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Assessment of Water Resources and Watershed Conditions in Ocmulgee National Monument, Georgia

Natural Resource Report NPS/SECN/NRR—2010/276

ON THE COVER
Late autumn, Ocmulgee National Monument's largest wetland, viewed from atop the Great Temple Mound
Photograph by: Michael Mallin

Assessment of Water Resources and Watershed Conditions in Ocmulgee National Monument, Georgia

Natural Resource Report NPS/SECN/NRR—2010/276

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Executive Summary

The purpose of this report was to locate and assess existing information pertaining to the water quality in and around Ocmulgee National Monument (OCMU), assess the present and likely future water conditions, and make recommendations to fill existing information gaps. Water quality and quantity, habitat issues, the potential for invasive species, trends in resource use in OCMU, and watershed influences and other stressors were addressed insofar as possible through available data and first-hand observations.

OCMU consists of two small tracts of land (701.5 acres in total) located on the eastern edge of the City of Macon in central Georgia. It also lies downstream and down-airshed from the "looming shadow" of the greater Atlanta metropolitan area. The monument consists of two parcels of land that are separated by about 2.5 miles, including the Main Unit (656.5 acres) and the much smaller Lamar Unit (45 acres). Drinking water for the monument is supplied from the Macon Water Authority (MWA), and wastewater is disposed of by that entity as well.

OCMU is a national historic treasure because it is the only known site in the eastern U.S. with a continuous history of native North Americans 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 Native American earth lodge, burial mound, other temple mounds, prehistoric trenches, and the site of a colonial British trading post. They also come to enjoy OCMU's greenspace – its hiking trails, diversity of bird species, and other of its natural resources.

The overall assessment of this Report is that the natural and cultural resources of OCMU are seriously threatened by upstream and encroaching urbanization, and by the multitude of water and air pollutants and other stressors associated with rapid human population growth, land development, and natural resource degradation and destruction. The five streams that flow through OCMU, including three perennial streams, all show signs of degradation from sedimentation, bank erosion, and trash accumulation. The two major streams, segments of the Ocmulgee River and its major tributary Walnut Creek, have been designated as impaired waters for biota and/or general recreation on the state's 303(d) list. The causes of impairment have been identified as urban nonpoint pollution, in particular, excessive sediment loading and high fecal coliform bacterial densities. The Ocmulgee River segment is also impaired for fish consumption because of high PCB content.

The Macon area also has a sad history of repeated destruction and degradation of Native American historic features, including sacred burial mounds, because of railroad construction, railroad track relocation, and highway construction through OCMU and adjacent mound areas, as well as farming and other activities. The ecosystems of OCMU, inherently highly vulnerable to edge and fragmentation effects, are threatened by yet another major connector highway that will cut between the two OCMU Units and bisect the Ocmulgee Old Fields Traditional Cultural Property. The National Parks Conservation Association, a nonprofit national advocacy organization dedicated to protecting, restoring, and enhancing national parks, included OCMU in 2002 on its list of America's Ten Most Endangered Parks in recognition of the fact that this connector road project has the potential to cause irreparable harm to OCMU. The Ocmulgee Old Fields Traditional Cultural Property was also listed by the National Trust for Historic

Preservation in 2003 on its list of the eleven most endangered historic places in the nation. Despite this potential for major impacts, the Georgia Department of Transportation indicated as of late 2008 that the plans to build the connector may proceed. The increased traffic is expected to increase nonpoint contaminant pollution on water resources and to adversely affect air quality.

The hydrology of OCMU, 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 about three feet ca. 20 years later. The levee effectively channelized the river, with attendant negative, sustained impacts on water quality and aquatic communities. Hydrologic data are not available for most of the Monument's surface waters, and there are no wells for tracking groundwater quality and supplies. The aquatic flora and fauna of OCMU are poorly known, other than species lists, and the water quality data for its streams mostly have been and continue to be collected an inadequate frequency of only seasonally to once or twice per year. Information is lacking, as well, on OCMU wetlands.

The airshed is in violation of federal ozone and fine particulate standards that threaten the health of OCMU staff and frequent visitors, and the high ozone concentrations may be damaging terrestrial plant foliage. OCMU also lies in an area that is prone to atmospheric acid deposition, and acidification, especially acid spates, likely is adversely affecting its surface waters.

Diverse exotic/invasive plant and animal species occur in both terrestrial and aquatic/wetland habitats of OCMU. Impacts on terrestrial ecosystems have been documented for some of these species, such as feral hogs, but effects on the Monument's aquatic and wetland resources have not been assessed. Other stressors to OCMU's natural and historic resources are 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.

Editor's Note: This assessment is based on the state of Ocmulgee National Monument in 2007. However, research on the natural resources of Ocmulgee National Monument is ongoing. Background information on the resources present (or thought to be present) within the park has been updated to reflect the most current data available, but in many cases we have presented information on the state of the park at the time the assessment was conducted.

Recommendations

OCMU, downstream and down-airshed from the Atlanta metropolitan area, is vulnerable to encroaching and surrounding urbanization. The NPS is ill-equipped to protect its vitally important water resources from airshed and watershed pollution and other stressors because the stressors, for the most part, are outside of NPS control. In addition, there is inadequate information on water quality conditions or aquatic community health. Few data are available on aquatic flora and fauna, mostly limited to surveys of species occurrence. The following recommendations can be addressed within NPS jurisdiction. These recommendations address pressing needs to help restore and protect the seriously degraded water resources of this historic national treasure.

Water Quality

- A top priority is to conduct a two-year water quality monitoring program in OCMU segments of the Ocmulgee River, Walnut Creek, and the small tributaries with biweekly or monthly sampling frequency (insofar as possible for the intermittent tributaries) to track water quality conditions in the park. Two stations on each stream, including inflow and outflow of the Ocmulgee River and Walnut Creek from OCMU, should be sampled for, at a minimum, water temperature, pH, dissolved oxygen, suspended solids, turbidity, nutrients (TN, TP, nitrate, ammonium, BOD_5), fecal coliform densities, and chlorophyll *a* concentrations. This effort should be repeated at five-year intervals. Additional effort also should be expended to include monitoring of storm events because they are known to contribute most nonpoint source pollution (for example, from urban runoff). Benchmarks for acceptable water quality should consider the information contained in *Table 15* for streams with designated use for Fishing.

- Data should be collected at least annually on toxic substance concentrations (PCBs, heavy metals, pesticides, pharmaceuticals) in sediments and fish or benthic faunal tissues. Published benchmarks for acceptable water quality for streams with designated use for Fishing should be used to evaluate the information.

- The origin of the high fecal coliform contamination affecting OCMU surface waters has been in contention (Chief Ranger G. LaChine, pers. comm.). While urban runoff clearly is a factor, the contribution from wildlife has not been assessed. A study should be undertaken over an annual cycle to apply state-of-the-art molecular "fingerprinting" techniques to assess the origin of fecal coliform contamination.

- The park should inventory changes in land use/land cover in the watersheds of Walnut Creek and the Ocmulgee River upstream from and surrounding the park, including traditional categories but also septic tanks in new subdivisions, new highway projects, new shopping centers, and other potential sources of water pollution. The data should be used to create GIS maps of these sources, which can be upgraded over time to help the NPS track pollution and its impacts in park waters.

Ecosystem and Community Health

- At least once per year during an appropriate seasonal timeframe, the macroinvertebrate communities (benthic fauna, aquatic insects) should be assessed in at least two stations on

the Ocmulgee River, Walnut Creek, and the three smaller streams in OCMU. Benchmarks should consider published descriptions of healthy macroinvertebrate communities in warmwater streams. The data should be used to track stream ecological condition (rated from Excellent to Poor) over time.

- At least once per year during an appropriate seasonal timeframe, the fish community in the park segments of the Ocmulgee River and Walnut Creek should be assessed. The fish data should be used to develop an Index of Biotic Integrity and an Index of Well-Being for fish population health over time.

- OCMU's wetland ecosystems should be mapped and assessed, at least at five-year intervals, for indices of diversity, function, and overall health.

- A sampling program should be developed to establish present conditions and track exotic invasive species affecting terrestrial as well as aquatic/wetland sources in OCMU, so that OCMU staff can develop active management strategies to optimize control. Assessment of exotic invasive species should be repeated at least at three-year intervals to enable detection of species that may rapidly invade.

- An updated biological inventory should be completed for herpetofauna, following the protocol outlined in Tuberville et al. (2005).

- A baseline biological inventory is needed for the composition and abundance of benthic microalgal assemblages in OCMU, following protocols in Wetzel and Likens (2001). The benthic microalgal (periphyton) data should be used to develop an index of biotic integrity (e.g. following Hill et al. 2000) for the Ocmulgee River and Walnut Creek in the park area.

- OCMU lies within a trough of the Atlanta airshed, and within the Macon-Warner Robins-Fort Valley combined statistical area. The NPS should assess incidence of foliar injury to park plants from ozone pollution, including common wetland bioindicator species such as yellow poplar and American elder. More generally, data are needed to assess the extent to which air pollution is affecting OCMU, and to forecast how increasing air pollution from the greater Atlanta and Macon metropolitan areas will affect its waters and other natural resources. Sampling devices should be installed to establish present conditions and track air pollutants such as ozone, $PM_{2.5}$, and mercury.

- OCMU's five streams should be the focus of stream restoration projects to assist in their recovery from excessive sedimentation, with highest priorities for Walnut Creek and the Ocmulgee River. Monument staff should monitor the streams for erosion of the stream banks, which is commonly related to upstream urban watershed activities, and for tree damage from beavers which can lead to increased bank erosion. Construction of beaver dams within the park should not be permitted, since this would increase on-site flooding and threaten cultural resources.

Groundwater

- OCMU's groundwater resources should be assessed through partnership with the USGS, including recharge/discharge areas, movement, and chemical quality.

Education Outreach

- OCMU should continue its excellent efforts to strengthen education outreach to teach visitors about the importance of greenspaces such as the monument in ecosystem sustainability.

Other Actions

- The NPS should seek cumulative mitigation (e.g. floodplain restoration) and push for a full Environmental Impact Statement of the I-16/I-75 project of GA DOT, which would widen I-16 through the monument under an Environmental Assessment. GA DOT is required to investigate and carefully consider cumulative impacts, which include past, present, and future impacts of this project. Thus, impacts from the original construction of I-16 and the associated installation of the Macon Levee should be assessed for their impacts on the monument, and these impacts should be mitigated within the framework of the present I-16/I-75 improvements project. Restoration of the floodplain would reduce flood magnitudes and frequencies. Alternative routing of I-16 that would avoid the TCP should be seriously considered as well.

- The NPS should pursue actions to protect remaining undeveloped lands (e.g. increase in greenspace setasides) adjacent to OCMU to target a goal of protecting and growing buffer areas around the park.

- Trash coming into OCMU from the City of Macon should be monitored (type, most frequent entry locations, weight). Trash collecting devices of the City, if present should be rigorously evaluated for their efficacy in keeping trash and other refuse from entering OCMU

Acknowledgments

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Abbreviations

BOD_5 – biochemical oxygen demand (five-day testing duration)

cfs – cubic feet per second

cfu – colony-forming units

CCC – criterion continuous concentration (U.S. EPA)

CAAE – Center for Applied Aquatic Ecology (of NCSU)

CMC – criterion maximum concentration (U.S. EPA)

COD – chemical oxygen demand

CPU – chloroplatinate units (U.S. EPA) for water color

DIP – dissolved inorganic phosphorus

DO – dissolved oxygen

DOC – dissolved organic carbon

DON – dissolved organic nitrogen

DOP – dissolved organic phosphorus

DP – dissolved organic phosphorus

GA – Georgia

GA DNR – Georgia Department of Natural Resources

GA DOT – Georgia Department of Transportation

ECHO ICIS – Enforcement and Compliance History Online Integrated Compliance Information System (of the U.S. EPA)

EPD – Environmental Protection Division (of GA DNR)

GIS – Geographic Information System

IPCC – United Nations Intergovernmental Panel on Climate Change

OCMU – Ocmulgee National Monument

m – meter

mgd – million gallons per day

mg/L – milligrams per liter (= parts per million)

µg/L – micrograms per liter (= parts per billion)

monument – Ocmulgee National Monument

MPN – most probable number

MS4 – municipal separate storm sewer system

MWA – Macon Water Authority

NARSAL – Natural Resources Spatial Analysis Laboratory

N – nitrogen (nutrient; excessive enrichment can degrade water quality)

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)

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

NPCA – National Parks Conservation Association

NPDES - National Pollutant Discharge Elimination System

NPS – National Park Service

NTU – nephelometric turbidity units

P - phosphorus (nutrient; excessive enrichment can degrade water quality)

PCS – Permit Compliance System (of the U.S. EPA)

$PM_{2.5}$ – particulate matter, diameter $\leq$ 2.5 µm (air pollutant)

PM_{10} – particulate matter, diameter $\leq$ 10 µm (air pollutant)

QA/QC – quality assurance/quality control (refers to standardized procedures for ensuring acceptable quality of data)

SECN – Southeast Coast Network of the National Park Service

SO_2 – sulfur dioxide (air pollutant)

SRP – soluble reactive phosphate

STORET – STOrage and RETrieval Environmental Data System (of the U.S. EPA)

SVOC – semi-volatile organic compounds, also called polycyclic aromatic hydrocarbons (air pollutants)

TCP – Traditional Cultural Property (Ocmulgee Old Fields)

TMDL – total maximum daily load

TSS – total suspended solids

USACE – United States Army Corps of Engineers

USDA – United States Department of Agriculture

USDI – United States Department of the Interior

U.S. EPA – United States Environmental Protection Agency

USGS – United States Geological Survey

VOC – volatile organic compound

WPCP – water pollution control plant

WQ – water quality

WRD – Wildlife Resources Division of GA DNR

WUI – Wildland-Urban Interface

Park Description

Background

Location, Size, and Boundaries

Ocmulgee National Monument (OCMU, 701.5 acres), located on the eastern edge of Macon (population 97,255 as of 2000 – thus, nearly a decade ago; www.census.gov) in Bibb County, central Georgia (*Figure 1*). OCMU is also 85 miles south of the greater Atlanta metropolitan area, and lies in its "long shadow" of urban sprawl and its multitude of associated effects. The Main Unit of OCMU (656.5 acres, 381 feet above mean sea level) is accessible from U.S. 80 East off Interstate 16. It has 5.5 miles of walking trails, a reconstructed 1,000-year-old ceremonial earth lodge near the visitor center, the Great Temple Mound about 0.5 mile 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 Unit (or Lamar Mounds and Village Unit; ~45 acres, 280 feet above mean sea level; *Figure 2*), is about 2.5 miles southeast of the Main Unit in low-lying floodplain, and is accessible by an unnumbered county road called Confederate Way (DeVivo 2006). OCMU has an estimated ~130,000 visitors per year (Chief Ranger G. LaChine, pers. comm.).

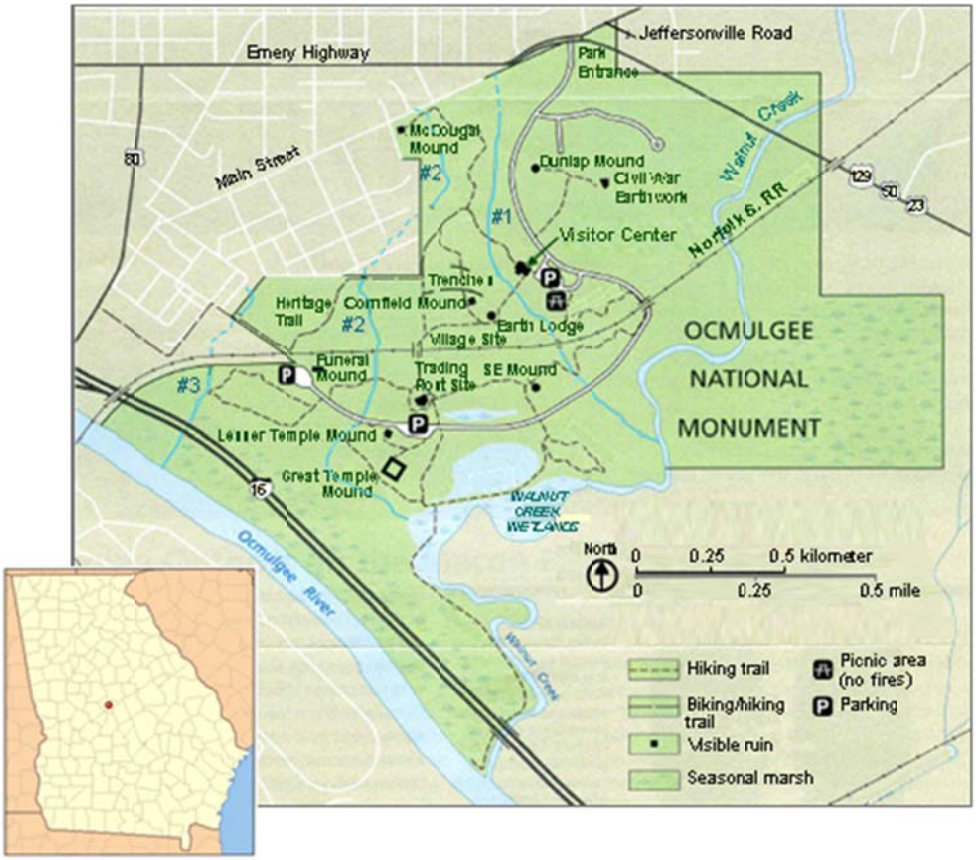

Figure 1. Location and map of the Main Unit of OCMU, mostly surrounded by the City of Macon; a second, much smaller unit, the Lamar Unit, is about two miles south near the Ocmulgee River (NPS 2008a). Extensive wetlands and the two major streams of OCMU, the Ocmulgee River and its tributary Walnut Creek, are shown as well as three smaller streams (#1-#3). Map modified from NPS (2008a).

OCMU is under the jurisdiction of the U.S. NPS but, as a U.S. National Monument, which all are declared by the President of the United States without Congressional approval, OCMU has received less funding and less protection than U.S. national parks. The NPS maintains a visitor center, archaeological museum, 6 miles of hiking trails linking historical monuments, a picnic area, and several archaeological ruins. The OCMU Superintendent has an office on-site (http://www.nps.gov/ocmu/). Land use within OCMU boundaries is predominantly riverine emergent wetland, as well as some upland grassy fields and forests (DeVivo 2006). The wetlands within and adjacent to OCMU contain one of the largest peat bogs in the Southeast, though they are not currently within the park's boundaries.

History of OCMU

Ocmulgee (pronounced oak-*mull*-ghee) National Monument is a memorial to the early Native Americans 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). OCMU is the only known site in the eastern U.S., and one of the few units under NPS jurisdiction, with a continuous history of native North Americans over the last 10,000 to 12,000 years, including rich archeology of the first agrarian civilization in eastern North America (NPS 2005). It preserves ruins, artifacts, and historical monuments that were created over at least 12,000 years of human habitation in this area. Archeological evidence suggests that the region was inhabited by a sequence of native southeastern cultures including Ice Age hunters (Pre-9000 BCE), Woodland Indians (1000 BCE - 900), early (900-1150) and late Mississippians (1150 – 1600), and Muscogee (Creek) Indians (1690 - 1715). The early Mississippians were an elite society supported by skilled farmers, and lived on the OCM site near the Ocmulgee River; they constructed a town of rectangular wooden buildings, large pyramidal temple mounds, and at least one burial mound. Originally from the central Mississippi Valley, these people were horticulturalists who grew corn, beans, squash, tobacco and other plants in small gardens throughout their settlements.

Mississippians were organized as chiefdoms or ranked societies wherein the elite sector, who made up a small percentage of the population, had a higher social standing than the commoners, who were responsible for growing food, making crafts, and protecting the chiefdoms. Historical and archaeological information shows that ceremonial and burial mounds, like those preserved at OCMU, were closely associated with Mississippian chiefs, who were believed to possess supernatural powers. Chiefs built their houses and placed temples to their ancestors on mounds, conducted rituals from the summit of mounds, and buried their ancestors within mounds. Mississippian towns containing one or more of these special structures served as the capitals of chiefdoms, and OCMU maintains four mounds built by the Mississippian culture.

Near the end of the late Mississippian period, Spaniard Hernando de Soto and his army traveled through the Southeast in search of riches, and the Mississippian culture that once inhabited OCMU and the surrounding area ended as European diseases introduced by early explorers and colonists devastated native populations in some areas. The desire for European goods and the trade in native slaves and deerskins caused entire social groups to relocate closer to or farther from European settlements. The result was the collapse of native chiefdoms as their populations were reduced, their authority structures were destroyed, and their people were scattered across the region.

The Earth Lodge or council chamber at OCMU, discovered by archeologists in 1934, was constructed by the Early Mississippians and is the largest, earliest, and best preserved of such structures known from the eastern U.S. (NPS 2005). It was built early in the last millennium (ca. 1015 CE) but burned in the 12th century. Although the great mounds of OCMU inspire awe and admiration, the history of how the pre-Columbian archeological resources faired prior to establishment of OCMU underscores the need for this national monument to preserve this early part of our country's heritage: In 1802 a fort was established at Ocmulgee, and in 1805 the Creek Indians were forced to cede their claims east of the Ocmulgee River (NPS 2005). They managed to retain title to 15 acres around the mounds until 1826, and by 1840 most of the site had been cleared for Anglican agriculture. In 1843 the Central of Georgia Railroad destroyed a large part of a major mound (later designated by archeologists as Mound B) and littered the landscape with artifacts and "a number of skeletons and human bones" (Hally 1994, in NPS 2005). In 1849 another mound (the McDougal Mound) similarly was destroyed to provide earth fill for Main Street in East Macon. In 1871 the Central of Georgia Railroad abandoned the first railroad line across the mound area and replaced it with a line farther north that destroyed another mound (Mound C) and "littered the landscape". The Great Temple Mound (designated by archeologists as mound A; *Plate 1*) remained relatively intact. The course of progressive degradation of most of the archeological resources in the area, through these and other actions such as plowing, was not altered until the 1930s.

Plate 1. Present-day view of the Great Temple Mound, OCMU (photo: picasaweb.google.com/.../fQXtp2v8x-n06KR7QoL89g, with permission).

