadata or other descriptive data files.	Unknown—most likely park personnel	Unknown	UTM Zone 17N	NAD 83	No
ocmu.shp	Southeast Coast Network Alternate Administrative Park Boundaries	Boundary	Vector polygon shapefile representing the administrative boundary for OCMU. This boundary was originally part of a larger NPS regional dataset and is intended for use at the regional level. The boundary appears to be an earlier version of the OCMU boundary described below.	SERO/ NPS	1: 10,000,000	UTM Zone 17N	NAD 83	Yes
ocmu_administrative.shp	Current NPS Administrative Boundary for Ocmulgee National Monument	Boundary	Vector polygon shapefile representing the NPS administrative boundary for OCMU. This boundary was originally part of a larger NPS regional dataset and is intended for use at the regional level. This boundary is also found in the state_regional_gis directory and it may need to be updated as the NPS national administrative boundary dataset is updated.	NPS	1: 10,000,000	UTM Zone 17N	NAD 83	Yes
ocmu_ cities.shp	Georgia DOT Statewide City Boundaries	Cities	This dataset contains the administrative boundaries for cities and towns in the corresponding county, including both incorporated and unincorporated municipalities in polygon format. Boundary lines were originally captured from the Georgia Department of Transportation's General highway Base Map. Where the boundary lines are coincident with visible features, they have been photorevised using the 1993 digital orthophoto quarter quadrangles (DOQQs) at 1:12,000-scale. The original dataset was clipped to the county boundaries that contain the parks.	GDOT	1: 31680	UTM Zone 17N	NAD 83	Yes

File_name	Layer_name	Category	Description	Source	Scale/ resolution	Project -ion	Datum	Meta data
ocmu_ ned.img	National Elevation Dataset (DEM)	Elevation	The U.S. Geological Survey has developed a National Elevation Dataset (NED). The NED is a seamless mosaic of best-available elevation data. The 7.5-minute elevation data for the conterminous United States are the primary initial source data. The dataset includes NED coverage for OCMU.	USGS	30M	UTM Zone 17N	NAD 83	Yes
ocmu_dem/ ocmu_demft (GRID files)	7.5-Minute Digital Elevation Model (DEM)	Elevation	Digital Elevation Model (DEM) is the terminology adopted by the USGS to describe terrain elevation data sets in a digital raster form. The7.5-minute DEM (30- by 30-m data spacing, cast on a Universal Transverse Mercator (UTM) projection) provides coverage in 7.5- by 7.5-minute blocks. These datasets are DEMs that cover the extent of OCMU. The dem ft. and dem mtr directories contain individual elevation data quads.	USGS	30M	UTM Zone 17N	NAD 83	Yes—text file only
hydro - dlg (directory)	Large-scale Digital Line Graph (DLG)	Hydro-graphy	Vector polyline shapefiles representing hydrographic DLGs in 7.5 minute blocks for the extent of OCMU and the surrounding areas. There is also a shapefile that has all of the individual quads merged together in order to form a continuous hydro coverage of the park.	USGS	1: 24,000	UTM Zone 17N	NAD 83	Yes—text file only
ga_dam_utm 17.shp	National Inventory of Dams	Hydro-graphy	This dataset provides a locational map of 75,187 dams in the Georgia. The National Inventory of Dams was originally developed by the U.S. Army Corps of Engineers and the Federal Emergency Management Agency. This database shows the age of the dam, number of people living downstream, and some inspection information.	EPA	unknown	UTM Zone 17N	NAD 83	Yes
ocmu_lakes.s hp	County Lakes	Hydro-graphy	This dataset contains polygonal hydrographic features including lakes, ponds, reservoirs, swamps, and islands for the county that contains the park. Multiple counties have been merged together where necessary to cover the full extent of a particular park.	GDOT	1: 24,000	UTM Zone 17N	NAD 83	Yes