Creation of OCMU

Through the persistence of local citizens, the federal Smithsonian Institution began archeological investigation of Ocmulgee in 1934, and Congress authorized establishment of OCMU in July of that year (NPS 2008a). Although federal funding was not appropriated to accomplish it, the F.D. Roosevelt administration's New Deal Civil Works Administration and Works Progress Administration supported the excavation effort. The remains of the Earth Lodge began to be exposed in March 1934. By 1936, local fund-raising efforts had secured only ~680 acres of land, but just before Christmas that year, reconstruction of the Earth Lodge began and President Roosevelt formally established OCMU under the NPS (NPS 2008a). The visitor's center was finally dedicated in November 1951, and OCMU was listed on the National Register of Historic Places as a historic unit of the NPS on 15 October 1966. The present monument of 702 acres is less than half the size that originally was authorized, as the remaining lands were never acquired. The Main Unit (657 acres), 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 (45 acres), the Lamar Unit (Lamar Mounds and Village Unit), is ~2.5 miles southeast, separated by privately owned lands (NPS 2008a). A spiral ramp that ascends one of the Lamar Mounds is the only one known to exist in the U.S. (Obey 2002).

Land Use / Land Cover in the Ocmulgee Watershed

The Ocmulgee River watershed, which includes OCMU at its southern end, has an area of 6,180 square miles. The most extensive urban development in the Ocmulgee watershed is concentrated in the upper watershed, followed by the Macon area.

The NCSU CAAE generated a land use-land cover map for the Ocmulgee River basin, and for the Walnut Creek sub-basin, (*Figure 2*) using the following procedure. The basin and sub-basin boundaries (8-digit Hydrologic Unit Code) Geographic Information System (GIS) data layer were provided by the U.S. Geological Survey (USGS), and National Land Cover data for 2001 (most recent dataset available) were downloaded from the USGS Seamless Data Distribution System (http://seamless.usgs.gov/). Using the Spatial Analyst extension of ArcGIS9.1, the land use classification system was modified to include eight general categories: urban areas, 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.

Land use/land cover data for the watersheds of the Ocmulgee River and Walnut Creek still retain a major proportion as forest/shrubs (~60%; Table 1). Overall, the total land use in the Ocmulgee River watershed is ~10.8% urban, 59.4% forest, 20.4% row crops/pasture /other grasses, and ~7.9% wetland. The total land use in the Walnut Creek watershed is ~23.3% urban, 62.7% forest, 21.2% row crops/ pasture/other grasses, and 3.3% wetland. The two watersheds upstream from and immediately adjacent to OCMU, however, are mostly urbanized.

Land use/land cover information available from 1974 - 2005 for the upper Ocmulgee watershed (*Figure 3*) more clearly indicates the influence of the greater Atlanta metropolitan area. Urban development (high- and low-intensity) increased by 324% over the ~30-year period, and by 67% from 1991-2005. During the past ~15 years, impervious area doubled (increase from 1991-2005, 103%), total forest cover decreased by 18%, row crops and pasture decreased by 7%, and forested wetlands decreased by 6%. Surprisingly, non-forested wetlands increased from 79 acres

in 1974 to 543 acres in 2005 (~587% increase), while the beaches-dunes-mud category of land cover decreased by 46% (*Table 2*).

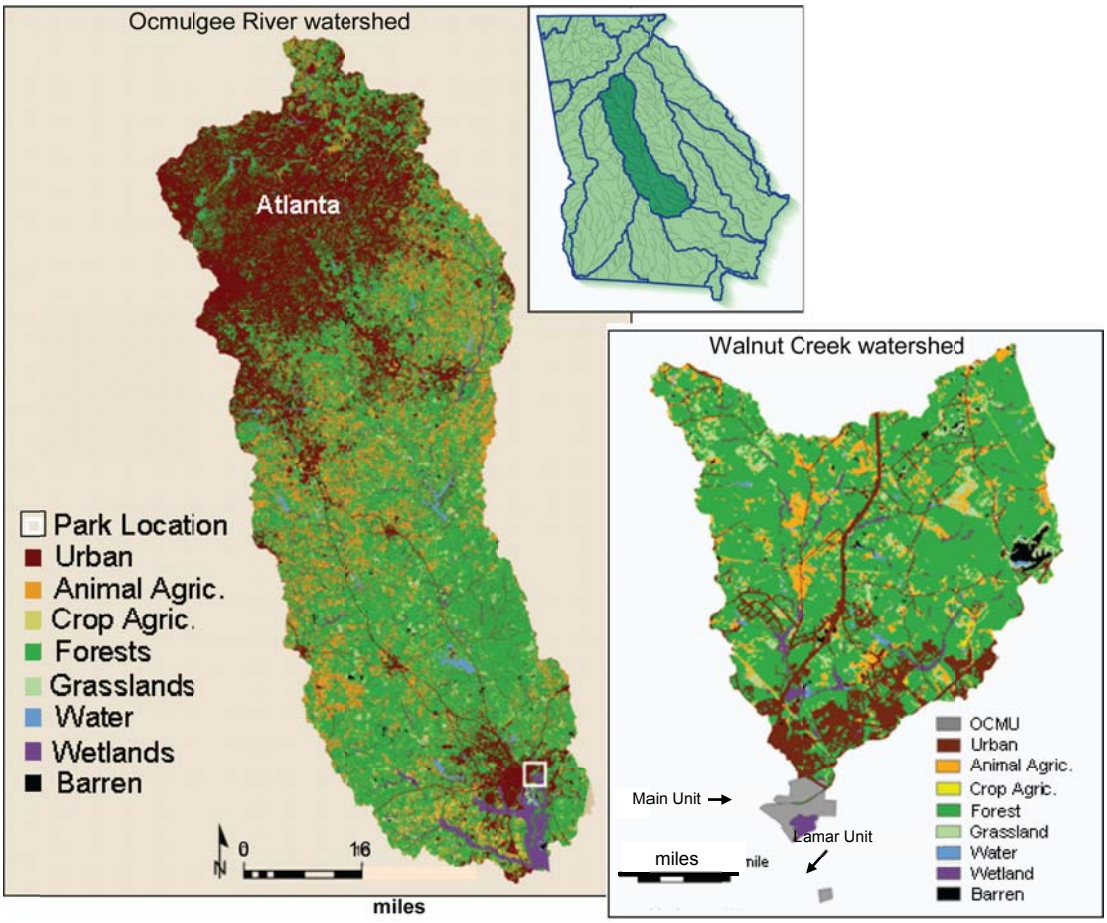

Figure 2. Center: The Ocmulgee River basin (from GA DNR 2004); left: land use/ land cover as of 2001 in the Ocmulgee River basin (HUC 03070103) (compiled by the NCSU CAAE); and right: land use-land cover in the Walnut Creek watershed which drains into OCMU.

Table 1. Land use in the Ocmulgee River and Walnut Creek watersheds (1,230,784 acres and 59,528 acres, respectively; GA DNR 2007a, based on 2001 land use/land cover data (most recent - Landsat Thematic Mapper images; Georgia National Land Cover Data).

Source	Ocmulgee River (acres)		Walnut Creek (acres)	
Open water	17,672	(1.4%)	595	(1.0%)
Low-intensity residential	77,944	(6.3%)	4,428	(7.4%)
High-intensity residential	31,339	(2.5%)	1,302	(2.2%)
High-intensity comm/ indust/ transp	15,149	(1.2%)	491	(0.8%)
Clearcut, sparse	4,835	(0.4%)	474	(0.8%)
Quarries, strip mines, gravel pits	4,970	(0.4%)	406	(0.7%)
Forest	731,014	(59.4%)	37,309	(62.7%)
Row crops, pasture	147,799	(12.6%)	6,330	(10.7%)
Other grasses (urban, recreational)	95,970	(7.8%)	6,225	(10.5%)
Woody wetlands	92,759	(7.5%)	1,884	(3.2%)
Emergent herbaceous wetlands	4,332	(0.4%)	84	(0.1%)

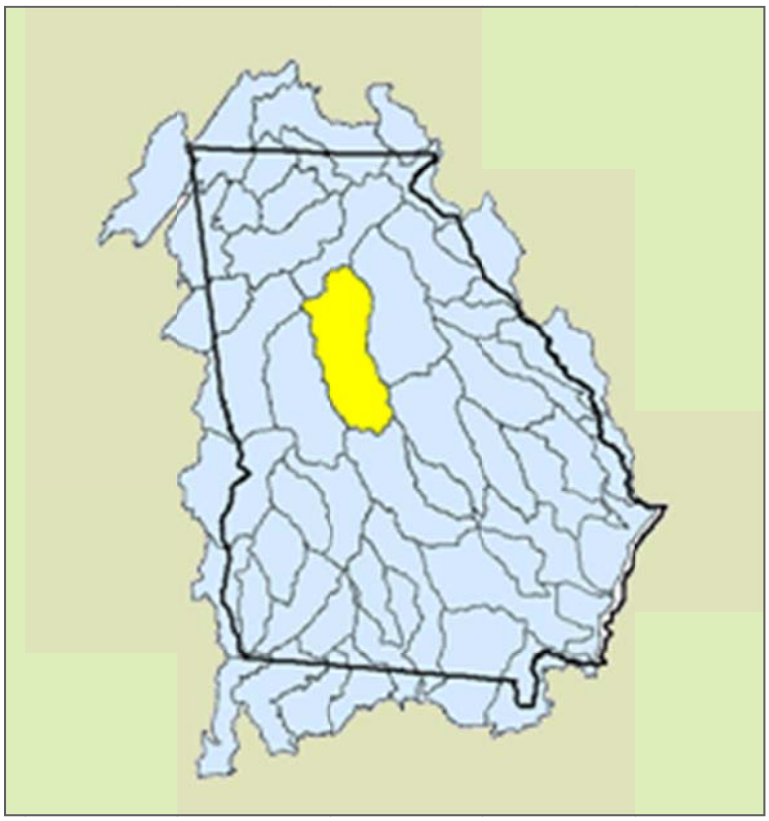

Figure 3. Location of the upper Ocmulgee watershed (1,915,802 acres or 2,993 square miles). From the Natural Resources Space Analysis Lab, University of Georgia (http://narsal.uga.edu/glut/watershed.php?watershed=46).

Hydrologic Information

The OCMU Area

The OCMU area has a humid, subtropical temperature, often reaching the mid-90s (^{o}F) or higher in summer and decreasing to the mid-40s during winter, with a mean annual temperature of ~60°F (GA DNR 2004). Mean annual precipitation is 45 inches (annual range, 40-52 inches), rarely as snowfall (Georgia State Climatology Office 2007).

Precipitation generally is greatest in February-March and least in October. A dry season extends from mid-summer to late fall (GA DNR 2004).

OCMU is located just below the Ocmulgee River Fall Line, a ~20-mile-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, GA to Augusta, GA 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).

Table 2. Changes in land use/land cover (data in acres) in the upper Ocmulgee River basin from 1974 through 2005. From the Natural Resources Space Analysis Lab, University of Georgia (available at: http://narsal.uga.edu/glut/watershed.php?watershed=46).

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%
Clearcut, 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 wetland-fresh	79	----	543	587%	----

Surface Waters

The Ocmulgee and Oconee Rivers are major tributaries of the Altamaha River system (*Figure 4*); they are located entirely within Georgia, and the Ocmulgee drains approximately 6,071 square miles. 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 4*). These three streams drain the eastern and southeastern Metropolitan Atlanta 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 eight miles farther downstream, converges with the Oconee River to form the Altamaha River. In the OCMU area, the Ocmulgee has a gently slope, flows through a wide floodplain, and meanders between sand bars, willow thickets, steep banks, and backwater sloughs (GA DNR 2004).

Surface water is the primary water source in the Piedmont Province of the Ocmulgee River basin (GA DNR 2004). 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 2006). Construction of I-16 by the federal government in the 1960s, directly through the monument's mile-long river boundary, severed the Macon Plateau Unit from the Lamar Unit and from the Ocmulgee River, and destroyed several archeological sites such as Adkins Mound (Obey 2002). Thus, although the NPS owns ~1 mile of riverfront, the monument is effectively cut off from it by the highway. The natural hydrology of OCMU is, at present, poorly understood (DeVivo 2006).

Figure 4. Map showing the Ocmulgee, Oconee, and Altamaha Rivers.

The Ocmulgee River forms the southwestern border of OCMU, and Walnut Creek (total length, 20 miles; watershed area 50.2 square miles), its largest tributary in the monument, forms part of its southeastern border (*Figure 1, Plate 2*). An 1827 map shows a different meandering pattern and a broader floodplain, and a series of oxbow lakes that no longer exist (*Figure 5*). Creation of the Macon levee in 1950 dramatically altered flooding patterns of the Ocmulgee River (*Figures 4, 5*). The levee channelized the river, increased its flow velocity and its depth, increased scouring and erosion, and increased the severity of flooding along the opposite, eastern shore by OCMU. In addition, about 20 years later the Macon levee was raised three feet as mitigation for

construction of interstate I-16, because that highway raised the projected 100-year flood level by that much (J. DeVivo, pers. comm.).

Portions of the Ocmulgee River basin, including the Macon area, were affected by massive flooding from Tropical Storm Alberto in 1994 (DeVivo 2006). As a result of this storm, the levee breached in an area that was once a backwater slough, portions of the tributary Walnut Creek "jumped channel" and were substantially altered (DeVivo 2006), and a pond (oxbow) near the railroad tracks through the monument was destroyed (Chief Ranger G. LaChine, pers. comm.). Road and railroad construction also altered hydrologic patterns. Floodplain development in this area remains a serious concern (Georgia Department of Community Affairs 2003, GA DNR 2004). Another major highway, the Fall Line Freeway (extension of the Eisenhower Parkway), is being constructed. This four-lane road between the two OCMU Units will bisect the Ocmulgee Old Fields Traditional Cultural Property (Obey 2002; GA DOT 2008; *Figure 6*; see p. 54 of this Report).

Plate 2. Walnut Creek, viewed from the railroad bridge in OCMU. Photo by Michael Mallin.

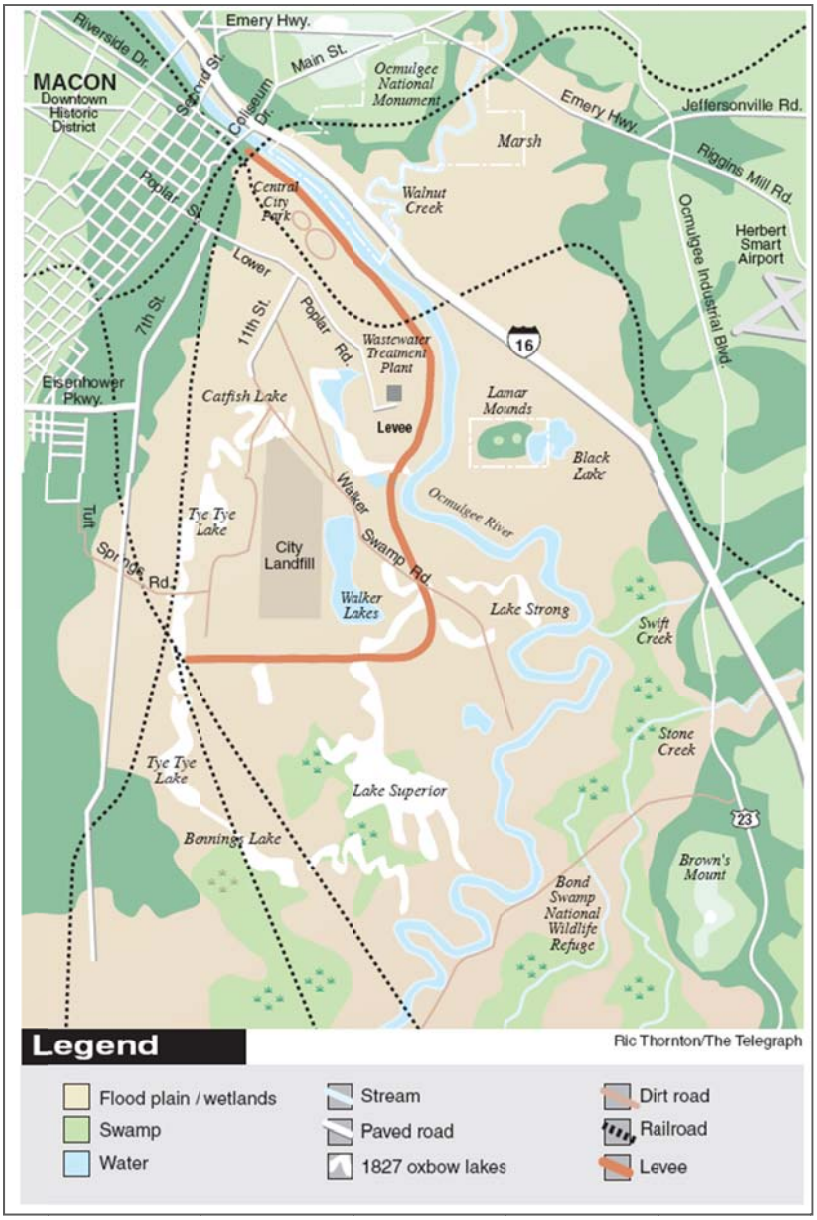

Figure 5. Map showing general features of the Ocmulgee River floodplain near OCMU. Note the meandering channel below the Macon levee, vs. the channelized river in the OCMU area. Other features include the City of Macon landfill across from the Lamar Unit, and the Macon WPCP which discharges ~0.18 mile below the Lamar Unit. Map by Ric Thornton, with permission from The Telegraph.

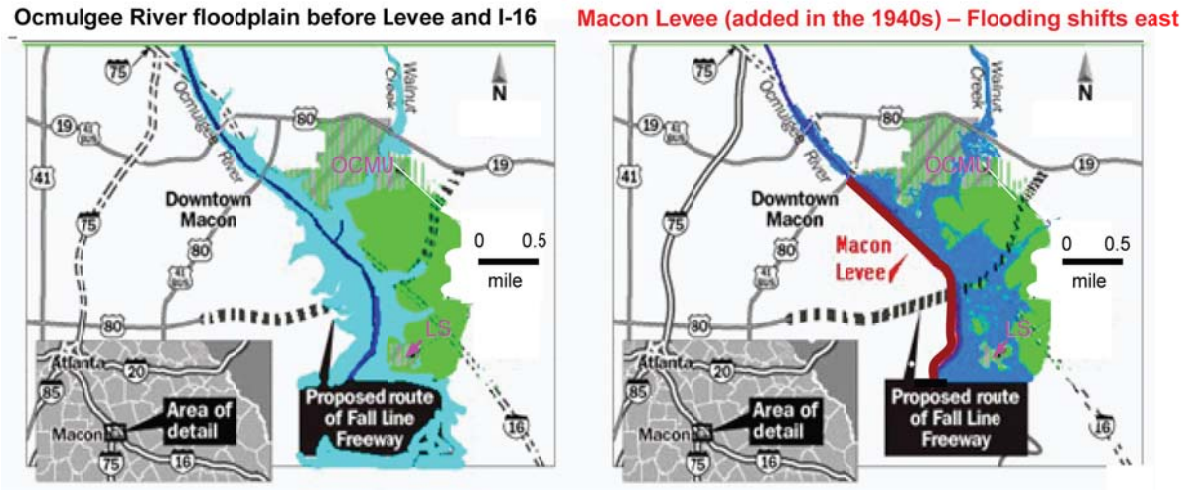

Figure 6. Maps showing floodstage in the Ocmulgee River, Macon (left) prior to construction of the Macon Levee and interstate highway I-16 (www.hollidaydental.com/flooding.htm), versus (right) the influence of the Macon Levee on river flooding (www.macon-bibb.com /Levee.html) . LS = the Lamar Unit of OCMU; bright green area ≡ the additional land that was proposed in 1935 for the national monument; route of the Fall Line Freeway under construction is also shown. Maps by Lindsay Holliday, with permission.

The USGS maintains a flow station in the Ocmulgee River just upstream from OCMU (site #02213000, Macon; latitude 32°50'19", longitude 83°37'14"; NAD83, Bibb County, Georgia, Hydrologic Unit 03070103; drainage area 2,240 square miles; datum of gage: 269.80 feet above sea level). This site is also upstream from the Macon levee, with monitoring of discharge and stage height. Discharge data have been recorded daily since February 1893 except for a ~15-year gap in the early 1900s; gage height has been recorded since October 1992. Real-time data (previous 60 days) are also available. The data show 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 (*Figure 7, Appendix 1*). High variation in gage height also is also apparent (range ~4.9 to 29 feet; median values at ~6 to 12 feet) (*Figure 7*).

The USGS also previously maintained a flow station on Walnut Creek (NAD27, site #02213050 in Jones County near Gray, GA), ~4.5 miles upstream from the northern boundary of OCMU (data available from 1961-1994; *Appendix 2*).

Walnut Creek and the three smaller streams in OCMU are characterized by severe stream bank alteration and sedimentation (*Plates 3-5*). The smaller, unnamed streams are of urban origin, and two of them are intermittent or partly intermittent (*Figure 1; Plates 4* and *5*). 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.).

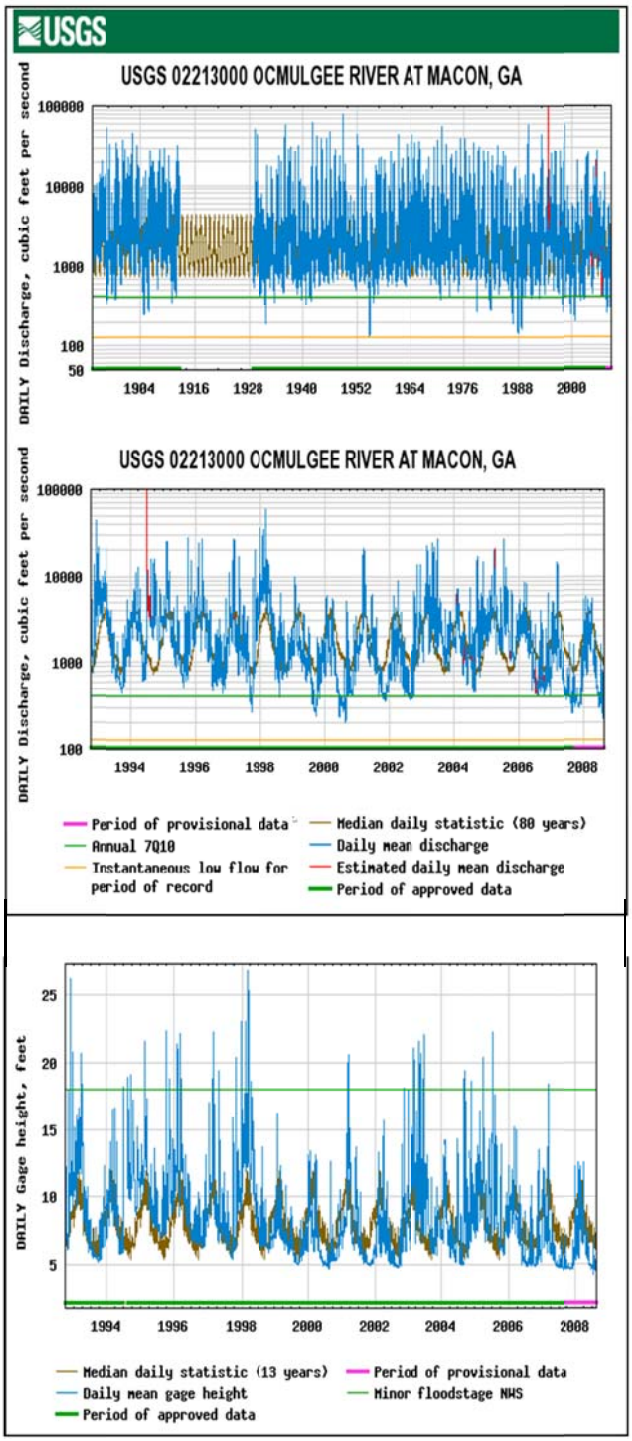

Figure 7. Upper panels: USGS daily discharge data at the Ocmulgee River station nearest OCMU over the period of record (1893-), and over the past ~15 years. From: http://ga2.er.usgs.gov/gawater/siteinfo.cfm?siteno=02213000&code=021. Lower panel: USGS gage height over the period of record (1992-). From: http://ga2.er.usgs.gov/gawater/siteinfo.cfm?siteno=02213000&code=021.

Plate 3. Left: Walnut Creek near its confluence with the Ocmulgee River, showing signs of heavy siltation. Right: the Walnut Creek delta at its confluence with the Ocmulgee River, showing extensive silt deposits. Photos by Michael Mallin and JoAnn Burkholder.

Plate 4. Left: origin of stream #1. Right: site where stream #2, when flowing, enters OCMU from an urban area. Photos by Michael Mallin.

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 OCMU parking lot and road. The NPS 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 OCMU property (*Plate 4*), flows through OCMU for a short distance, leaves OCMU and flows through an economically

depressed part of Macon, re-enters OCMU, 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.).

Plate 5. Left: Channel of stream #3 showing signs of heavy siltation. Right: Deeply incised channel of stream #3 just outside OCMU. Photos by Michael Mallin.

Stream #3 originates in Macon and is fed by the city's storm sewer system. It flows along the OCMU periphery (*Plate #5*), flows through an inaccessible area of OCMU, 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 OCMU, which may flow under the railroad tracks during prolonged wet periods (Chief Ranger G. LaChine, pers. comm.).

Wetlands and Ponds

About 40% of the existing acreage of OCMU is wetlands (*Figure 1*), and the large tract of undeveloped wetlands outside of the southeastern edge of the monument is considered one of the biggest, oldest peat bogs in the Southeast (DeVivo 2006). Bond Swamp National Wildlife Refuge, which contains a great 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 6 miles south of Macon and OCMU. Thus, OCMU is along a fragmented greenway corridor for wetland species. The OCMU wetlands have not been mapped for vegetation (Chief Ranger G. LaChine, pers. comm.).

The monument's wetlands are diverse in size and origin (*Plate 6*). For example, the small Clay Hole Pond on the OCMU property was an open pit mine in the late 1800s – early 1900s (Chief Ranger G. LaChine, pers. comm.). This depression, bisected by the OCMU road, is very shallow (usually less than a foot 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.) (*Frontspiece and Plates 6, 7*). After completing an environmental assessment, the NPS recently constructed a boardwalk to/across it as part of a hiking trail (*Plate 7*). This large pond/wetland area is popular with visitors (Chief Ranger G. LaChine, pers. comm.).

Plate 6. 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. Photos by Michael Mallin and JoAnn Burkholder.

Plate 7. Recently constructed catwalk and bridge over OCMU's largest wetland, planned to enhance environmental education of visitors about the value of wetlands. Photos by Michael Mallin.

Groundwater Resources

The Ocmulgee River in the OCMU region receives a substantial contribution of water from groundwater baseflow during dry periods. The surficial aquifer system consists of unconfined sediments; wells typically are 11-300 feet deep and yield 2-25 gallons per minute (Leeth et al. 2006).

Located just below the Fall line in the uppermost portion of the Coastal Plain, OCMU is underlain by the Cretaceous Aquifer system which consists of sand and gravel along with layers of clay and silt that function as confining beds (Clark and Pierce 1985, GA DNR 2004). Wells typically are 40-600 feet deep and yield 1-25 gallons per minute, although yield can exceed 500 gallons per minute (Leeth et al. 2006). Systematic well-siting techniques have resulted in routinely high-yielding wells (more than 100 gallons per minute), and although present groundwater supplies are adequate, it is anticipated that groundwater use for municipal supplies will continue to increase in this region with increasing population growth (Tyson 1993).

Biological Resources

Prior to channelization of the Ocmulgee River by the Macon levee, the Ocmulgee River flooded regularly, 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, relatively few mussels, and low fish species richness (Wisniewski et al. 2005; see below).

Microalgae

There have been no published studies of the microalgal assemblages in Walnut Creek, the portion of the Ocmulgee River that runs along the boundary of OCMU, or OCMU wetlands.

Wetland and Aquatic Macrophytes

This region of the Ocmulgee River basin has extensive marshes and interior swamps dominated by cypress and gum (GA DNR 2004). Both the southwestern and southeastern borders of OCMU are floodplain forest and, as mentioned, about 40% of the monument area is wetlands (*Figure 1, Frontspiece and Plate 6*). The small Lamar Unit (*Figure 2*) consists primarily of river floodplain habitat.

A total of 199 species of vascular wetland and aquatic plants, including 5 ferns and 12 exotic species, have been listed as present at OCMU (*Tables 3* and *4*). Four species (bladderwort, minute duckweed, giant duckweed, and narrowleaf naiad) are aquatic, whereas the remainder are wetland/amphibious. Wetland and aquatic species are important to the plant diversity of the OCMU ecosystem, comprising ~47.5% of the vascular plant species (*Plate 8*).

Plate 8. Wetland vegetation in OCMU in autumn. Photo by Michael Mallin.

At least three major disturbances – construction of Interstate I-16 and construction/modifications of the Macon levee – have substantially altered wetland and aquatic vegetation. The bridging from construction of Interstate I-16 prevented surface waters from their natural flow toward the Ocmulgee River (Rood and Lackey 2002). The crossing of the I-16 roadbed with a pre-existing railroad bed impounded waters on OCMU's southeastern border, and transformed the area from a forested wetland plant community with rich organic soils to an open aquatic wetland with emergent and floating vegetation. The Macon levee, parallel to the Lamar Unit of OCMU on the other side of the Ocmulgee River, has caused more severe flooding on the eastern shore (*Figure*

6), which has led to increased erosion and tree loss (Chief Ranger G. LaChine, pers. comm.). The resulting spaces have become overgrown with the exotic tree species Chinese privet, which tends to out-compete native, beneficial wetland tree species such as swamp chestnut and river birch.

Terrestrial Vegetation

Five major terrestrial habitats at OCMU include creek and river edges (which can also be wetlands), bottomland forest, upland oak-hickory forest, upland mixed hard-wood-pine forest, and regularly maintained road edges and fields. Uplands in the northern area of OCMU are covered by subclimax hardwood / mixed hardwood-pine forests with an understory of grass and sedge savannas (GA DNR 2004). Much of the Main Unit of OCMU, including the earthen works, has been cleared of trees and is maintained mechanically as open grasslands. A total of 208 terrestrial vascular plants (not considering bryophytes) are listed as present in OCMU (NPS 2008b). Two species, mimic trillium (*Trillium decipiens*) and daisy (prairie) fleabane (*Erigeron strigosus*), are species of concern: Mimic trillium has a global ranking of G3 (rare and local throughout its range, or in a special habitat, or narrowly endemic) and a state ranking of S3 (rare or uncommon in Georgia, on the order of 21-100 occurrences (GA DNR 2008a,b). Daisy fleabane (*E. strigosus* var. *calcicola*) has a global ranking of G5 (demonstrably secure globally), but a state ranking of S1 (critically imperiled in the state because of extreme rarity based upon 5 or fewer documented occurrences). A third species, glade wildflower (*Anemone berlandieri*), is also included in GA DNR's list of species of concern, although it is listed as G4 (apparently secure globally, and of no immediate conservation concern).

Table 3. Wetland and aquatic plant flora, excluding ferns (based upon Godfrey and Wooten 1981a,b), listed as occurring in OCMU (NPS 2008b). Asterisks (*) ≡ non-native species.

Alabama supplejack (*Berchemia scandens*)
Alder (*Alnus serrulata*)
Alligatorweed (*Alternanthera philoxeroides*)
American buckwheat vine (redvine) (*Brunnichia ovata*)
American elder (*Sambucus canadensis*)
American elm (*Ulmus americana*)
American holly (*Ilex opaca*)
American hornbeam (*Carpinus caroliniana*)
American pokeweed (*Phytolacca americana*)
American sycamore (*Platanus occidentalis*)
American witchhazel (*Hamamelis virginiana*)
Amphibious sedge (*Carex amphibola*)
Aneilima (Asian spiderwort) (*Murdannia keisak*)
Angelicatree (*Aralia spinosa*)
Anglestem primrose-willow (anglestem waterprimrose) (*Ludwigia leptocarpa*)
Annual blue grass (walkgrass) (*Poa annua*)
Arizona bog violet (*Viola affinis*)
Arrow-wood (blackhaw, possumhaw viburnum) (*Viburnum nudum*)
Arrow-leaf tearthumb (*Polygonum sagittatum*)
Ashleaf maple (box elder) (*Acer negundo*)
Atamasco lily (*Zephyranthes atamasco*)
Azure bluet (*Houstonia caerulea*)
Bagpod (*Glottidium vesicarium*)
Barnyard grass (watergrass) (*Echinochloa crus-galli*)*
Beaked panicgrass (*Panicum anceps*)
Bearded (long-bracted) beggerticks (*Bidens aristosa*)
Bedstraw (*Galium aparine*)
Bent sedge (broom sedge) (*Carex scoparia*)
Bigroot morning glory (*Ipomoea pandurata*)
Black gum (sour gum) (*Nyssa sylvatica* var. *biflora*)
Black willow (*Salix nigra*)
Blue mistflower (*Conoclinium coelestinum*)
Blue (mad dog) skullcap (*Scutellaria lateriflora*)
Bitternut hickory (*Carya cordiformis*)
Bladderwort (swollen bladderwort) (*Utricularia inflata*)
Bog hemp (small-spike false nettle (*Boehmeria cylindrica*)
Branched foldwing (*Dicliptera brachiata*)
Brazilian vervain (*Verbena brasiliensis*)
Brazilian watermilfoil (parrot feather) (*Myriophyllum aquaticum*)*
Bristly greenbrier (*Smilax tamnoides*)
Broadleaf arrowhead (wapato) (*Sagittaria latifolia*)
Broadleaf carpetgrass (*Axonopus compressus*)
Broadleaf uniola (*Chasmanthium latifolium*)
Broomsedge (*Andropogon virginicus, A. virginicus* var. *virginicus*)
Bullbrier (*Smilax rotundifolia*)
Bulrush (woolgrass) (*Scirpus cyperinus*)
Buttonbush (*Cephalanthus occidentalis*)
Camphor pluchea (*Pluchea camphorata*)
Canada clearweed (*Pilea pumila*)
Canada goldenrod (*Solidago canadensis*)
Carolina ash (*Fraxinus caroliniana*)
Carolina bristlemallow (*Modiola caroliniana*)
Carolina elephantsfoot (*Elephantopus carolinianus*)
Cardinal flower (*Lobelia cardinalis*)
Carolina jessamine (*Gelsemium sempervirens*)
Carolina ponysfoot (*Dichondra carolinensis*)
Cat greenbrier (*Smilax glauca*)
Chapman's bluegrass (*Poa chapmaniana*)
Cherrybark oak (Texas oak) (*Quercus pagoda*)
Chervil (hairy-fruit chervil) (*Chaerophyllum tainturieri*)
Chinese (Japanese) honeysuckle (*Lonicera japonica*)*
Climbing hempvine (*Mikania scandens*)
Clustervine (hairy clustervine) (*Jacquemontia tamnifolia*)
Cocklebur (rough cocklebur) (*Xanthium strumarium*)
Common Chinese privet (*Ligustrum sinense*)*
Common cottonwood (*Populus deltoides*)
Common persimmon (*Diospyros virginiana*)
Common (lamp) rush (*Juncus effusus*)
Common trumpetcreeper (*Campsis radicans*)
Coral greenbrier (*Smilax walteri*)
Creeping primrose-willow (creeping waterpurslane) (*Ludwigia repens*)
Creeping seedboxcylindricfruit (primrose-willow) (*Ludwigia glandulosa*)
Cross-vine (trumpet-flower) (*Bignonia capreolata*, or *Anisostichus capreolata, A. crucifera*)
Curley dock (*Rumex crispus*)*
Curltop ladysthumb (*Polygonum lapathifolium*)
Dallas (water) grass (*Paspalum dilatatum*)*
Darkgreen sedge (*Carex venusta*)
Desert false indigo (*Amorpha fruticosa*)
Devil's darning needles (*Clematis virginiana*)
Dogfennel (*Eupatorium capillifolium*)
Dogtooth violet (*Erythronium americanum*)
Dotted smartweed (*Polygonum punctatum*)
Dwarf palmetto (*Sabal minor*)
Drooping melonnettle (Guadeloupe cucumber) (*Melothria pendula*)
Duckweed (minute duckweed) (*Lemna perpusilla*)

Table 3. (Continued).

Dwarf St. Johnswort (*Hypericum mutilum*)	Mountain azalea (*Rhododendron canescens*)
Early woodbuttercup (*Ranunculus abortivus*)	Mulberry (white mulberry) (*Morus alba*)*
Eastern baccharis (*Baccharis halimifolia*)	Muscadine grape (*Vitis rotundifolia*)
Eastern bluestar (*Amsonia tabernaemontana*)	Narrowleaf naiad (needleleaf waternymph) (*Najas filifolia*)
Eastern poison ivy (*Toxicodendron radicans*)	Northern spicebush (*Lindera benzoin*)
Eastern swampprivet (*Texas forestiera*) (*Forestiera acuminata*)	Overcup oak (*Quercus lyrata*)
Eastern sweetshrub (Calycanthus floridus)	Partridgeberry (*Mitchella repens*)
Fetterbush lyonia (*Lyonia lucida*)	Pecan (*Carya illinoensis*)
Fivelobe cucumber (*Cayaponia quinqueloba*)	Peppervine (*Ampelopsis arborea*)
Fringed sedge (*Carex crinita*)	Pine barren flatsedge (*Cyperus retrorsus*)
Giant cane (*Arundinaria gigantea*)	Pignut hickory (*Carya glabra*)
Giant duckweed (*Spirodela polyrhiza*)	Pitted (white) morning glory (*Ipomoea lacunosa*)
Giant sedge (*Carex gigantea*)	Planertree (water elm) (*Planera aquatica*)
Greater bladder sedge (*Carex intumescens*)	Poor-joe (rough buttonweed) (*Diodia teres*)
Green ash (*Fraxinus pennsylvanica*)	Possum-haw (*Ilex decidua*)
Green dragon (*Arisaema dracontium*)	Prickly bog sedge (*Carex atlantica*)
Green flatsedge (*Cyperus virens*)	Prickly Florida blackberry (*Rubus argutus*)
Green hawthorn (*Crataegus viridis*)	Primrose violet (*Viola primulifolia*)
Hairy bittercress (*Cardamine hirsuta*)	Pretty verbena (purpletop vervain) (*Verbena bonariensis*)
Hairy smartweed *(Polygonum hirsutum*)	Purple false foxglove (*Agalinis purpurea*)
Hedgehog woodrush (*Luzula echinata*)	Rattail smutgrass (*Sporobolus indicus* or *Sporobolus poiretii*)
Herbwilliam (threadleaf mockbishopweed) (*Ptilimnium capillaceum*)	Red maple (*Acer rubrum*)
Hop sedge (*Carex lupulina*)	Red mulberry (*Morus rubra*)
Horsetail (scouringrush) (*Equisetum hyemale*)	Red-root flat sedge (redroot nutgrass) (*Cyperus erythrorhizos*)
India (Indian) heliotrope (turnsole) (*Heliotropium indicum*)	Rice cut grass (*Leersia oryzoides*)
Jack-in-the-pulpit (*Arisaema triphyllum*)	River birch (*Betula nigra*)
Japanese mazus (*Mazus pumilus*)*	Saw greenbrier (*Smilax bona-nox*)
Japanese stiltgrass (Nepalese browntop)* (*Microstegium vimineum*)	Scaldweed (*Cuscuta gronovii*)
Jewelweed (*Impatiens capensis*)	Shagbark hickory (*Carya ovata*)
Johnson grass (*Sorghum halepense*)*	Shallow sedge (*Carex lurida*)
Jumpseed (Virginia smartweed) (*Polygonum virginianum*)	Sheep (red) sorrel (*Rumex acetosella*)*
Juniper leaf (*Polypremum procumbens*)	Silver maple (*Acer saccharinum*)
Largeseed (southern) forget-me-not) (*Myosotis macrosperma*)	Smallflower baby blue eyes (*Nemophila aphylla*)
Large (spotted) spurge (*Chamaesyce maculata*)	Southern magnolia (*Magnolia grandiflora*)
Laurel greenbrier (*Smilax laurifolia*)	Southern red oak (*Quercus falcata*)
Laurel oak (*Quercus laurifolia*)	St. Andrew's cross (*Hypericum hypericoides*)
Leathery rush (*Juncus coriaceous*)	Strawcolored flatsedge (*Cyperus strigosus*)
Little bluestem (*Schizachyrium scoparium*, or *Andropogon scoparius*)	Swamp bay (*Persea palustris*)
Little quakinggrass (*Briza minor*)	Swamp chestnut oak (*Quercus michauxii*)
Lizard's tail (*Saururus cernuus*)	Swamp smartweed (*Polygonum hydropiperoides*)
Louisiana sedge (*Carex louisianica*)	Swamp sneezeweed (swamp sunflower) (*Helianthus angustifolius*)
Mexican (red) morningglory (redstar) (*Ipomoea coccinea*)	Swamp tupelo *(Nyssa biflora*)
Moistbank pimpernel (shortstalk lindernia) (*Lindernia dubia*)	Sweetbay (*Magnolia virginiana*)
	Sweetgum (*Liquidambar styraciflua*)
	Switchgrass (*Panicum virgatum*)
	Thinfruit sedge (*Carex flaccosperma*)
	Tulip poplar (*Liriodendron tulipifera*)
	Vasey grass (*Paspalum urvillei*)*

Table 3. (Continued).

Virginia buttonweed (*Diodia virginiana*)	White grass (*Leersia virginica*)
Virginia dayflower (*Commelina virginica*)	Whorled marshpennywort (whorled pennyroyal) (*Hydrocotyle verticillata*)
Virginia iris (*Iris virginica*)	Willow oak (*Quercus phellos*)
Virginia sweetspire (*Itea virginica*)	Winged elm (*Ulmus alata*)
Virginia wild rye (*Elymus virginicus*)	Wingleaf primrose-willow (*Ludwigia decurrens*)
Water oak (*Quercus nigra*)	Yaupon (*Ilex vomitoria*)
Water primrose (*Ludwigia peruviana*)*	Yellow crownbeard (*Verbesina occidentalis*)
Water hickory (*Carya aquatica*)	Yellow thistle (*Cirsium horridulum*)
Waterpod (*Hydrolea quadrivalvis*)	
White edge sedge (*Carex debilis*)	

Table 4. Wetland fern species listed as occurring in OCMU (NPS 2008b).

Asplenium ladyfern (Athyrium filix-femina spp. asplenioides) – shaded woods, swamps, stream banks, acid bogs
Chainfern (Woodwardia areolata) – acidic bogs, wet woods
Common ladyfern (Athryium filix-femina) - moist to wet forested thickets, along streambanks, in swamps
Royal fern (Osmunda regalis var. spectabilis) – swampy areas, fens, damp woodlands
Sensitive fern (Onoclea sensibilis) – open swamps, marshes, low woods

Aquatic Macroinvertebrates

Information on aquatic macroinvertebrates is lacking for OCMU. In the larger Altamaha River basin, which includes the Ocmulgee River basin, 16 mussel species including seven endemic species have been reported (Wisniewski et al. 2005). Three endemic species are rare (below), whereas the percentage of sites occupied by the four other endemic species, including the Georgia elephantear (*Elliptio dariensis*), the Altamaha slabshell (*Elliptio hopetonensis*), the Altamaha lance (*Elliptio shepardiana*), and the Altamaha pocketbook (*Lampsilis dolabraeformis*), has increased over the past 40 years (Wisniewski et al. 2005).

Fish

Nearly 20 years ago, Evans (1991) reported that the diverse fish fauna of the Ocmulgee River basin included 105 species representing 21 different families, with 1 endangered species (the Altamaha shiner, *Cyprinella xaenura*) and 2 rare species (the goldstripe darter, *Etheostoma parvipinne* and the redeye chub, *Notropis harperi*; GA DNR 2004). However, OCMU has a sparse fish fauna – only 31 species of uncertain abundance or health, and none of the rare or endangered species (*Table 5*). GA DNR (2004) reported at least 15 species of exotic fishes in the watershed, many of which are well established and detrimental to native fish populations. OCMU is disproportionately represented by non-native fish species; about 20% of its 31 species are non-native, including the common carp, longear sunfish, shoal bass, white crappie, channel catfish, and flathead catfish. Recreational fishing is allowed at OCMU, and largemouth bass and carp are common catches (Watson 2005).