File_name	Layer_name	Category	Description	Source	Scale/ resolution	Project -ion	Datum	Meta data
ocmu_rivers. shp	County Rivers	Hydro- graphy	This dataset contains linear hydrographic features, including rivers, streams, and artificial flow paths through water bodies for the county that contains the park. Multiple counties have been merged together where necessary to cover the full extent of a particular park.	GDOT	1: 24,000	UTM Zone 17N	NAD 83	Yes
ocmu_tiger_h ydro.shp	Tiger 98 Hydrography (UTM)	Hydro- graphy	This dataset contains Tiger 98 coverages for hydrographic features at the county level. Multiple counties have been merged together where necessary to cover the full extent of a particular park.	US Census Bureau	1: 100,000	UTM Zone 17N	NAD 83	Yes
rivers021.shp	Georgia DOT Linear Hydrographic Features	Hydro- graphy	This dataset contains linear hydrographic features, including rivers, streams, and artificial flow paths through water bodies for the county that contains the park. Multiple counties have been merged together where necessary to cover the full extent of a particular park. This dataset is apparently a copy of the ocmu_rivers dataset described above.	GDOT	1: 24,000	UTM Zone 17N	NAD 83	Yes—text file only
MACEASHP. shp	Large-scale Digital Line Graph (DLG)	Hypso- graphy	Vector polyline shapefile representing hypsographic DLGs in 7.5 minute block for the extent of OCMU.	USGS	1: 24,000	UTM Zone 17N	NAD 83	Yes—text file only
nwi (directory)	National Wetlands Inventory	NWI	NWI digital data files are records of wetlands location and classification as developed by the U.S. Fish & Wildlife Service. The directory contains polygon and line NWI data for the extent of OCMU. There are also a number of duplicate files that have been altered in some way but there is no source documentation.	USFWS	1: 24,000	UTM Zone 17N	NAD 83	Yes
ocmu_ place.shp	Georgia GNIS Place Features	Cultural	This dataset is an automated inventory of physical and cultural geographic features located throughout the United States. The particular focus of this dataset is on cultural features such as parks, subdivisions, and shopping centers. The original dataset was clipped to the county boundary that contains OCMU.	USGS	1: 24,000	UTM Zone 17N	NAD 83	Yes

File_name	Layer_name	Category	Description	Source	Scale/ resolution	Project -ion	Datum	Meta data
ocmu_ airports.shp	Georgia Airports	Trans- portation	This dataset contains aircraft facilities, including public and private airports and stolports. The original dataset was clipped to the county boundary that contains OCMU.	USGS	1: 24,000	UTM Zone 17N	NAD 83	Yes
pipetran (dlg - directory)	Large-scale Digital Line Graph - Pipelines	Trans- portation	Vector polyline shapefiles representing pipeline DLGs in 7.5 minute blocks for the extent of OCMU and the surrounding areas.	USGS	1: 24,000	UTM Zone 17N	NAD 83	Yes—text file only
ocmu_ utilities .shp	Georgia DOT Transportation and Utility Lines	Trans- portation	This dataset contains utility pipelines and transmission lines. The original dataset was clipped to the county boundary that contains OCMU.	GDOT	1: 31,680	UTM Zone 17N	NAD 83	Yes
ut_comb 021.shp	Georgia DOT Transportation and Utility Lines (Bibb County)	Trans- portation	This dataset contains utility pipelines and transmission lines. The dataset is the same as the one above except that it only covers Bibb County.	GDOT	1: 31,680	UTM Zone 17N	NAD 83	Yes
railroad (dlg - directory)	Large-scale Digital Line Graph - Railroads	Trans- portation	Vector polyline shapefiles representing railroad DLGs in 7.5 minute blocks for the extent of OCMU and the surrounding areas.	USGS	1: 24,000	UTM Zone 17N	NAD 83	Yes—text file only
ocmu_ railroads.shp	Georgia DOT Railways	Trans- portation	This dataset contains centerlines for public railways. The original dataset was clipped to the county boundary that contains OCMU.	GDOT	1: 31,680	UTM Zone 17N	NAD 83	Yes
rail021 .shp	Georgia DLG-F Railway (Bibb County)	Trans- portation	This dataset contains railway features including railroads, rail yards, and public transit rail lines. Features were originally captured from the Georgia Department of Transportation's General Highway Base Map. They have been updated and photorevised using 1:12,000 1993 orthophotography. The dataset is the same as the one above except that it only covers Bibb County.	GDOT	1: 31,680	UTM Zone 17N	NAD 83	Yes—text file only