Table 5. Fish species listed as occurring at OCMU, documented through one or more types of evidence as references, vouchers, and observations (NPS 2008b). Asterisk (*) ≡ probably present (cited on the OCMU species list but not documented in the most current inventory); double asterisk (**) ≡ non-native species.

American eel (*Anguilla rostrata*)	Golden shiner (*Notemigonus crysoleucas*)
Banded (diamond or little) sunfish (*Enneacanthus obesus*)	Grass (redfin) pickerel (*Esox americanus*)
Black crappie (*Pomoxis nigromaculatus*)	Largemouth bass (*Micropterus salmoides*)
Black (gray or striped) mullet (*Mugil cephalus*)	Longear sunfish (*Lepomis megalotis*)**
Blackbanded darter (*Percina nigrofasciata*)	Ocmulgee shiner (*Cyprinella callisema*)
Bluegill (*Lepomis macrochirus*)	Okefenokee pygmy sunfish (*Elassoma okefenokee)*
Bluespotted sunfish (*Enneacanthus gloriosus*)	Redbreast sunfish (*Lepomis auritus*)
Bowfin (*Amia calva*)	Redear sunfish (*Lepomis microlophus*)
Brook silverside (*Labidesthes sicculus*)	Shoal bass (*Micropterus cataractae*)**
Chain pickerel (*Esox niger*)	Spottail shiner (*Notropis hudsonius*)
Channel (graceful) catfish (*Ictalurus punctatus*)**	Spotted sucker (*Minytrema melanops*)
Coastal shiner (*Notropis petersoni*)	Spotted sunfish (*Lepomis punctatus*)
Common (European) carp (*Cyprinus carpio*)**	Taillight shiner (*Notropis maculatus*)
Eastern mosquitofish (*Gambusia holbrooki*)	Warmouth (*Lepomis gulosus*)
Flathead catfish (*Pylodictis olivaris*)**	White crappie (*Pomoxis annularis*)**
Flier (peacock or round sunfish) (*Centrarchus macropterus*)	

Amphibians and Reptiles

OCMU is located along the boundary between the Piedmont and Coastal Plain, and, as a result, resident herpetofauna include species characteristic of both physiographic provinces (Tuberville et al. 2005). OCMU has 25 species of amphibians (16 frogs and toads, 9 newts and salamanders) and 35 species of reptiles (8 lizards, 20 snakes, 7 turtles) (*Table 6, Plate 9*). In a comparison of 16 parks that included OCMU, Tuberville et al. (2005) noted that larger parks had higher species richness. OCMU is smaller than many of the parks, which would suggest it is a fragile ecosystem that is highly vulnerable to edge and fragmentation effects (*Figure 8*).

Table 6. Herpetofauna of OCMU, documented through one or more types of evidence as references, vouchers, and observations (Tuberville et al. 2005, NPS 2008b). Asterisk (*) ≡ probably present (cited on the OCMU species list but not documented in the most current inventory); double asterisk (**) ≡ non-native species.

AMPHIBIANS

Frogs and Toads

American bullfrog (*Rana catesbeiana*)
American toad (*Bufo americanus*)
Bird-voiced treefrog (*Hyla avivoca*)
Eastern narrow-mouthed toad (*Gastrophryne carolinensis*)
Fowler's toad (*Bufo fowleri*)
Gray (Cope's gray) treefrog (*Hyla versicolor*)
Green frog (*Rana clamitans*)
Green treefrog (*Hyla cinerea*)
Northern cricket frog (*Acris crepitans*)
Ornate chorus frog (*Pseudacris ornata*)
Southern chorus frog (*Pseudacris nigrita*)
Southern cricket frog (*Acris gryllus*)
Southern (Florida) leopard frog (*Rana spenocephala*)
Southern toad (*Bufo terrestris*)
Spring peeper (*Pseudacris crucifer*)
Squirrel treefrog (*Hyla squirella*)

Newts and Salamanders

Dusky salamander (*Desmognathus fuscus*)
Dwarf waterdog (*Necturus punctatus*)*
Marbled salamander (*Ambystoma opacum*)
Red salamander (*Pseudotriton ruber*)
Ocmulgee slimy salamander (*Plethodon ocmulgee*)
Southern dusky salamander (*Desmognathus auriculatus*)
Southern two-lined salamander (*Eurycea cirrigera*)
Three-lined salamander (*Eurycea guttolineata*)
Two-toed amphiuma (*Amphiuma means*)

REPTILES

Crocodilians and Lizards

American alligator (*Alligator mississippiensis*)
Broadheaded skink (*Eumeces laticeps*)
Eastern fence lizard (*Sceloporus undulatus*)
Five-lined (common) skink (*Eumeces fasciatus*)
Green anole (*Anolis carolinensis*)
Little brown (ground) skink (*Scincella lateralis*)
Six-lined racerunner (*Cnemidophorus sexlineatus*)
Southeastern five-lined skink (*Eumeces inexpectatus*)

Snakes

Brown watersnake (*Nerodia taxispilota*)**
DeKay's (Florida) brown snake (*Storeria dekayi*)
Common garter snake (*Thamnophis sirtalis*)*
Common kingsnake (*Lampropeltis getula*)
Corn snake (*Elaphe guttata*)
Cottonmouth (*Agkistrodon piscivorus*)
Eastern hog-nosed snake (*Heterodon platirhinos*)
Eastern ribbon snake (*Thamnophis sauritus*)
Eastern rat snake (*Elaphe obsoleta*)
Eastern worm snake (*Carphophis amoenus*)
Gray rat snake (*Elaphe obsoleta spiloides*)
Northern water snake (*Nerodia sipedon*)
Plain-bellied watersnake (*Nerodia erythrogaster*)
Racer (eastern racer) (*Coluber constrictor*)
Ring-necked snake (*Diadophis punctatus*)
Rough green snake (*Opheodrys aestivus*)**
Smooth earth snake (*Virginia valeriae*)
Southern (common) copperhead (*Agkistrodon contortrix*)
Southern (banded) watersnake (*Nerodia fasciata*)
Timber rattlesnake (*Crotalus horridus*)

Turtles

Common (eastern) box turtle (*Terrapene carolina*)
Common (eastern) mud turtle (*Kinosternon subrubrum*)
Common musk turtle (stinkpot) (*Sternotherus odoratus*)
Common (pond) slider (*Trachemys scripta*)
Common snapping turtle (*Chelydra serpentina*)
Eastern painted turtle (*Chrysemys picta*)
River cooter (*Pseudemys concinna*)

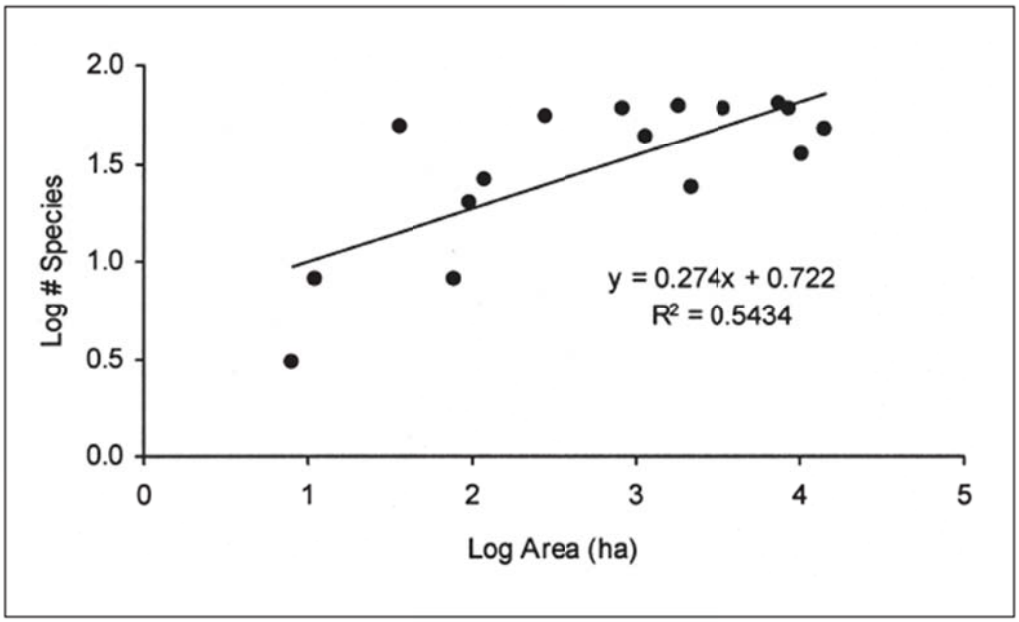

Figure 8. Relationship between land area (in hectares) and species richness, excluding exotic (introduced) species, among 16 parks within the Southeast Coast Network of the NPS, including OCMU, showing the strong positive linear relationship between (log-transformed) land area and species richness (P = 0.001). From Tuberville et al. (2005), with permission from Southeastern Naturalist.

Plate 9. Turtles sunning in autumn in an OCMU wetland. Photo by Michael Mallin.

Birds

The NPS (2008b) lists 172 species of birds that have been reported at or near OCMU (Table 7). Of these, 19% (33 species) are closely associated with aquatic habitats, including the endangered wood stork which forages at OCMU during summer months. Wading birds are abundant (Chief Ranger G. LaChine, pers. comm.). Migratory birds use OCMU as a stopover during spring and fall migrations, and recreational birding is a popular activity (Watson 2005). Although the area is important for birds during all seasons, OCMU does not have an active monitoring program (Watson 2005). An Avian Conservation Implementation Plan has been developed for OCMU, and was designed to help identify and prioritize bird conservation opportunities (Watson 2005).

Mammals

Despite heavy impacts on its natural resources by surrounding urbanization, there is abundant wildlife at OCMU, probably because a Greenway connects it to natural areas to the south (DeVivo 2006). The first comprehensive survey of terrestrial mammalian fauna of OCMU, excluding bats, was completed in 2003 (D. Webster, UNC Wilmington, notes). A total of 44 species were listed as occurring (32) or probably occurring (12) at OCMU (*Table 8*), including 8 species (18%) closely associated with aquatic habitats and 6 exotic species (below). In addition, the NPS has evidence that the American black bear occurs in the park (J. DeVivo, pers. comm.). All 45 species have broad habitat tolerances and widespread geographic distributions in the eastern U.S. (Hall 1981, Choate et al. 1994). Species closely associated with aquatic habitats include the American beaver, common muskrat, marsh rabbit, marsh rice rat, northern river otter, swamp rabbit, and the large exotic rodent nutria (below). Among these, swamp rabbits generally occur above the Fall Line in the Piedmont, whereas marsh rabbits tend to occur below the Fall Line in the Coastal Plain (Hall 1981). Both species have been reported from Bibb County (Golley 1962). They were not found in the 2003 survey, but both may occur in OCMU.

Two species of mammals that were once widely distributed in the eastern U.S. (mountain lion, *Puma concolor*; red wolf, *Canis rufus*) have been reported as extirpated from the OCMU region (D. Webster, UNC Wilmington, unpublished notes). The white-tailed deer is the only large indigenous mammal presently in OCMU and the surrounding area (GA DNR 2004; DeVivo 2006). Beavers and other small mammals, including raccoons, opossums, flying squirrels, rabbits and numerous species of ground-dwelling rodents are also abundant within OCMU (GA DNR 2004; DeVivo 2006).

Table 7. Bird species that have been observed at OCMU (NPS 2008b). Asterisk (*) ≡ species documented near OCMU, and OCMU has appropriate habitat; asterisks (**) ≡ non-native species; L ≡ listed (imperiled).

Species associated with aquatic habitats

American coot (*Fulica americana*)
American wigeon (*Anas americana*)
Anhinga (*Anhinga anhinga*)
Belted kingfisher (*Megaceryle alcyon*)
Blue-winged teal (*Anas discors*)
Canada goose (*Branta canadensis*)
Common snipe (*Gallinago gallinago*)
Double-crested cormorant (*Phalacrocorax auritus*)
Gadwall (*Anas strepera*) *
Glossy ibis (*Plegadis falcinellus*)
Great blue heron (*Ardea herodias*)
Great egret (*Ardea alba*)
Greater yellowlegs (*Tringa melanoleuca*)
Green heron (*Butorides virescens*)
Green-winged teal (*Anas crecca*)*
Least sandpiper (*Calidris minutilla*)*
Lesser yellowlegs (*Tringa flavipes*)
Little blue heron (*Egretta caerulea*)
Louisiana waterthrush (*Seiurus motacilla*)
Mallard (*Anas platyrhynchos*)
Northern shoveler (*Anas clypeata*)
Northern waterthrush (*Seiurus noveboracensis*)
Osprey (*Pandion haliaetus*)
Pied-billed grebe (*Podilymbus podiceps*)
Red-winged blackbird (*Agelaius phoeniceus*)
Ring-billed gull (*Larus delawarensis*)
Ring-necked duck (*Aythya collaris*)
Snowy egret (*Egretta thula*)
Solitary sandpiper (*Tringa solitaria*)
Spotted sandpiper (*Actitis macularia*)
White ibis (*Eudocimus albus*)
Wood duck (*Aix sponsa*)
Wood stork (*Mycteria americana*) L

Other species

Acadian flycatcher (*Empidonax virsecens*)
American crow (*Corvus brachyrhynchos*)
American goldfinch (*Carduelis tristis*)
American kestrel (*Falco sparverius*)
American redstart (*Setophaga ruticilla*)
American robin (*Turdus migratorius*)
Bank swallow (*Riparia riparia*)
Barn swallow (*Hirundo rustica*)
Barred owl (*Strix varia*)
Bay-breasted warbler (*Dendroica castanea*)
Black-and-white warbler (*Mniotilta varia*)
Black-throated blue warbler (*Dendroica caerulescens*)
Black-throated green warbler (*Dendroica virens*)
Black vulture (*Coragyps atratus*)
Blackburnian warbler (*Dendroica fusca*)
Blackpoll warbler (*Dendroica striata*)
Blue-gray gnatcatcher (*Polioptila caerulea*)
Blue-headed (solitary) vireo (*Vireo solitarius*)
Blue jay (*Cyanocitta cristata*)
Blue grosbeak (*Guiraca caerulea*)
Blue-winged warbler (*Vermivora pinus*)
Broad-winged hawk (*Buteo platypterus*)
Brown creeper (*Certhia americana*)
Brown-headed cowbird (*Molothrus ater*)
Brown-headed nuthatch (*Sitta pusilla*)
Brown thrasher (*Toxostoma rufum*)
Canada warbler (*Wilsonia canadensis*)
Carolina chickadee (*Poecile carolinensis*)
Carolina wren (*Thryothorus ludovicianus*)
Cattle egret (*Bubulcus ibis*)
Cape May warbler (*Dendroica tigrina*)
Cedar waxwing (*Bombycilla cedrorum*)
Cerulean warbler (*Dendroica cerulea*) L
Chestnut-sided warbler (*Dendroica pensylvanica*)
Chimney swift (*Chaetura pelagica*)
Chipping sparrow (*Spizella passerina*)
Chuck-will's widow (*Caprimulgus carolinensis*)*
Common grackle (*Quiscalus quiscula*)
Common ground-dove (*Columbina passerina*)
Common nighthawk (*Chordeiles minor*)
Common yellowthroat (*Geothlypis trichas*)
Cooper's hawk (*Accipiter cooperi*)
Dark-eyed junco (*Junco hyemalis*)
Downy woodpecker (*Picoides pubescens*)
Eastern bluebird (*Sialia sialis*)
Eastern kingbird (*Tyrannus tyrannus*)
Eastern meadowlark (*Sturnella magna*)
Eastern phoebe (*Sayornis phoebe*)
Eastern screech owl (*Megascops asio*)
Eastern wood-pewee (*Contopus virens*)
European starling (*Sturnus vulgaris*)**
Evening grosbeak (*Coccothraustes vespertinus*)
Field sparrow (*Spizella pusilla*)
Fish crow (*Corvus ossifragus*)
Fox sparrow (*Passerella iliaca*)
Golden-crowned kinglet (*Regulus satrapa*)
Golden-winged warbler (*Vermivora chrysoptera*) L
Gray catbird (*Dumetella carolinensis*)
Gray-cheeked thrush (*Catharus minimus*)

Table 7. (Continued).

Great crested flycatcher (*Myiarchus crinitus*)
Great horned owl (*Bubo virginianus*)
Hairy woodpecker (*Picoides villosus*)
Hermit thrush (*Catharus guttatus*)
Hooded warbler (*Wilsonia citrina*)
House finch (*Carpodacus mexicanus*)
House sparrow (*Passer domesticus*)**
House wren (*Troglodytes aedon*)
Indigo bunting (*Passerina cyanea*)
Kentucky warbler (*Oporornis formosus*)
Killdeer (*Charadrius vociferus*)
Loggerhead shrike (*Lanius ludovicianus*)
Magnolia warbler (*Dendroica magnolia*)
Merlin (*Falco columbarius*)
Mississippi kite (*Ictinia mississippiensis*)
Mourning dove (*Zenaida macroura*)
Northern bobwhite (*Colinus virginianus*)
Northern cardinal (*Cardinalis cardinalis*)
Northern flicker (*Colaptes auratus*)
Northern harrier (*Circus cyaneus*)
Northern mockingbird (*Mimus polyglottos*)
Northern (Baltimore) oriole (*Icterus galbula*)
Northern parula (*Parula americana*)
Northern rough-winged swallow (*Stelgidopteryx serripennis*)
Orange-crowned warbler (*Vermivora celata*)
Orchard oriole (*Icterus spurius*)
Ovenbird (*Seiurus aurocapillus*)
Palm warbler (*Dendroica palmarum*)
Philadelphia vireo (*Vireo philadelphicus*)
Pileated woodpecker (*Dryocopus pileatus*)
Pine siskin (*Carduelis pinus*)
Pine warbler (*Dendroica pinus*)
Prairie warbler (*Dendroica discolor*)
Prothonotary warbler (*Protonotaria citrea*)
Purple finch (*Carpodacus purpureus*)
Purple martin (*Progne subis*)
Red-bellied woodpecker (*Melanerpes carolinus*)
Red-breasted nuthatch (*Sitta canadensis*)
Red-eyed vireo (*Vireo olivaceus*)
Red-headed woodpecker (*Melanerpes erythrocephalus*)
Red-shouldered hawk (*Buteo lineatus*)
Red-tailed hawk (*Buteo jamaicensis*)
Rock dove (*Columba livia*)**
Rose-breasted grosbeak (*Pheucticus ludovicianus*)
Ruby-crowned kinglet (*Regulus calendula*)
Ruby-throated hummingbird (*Archilochus colubris*)
Rufous-sided (eastern) towhee (*Pipilo erythrophthalmus*)
Rusty blackbird (*Euphagus carolinus*)
Sandhill crane (*Grus canadensis*)
Savannah sparrow (*Passerculus sandwichensis*)
Scarlet tanager (*Piranga olivacea*)
Semipalmated sandpiper (*Calidris pusilla*)
Sharp-shinned hawk (*Accipiter striatus*)
Song sparrow (*Melospiza melodia*)
Summer tanager (*Piranga rubra*)
Swainson's thrush (*Catharus ustulatus*)
Swainson's warbler (*Limnothlypis swainsonii*)
Swamp sparrow (*Melospiza georgiana*)
Tennessee warbler (*Vermivora peregrina*)
Tufted titmouse (*Baeolophus bicolor*)
Turkey vulture (*Cathartes aura*)
Veery (*Catharus fuscescens*)
Whip-poor-will (*Caprimulgus vociferus*)*
White-breasted nuthatch (*Sitta carolinensis*)
White-crowned sparrow (*Zonotrichia leucophrys*)
White-eyed vireo (*Vireo griseus*)
White-throated sparrow (*Zonotrichia albicollis*)
Wild turkey (*Meleagris gallopavo*)
Wilson's plover (*Charadrius wilsonia*) [L]
Winter wren (*Troglodytes troglodytes*)
Wood thrush (*Hylocichla mustelina*)
Worm-eating warbler (*Helmitheros vermivorus*)
Yellow-bellied flycatcher (*Empidonax flaviventris*)
Yellow-bellied sapsucker (*Sphyrapicus varius*)
Yellow-billed cuckoo (*Coccyzus americanus*)
Yellow-breasted chat (*Icteria virens*)
Yellow-rumped warbler (*Dendroica coronata*)
Yellow-throated vireo (*Vireo flavifrons*)
Yellow-throated warbler (*Dendroica dominica*)
Yellow warbler (*Dendroica petechia*)

Table 8. Mammals listed as occurring at OCMU (*, probably present; **, exotic introduced species; D. Webster, UNCW data for the NPS, and NPS 2008b).

Species associated with aquatic habitats	
American beaver (Castor canadensis)	Muskrat (muskbeaver) (Ondatra zibethicus)
American mink (Mustela vison)*	Northern river otter (Lontra canadensis)
Marsh rabbit (Sylvilagus palustris)*	Nutria (coypu) (Myocastor coypus) **
Marsh rice rat (Oryzomys palustris)*	Swamp rabbit (Sylvilagus aquaticus)*
Other species	
American black bear (Ursus americanus)	Golden mouse (Ochrotomys nuttalli)*
Big brown bat (Eptesicus fuscus)	Hispid cotton rat (Sigmodon hispidus)
Bobcat (Lynx rufus)	House mouse (Mus musculus) **
Brazilian free-tailed bat (Tadarida brasiliensis)	Least shrew (Cryptotis parva)*
Common gray fox (Urocyon cinereoargenteus)	Long-tailed weasel (Mustela frenata)*
Cotton mouse (Peromyscus gossypinus)	Northern raccoon (Procyon lotor)
Coyote (Canis latrans)	Norway rat (Rattus norvegicus)* **
Eastern chipmunk (Tamias striatus)	Oldfield mouse (Peromyscus polionotus)
Eastern cottontail (Sylvilagus floridanus)	Rafinesque's (eastern) big-eared bat (Corynorhinus rafinesquii)
Eastern gray squirrel (Sciurus carolinensis)	Red fox (Vulpes vulpes)
Eastern harvest mouse (Reithrodontomys humulis)*	Seminole bat (Lasiurus seminolus)
Eastern mole (topos) (Scalopus aquaticus)	Southeastern shrew (Sorex longirostris)*
Eastern pipistrelle (Pipistrellus subflavus)	Southern flying squirrel (Glaucomys volans)*
Eastern red bat (Lasiurus borealis)	Southern short-tailed shrew (Blarina carolinensis)
Eastern woodrat (Neotoma floridana)	Striped skunk (Mephitis mephitis)*
Evening bat (Nycticeius humeralis)	Virginia opossum (Didelphis virginiana)
Feral cat (Felis catus)**	White-tailed deer (Odocoileus virginianus)
Feral dog (Canis familiaris)**	Woodland (pine) vole (Microtus pinetorum)
Feral pig (Sus scrofa)**	

Rare, Threatened, and Endangered Species

Two terrestrial plant species, glade windflower (*Anemone berlandieri*) and cedar glade (*Erigeron strigosus* [var. *calcicola*]), are listed as protected species in Georgia (GA DNR 2008a). Glade windflower, found in granite outcrop ecotones or openings over rocks, is listed as S1S2 (S1 ≡ critically imperiled, rare with 5 or fewer known occurrences; S2 – imperiled, rarity with 6 to 20 known occurrences). Cedar glade is listed as S1.

Three wetland species (bent sedge, darkgreen sedge, and fivelobe cucumber) and one aquatic species (narrowleaf naiad; *Plate 10*) inhabiting OCMU are listed by GA DNR (2008b) as species of concern: All three species have a G5 (bent sedge – demonstrably secure globally) or G4 global ranking (darkgreen sedge and fivelobe cucumber – apparently secure globally), but a state ranking of S1. Narrowleaf naiad is the species of most concern; its global ranking is G1 (critically imperiled globally because of extreme rarity), its state ranking is S1, and it is also on the U.S. Fish and Wildlife federal endangered species list (GA DNR2008b).

Plate 10. Narrowleaf naiad (*Najas flexilis*), an endangered aquatic species that occurs in OCMU. From Sue Scott, with permission (www.arkive.org/.../Najas_flexilis/**).**

In the larger Altamaha River basin including the Ocmulgee River basin, three endemic species of mussels are rare including the Altamaha arcmussel (*Alasmidonta arcula*), the Altamaha spiny mussel (*Elliptio spinosa*), and the inflated floater (*Pyganodon gibbosa*), and the percentage of sites occupied by these species have declined over the past 40 years (Wisniewski et al. 2005). It is not known whether these species inhabit OCMU waters.

No amphibians, reptiles or fish that occur at OCMU are considered as imperiled (rare, threatened or endangered) by state or federal authorities. GA DNR (2008b) has listed the following bird species: cerulean warbler – rare (R, protected); Wilson's plover – threatened (T, likely to become an endangered species in the foreseeable future throughout all or part of its range); and wood stork and golden-winged warbler – endangered (E, in danger of extinction throughout all or part of its range). The wood stork is also federally listed as an endangered species (LE; U.S. Fish and Wildlife Service; source: http://georgiawildlife.dnr.state.ga.us/content/protectedbirds.asp). One mammal, Rafinesque's big-eared bat, is listed by GA DNR (2008b) as rare.

Exotic/Invasive Species

Numerous exotic plant species are found at OCMU, most of which have been introduced to adjacent lands as a result of landscaping or ornamental efforts. Species that have been managed in OCMU include common Chinese privet, which is located primarily within the wetlands (*Table 2*); American pokeweed (Japanese honeysuckle), which can also be a wetland species (*Table 2*); kudzu (*Pueraria montana*); and chinaberry (*Melia azedarach*), which has been controlled where it is affecting cultural resources (USDI-NPS 2000, DeVivo 2006). Tree of heaven (*Ailanthus altissima*) populations in OCMU have also been expanding over the past several years (DeVivo 2006). The aquatic weeds Brazilian parrotfeather and nuisance water primrose can be abundant

in the large pond of OCMU's Main Unit (first author's observation, November 2007; the latter species has been added to the species list for this report).

The southern pine beetle, *Dentroctonus frontalis*, considered the most destructive forest insect pest in the southeastern U.S. (Clarke 1995), have historically caused heavy damage to OCMU's loblolly pine stands. The red imported fire ant (*Solenopsis invicta*), an invasive species from South America introduced to the U.S. in the 1930s (Porter and Savignano 1990), is present in OCMU (DeVivo 2006). This aggressive species has largely displaced the two fire ant species native to the Southeast, *Solenopsis geminata* and *Solenopsis exloni* (Porter and Savignano 1990).

Six exotic animal species are established at OCMU including the ubiquitous house mouse; Norway rat; feral pigs, cats and dogs; and the wetland rodent nutria. Populations of feral-boar hybrids have become a threat to both natural and cultural resources through their foraging and wallowing activities, especially in the wetlands east of Walnut Creek and in the Lamar Unit (GA DNR 2004; D. Webster, UNC Wilmington notes). OCMU has an active trapping and eradication program that has removed more than 150 individuals, but OCMU is likely to continue receiving individuals from source populations outside its boundaries (DeVivo 2006). Feral cats pose a potential threat to populations of migratory songbirds, reptiles, and small mammals (DeVivo 2006), and feral dogs are also present. In addition, within the past ~decade, coyotes have established in OCMU, with as-yet unknown consequences for the ecosystem (Watson 2005, DeVivo 2006).

Because of their association with wetlands, nutria merit special mention. The impacts of these large rodents on native plant communities have not been adequately assessed, but they can rapidly reduce wetland plant diversity through their foraging activity.

Assessment of OCMU Water and Air Resources

OCMU's drinking water is supplied from the Ocmulgee River by the MWA. OCMU has a sewage lift station adjacent to the railroad tracks, and several miles of underground sewage lines, built from the 1920s (USDI-NPS 2000, Chief Ranger G. LaChine, pers. comm.). The monument was affected for years by sewage spills from the old pipes, but all of the sewage lines finally were relined by 2006 (Chief Ranger G. LaChine, pers. comm.).

Surface Water Quality

Locations for sampling stations near or within OCMU, discussed in this section, were obtained from the U.S. EPA STORET. Latitudes and longitudes for these sites were imported from Microsoft Excel into ArcMap and converted to GIS point files.

OCMU 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 (*Table 8*, *Appendix 3*). As mentioned, the USGS previously maintained flow/ water quality stations on the Ocmulgee River (USGS #02213000) and Walnut Creek (NAD27, site #02213050 in Jones County near Gray, GA), ~4.5 miles upstream from the northern boundary of OCMU. However, water quality data are only available from the 1960s- mid-1970s. The NPS maintained 15 water quality sampling stations in or within ~15 miles of OCMU from 1986 to 1996, including 11 stations in OCMU (*Table 8, Figure 9*).

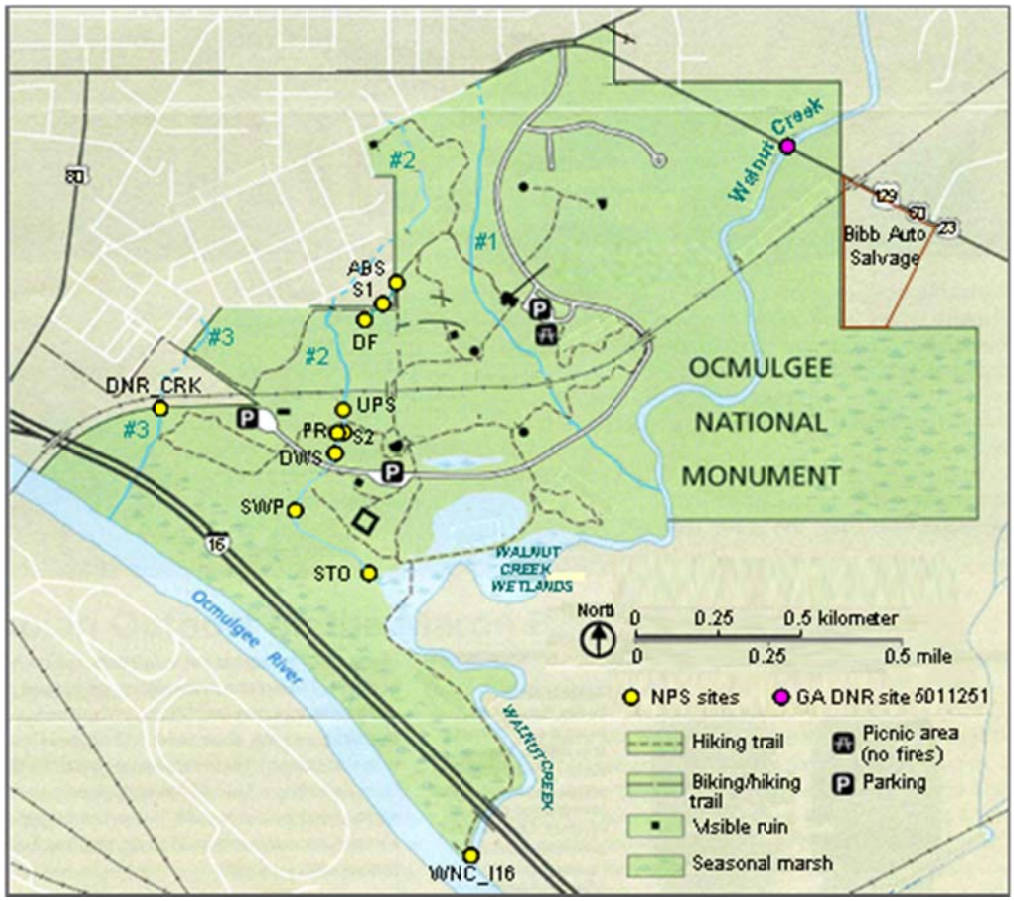

Figure 9. Twelve previous water quality sampling stations in OCMU, including 11 NPS stations (1986-1996), and 1 GA DNR station (~1 year, Jan. 1999 – Jan or March 2000; see *Table 8*). The location of a large junkyard, Bibb Auto Salvage along the northeastern border of OCMU, is also shown.

Previous data inventories and analyses carried out by the NPS (2002) within OCMU indicated that pH, fecal coliform bacterial densities, turbidity, lead, copper, zinc, and chlorine all exceeded Georgia water quality criteria at least once. The pH was outside the range (6.5-9) considered acceptable by the U.S. EPA (chronic criterion for freshwater aquatic life) in about 5% of the samples taken in both the Ocmulgee River and Walnut Creek.

Fecal coliform densities violated the standard for drinking water sources in 65% of the Ocmulgee River samples, and turbidity exceeded 50 NTU in about 20% of the samples (NPS 2002). From 1999-2000, the GA DNR-EPD sampled two sites in the vicinity, one on the Ocmulgee River and the other on Walnut Creek (*Tables 9* and *10, Figure 10*). Water quality sampling has not been conducted by the County in the OCMU area (C. Brooks, Bibb County Engineer, pers. comm.).

Table 9. Surface water quality datasets in the OCMU area (within about 1 mile upstream from the monument) from the past ten or more years, and present status.

Source	Data Description	Present Status (2007-2008)
Bibb County Engineering (C. Brooks, Engineer IV)	NPDES stormwater monitoring data	Stated that no WQ sampling has been conducted in the OCMU area as specified (see table legend). The county is a co-applicant with the City of Macon for two Phase I MS4 stormwater permits.a
City of Macon Engineering (D. Tavakol, Interim City Engineer)	NPDES stormwater monitoring data	Data were provided for Walnut Creek (Jacksonville Rd. site) on 3 dates in 2007-2008 (collected for the City by a consulting firm, Analytical Environmental Services, Inc.); described as the only data collected by the City within the OCMU area as specified (see table legend).
Macon Water Authority (M. Wyzalek, Laboratory and Environmental Compliance Manager)	EPA ICR and Ocmulgee Watershed Study data	Partial monthly data were provided from 2 sites within a 10-mile radius of OCMU (requested total sampling duration was not provided). Other requested data and a requested map of the sanitary sewers were not made available (but note that a GIS layer for Macon sewer lines does not yet exist)
GA DNR-EPD	303(d) list of impaired streams	Status available through 2008 (GA DNR 2008c,d)
U.S. EPA	STORET data [b] (Upper Ocmulgee watershed, HUC 03070103)	Data available for 17 locations in the OCMU vicinity (Ocmulgee River and Walnut Creek), including 15 NPS sites and 2 GA DNR sites; few data from the past ten years.
Mercer University (Dr. B. Roodand volunteer group, the Ocmulgee River Initiative, Inc. [ORI] along with a recently initiated ORI Stream Watch Program)	Water quality data (Spring Street, Macon)	Data collected on the Ocmulgee River for 14 years ongoing, with ~quarterly sampling of one site near OCMU. Data summaries for turbidity, specific conductance, color, inorganic N (ammonium, nitrate, nitrite), and phosphate were provided from 1996-2000.

[a] For the MS4 stormwater permits (#GAS000203 and #GAS000204), the detailed facility reports indicate no inspection or compliance data. Industrial facilities and developers apply for their own stormwater permits separately from the County, and the County does not keep records of these. They are also sporadic/missing on the EPA ECHO ICIS-NPDES search engine (incomplete) and the EPA Envirofacts PCS system (the latter is older and outdated).

[b] The STORET data include 15 NPS sites (sampled from 1986-1996) and 2 GA DNR-EPD sites (sampled from 1999-2000 - one on the Ocmulgee River, the other on Walnut Creek) in or near OCMU. Data were also available for 2 other GA DNR-EPD sites (1 on the Ocmulgee River and 1 on Walnut Creek), but they were not included in this report because they are distant ($\geq$ 10 miles upstream) from OCMU. It should be noted that the watershed summaries in STORET often contained duplicate data from GA DNR, including one entry from GA DNR EPD and a second entry from a newer framework, the Water Quality Exchange (GEPD_WQX). The fact that duplication was inconsistent among dates, and that within a date frequently some but not all parameters were duplicated, necessitated intensive record-by-record inspection.

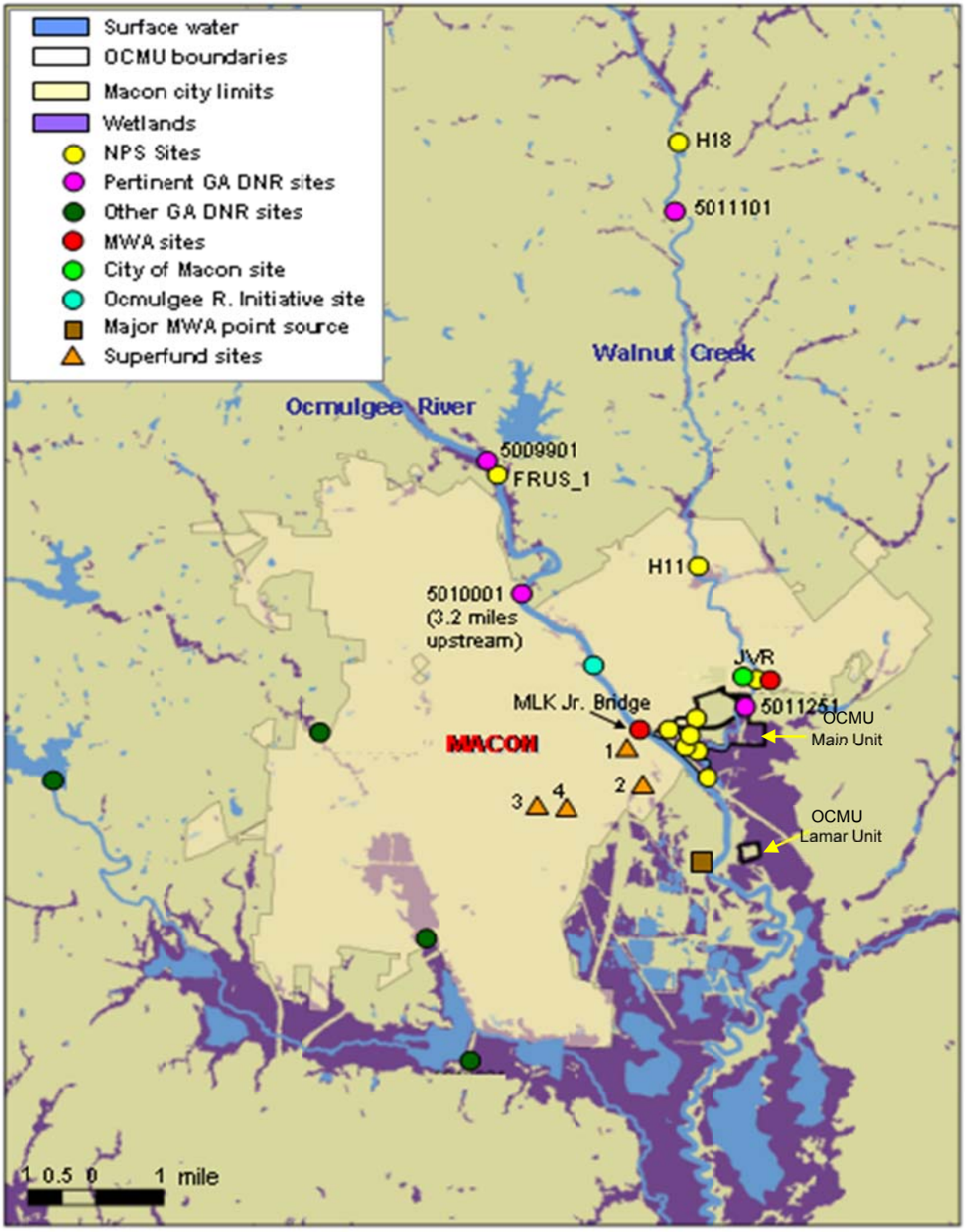

Figure 10. Map of the Macon area showing OCMU, the Macon city limits, surface waters, wetlands, and historic as well as historic and present water quality sampling stations (note that Georgia Power Plant's NPDES site is north of the area shown, whereas the MWA and Macon wastewater treatment plant major point sources are slightly downstream (0.18 mile) from the Lamar Unit of OCMU). There are 11 NPS WQ sampling sites in close proximity within OCMU (see *Figure 9*); some are obscured here. Superfund sites in the area include (1) Macon Gas Light & Water Company (~0.5 mile west of the OCMU boundary bordered by the Ocmulgee River), (2) Walker Lakes Dump Site (0.75 mile west of OCMU), (3) Ash & Broadway, and (4) Archer Daniels Midland (ADM) Inc. (both ~2 miles west of OCMU).

Table 10. Available data for surface water quality in the OCMU area from 1999 to the present (sources: GA DNR-EPD via STORET, MWA, and City of Macon). Note that U.C. ≡ unacceptable conditions. **Underline and bold** ≡ data in violation of state standard (GA DNR 2008d – see pp. 44-46 of this Report), except for fecal coliforms for which the data suggest degraded conditions[a]. **Blue and bold** ≡ can support noxious algal blooms (NO_3^-+NO_2^- – see Mallin 2000), or data exceeded recommended values to protect aquatic life (BOD_5 - see Mallin 2006). **Bold shaded** ≡ data exceeded recommended values for acceptable water quality (U.S. EPA 2000: for TSS, 25 mg/L maximum, and < 10 mg/L increase from a sudden spike; for metals (Al, Cu, Hg, Pb, Ni, Zn), see pp. 46-48 of this Report). Note that U.S. EPA (2002) recommends that pH should be maintained within the range 6.5-9; this Report, however, follows Georgia regulations (pH ≥ 6.0).

Parameter	Date	n	Mean (range) or single value (sv)	Median	Number of UCs
Walnut Creek, OCMU					
GEPD 5011251 (Walnut Creek, NE boundary of OCMU; lat. 32.8461, long. -83.5956 – GA DNR)					
Temperature (^oC)	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 (3 - 40)	9	---
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**	**11**
NH_4^+N (µg/L)	Jan 99 - Dec 00	56	56 (30 - **130**)	40.5	**1**
TP (µg/L)	Jan 99 - Jan 00	12	29 (20 - 50)	26	---
TOC (mg/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**)	2	**1**
Fecal coliforms (mpn/100 mL)	Jan 99 - Oct 00	16	**7,168** (20 - **92,000**)	**945**	**10** (**10**)
Toxics - Water	16-Sep-99	8-Mar-00			
Antimony	1 µg/L	1 µg/L			
Arsenic	2 µg/L	2 µg/L			
Cadmium	0.5 µg/L	0.5 µg/L			
Calcium	11,000 µg/L	7,800 µg/L			
Chromium	1 µg/L	1 µg/L			
Copper	1 µg/L	1 µg/L			
Lead	2 µg/L	1 µg/L			
Magnesium	4,200 µg/L	3,300 µg/L			
Mercury	0.1 µg/L[b]	0.1 µg/L*			
Nickel	1 µg/L	1 µg/L			
Selenium	2 µg/L	2 µg/L			
Thallium	2 µg/L	2 µg/L			
Zinc	5 µg/L	6 µg/L			

Table 10. (Continued).

Parameter	Date	n	Mean (range) or single value (sv)	Median	Number of UCs
Upstream from OCMU – Walnut Creek					
JVR - Walnut Creek Bridge, Jeffersonville Rd. (0.4 mile upstream; lat. 32.8521, long. - 83.5934 – MWA)					
Temperature (^{o}C)	Jun 07 - Aug 08	10	18.6 (9 – 26.5)	19.3	---
Turbidity (NTU)	Nov 05 - Aug 08	33	18.5 (1.6 - 250)	7.3	---
Spec. cond. (µmhos/cm)	May 07 - Aug 08	12	132.7 (74.7 - 250)	122	---
DO (mg/L)	May 07 - Aug 08	11	7.9 (5.4 - 10.4)	8.4	---
pH	Apr 07 - Aug 08	13	7.0 (6.3 - 7.8)	6.9	---
Color	Nov 05 - Aug 08	33	89.4 (15 - 1,200)	30	---
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**		
Tetrachloroethane (volatile organic, µg/L)	sv 8.8	BRL	BRL		
Ocmulgee River near OCMU					
MLK Jr. Blvd. Bridge (adjacent to OCMU; lat. 32.8387, long. - 83.6205 – MWA)					
Temperature (^{o}C)	Dec 07 - Aug 089		19.4 (11 - 29.5)	17.5	---
Turbidity (NTU)	Oct 05 - Aug 0835		12.9 (1.4 - 60)	7.1	---
Spec. cond. (µmhos/cm, field)	May 07 - Aug 0813		154.8 (23 - 235)	149	---
DO (mg/L)	May 07 - Aug 0811		8.4 (6.8 - 10.4)	8.1	---
pH	Apr 07 - Aug 0813		7.3 (6.4 - 7.99)	7.3	---
Color	Oct 05 - Aug 0834		45.1 (10 - 150)	30	---
Fecal coliforms (mpn/100 mL)	May 05 - Aug 0839		**318** (0 - **10,600**)	20	**3** (**1**)

Table 10. (Continued).