File_name	Layer_name	Category	Description	Source	Scale/ resolution	Project -ion	Datum	Meta data
roadtrail (dlg - directory)	Large-scale Digital Line Graph - Roads	Trans- portation	Vector polyline shapefiles representing road DLGs in 7.5 minute blocks for the extent of OCMU and the surrounding areas.	USGS	1: 24,000	UTM Zone 17N	NAD 83	Yes—text file only
ocmu_ road.shp	Georgia County Roads	Trans- portation	This dataset contains public roads including interstates, state highways, county roads and city streets. Features were originally captured from the GA DOT's General Highway Base Map. They have been updated and photorevised using 1:12,000 '93 and '99 orthophotography. The original dataset was clipped to the county boundary that contains OCMU.	GDOT	1: 31,680	UTM Zone 17N	NAD 83	Yes
roadtrail - trails - River_Trail (directory)	None - OCMU River Trail Mapping Data	Trans- portation	This directory contains a number of shapefiles that represent the River Trail located in the southern part of OCMU. The exact purpose of the data is not clear but they appear to support a map document named ocmu_river_trail_map that is dated December, 2004.	Un- known	unknown	UTM Zone 17N	NAD 83	No
trails.shp	Ocmulgee National Monument Trails	Trans- portation	This dataset represents the trails that are found in OCMU. The originator is unknown and there is no metadata but the trails are named and appear to be accurately represented.	Un- known	1: 24,000(?)	UTM Zone 17N	NAD 83	Yes
ocmu_cultura l.shp	Georgia GNIS Cultural Features	Cultural	This dataset is an automated inventory of physical and cultural geographic features located throughout the United States. The particular focus of this dataset is on cultural features such as churches, cemeteries, schools, and government properties. The original dataset was clipped to the county boundary that contains OCMU.	USGS	1: 24,000	UTM Zone 17N	NAD 83	Yes
crdata (directory)	None - OCMU Cultural Resources	Cultural	This directory contains the location of the earthlodge, trading post and mounds as well as the perimeters of these and other resources. The source is unknown and there is no metadata or other descriptive data files.	Un- known	Unknown	UTM Zone 17N	NAD 83	No

File_name	Layer_name	Category	Description	Source	Scale/ resolution	Project -ion	Datum	Meta data
ocmu_ecoregion.shp	USGSWR ecoregion (GA) - Aquatic ecoregions of the conterminous United States	Ecology	Ecoregions are based on perceived patterns of a combination of causal and integrative factors including land use, land surface form, potential natural vegetation, and soils (Omernik, 1987). This is a copy of the ecoregion coverage of Omernik (1987) with some item names modified. The original dataset was clipped to the county boundary that contains OCMU.	USGS	1: 7,500,500	UTM Zone 17N	NAD 83	Yes
physio_utm17.shp	Physiographic Map of Georgia	Geology	This is a physiographic map of Georgia showing Division, Province and Section.	Georgia Geo-logic Survey	1: 2,000,000	UTM Zone 17N	NAD 83	Yes
ocmu_ landform .shp	Georgia GNIS Landform Features	Geo-logy	This dataset is an automated inventory of physical and cultural geographic features located throughout the United States. The particular focus of this dataset is on physical landform features. The original dataset was clipped to the county boundary that contains OCMU.	USGS	1: 24,000	UTM Zone 17N	NAD 83	Yes
geology .shp	Digital Geology Map of Georgia (Ver. 2)	Geo-logy	This database delineates mapped geologic units for the state of Georgia. The geologic unit descriptions are based on field observations and outcrop or and specimen identification of rock types. Groupings of rock types within units are based on relative percentages estimated in the field.	Georgia Geologic Survey	1: 500,000	UTM Zone 17N	NAD 83	Yes
ocmu_ landfill .shp	Documentation Report 00-20. Solid Waste Landfills Within The State Of Georgia, Permitted Through December 1999	Land Use	This database contains locations and associated information for 522 EPD permitted solid waste disposal facilities (landfills) within the state of Georgia. Information in the database includes the landfill name, county location, latitude and longitude coordinates (in degrees, minutes, seconds) for the facility's weigh station or facility entrance, major river basin where site is located, and an 8-digit U.S. Geological Survey hydrologic unit code for the associated river basin. The original dataset was clipped to the county boundary that contains OCMU.	Geologic Survey Branch, Environmental Protection Division, Georgia Department of Natural Resources	1: 24,000	UTM Zone 17N	NAD 83	Yes

File_name	Layer_name	Category	Description	Source	Scale/ resolution	Project -ion	Datum	Meta data
ocmu_ bac.shp	Bacteria Monitoring Stations	Monit- oring	This data set provides a location map of selected water quality monitoring stations for 10 bacteria-related parameters from the U.S. EPA Storage and Retrieval of US Waters Parametric Data (STORET). The data set was prepared to support the U.S. EPA BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) System. The original dataset was clipped to the county boundary that contains OCMU.	EPA, Office of Water/ OST	1: 100,000	UTM Zone 17N	NAD 83	Yes
ocmu_ ga_nsi .shp	USEPA National Sediment Inventory (NSI) Version 1.2 for the Conterminous U.S.	Monit- oring	This dataset describes the accumulation of chemical contaminants in river, lake, ocean, and estuary bottoms and includes a screening assessment of the potential for associated adverse effects on human and environmental health. The data set was prepared to support the U.S. EPA BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) System. The original dataset was clipped to the county boundary that contains OCMU.	EPA, Office of Water/ OST	1: 100,000	UTM Zone 17N	NAD 83	Yes
ocmu_ ga_rcris .shp	EPA/OSW Resource Conservation and Recovery Information System (RCRIS) for the United States	Monit- oring	This dataset describes locations that are monitored by the Resource Conservation and Recovery Information System (RCRIS) due to their being generators, transporters, treaters, storers, and/or disposers of hazardous waste. The system is used primarily used to track handler permit or closure status, compliant with Federal and State regulations, and cleanup activities. The data set was prepared to support the U.S. EPA BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) System. The original dataset was clipped to the county boundary that contains OCMU.	EPA, Office of Water/ OST	1: 100,000	UTM Zone 17N	NAD 83	Yes

File_name	Layer_name	Category	Description	Source	Scale/ resolution	Project -ion	Datum	Meta data
ocmu_ ga_tri .shp	EPA - USEPA Toxic Release Inventory Facilities for Georgia	Monit- oring	This database contains data on annual estimated releases of over 300 toxic chemicals to air, water, and land by the manufacturing industry. The data includes the location of the facility where chemicals are manufactured, processed, or otherwise used; amounts of chemicals stored on-site; estimated quantities of chemicals released; on-site source reduction and recycling practices; and estimated amounts of chemicals transferred to treatment, recycling, or waste facilities. The data set was prepared to support the U.S. EPA BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) System. The original dataset was clipped to the county boundary that contains OCMU.	EPA, Office of Water/OST	1: 100,000	UTM Zone 17N	NAD 83	Yes
ocmu_ ga_wq_ stat .shp	EPA's STORET Water Quality Monitoring and Data Summaries for CONUS	Monit- oring	This data set provides statistical summaries of water quality monitoring for 47 physical and chemical-related parameters. The parameter specific statistics were computed by station for 5-year intervals from 1970 to 1994 and a three year interval from 1995 to 1997 from the U.S. EPA Storage and Retrieval of US Waters Parametric Data (STORET). The data set was prepared to support the U.S. EPA BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) System. The original dataset was clipped to the county boundary that contains OCMU.	EPA, Office of Water/OST	1: 100,000	UTM Zone 17N	NAD 83	Yes
ocmu_ gage .shp	USEPA STORET Stream Flow Data from Gaging Stations in CONUS	Monit- oring	This data set provides an inventory of surface water gaging station data including 7-Q-10 low and monthly stream flow. The data set was prepared to support the U.S. EPA BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) System. The original dataset was clipped to the county boundary that contains OCMU.	EPA, Office of Water	1: 100,000	UTM Zone 17N	NAD 83	Yes