Parameter	Date	n	Mean (range) or single value (sv)	Median	Number of UCs
Upstream from OCMU – Ocmulgee River					
GEPD 5010001 (3.2 miles upstream – Ocmulgee River; lat. 32.8697, long. - 83.6542 – GA DNR)					
Temperature (^{o}C)	Jan 99 - Dec 00	43	20.4 (5 - 34.5)	20.5	---
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 (1 - 34)	5.5	---
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** (20 - **840**)	460	**23**
NH_4^+N (µg/L)	Jan 99 - Dec 00	24	40 (30 - **130**)	30	**1**
TKN (µg/L)	Jan 99 - Dec 00	24	**1,055** (180 – **19,000**)	**270**	24
TP (µg/L)	Jan 99 - Dec 00	24	28 (20 - 60) 22	---	
BOD_5 (mg/L)	Jan 99 - Dec 00	24	2 (2 - 2)	2	---
Fecal coliforms (mpn/100 mL)	Jan 99 - Oct 99	16	194 (20 - **700**)	65	**4** (**2**)
Toxics – Water	1-Feb-99	16-Sep-99	8 Mar 00	13-Jun-00	14-Nov-00
Antimony	1 µg/L	1 µg/L	1 µg/L	1 µg/L	1 µg/L
Arsenic	2 µg/L	2 µg/L	2 µg/L	3 µg/L	4 µg/L
Cadmium	0.5 µg/L	0.5 µg/L	0.5 µg/L	0.5 µg/L	0.5 µg/L
Calcium	6.1 mg/L	12.0 mg/L	7.1 mg/L	10.0 µg/L	11.0 mg/L
Chromium	6 µg/L	1 µg/L	1 µg/L	3 µg/L	1 µg/L
Copper	7 µg/L	1 µg/L	1 µg/L	1 µg/L	2 µg/L
Lead	6 µg/L	1 µg/L	1 µg/L	2 µg/L	2 µg/L
Magnesium	2.8 mg/L	2.7 mg/L	2.0 mg/L	2.5 mg/L	2.4 mg/L
Mercury	0.1 µg/L	0.1 µg/L	0.1 µg/L	0.1 µg/L	0.1 µg/L
Nickel	3 µg/L	1 µg/L	1 µg/L	2 µg/L	1 µg/L
Selenium	2 µg/L	2 µg/L	2 µg/L	2 µg/L	4 µg/L
Thallium	2 µg/L	2 µg/L	2 µg/L	2 µg/L	2 µg/L
Zinc	25 µg/L	3 µg/L	1 µg/L	7 µg/L	15 µg/L

[a] Data were not collected with sufficient frequency to enable calculation of geometric means, used for the State standards (see pp. 41-42 of this Report). Unacceptable water quality (last column of table, 1st number) exceeded the fecal bacteria water quality standard values considered for geometric means (> 200 mpn/100 mL in May - Oct; > 1,000 mpn/100 mL during Nov - Apr) and suggest degraded conditions. The 2nd number in the "Unacceptable" column, in parentheses, is the number of samples with fecal coliform densities > 400 mpn/100 mL, in consideration of the U.S. EPA's (2003) recommendation for data collected with insufficient frequency to determine geometric means by the State's criteria.

[b] Detection limit with the method used.

The City of Macon Engineering section sent data for sampling of Walnut Creek near OCMU on three dates in 2007-2008 for limited parameters (Tables 9 and 10). Macon's Stormwater Manage-ment Program was enacted in 1995, and water quality monitoring began in 1996 (D. Tavakol, Interim City Engineer, pers. comm.). The City has conducted the sampling in-house and sends the samples to a consulting firm for analysis. Renewal of the City's Stormwater Management Plan was rejected by GA DNR in 2004 because of failure to protect stormwater runoff from pollution (Duncan 2004), but was later accepted after the City contracted with a stormwater consultant.
The MWA provided a partial dataset for monthly water quality at two sites near OCMU (Figure 10). Turbidity and color were sampled from 2005-2008, whereas DO, pH and conductivity were added to the sampling protocol in 2008. In addition, fecal coliform bacteria were sampled at the Ocmulgee River site. Although sparse, the data for both the Ocmulgee River and Walnut Creek near OCMU indicate water quality degradation from excessive fecal coliform densities, excessive organic pollution (as BOD5), and nutrient over-enrichment (nitrate + nitrite).

A one-year ~monthly sampling effort by the GA DNR in Walnut Creek at the northeast boundary of OCMU (station #GEPD 5011251) revealed median nitrate concentrations of 205 µg/L (maximum 340 µg/L), which is excessive when compared to inorganic N levels known to promote noxious algal blooms (Mallin 2000). Biochemical oxygen demand (BOD5) exceeded U.S. EPA recommended values to protect aquatic life on 1 of 12 dates. Fecal coliform bacteria indicated degradation from sewage and animal wastes; values exceeding 200 mpn/100 mL were recorded on 13 of 16 sampling dates, with a median count of 945 mpn/100 mL, and a maximum of 92,000 mpn/100 mL.

At the JVR site 0.4 mile upstream from OCMU, MWA data available for a small set of parameters from 2005-2008, not including fecal coliforms, indicated high maximal turbidity (250 NTU) and color (1,200). Also at the JVR site, the sparse City of Macon dataset – comprising the most recent water quality data – was troubling as well: Although samples were collected on only 3 dates in 2007-2008, violations of the state water quality standards or the U.S. EPA's recommended guidelines to protect aquatic life were reported for most parameters measured (BOD5, TSS, TDS, fecal coliform bacteria, total coliform bacteria / Escherichia coli, lead, zinc). Moreover, two of the three nutrient variables (TP, NOx) exceeded levels known to promote noxious algal blooms on 2 of 3 dates (e.g. see Plate 11). The median TSS concentration (87 mg/L) indicated extreme degradation from an urban/industrial load of suspended sediments (as shown in Plate 3); median and total fecal coliform/E. coli densities (4,500 mpn/100 mL and 16,000 mpn/100 mL, respectively) indicated degraded conditions for fishing and other human recreational contact; and the median zinc and lead concentrations indicated toxic conditions for aquatic life.

Plate 11. Algal bloom in a backwater area of Walnut Creek, OCMU, November 2007. Photo by Michael Mallin.

The Ocmulgee River adjacent to OCMU, by comparison, was less degraded according to MWA data (MLK Jr. Blvd. Bridge, taken ~monthly or less frequently) from 2005-2008. The mean and maximal fecal coliform concentrations (318 mpn/100 mL and 10,600 mpn/100 mL, respectively) suggested degraded conditions. GA DNR data from a site 3.2 miles upstream of OCMU (station GEPD 5010001) indicated excessive nitrate concentrations and fecal coliform densities in excess of 200 mpn/100 mL on 6 of 16 sampling dates during 1999. Data from the nonprofit Ocmulgee River Initiative (~quarterly, 1996-2000; *Table 11*) indicated moderate inorganic N and P concentrations on most sampling dates. Thus, collectively the available surface water quality data for Walnut Creek and the Ocmulgee River support Byrne's (2004) "potential red flag" status for OCMU waters considering total and fecal coliforms, and degraded conditions with respect to some other parameters, such as inorganic N, since that assessment was contributed.

Table 11. Data from the Ocmulgee River Initiative, Inc. for water quality of the Ocmulgee River at Spring Street, ~0.4 mile upstream from OCMU (latitude 32.5043, longitude -83.3740), sampled approximately seasonally (courtesy of B. Rood, Mercer University).

Date	Conductivity (µmhos/cm)	Turbidity (NTU)	Color (CPU)	$NO_3^-N + NO_2^-N$ (µg/L)	NH_4^+N (µg/L)	DIP (SRP) (µg/L)
Summer 1996	84	377	----	4	0	90
Fall 1996	133	13	5	8	10	50
Winter 1996-7 (bridge)	----	25	25	23	70	0
Spring 1997	101	13	25	8	40	80
Fall 1997	106	4	35	40	70	20
Winter 1997-8	79	12	60	90	100	10
Spring 1998	19	6	50	54	80	10
Summer 1998	15	1	----	22	30	10

Summer 2000	165	1	25	120	120	0

Drinking Water

Drinking water is supplied to OCMU from the MWA as mentioned (Chief Ranger G. LaChine, pers. comm.) and, so, is not at risk from fecal bacteria.

Groundwater Quality

Data are not available to assess groundwater quality in OCMU. Water from the Cretaceous aquifer system underlying OCMU often is acidic (pH below 7.0) because of substantial carbon dioxide, and can be corrosive (Tyson 1993).

Sources of Pollutants

Point Sources

NPDES permit information and any compliance actions were accessed from the U.S. EPA Enforcement and Compliance History Online (ECHO) Permit Compliance System, or from the modernized ECHO Integrated Compliance Information System (http://www.epa-echo.gov/echo/compliance_report_water.html). Unfortunately, the position locations of the NPDES point sources in Bibb County, as downloaded from the U.S. EPA website, contained various errors. The GIS coordinates were listed in decimal degrees but, when plotted, were clearly incorrect and showed the site locations as given in Emanual County, ~63 miles due-east of Bibb County.

An updated draft of NPDES permit locations was provided by the GA DNR EPD's Watershed Protection Branch, but some locations still were suspect. For example, the new draft location for #GA0024538 (Macon Water Authority sewerage system, Poplar St. site) locates the site slightly downstream (0.18 mile) from the Lamar Unit of OCMU, but the longitude data from the U.S. EPA ICES website places the site directly across from the Lamar Unit. As another example, #GA0002364 (Brosnan Yard of the Southern Railway) is described by the U.S. EPA ICIS website as discharging into the Ocmulgee River, whereas the draft site information from GA DNR locates the site ~2 miles west of the river. In addition, there were discrepancies depending upon how the ICIS NPDES system was searched. A search by Bibb County produced a different

NPDES listing than a search by city (Macon), although many of the NPDES sources actually were within both within both city and county limits.

Based upon state (GA DNR) and federal (U.S. 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 OCMU: The Georgia Power Plant (#GA0026069) is about 9.5 miles upstream from the Main Unit of OCMU. Because of the distance, this point source is not considered to be a major influence on OCMU. The MWA site mentioned above is slightly downstream from the Lamar Unit, as mentioned (*Figure 10*); a second site (#GA0024546, MWA – Rocky Creek) also is downstream (~1.6 miles) and southwest from the Lamar Unit. Thus, the water resource degradation at OCMU is mainly being caused by nonpoint sources. It should also be mentioned that OCMU has one aboveground 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 G. LaChine, pers. comm.).

Nonpoint Sources

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 OCMU. In addition, the uppermost portion of the Ocmulgee River basin contains part of the rapidly expanding major Atlanta Metropolitan area, Potential anthropogenic sources of contaminants include municipal and industrial wastewater discharges, stormwater runoff, agricultural and timbering operations, mining and quarrying activities, recreational use, and atmospheric deposition (NPS 2002). For example, auto salvage/junkyards are adjacent to OCMU's Main Unit (*Figure 9, Plate 12*), and tires from the junkyards have sometimes washed into OCMU property, suggesting that dissolved pollutants from these operations are also affecting OCMU. Macon's 11th Street Phase I sanitary landfill is in the floodplain near the western shore of the Ocmulgee River opposite the Lamar Unit (*Figure 5*). This landfill stopped accepting wastes in 1982, but likely is contaminating groundwater that provides part of the Ocmulgee River flow. Several Superfund sites that may be affecting water resource quality at OCMU are also in the Macon area (*Figure 10*), 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 12*), is high surrounding OCMU and in the upstream Ocmulgee River and Walnut Creek watersheds (*Figure 2*). The Ocmulgee River and Walnut Creek segments upstream from and adjacent to monument boundaries are degraded from the City of Macon's urban development (see pp. 30-37 of this Report). OCMU 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 east Macon and sometimes carries large amounts of trash, pollution, as well as occasional raw sewage into OCMU (USDA-NPS 2000; Chief Ranger G. LaChine, pers. comm.).

The location of OCMU downstream and down-airshed from the greater Atlanta metropolitan 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 (see below). The wide range of urban land uses and activities occurring in the watersheds are harmful to OCMU's water resources. These sources also contribute to acid deposition which can contribute to acidification

and nutrient over-enrichment of surface waters (Baker and Christensen 1992). The OCMU area lies within a region that has been evaluated as most at risk in the U.S. for continued acid deposition (Herlihy et al. 1991; below).

Plate 12. The large Bibb Auto Salvage junkyard in a former wetland along the OCMU boundary (see *Figure 9*). Another company, Sadisco of Macon, is ~2.5 miles upstream from the Monument in the Walnut Creek watershed and engages in storage and disposal of wrecked vehicles. Photo by Michael Mallin.

Table 12. Mean concentrations of pollutants in precipitation events, depending upon the amount of impervious surface area (imperv. ≡ imperviousness; TCu ≡ total copper; TZn ≡ total zinc). From the ARC (1998) in Georgia Department of Community Affairs (2003).

		Event Mean Concentrations (mg/L)									
Land Use	**% Impervious**	**BOD**	**TDS**	**COD**	**TSS**	**TP**	**TKN**	**NO_3^-N + NO_2^-N**	**TCu**	**TZn**	**NH_4^+N**
Forest/open	0.5	8	100	51	216	0.09	0.46	0.25	0	0	0
Agriculture	0.5	4	678	72	400	0.4	209	0.5	0.04	0.1	0.001
Large-lot single family (> 2 acre)	10	10.1	91	58	235	0.19	0.66	0.34	0.01	0.04	0
Low-density single family (1-2 acres)	12	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 acre)	19	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	10.8	100	83	140	0.47	2.36	0.96	0.05	0.12	0.003
Townhouse/apartment	48	10.8	51	70	109	0.19	1.24	0.69	0.02	0.14	0.003
Commercial	85	9.71	100	190	248	0.66	3.2	1.18	0.04	0.28	0.005
Office/light industrial	70	15	58	77	93	0.66	3.2	1.18	0.04	0.19	0.003
Heavy industrial	80	9.7	100	61	91	0.24	1.28	0.63	0.04	0.19	0.001
Average	**35.1**	**10.41**	**145**	**93**	**209**	**0.36**	**22.1**	**0.87**	**0.03**	**0.14**	**0.0024**

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 OCMU's 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 (*Plates 3-5*). Excessive sediment loading has been related mostly to urban runoff, industrial/mining activities, and agricultural land uses (*Table 13*). 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.

The overall 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 OCMU are visibly obvious (*Plates 3-5*) and Walnut Creek, including the OCMU segments, are impaired and only partially supporting their designated uses for fish/fishing because of habitat degradation from excessive sedimentation and other urban runoff effects (see below). Both Walnut Creek and the Ocmulgee River in the vicinity of OCMU 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, 2008c,d). In addition, the Ocmulgee River in the vicinity of the Lamar Unit is impaired for excessive polychlorinated biphenyls (PCBs) in fish tissues (below). There is no natural

source for this group of toxic substances; rather, PCB contamination is of industrial origin (GA DNR 2007b).

Table 13. Estimated contributions of various land use / land cover categories to suspended sediment loading (GA DNR 2007a). Note that avg. ≡ average, N.A. ≡ not available, and units for the last column are tons/acre/year.

LAND USE	AVG. LAND COVER (%)	AVG. SEDIMENT LOAD (%)	AVG. SEDIMENT LOAD
Open Water	0.7	0.0	0.01
Urban	13.3	14.7	0.27
Roads	N.A.	29.9	NA
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

Assessment of Biological Resources With Respect To Water and Air Quality

The water use classification for the Ocmulgee River and Walnut Creek near OCMU is fishing. The fishing classification, as stated in Georgia's Rules and Regulations for Water Quality Control Chapter 391-3-6-.03(6)(c), is established to protect the "Propagation of Fish, Shellfish, Game and Other Aquatic Life; secondary contact recreation in and on the water; or for any other use requiring water of a lower quality" (GA DNR 2008e). In addition, the Ocmulgee River segment from GA Highway 18 to the Macon Water Intake is classified as Drinking Water (Water Quality Control, Chapter 391-3-6(13)).

Water Quality Standards

The state of Georgia has ambient water quality standards for common water quality parameters including dissolved oxygen (> 5 mg/L daily average), pH (between 6.0 and 8.5), turbidity (50 NTU for freshwater), pH, and temperature (GA DNR 2008e) (*Appendix 4*). In addition, water quality samples collected within a 30-day period that have a geometric mean fecal coliform count exceeding 200 mpn /100 mL during May through October, or exceeding 1,000 cfu/100 mL during November through April, are in violation of the bacteria water quality standard for drinking water. For streams designated for fishing such as Walnut Creek and most segments of the Ocmulgee River, samples that have a geometric mean 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. The state has also developed water use classifications, and in-stream water quality standards for each use (e.g. *Table 14*).

Georgia's *Rules and Regulations for Water Quality Control*, Chapter 391-3-6-.03(5)(c) state 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 (*Appendix 5*). 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 2008c,d). 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 2004). A stream is placed on the "partial support" list if more than 10% of the samples exceed the fecal coliform criteria and on the not support list if more than 25% of the samples exceed the standard.

Georgia also has an in-stream criterion for PCBs, found in Georgia's Rules and Regulations for Water Quality Control, Chapter 391-3-6, revised in November 2005: Georgia Regulation 391-3-6-.03(5)(e)(iv) states that "Instream concentrations of chemical constituents [including PCBs] listed by the U.S. EPA as toxic priority pollutants pursuant to Section 307(a)(1) of the Federal Clean Water Act (as amended) shall not exceed indicated criteria under annual average or higher stream flow conditions" (GA DNR 2007b, 2008e). The state's in-stream target, 0.00017 µg/L, is protective of the GA DNR fish consumption advisory action level of 0.1 mg/kg, and the Federal Drug Administration action level of 2.0 mg/kg for fish consumption.

GA DNR's management strategies to reduce contamination in impaired streams in urban areas include sustained compliance with NPDES permit limits and requirements; adoption of National Resource Conservation Service Conservation Practices; application of best-management practices that are appropriate to specific agricultural and urban land uses; further development and streamlining of mechanisms for identifying, reporting, and correcting illicit connections, breaks, and other sanitary sewer or waste containment problems; for fecal coliforms, adoption of local ordinances requiring periodic septic system inspection, pumpout, and maintenance; and public education (GA DNR 2004, 2008c).

Table 14. Georgia water use classifications and in-stream water quality standards for each use (GA DNR 2008d; Georgia's Rules and Regulations for Water Quality Control, Chapter 391-3-6-.03(6)(a), 391-3-6-.03(6)(b), and 391-3-6-.03(6)(c)).

USE CLASSIFICATION	BACTERIA (fecal coliforms)		DISSOLVED OXYGEN (except trout streams)[a]		pH	TEMPERATURE (except trout streams)[a]	
	30-day geom. mean[b]	Maximum	Daily Avg. (mg/L)	Minimum (mg/L)	Std. Units	Maximum Rise (°F)	Maximum (°F)
Drinking Water requiring treatment	1,000 Nov-Apr 200 May-Oct	4,000 Nov-Apr ----	5.0	4.0	6.0-8.5	5	90
Recreation	200 (frw.) [c] 100 (coastal)	----	5.0	4.0	6.0-8.5	5	90
Fishing	1,000 Nov-Apr 200 May-Oct	4,000 Nov-Apr	5.0	4.0	6.0-8.5	5	90
Coastal Fishing [d]							
Wild River	No alteration of natural water quality						
Scenic River	No alteration of natural water quality						

[a] 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 alterati allowed in Primary Trout Streams, and a temperature change of 2°F is allowed in secondary Trout Streams.

[b] Fecal coliform densities are in units of number / 100 mL (Geom. ≡ geometric). Geometric means should be "based on at least 4 sa 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 the Nth root of their product. Example: the geometric mean of 2 and 18 is the square root of 36. Note: U.S. EPA (2003) recommend consideration of 400 mpn/100 mL as the highest acceptable level of fecal coliforms if samples are taken less frequently.

[c] Frw. ≡ freshwater.

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

Other recommended guidelines for acceptable water quality in waters designated for use as Fishing and general recreation have been published by the U.S. EPA (2000, 2002, 2003) and other sources (*Table 15*). The Clean Water Act requires the U.S. EPA to develop criteria (i.e. recommendations) for water that are designed in part to protect aquatic life. The criteria are approaches that differ from the U.S. EPA water quality criteria, but these criteria are meant to provide useful guidance.

Table 15. Summary of Georgia state standards for acceptable water quality in waters classified as Fishing designated use (GA DNR – excluding temperature); conditions for acceptable water quality recommended by other sources; and status of the Ocmulgee River and Walnut Creek in the monument within the past decade (U.C. ≡ unacceptable conditions; U.C.C. ≡ unacceptable conditions common).. See *Table 10, Appendix 3,* and text description for more information on available data.

Parameter	GA DNR	Other Recommendation(s) or Guideline(s)	KEMO NBP
General Water Quality Parameters			
Dissolved oxygen (mg/L)	≥ 5 daily avg.; minimum 4	≥ 4 (U.S. EPA 2000)	Few dates with DO < 5
pH	≥ 6.0, ≤ 8.5	> 6.5, < 9.0 (U.S. EPA 2000)	No violations
Fecal Coliforms (cfu/100 mL)	≤ 1,000 Nov-Apr; ≤ 200 May-Oct (g.m.)	400 for data collected with insufficient frequency to calculate g.m.s by the State's criteria (U.S. EPA 2003)	Insufficient data collection for g.m.s, but some values > 400 indicate degraded conditions (max. 51,600)
Nutrients	----	< 100 µg/L for total phosphorus and for inorganic nitrogen nitrate+nitrite, and/or ammonium) to discourage noxious algal blooms (Mallin 2000)	Data indicate excessive conditions especially for inorganic N
Biochemical oxygen demand	----	Less than 3.0 mg/L as the 5-day biochemical oxygen demand (BOD_5) (Mallin et al. 2006)	Limited data - 1 U.C.
Total suspended solids (TSS)	----	≤ 25 mg/L, and < 10 mg/L increase from a sudden spike (U.S. EPA 2000)	Limited data - no U.C.s
Toxic metals (µg/L)			
Aluminum	Equations*	CMC 750, CCC 87 (U.S. EPA 2000, 2002**	Limited data – U.C.C.
Cadmium	"	CMC 2, CCC 0.25 (U.S. EPA 2000, 2002)**	Limited data – U.C.C. In John Ward Cr.
Chromium III	"	CMC 570, CCC 74 (U.S. EPA 2000, 2002)**	Data not available
Chromium IV	"	CMC 16, CCC 11 (U.S. EPA 2000, 2002)**	Data not available
Copper	"	CMC 13, CCC 9 (U.S. EPA 2000, 2002)**	1 U.C.C.
Lead	"	CMC 65, CCC 2.5 (U.S. EPA 2000, 2002)**	Several U.C.
Mercury	"	CMC 1.4, CCC 0.77 (U.S. EPA 2000, 2002)**	Data not available
Nickel	"	CMC 470, CCC 52 (U.S. EPA 2000, 2002)**	Data not available
Zinc	"	CMC 120, CCC 87 (U.S. EPA 2000, 2002)**	No U.C.