File_name	Layer_name	Category	Description	Source	Scale/ resolution	Project -ion	Datum	Meta data
gsm soilmu_ a_ga .shp	State Soil Geographic (STATSGO) data base for Georgia	Soils	This data set is a digital general soil association map developed by the National Cooperative Soil Survey. It consists of a broad based inventory of soils and nonsoil areas that occur in a repeatable pattern on the landscape and that can be cartographically shown at the scale mapped. The soil maps for STATSGO are compiled by generalizing more detailed soil survey maps. The data is in both shapefile and coverage formats and is accompanied by a large amount of descriptive tabular data.	U.S. Department of Agriculture, Soil Conservation Service	1: 250,000	UTM Zone 17N	NAD 83	Yes—text file only
ga_stats go.shp	State Soil Geographic (STATSGO) data base for Georgia	Soils	This data set is a digital general soil association map developed by the National Cooperative Soil Survey. It consists of a broad based inventory of soils and nonsoil areas that occur in a repeatable pattern on the landscape and that can be cartographically shown at the scale mapped. The soil maps for STATSGO are compiled by generalizing more detailed soil survey maps. The data is in both shapefile and coverage formats and is accompanied by a large amount of descriptive tabular data. This dataset is similar to the STATSGO sets described above but it has been clipped by some layer that included the state of Georgia and surrounding areas in the neighboring states.	U.S. Department of Agriculture, Soil Conservation Service	1: 250,000	UTM Zone 17N	NAD 83	Yes
ssurgo (directory)	Soil Survey Geographic (SSURGO) database for Bibb County, Georgia	Soils	This dataset is a SSURGO digital soil survey and generally is the most detailed level of soil geographic data developed by the National Cooperative Soil Survey. The data is divided into spatial files in poly, line, and point formats and descriptive attribute files in text and database tabular formats.	U.S. Department of Agriculture, Natural Resources Conservation Service	1: 12,000	Geog-raphic CS	NAD 83	Yes—text file only

File_name	Layer_name	Category	Description	Source	Scale/ resolution	Project -ion	Datum	Meta data
ssurgo_ nps (directory)	NPS - Soil Survey Geographic (SSURGO) database for Ocmulgee National Monument, Georgia	Soils	This data set is a digital soil survey and generally is the most detailed lever of soil geographic data. Specifically, the data set is identical to the one listed above except that it has undergone some additional processing by NPS personnel such as clipping the set to the park extent and adding the musym names to the attribute table.	NPS—GRD - SIMP	1: 24,000	UTM Zone 17N	NAD 83	Yes
SREL_ Inv (directory)	Herpetofaunal Species Locations	Species	This directory contains the locations of herpetofauna found in Ocmulgee National Monument (OCMU) during a study performed by Tuberville, Willson, Dorcas, and Gibbons in conjunction with the Savannah River Ecology Laboratory (SREL) between May 2001 and October 2003. Please refer to: "Herpetofaunal Species Richness of Southeastern National Parks." Southeastern Naturalist 4.3 (2005): 537-569 for more detailed information about the study. The data is divided into one spatial file and one tabular file in order to provide all of the features found during the study as some of the sampling locations were not defined spatially.	SREL/ SECN	1: 15,000	UTM Zone 17N	NAD 83	Yes
watershd (directory)	Georgia Hydrologic Unit Boundries, 2-, 4-, 6-, 8-, 10-, and 12-digit.	Water-shed	This directory contains shapefile data sets of the 2-, 4-, 6-, 8-, 10-, and 12-digit hydrologic unit boundaries for Georgia and parts of Alabama, South Carolina, North Carolina, Florida, and Tennessee. The boundaries were delineated on 1:24,000 7.5 minute USGS topographic quadrangles which were scanned into a digital image and vectorized interactively on a computer graphic display. The hydrologic unit polygons are tagged with the appropriate 2-, 4-, 6-, 8-, 10-, and 12-digit codes but they are not named.	USGS	1: 24,000	UTM Zone 17N	NAD 83	Yes—text file only