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

** 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.

In addition to these standards, Phase I NPDES permits regulate stormwater discharges associated with specific industrial activities (including construction sites ≥ 1 acre in area) and large and medium municipal separate storm sewer systems (MS4s) that serve populations of 100,000 or more. MS4 permits are supposed to 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 2004). The intent is to reduce exposure of stormwater to pollutants. In the OCMU area, storm sewer Phase I MS4 permits (SWP storm sewer systems) include #GAS00020 to the City of Macon and #GAS000204 to Bibb County. A total of 17.5% and 11% of the Ocmulgee River basin and the Walnut Creek basin, respectively, is in a MS4 area (GA DNR 2007c).

Impaired Surface Water Quality and Habitat

The most recent GA DNR (2008c,d) 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. Estimated sources of the sediment loads are listed in *Table 16*); such partitioning among land use types was not attempted for sources of fecal coliforms. Overwhelmingly, the major cause (nearly 80%) of the impairment 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; http://oaspub.epa.gov/tmdl/enviro.control?p_list_id=GA-R031300020208) (*Table 17*). The Ocmulgee River (segment from Beaverdam Creek to Walnut Creek – 10 miles), including the Main Unit of OCMU, is listed as impaired because of fecal coliform bacteria. This segment is classified for use as drinking water. In addition, the segment of the Ocmulgee River from Walnut Creek to Tobesofkee Creek (11 miles), including the Lamar Unit of OCMU, is 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 2007d). PCB exposure has been related to an array of adverse health effects in fish, birds, and mammals, including toxic effects on the 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 16. Estimated contribution of land use type to sediment loading in Walnut Creek (GA DNR 2007a).

Source	Walnut Creek (tons per year)	
Open water	0.00	(0.00%)
Low-intensity residential	115.20	(1.77%)
High-intensity residential	2.52	(0.04%)
High-intensity comm/ indust/ transp	0.34	(0.01%)
Clearcut, sparse	0.00	(0.00%)
Quarries, strip mines, rocks	5,145.25	(79.26%)
Roads	545.06	(8.40%)
Transitional	24.88	(0.38%)
Deciduous forest	14.48	(0.22%)
Evergreen forest	4.15	(0.06%)
Mixed forest	0.52	(0.01%)
Row crops, pasture	322.46	(4.97%)
Other grasses (urban, recreational)	123.10	(1.90%)
Woody wetland	193.63	(2.98%)
Non-forested wetland (fresh)	---	---

Table 17. TMDLs for the Ocmulgee River and Walnut Creek, including stream segments within and in the vicinity of OCMU (GA DNR 2007a,b,c).

Stream	Present Load	Reduction Needed	Allowable Avg. Load (TMDL)
Sediment TMDL (Biota-Impacted, Not Supporting, 2002)			
Walnut Creek	6,491.6 tons/year	83.60%	1,067.3 tons/year
Fecal Coliform TMDL (General Recreation, Partially Supporting, 2007)[a]			
Ocmulgee River	4.55×10^{14} counts/30 days	25% counts/30 days	3.41×10^{14}
Walnut Creek	1.47×10^{13} counts/30 days	72% counts/30 days	4.07×10^{12}
PCB TMDL (Fish consumption, Partially Supporting, 2007)			
Ocmulgee River	0.26 mg/kg[b]	62%	1.1×10^{-3} kg/day[b]

[a] 30-day geometric mean for bacterial counts (colony-forming units)

[b] Average fathead catfish tissue concentration in 1999. Georgia's fish consumption guidelines are conservatively triggered at concentrations > 0.1 mg/kg (vs. the FDA's action level of 2.0 mg/kg). Based on the U.S. EPA's published PCBs bioaccumulation factor, the TMDL can be attained at water concentrations < 0.0032 µg PCBs/L. This TMDL is based upon the U.S. EPA human health criterion of 0.00017 µg PCBs/L. The PCB TMDL = the annual average flow near Macon (~2,700 cfs) times the water quality standard.

Air Quality Standards

The federal Clean Air Act has set standards for six "criteria" pollutants (GA DNR 2007e; *Table 18*). These standards 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 $\leq$ 15 µg $PM_{2.5}$ /m^3. As an additional requirement (recently altered as of Dec. 2006), the 98th percentile 24-hour concentration must be $\leq$ 35 µg $PM_{2.5}$ /m^3 (GA DNR 2007e). The regulatory standard is health-based, and concentrations above the standards are considered unhealthy for sensitive groups (GA DNR 2007e). Another set of compounds, for which ambient air regulatory standards have not been set, is monitored in the Air Toxics Network; sources of

these substances include vehicle emissions, stationary source emissions, and natural sources. Data from EPD's continuous monitors are published on EPD's web site at http://www.georgiaair.org/amp. The data are updated hourly.

GA DNR monitors air quality at three sites in Macon near OCMU, including Allied Chemical (site 130210007; parameters $PM_{2.5}$, 24-hour FRM and speciation; PM_{10};), Georgia Forestry Commission (site 130210012; parameters $PM_{2.5}$, 24-hour FRM; SO_2; VOCs, SVOCs, and trace metals), and Lake Tobesofkee (site 130110013; parameters ozone, NO_y) (GA DNR 2007e). The area is 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 2007e). In addition, all of Bibb County is a non-attainment area for $PM_{2.5}$.

Ozone is monitored in March through October since that period is when ozone production mostly occurs. 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. Of more concern than acute affects are potential 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.

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 (GA DNR 2007e). The state monitors 53 particle species such as gold, sulfate, lead, arsenic and silicon. 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 (Schwela 2000, U.S. EPA 2004, GA DNR 2007e). Mounting evidence indicates that $PM_{2.5}$ also 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 impair visibility and contribute to haze in the humid conditions that characterize the north Georgia climate (U.S. EPA 2004).

Table 18. U.S. EPA standards for six "criteria" pollutants as required by the Clean Air Act, indicating recent modifications (cross-outs; GA DNR 2007b).

Compound	Primary Standard	Secondary Standard	Units	Time Interval
Sulfur dioxide (SO2)	----	0.50	ppm	3-hour
	0.14	----	ppm	24-hour
	0.03	----	ppm	annual mean
Particulate matter (PM2.5)	15.0	same as primary	µg/m3	annual arithmetic mean (3 years)
	98th percentile 65.0 a/35.0	same as primary	µg/m3	24-hour
Particulate matter (PM10)	50.0 b	same as primary	µg/m3	annual arithmetic mean
	150.0	same as primary	µg/m3	24-hour
Carbon monoxide (CO)	2nd maximum 35.0	----	ppm	1-hour
	2nd maximum 9.0	----	ppm	8-hour average
Ozone (O3)	4th maximum 0.085	same as primary	ppm	8-hour average
Nitrogen dioxide (NO2)	0.053	same as primary	ppm	annual mean
Lead (Pb)	1.5	same as primary	µg/m3	calendar quarter

Air Resources

OCMU is within a class II airshed under the Clean Air Act (GA DNR 2007e, DeVivo 2006). 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 OCMU because violations of the federal/state ozone standard are already occurring, and considering that the Atlanta and Macon metropolitan population centers are projected to con-tinue rapid growth (Atlanta Regional Commission 2007). Atlanta and all of Bibb County have been in violation of the ozone standard every year since 2005 (GA DNR 2007e; e.g. *Figure 11*).

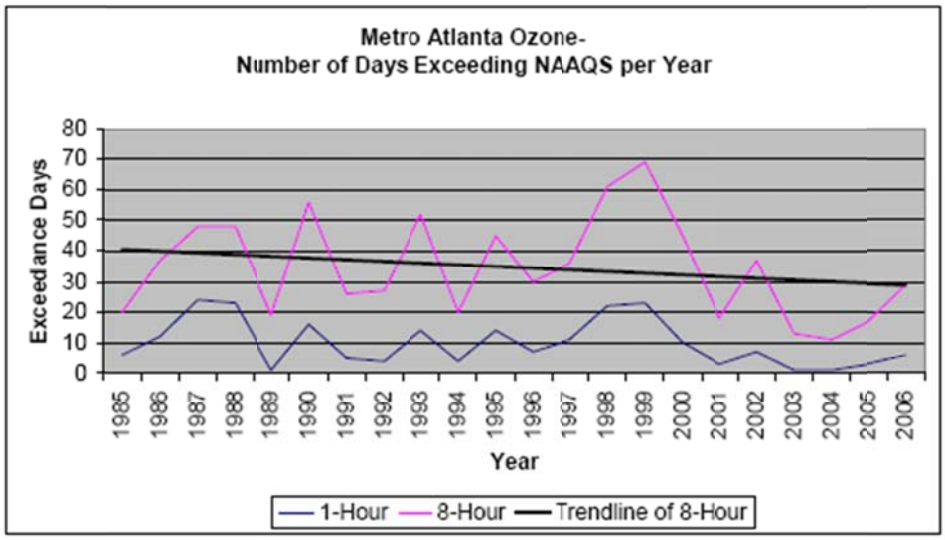

Figure 11. Metropolitan Atlanta ozone – number of violation days per year (GA DNR 2007e).

All of Bibb County has been in violation of the annual arithmetic mean $PM_{2.5}$ concentration ($\leq$ 15 µg $PM_{2.5}$ /m^3) each year for the past five years, and in violation of the 98th percentile 24-hour concentration ($\leq$ 35 µg $PM_{2.5}$ /m^3) during 2000-2002 (*Figure 12*). It is anticipated that air quality, including smog, ozone, particulates, and many other contaminants (GA DNR 2007e), will continue to degrade with increasing population growth (Atlanta Regional Commission 2007).

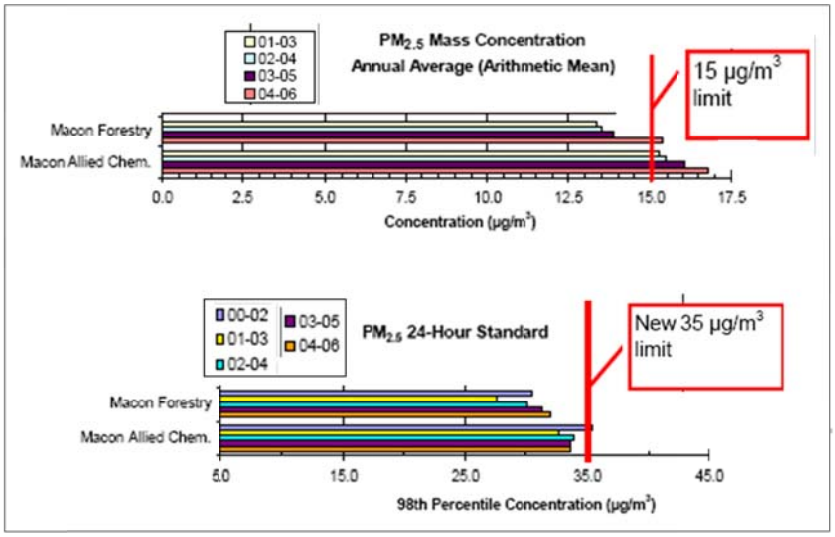

Figure 12. $PM_{2.5}$ design value, daily standard, showing exceedances at Macon of the old standard in all years, and exceedances of the new standard in 2000-2002 (modified from GA DNR 2007e).

Acid deposition can adversely affect or kill aquatic life and harm human health (Abelson 1987, Baker and Christensen 1992), and can act synergistically with ozone to harm human health as well (Abelson 1987). There are four acid deposition sites in Georgia, including three in north Georgia (Summer- Dawsonville, and Hiawassee) and one in central eastern Georgia (McDuffie

County). The four sites monitor acid deposition weekly, and the data show a significant increasing trend for acid deposition in north Georgia (*Figure 13*).

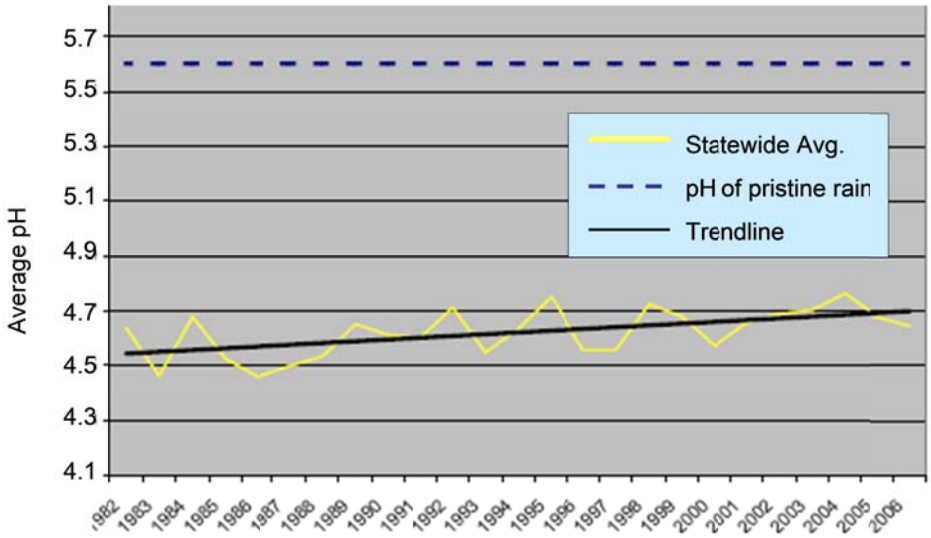

Figure 13. Statewide acid deposition trends (1982-2006; from GA DNR 2007b).

It should also be noted that the largest coal-fired power plant in the U.S., Georgia Power's Robert W. Scherer Plant, is just north of Macon in Juliette, GA. The Scherer coal-fired power plant emits ~25.3 million tons of carbon dioxide (CO_2) per year, more than Brazil's entire power sector (Goodell 2006), and it is ranked 20th in the world for CO_2 emissions (2007 list of the Center for Global Development). In addition to CO_2 emissions, this power plant also discharges substantial sulfur dioxide (SO_2, involved in acid deposition), mercury and other toxic pollutants to the airshed of OCMU. Deposition of airborne toxic substances from various sources may be contributing to the elevated concentrations of certain heavy metals (e.g. lead, zinc) that have been detected in surface waters in OCMU (DeVivo 2006).

Surface Water Quantity

The primary demands for water supply in the Ocmulgee basin in the vicinity of OCMU are municipal and industrial use and recreation (GA DNR 2004). As a result of rapid population growth in Atlanta and surrounding regions, increasing water use is expected to result in reduction in surface water flow (GA DNR 2004). Pressure to impound headwater streams to create water supply reservoirs has the potential to reduce the amount of water that ultimately reaches OCMU (DeVivo 2006). The volume of flow in the Ocmulgee River would be significantly reduced as a result of increasing demands for freshwater supplies by the rapidly growing city of Atlanta, such as plans to construct large reservoirs upstream from OCMU for water supply (Georgia Department of Audits and Accounts 2005).

Drinking Water

Treated water from the Ocmulgee River is the potable water source for OCMU. Pollution from urban and industrial sources in the Macon area and in the upstream watershed will increasingly challenge potable water treatment plant operators to maintain drinking water free from an array of toxic substances.

Groundwater

Because of the increased use of groundwater over the past few decades, there is increasing concern about declining groundwater levels and whether water is being removed faster than it is being recharged (Tyson 1993). Although surface waters mostly are used for potable supplies, groundwater resources may become a potential supplemental resource during peak demand periods, under drought conditions, and as water demand increases in the Macon-Warner Robins-Fort Valley combined statistical area (Georgia Department of Audits and Accounts 2005). The extent to which groundwater quality is being contaminated by various urban sources is poorly known.

Ecosystem Effects

Urban Pollution and Aquatic Food Webs

The available data, although sparse, are compelling in their clear illustration of degraded surface water quality within and near OCMU. During 1998-2003, GA DNR (Wildlife Resources Division) studied fish populations in the Ocmulgee River basin, and used an Index of Biotic Integrity (IBI) and modified Index of Well-Being (IWB) to identify fish population health as Excellent, Good, Fair, Poor, or Very Poor. Walnut Creek was among the 41 stream segments in that were evaluated as impaired. Upper Walnut Creek (drainage area at the assessment point, 8.5 square miles) received a Very Poor ranking by both indices; lower Walnut Creek (drainage area at the assessment point, 31.0 miles), including OCMU, received a Poor ranking by both indices (GA DNR 2007a). As mentioned, the general cause identified for the impairment is lack of viable fish habitat due to stream sedimentation (GA DNR 2007a). Fish are at the apex of the stream food webs. Their Poor to Very Poor rankings suggest that urban pollution has caused serious degradation and loss of biodiversity for the aquatic flora and fauna of Walnut Creek in other trophic levels, as well. The stream and wetland food webs likely are also affected by pathogenic microbes whose presence is indicated, to some extent, by high fecal coliform bacteria densities, and by toxic substances from urban runoff.

Air Pollution and OCMU Land Resources

There is a high potential that terrestrial communities in the monument are being adversely affected by air pollutants such as ozone that can cause foliar injury, but data for assessment are not available (DeVivo et al. 2005). The Scherer Plant is a major emitter of CO_2, mercury, particulates, sulfur dioxide, and nitrous oxides (see **http://www.opc.com/**TheEnvironment/FutureImprovements/index.htm). Mercury contamination has resulted in fish consumption advisories for some segments of the Ocmulgee River, tributaries, and run-of-river impoundments in Bibb County (GA DNR 2007d) (below). By 2013, the power plant plans to complete an air quality control system that reportedly will remove more than 80% of the mercury, particulates, sulfur dioxide and nitrous oxides from emissions (base, emissions in 2000). While these estimated reductions would be significant, the remainder still would represent a major source of air quality degradation affecting OCMU. Elevated CO_2 emissions in the Macon area, from the Scherer Plant and other sources, are contributing to global warming which is projected to have long-term, significant adverse impacts on ecosystems in central Georgia, as across the globe (Penuelas and Filella 2001, United Nations IPCC 2007).

Invasive/Exotic and Nuisance Species

Invasive/exotic and nuisance species are a major concern at OCMU. The monument is 1 of 14

park units included in the NPS Southeast Coast Network's Exotic Plant Management module that is being managed by Cumberland Island National Seashore (DeVivo 2006). Little is known about the potential for impacts from exotic/invasive terrestrial animal species, and information is lacking as to whether exotic aquatic species threaten OCMU's surface waters and wetlands.

Disruptive and invasive plant species include privet (mostly in wetlands), kudzu, Chinaberry (which has been controlled to avoid impacts on cultural resources), tree of heaven, and Japanese honeysuckle. Among exotic animal species, fire ants are spreading throughout OCMU (USDI-NPS 2000). They pose a threat to native ant species, potentially degrade cultural resources, and adversely affect visitor experiences (DeVivo 2006). Southern pine beetles have caused heavy damage to OCMU's loblolly pine stands (DeVivo 2006). Within the past decade, feral hogs caused substantial damage to natural resources in both the Main Unit and the Lamar Unit (USDI-NPS 2000). OCMU has a trapping/eradication program that has removed more than 150 feral hogs (DeVivo 2006; Chief Ranger G. LaChine, pers. comm.). As mentioned, nutria are a concern for wetland communities at OCMU, with as-yet-unassessed impacts.

Nuisance beaver populations have destroyed many trees at OCMU (Chief Ranger G. LaChine, pers. comm.). Feral dogs and cats have also are a concern, especially the potential for feral cats to affect migratory songbirds and herpetofauna (DeVivo 2006). An additional concern is that increased urbanization surrounding OCMU may promote an increase in foxes, coyotes (recently established, with unknown impacts), and deer (the latter, potentially leading to poaching).

<u>Additional Fragmentation and Destruction of OCMU Ecosystems by Major Roads</u>
Notwithstanding the fact that an interstate highway and a four-lane state highway were built after OCMU was created and already transect it, the GA DOT plans to build a major connector highway through OCMU wetlands. GA DOT first began plans for the four-lane "Fall Line Freeway" in 1985, and views this highway that will connect the cities of Augusta, Macon, and Columbia across Georgia as an economic catalyst that will create an easier path for freight trucks. Nearly 80% (170 miles) of the Fall Line Freeway was constructed by 2006, including the entire route between Columbus and Macon. The planned route will bisect the Ocmulgee Old Fields Traditional Cultural Property and further degrade OCMU. The Ocmulgee Old Fields Traditional Cultural Property, regarded as sacred by Native Americans (Obey 2002), encompasses both OCMU and the Bond Swamp National Wildlife Refuge which is managed by the U.S. Fish and Wildlife Service.

The National Parks Conservation Association, a nonprofit national advocacy organization dedicated to protecting, restoring, and enhancing national parks, included OCMU in 2002 on its list of America's Ten Most Endangered Parks in recognition of the fact that this connector road project has the potential to cause irreparable harm to OCMU (Obey 2002). The Ocmulgee Old Fields Traditional Cultural Property was also listed in 2003 by the National Trust for Historic Preservation (2008) among the Eleven Most Endangered Historic Places in the nation, because of "poor public policy and road construction". Despite this potential for major impacts, the Georgia Department of Transportation has indicated that the plans to build the connector may proceed (GA DOT 2008). The increased traffic is expected to increase nonpoint contaminant pollution on water resources and to adversely affect air quality (DeVivo 2006).