File_name	Layer_name	Category	Description	Source	Scale/ resolution	Project -ion	Datum	Meta data
huc 12 (directory)	Georgia Hydrologic Unit Boundries, 8-, 10-, and 12-digit.	Water-shed	This directory contains shapefile data sets of the 8-, 10-, and 12-digit hydrologic unit boundaries for Georgia and parts of Alabama, South Carolina, North Carolina, Florida, and Tennessee. The boundaries were delineated on 1:24,000 7.5 minute USGS topographic quadrangles which were scanned into a digital image and vectorized interactively on a computer graphic display. The hydrologic unit polygons are tagged with the appropriate 8, 10, and 12 digit codes. The directory also contains coverage files and a series of tabular data sets that describe the same huc areas. The data is projected in both UTM 16 and 17, NAD 83.	USGS	1: 24,000	UTM Zone 17N	NAD 83	Yes—text file only
wetlands 021.shp	Georgia DOT Polygonal Hydrography —Bibb County Wetlands	Wet-lands	This dataset contains polygonal hydrographic features including lakes, ponds, reservoirs, swamps, and islands for the county that contains the park. Multiple counties have been merged together where necessary to cover the full extent of a particular park.	GDOT	1: 31,680	UTM Zone 17N	NAD 83	Yes—text file only
doqq (directory)	Digital Orthophoto Quadrangles	Images	This directory contains B&W 3.75 minute DOQQ imagery in MrSID format that cover the extent of OCMU (circa 1993). There are also a large number of quads that cover the areas surrounding the park.	USGS	1 meter	Un-known	Un-known	Yes—text file only
doqq_ 1999 (directory)	1999 Color Infrared DOQQs for the state of Georgia	Images	This directory contains color infrared DOQQ imagery in MrSID format that covers the extent of OCMU. The original dataset apparently covered the entire state. The directory also includes a DOQQ index for the state of Georgia.	Center for GIS, Ga. Tech.	1 meter	UTM Zone 17N	NAD 83	Yes—text file only

File_name	Layer_name	Category	Description	Source	Scale/ resolution	Project -ion	Datum	Meta data
drg (directory)	Digital Raster Graphics (DRGs)	DRGs	This directory contains non-collared digital raster graphics (DRGs), which are scanned images of U.S. Geological Survey (USGS) topographic maps that cover the extent of OCMU in a variety of formats. The images inside the map neatline are georeferenced to the surface of the Earth. Specifically, the directory contains individual unprojected quarter quad images and a projected mosaic. The directory also includes a DOQQ index for the state of Georgia.	USGS	1:24,000/1: 100,000	UTM Zone 17N	NAD 83	Yes—text file only
ocmu_ gap.img	1998 vegetation/lan d cover map of Georgia	Images	This statewide land cover map was produced from Landsat TM imagery with a spatial resolution of 30x30m as a part of the Georgia GAP Analysis Project. The original dataset was clipped to the spatial extent of OCMU and the surrounding areas. A table that contains the key that defines the land cover codes found in the image attribute table is also included in the same directory.	Natural Resource Spatial Analysis Laboratory, Institute of Ecology, University of Georgia	30 meters	UTM Zone 17N	NAD 83	Yes
imagery (directory)	Assorted OCMU Imagery	Images	This directory contains two subdirectories. The first (Aerials) contains a number of unprojected color images of OCMU and the surrounding areas. According to the photo stamp, the acquisition dates were sometime during 1990. There is no source information or metadata. The second subdirectory (photos) is a copy of most of the doqq directory described above.	Unknown	1:3600 per photo stamp	Un-known	Un-known	No
ocmu_ landsat .img	WEBMAP.LAN DSAT_L277 (Landsat Orthoimagery Mosaic)	Images	The Landsat Mosaic orthoimagery database contains Landsat Thematic Mapper imagery for the conterminous United States. The more than 700 Landsat scenes have been resampled to a 1-arc-second (approximately 30-meter) sample interval in a geographic coordinate system using the North American Horizontal Datum of 1983. The original image was clipped to include the area containing and surrounding the park area.	USGS	30 meter	UTM Zone 17N	NAD 83	Yes

File_name	Layer_name	Category	Description	Source	Scale/ resolution	Project -ion	Datum	Meta data
maps (directory)	Assorted OCMU Map Documents	Images	This directory contains a number of maps that focus primarily on general park location and fire management related themes. Of note, the ocmu_river_trail_map document that was mentioned in the River_Trail directory described above is also found in this directory. The maps are in .tif format and most have an accompanying .pdf and .mxd file.	Unknown—most likely park personnel	N/A	Other	Other	No
NAIP_ 2005 (directory)	NAIP Digital Georectified Image(s)	Images	This directory contains true color digital ortho quarter quad imagery from the National Agricultural Imagery Program (NAIP) in GeoTIFF format. NAIP acquires digital ortho imagery during the agricultural growing seasons in the continental U.S. Specifically, the directory contains 2005 NAIP imagery for the extent of OCMU and the surrounding areas.	USDA-FSA-APFO Aerial Photograph y Field Office	1 and 2 Meter	UTM Zone 17N	NAD 83	Yes
ocmu_ 2005.sid	National Agriculture Imagery Program (2005) Bibb County, GA	Images	This directory contains essentially the same imagery as described above with the following exceptions: the imagery is a part of a county mosaic that has been clipped to the areas that contain OCMU and the immediately surrounding areas and the imagery is in a preliminary stage whereas the imagery described above is the final product. All of the other information stated in the aforementioned description applies to the imagery in this directory as well.	USDA-FSA-APFO Aerial Photograph y Field Office	1 and 2 Meter	UTM Zone 17N	NAD 83	Yes
ocmu_nlcd.im g	Georgia Land Cover Dataset	Images	The National Land Cover Dataset was compiled from Landsat satellite TM imagery (circa 1992) with a spatial resolution of 30 meters and supplemented by various ancillary data (where available). The original image was clipped to include the area containing and surrounding the park area.	USGS	30 meter	UTM Zone 17N	NAD 83	Yes

File_name	Layer_name	Category	Description	Source	Scale/ resolution	Project -ion	Datum	Meta data
ocmu_nlcd01 .img	National Land Cover Database Zone 54 & 55 Land Cover Layer	Images	This dataset (NLCD 2001) is an update of the 1992 NLCD described above. The extent covers the extent of OCMU and the surrounding areas. Note: there are two metadata files associated with this dataset due to it is spanning of two land use zones (54, 55) - both files are provided in the dataset file folder.	USGS	30 meter	UTM Zone 17N	NAD 83	Yes
SPOT—109340-05 (directory)	OCMU SPOT Imagery	Images	This directory contains 2004 color GeoTIFF SPOT imagery that covers the extent of OCMU. There are two metadata sources: one is in pdf form and the other is in dimap form. The dimap metadata can be opened with an internet browser.	Spot Image	20 meter	Unknow n	WGS 84	Yes—text file only
SPOT—109340-07 (directory)	OCMU SPOT Imagery	Images	This directory contains 2004 grayscale GeoTIFF SPOT imagery that covers the extent of OCMU. There are two metadata sources: one is in pdf form and the other is in dimap form. The dimap metadata can be opened with an internet browser.	Spot Image	10 meter	Unknow n	WGS 84	Yes—text file only
SPOT—109340-09 (directory)	OCMU SPOT Imagery	Images	This directory contains 2002 grayscale GeoTIFF SPOT imagery that covers the extreme eastern portion of OCMU. There are two metadata sources: one is in pdf form and the other is in dimap form. The dimap metadata can be opened with an internet browser.	Spot Image	10 meter	Unknow n	WGS 84	Yes—text file only
SPOT—109340-11 (directory)	OCMU SPOT Imagery	Images	This directory contains 2002 color GeoTIFF SPOT imagery that covers the extreme eastern portion of OCMU. There are two metadata sources: one is in pdf form and the other is in dimap form. The dimap metadata can be opened with an internet browser.	Spot Image	20 meter	Unknow n	WGS 84	Yes—text file only

NPS 363/140239, September 2017

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