Human Health Issues

The high fecal coliform densities in OCMU's larger perennial streams (the Ocmulgee River and Walnut Creek), and likely in the smaller streams that originate in Macon, jeopardize use of these surface waters for general recreation. In recognition of this fact, OCMU has posted signs to protect people who visit the monument (*Plate 13*). In addition, toxic PCBs and associated other toxic substances such as mercury threaten fish consumption; thus, the present GA DNR advisory recommends consuming only 1 meal per month of flathead catfish because of PCB contamination, and in a segment of the Ocmulgee River about 13 miles downstream from OCMU (6 miles downstream from Tobesofkee Creek), advisories are in place for both flathead catfish (1 meal per month be cause of PCBs and mercury contamination) and largemouth bass (1 meal per week because of mercury contamination) (GA DNR 2007d). The U.S. EPA has classified PCBs as probable human carcinogens (GA DNR 2007b and references therein). There is concern at OCMU about protecting the health safety of recreational fishers visiting the monument because the state has not posted warning signs about limiting fish consumption.

Plate 13. Sign posted by the NPS at OCMU to help protect the health of visitors and their pets. Photo by Michael Mallin.

There is strong potential for adverse chronic impacts of ozone and $PM_{2.5}$ air pollutants on the health of OCMU staff and frequent visitors. Air quality in the Macon/OCMU area was evaluated as only "moderate" for 166 days in 2006 because of ozone and particulates, and was "unhealthy

for sensitive groups" (e.g. children, the elderly, and immunocompromised individuals) for 4 days (*Tables 19* and *20*). Pollutants involved in acid deposition – SO_2, mostly from coal-fired power plants such as the Scherer Plant, and nitrogen oxides (NO_x, mostly from car exhausts) – form fine particulate matter that can be transported long distances across airsheds (Schwela 2000). Elevated levels of these fine particles have been linked to increased illness and premature death from heart and lung disorders such as asthma and chronic bronchitis. NO_x also react with volatile organic compounds to form ozone which, as mentioned, causes lung inflammation, asthma, emphysema, and increased morbidity/ mortality risks in humans. Acid precipitation causes and aggravates many human respiratory diseases, and is estimated to be the third largest cause of lung disease in the U.S. (after smoking and indoor radon).

Table 19. U.S. EPA's Air Quality Index (AQI) criteria (modified from GA DNR 2007b).

Maximum Pollutant Concentration								
$PM_{2.5}$ (24hr) µg/m^3	**PM_{10} (24hr) µg/m^3**	**SO_2 (24hr) ppm**	**O_3 (8hr) ppm**	**CO (8hr) ppm**	**NO_2 (1 hr) ppm**	**AQI Value**	**Descriptor (color-coded)**	**EPA Health Advisory**
≤ 15.4	≤ 54	≤ 0.034	≤ 0.064	≤ 4.4	None	**0-50**	GOOD	Air quality satisfactory; little or no risk from air pollution
15.5 - 40.4	55- 154	0.035 - 0.144	0.065 - 0.084	4.5 - 9.4	None	**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	0.145 - 0.224	0.085 - 0.104	9.5 - 12.4	None	**101 - 150**	UNHEALTY for Sensitive Groups	Sensitive groups (people with lung or heart disease) are at greater risk from exposure to particulate pollution, ozone
65.5 - 150.4	255 - 354	0.225 - 0.304	0.105 - 0.124	12.5 - 15.4	None	**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	0.125 - 0.374	15.5 - 30.4	0.65 - 1.24	**201 - 300**	VERY UNHEALTHY	AQI values trigger a health alert; everyone sustain more serious health effects. If related to high ozone, If related to high ozone, 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

Table 20. U.S. EPA air quality index (AQI) for population centers in the Ocmulgee River Basin in 2006 (pollutants monitored – O_3, SO_2, CO, NO_2, PM_{10}, $PM_{2.5}$).

	Number of Days per AQI Category in 20006					
	Good (0-50)	**Moderate (51-100)**	**Unhealthy for Sensitive Groups (101-150)**	**Unhealthy (151-200)**	**Very Unhealthy (201-300)**	**Pollutants Monitored in 2006**
Atlanta	119	210	28	8	0	O_3, SO_2, CO, NO_2, PM_{10}, $PM_{2.5}$
Macon	195	166	4	0	0	O_3, PM_{10}, $PM_{2.5}$

*Values do not add up to 365 because of limited monitoring in cool-weather months. Air quality in this area is likely cleaner during these months than during the warmer months.

Elevated CO_2 emissions in the Macon area, from the Scherer Plant and other sources, are contributing to global warming which is projected to have long-term, significant repercussions for adverse human health impacts in OCMU and the surrounding region (e.g. Cifuentes et al. 2001, Patz et al. 2005).

Other Issues of Concern

Population Growth

OCMU is under progressive siege from rapidly expanding urbanization. As of 2007, the Macon Metropolitan Statistical Area had an estimated population of 229,846 and the population of the Macon-Warner Robins-Fort Valley combined statistical area was 386,534. Although Macon is only

Georgia's sixth-largest city in population and only its fifth largest metropolitan statistical area, Macon's combined statistical population area is the third largest in the state behind Atlanta and Augusta (Georgia Department of Audits and Accounts 2005, Atlanta Regional Commission 2007). Moreover, the upper Ocmulgee River basin contains part of the expanding Atlanta Metropolitan Area, which is adding more than 100,000 new residents per year (e.g. April 2006 – April 2007; Atlanta Regional Commission 2007). More than four million people now reside there – a population larger than 24 states, according to 2006 U.S. Census estimates.

Physical Impacts From Activities in OCMU

OCMU is popular for hikers and other visitors to the Macon area. OCMU's Ocmulgee Indian Celebration alone attracts 14,000 people every September, and OCMU staff also engage in various other education outreach activities such as ranger-led walks, exhibits, and the Lantern Light Tours in March. The NPS plans to expand the network of trails within the Main Unit of OCMU to link to the Ocmulgee Heritage Trail, a Greenway Trail along the OCMU riverfront that is being developed by the City of Macon (NPS 2007). The Trail will provide additional recreational opportunities for the entire population including disabled people. The NPS also is adding signs to the boardwalk area, and other features that will assist in educating visitors about the value of wetlands. There is public interest, as well, in the remote Lamar Unit, and the NPS hopes to provide additional educational and interpretative opportunities there (NPS 2007).

Hiking trails in OCMU receive heavy use, which is projected to increase with the creation of the Greenway Trail. Heavy rains, especially during summer months, have caused washout and erosion in some trail sections that are also a potential safety problem.

Railroad Maintenance

The CSX railroad line that passes through OCMU is routinely maintained by spraying herbicides to control plant growth on and adjacent to the railroad bed. Effects of these herbicides on OCMU flora and fauna have not been assessed (DeVivo 2006).

Other Continuous Land Issues and Impacts

OCMU is immediately adjacent to Macon along its north/northwest boundaries, including housing projects and other economically depressed areas. Spillover crime from the city is a concern.

The monument sustains frequent illicit dumping and other inputs of trash and other refuse (Chief Ranger G. LaChine, pers. comm.). The City of Macon installed a catchment facility, paid for by the NPS, but there are concerns as to whether the catchment is effective in reducing the refuse entering OCMU because of its large grid mesh size (~12 inches) and because of obvious signs of debris spillover into OCMU.

Robbins Air Force Base is about 14.2 miles south of the Lamar Unit, with associated noise and air pollution from incoming/outgoing flights.

OCMU's necessary eradication program to control proliferating feral hogs is unpopular with some hunters who have aggressively, sometimes threateningly conveyed their disapproval to OCMU staff (Chief Ranger G. LaChine, pers. comm.).

Synopsis of Stressors to Ocmulgee National Monument

The present and potential stressors that are affecting or may affect OCMU are summarized in *Table 21*). Overwhelmingly, the most pressing stress on the natural resources of OCMU is from adjacent and upstream urbanization and its multitude of associated impacts – the encroaching development pressures associated with Macon, and the voracious, rapidly expanding and massive development of the greater Atlanta metropolitan area. The amount of stormwater runoff from urban areas has increased dramatically over the past 30 years in these urbanizing areas (Georgia Department of Audits and Accounts 2005).

The increasing demands on water supplies from human population growth may pose a threat to surface and groundwater resources in the vicinity of OCMU in the coming decades. At present, though, human population growth and urban sprawl with accompanying water and air degradation are the major stressors affecting OCMU's surface waters and other natural resources. In a situation that typifies many other parks in the SECN (Byrne 2004), the surface waters of OCMU are downstream from 303(d)-listed degraded waters outside NPS jurisdiction.

Thus, it is not surprising that OCMU's surface waters also are included in the state's 303(d) list as impaired for supporting fish because of excessive sedimentation (Walnut Creek), and impaired for general recreation (John Ward Creek) because of high fecal coliforms (both Walnut Creek and the Ocmulgee River, for which at least some data are available; the smaller streams in OCMU likely are similarly affected). Sedimentation from development-related land disturbance

excessive nutrients, heavy metals, pesticides, and other toxic contaminants are adversely a upstream of OCMU, and surrounding it, is seriously affecting Walnut Creek in OCMU, in terms of both water quality and aquatic life. There is high potential that associated pollutants such as affecting OCMU's streams as well. Microbial pathogens that may be present, indicated to some extent by high fecal coliforms, may be adversely affecting fish and other aquatic life.

Table 21. 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).

Stressor	Surface Waters	Groundwater	Airshed	Forest	Human Health
Acidification	EP	ND	EP	EP	EP
Algal blooms	EP	NA	NA	NA	ND
Encroaching urbanization	EP	ND	EP	EP	EP
Erosion (including dust)	EP	ND	EP	EP	EP
Excessive nutrients*	EP	ND	EP	EP	NP
Exotic invasive species	EP	NA	ND	EP	ND
Fecal bacteria	EP	ND	NA	ND	EP
Habitat disruption	EP	EP	NA	EP	EP
Highway construction	EP	ND	EP	EP	EP*
Hypoxia	EP	NA	NA	NA	NP
Metals contamination	EP	ND	ND	ND	EP
Ozone pollution	ND	NA	EP	EP	EP
Other toxic substances	ND	ND	EP	ND	ND
Sedimentation (including dust)	EP	ND	EP	NA	EP
Trash/refuse pollution	EP	ND	NA	EP	ND
Water demand	PP	PP	NA	ND	NA

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

There is high potential that surface water quality and aquatic communities are sustaining impacts from air pollution including acidification, mercury and other heavy metals, pesticides etc. The seasonal or lower frequency of sampling to evaluate water quality is insufficient to detect the spikes in these pollutants that are known to occur depending upon weather patterns. Thus, for example, available pH data are inadequate to evaluate the extent to which acid spates (sudden influxes of highly acidic water at the beginning of storm events) are affecting the aquatic food webs (Morris et al. 1989). Air pollution likely is also adversely affecting terrestrial vegetation, for example, as foliar damage from high ozone in the OCMU area. In addition, the high ozone and $PM_{2.5}$ levels in the OCMU airshed pose a threat to the health of the staff and frequent visitors.

A diverse group of invasive/exotic and nuisance plant and animal species threatens the natural resources of OCMU and is a major concern. In addition to known significant effects of exotic species on land resources, increasing urbanization surrounding OCMU may be promoting an increase in nuisance native or invasive species such as foxes, coyotes and deer, and associated negative effects. It is also likely that various noxious wetland plant species and the wetland

rodent, nutria are seriously affecting OCMU's aquatic and resources but, aside from species lists, little is known about aquatic impacts from invasive/exotic species.

The new major highway corridor that is planned for construction through or near OCMU, as well as other encroaching development within the existing greenway corridor, are contributing to the fragmentation of the monument's natural resources (USDI-NPS 2000). The looming major factor that will exacerbate all of these stresses is the progressive urbanization of theMacon-Warner Robins-Fort Valley combined statistical area in the OCMU area, and the rapid, extreme population growth of the Atlanta metropolitan area in the upper watershed and airshed.

Recommendations to Address Impairments, Potential Impacts, and Undocumented Water Bodies

General Comments

Government-managed lands comprise 29% of the U.S. land area (Gibbons et al. 1997), including more than 32 million hectares set aside within the National Park System (Stohlgren et al. 1995). Thus, the National Park System is a major factor in the potential for this nation to protect natural lands and biodiversity. The parks and their natural resources are supposed to be "protected lands" for present and future generations of U.S. citizens, but external encroaching stressors from watershed development and habitat fragmentation are seriously threatening these critically important refuge areas, including OCMU. OCMU, downstream and down-airshed from the Atlanta metropolitan area, is vulnerable to encroaching and surrounding urbanization. The NPS is ill-equipped to protect its vitally important water resources from airshed and watershed pollution and other stressors because the stressors, for the most part, are outside of NPS control. In addition, there is inadequate information on water quality conditions or aquatic community health. Few data are available on aquatic flora and fauna, mostly limited to surveys of species occurrence.

Within the past decade, GA DNR has developed several TMDLs for the Ocmulgee River and Walnut Creek segments that include OCMU (GA DNR 2007a,b,c). The TMDLs are supposed to be "platforms for establishing courses of actions to restore water quality" (GA DNR 2004); procedures are to be set in place to track and evaluate implementation of corrective management practices and activities. It is imperative that the state of Georgia legislature and environmental agency track and ensure the effectiveness of the TMDLs for the Ocmulgee River and Walnut Creek. The following additional recommendations can be addressed within NPS jurisdiction.

Specific Recommendations

Water Quality

- A top priority is to conduct a two-year water quality monitoring program in OCMU segments of the Ocmulgee River, Walnut Creek, and the small tributaries with biweekly or monthly sampling frequency (insofar as possible for the intermittent tributaries) to track water quality conditions in the park. Two stations on each stream, including inflow and outflow of the Ocmulgee River and Walnut Creek from OCMU, should be sampled for, at a minimum, water temperature, pH, dissolved oxygen, suspended solids, turbidity, nutrients (TN, TP, nitrate, ammonium, BOD_5), fecal coliform densities, and chlorophyll *a* concentrations. This effort should be repeated at five-year intervals. Additional effort also should be expended to include monitoring of storm events because they are known to contribute most nonpoint source pollution (for example, from urban runoff). Benchmarks for acceptable water quality should consider the information contained in *Table 15* for streams with designated use for Fishing.

- Data should be collected at least annually on toxic substance concentrations (PCBs, heavy metals, pesticides, pharmaceuticals) in sediments and fish or benthic faunal tissues. Published benchmarks for acceptable water quality for streams with designated use for Fishing should be used to evaluate the information.

- The origin of the high fecal coliform contamination affecting OCMU surface waters has been in contention (Chief Ranger G. LaChine, pers. comm.). While urban runoff clearly is a factor, the contribution from wildlife has not been assessed. A study should be undertaken over an annual cycle to apply state-of-the-art molecular "fingerprinting" techniques to assess the origin of fecal coliform contamination.

- The park should inventory changes in land use/land cover in the watersheds of Walnut Creek and the Ocmulgee River upstream from and surrounding the park, including traditional categories but also septic tanks in new subdivisions, new highway projects, new shopping centers, and other potential sources of water pollution. The data should be used to create GIS maps of these sources, which can be upgraded over time to help the NPS track pollution and its impacts in park waters.

Ecosystem and Community Health

- At least once per year during an appropriate seasonal timeframe, the macroinvertebrate communities (benthic fauna, aquatic insects) should be assessed in at least two stations on the Ocmulgee River, Walnut Creek, and the three smaller streams in OCMU, following the protocol in Barbour et al. (1999). Benchmarks should consider published descriptions of healthy macroinvertebrate communities in warmwater streams (e.g. Barbour et al. 1999, GA 2007). The data should be used to track stream ecological condition (rated from Excellent to Poor) over time.

- At least once per year during an appropriate seasonal timeframe, the fish community in the park segments of the Ocmulgee River and Walnut Creek should be assessed, following the protocol outlined in Barbour et al. (1999). The fish data should be used to develop an Index of Biotic Integrity and an Index of Well-Being for fish population health over time (Barbour et al. 1999).

- OCMU's wetland ecosystems should be mapped and assessed, at least at five-year intervals, for indices of diversity, function, and overall health.

- A sampling program should be developed to establish present conditions and track exotic invasive species affecting terrestrial as well as aquatic/wetland sources in OCMU, so that OCMU staff can develop active management strategies to optimize control. Assessment of exotic invasive species should be repeated at least at three-year intervals to enable detection of species that may rapidly invade.

- An updated biological inventory should be completed for herpetofauna, following the protocol outlined in Tuberville et al. (2005).

- A baseline biological inventory is needed for the composition and abundance of benthic microalgal assemblages in OCMU, following protocols in Wetzel and Likens (2001). The benthic microalgal (periphyton) data should be used to develop an index of biotic integrity (e.g. following Hill et al. 2000) for the Ocmulgee River and Walnut Creek in the park area.

- OCMU lies within a trough of the Atlanta airshed, and within the Macon-Warner Robins-Fort Valley combined statistical area. The NPS should assess incidence of foliar injury to park plants from ozone pollution, including common wetland bioindicator species such as yellow poplar and American elder. More generally, data are needed to assess the extent to which air pollution is affecting OCMU, and to forecast how increasing air pollution from the greater Atlanta and Macon metropolitan areas will affect its waters and other natural resources. Sampling devices should be installed to establish present conditions and track air pollutants such as ozone, $PM_{2.5}$, and mercury.

- OCMU's five streams should be the focus of stream restoration projects to assist in their recovery from excessive sedimentation, with highest priorities for Walnut Creek and the Ocmulgee River. Monument staff should monitor the streams for erosion of the stream banks, which is commonly related to upstream urban watershed activities, and for tree damage from beavers which can lead to increased bank erosion. Construction of beaver dams within the park should not be permitted, since this would increase on-site flooding and threaten cultural resources.

Groundwater

- OCMU's groundwater resources should be assessed through partnership with the USGS, including recharge/discharge areas, movement, and chemical quality.

Education Outreach

- OCMU should continue its excellent efforts to strengthen education outreach to teach visitors about the importance of greenspaces such as the monument in ecosystem sustainability.

Other Actions

- The NPS should seek cumulative mitigation (e.g. floodplain restoration) and push for a full Environmental Impact Statement of the I-16/I-75 project of GA DOT, which would widen I-16 through the monument under an Environmental Assessment. GA DOT is required to investigate and carefully consider cumulative impacts, which include past, present, and future impacts of this project. Thus, impacts from the original construction of I-16 and the associated installation of the Macon Levee should be assessed for their impacts on the monument, and these impacts should be mitigated within the framework of the present I-16/I-75 improvements project. Restoration of the floodplain would reduce flood magnitudes and frequencies. Alternative routing of I-16 that would avoid the TCP should be seriously considered as well.

- The NPS should pursue actions to protect remaining undeveloped lands (e.g. increase in greenspace setasides) adjacent to OCMU to target a goal of protecting and growing buffer areas around the park.

- Trash coming into OCMU from the City of Macon should be monitored (type, most frequent entry locations, weight). Trash collecting devices of the City, if present should be rigorously evaluated for their efficacy in keeping trash and other refuse from entering OCMU.

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Appendix A. Discharge Data for USGS Gaging Stations near Ocmulgee National Monument

Table A-1. USGS discharge data for the Ocmulgee River near OCMU . The USGS maintains a flow station in the Ocmulgee River just upstream from OCMU (site #02213000, Macon; latitude 32°50'19", longitude 83°37'14"; NAD83, Bibb County, Georgia, Hydrologic Unit 03070103; drainage area 2,240 square miles; datum of gage: 269.8 feet above mean sea level).

00060, Discharge, cubic feet per second,												
YEAR	Monthly mean in cfs (Calculation Period: 1893-02-01 -> 2007-09-30) Period-of-record for statistical calculation restricted by user											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1893		4,417	3,547	1,939	1,844	2,353	1,410	2,111	2,507	1,904	1,551	1,793
1894	2,246	3,716	3,149	2,408	1,463	1,359	2,392	3,413	2,723	2,515	1,979	2,461
1895	3,759	2,610	6,120	4,247	3,244	2,317	3,598	3,887	2,501	1,036	1,015	1,284
1896	3,150	3,678	2,885	1,449	1,001	888.4	8,180	1,150	607.9	486.6	2,893	2,999
1897	1,369	3,873	8,268	4,736	1,693	1,732	1,913	1,759	715.2	622.2	779.7	1,059
1898	1,300	964.3	1,264	2,617	909.0	652.5	1,644	4,336	5,722	5,414	3,503	3,566
1899	5,568	8,138	5,494	4,482	2,112	1,331	1,198	1,071	880.2	1,339	987.0	1,581
1900	1,530	7,557	4,663	5,795	2,871	6,665	3,617	1,995	2,562	1,876	2,307	3,874
1901	4,593	4,510	3,760	5,541	2,806	3,322	2,307	4,295	3,249	1,412	1,103	3,476
1902	1,988	6,569	10,180	4,736	2,292	1,630	1,168	1,624	1,376	1,429	1,423	2,961
1903	2,191	8,966	7,852	5,002	2,991	4,428	2,557	2,460	2,377	1,109	1,235	1,271
1904	2,064	3,150	2,214	1,535	1,120	1,029	771.9	3,035	671.0	299.7	602.2	1,295
1905	1,599	4,659	1,815	1,485	1,539	1,071	1,878	1,466	533.3	696.6	809.8	4,900
1906	6,196	2,554	6,228	2,688	1,645	4,464	3,053	3,454	3,013	4,870	1,797	2,013
1907	2,496	4,413	3,434	3,014	2,085	1,876	1,590	1,410	1,575	824.0	2,291	4,936
1908	4,768	8,447	4,817	6,967	3,301	2,750	2,247	3,071	1,640	1,180	1,426	2,770
1909	2,194	7,350	9,065	3,580	3,238	3,188	2,325	3,374	1,779	1,570	1,184	1,552
1910	2,334	4,277	4,453	2,978	1,851	1,926	4,398	1,262	1,188	1,127	785.1	1,045
1928										1,681	1,932	1,744
1929	1,800	7,519	16,370	4,397	5,419	3,690	2,614	2,141	3,615	6,404	3,764	3,765
1930	3,834	3,692	4,522	3,379	2,386	1,256	1,685	1,044	1,528	932.2	2,834	2,984
1931	2,645	2,163	2,115	2,432	2,417	710.9	1,575	940.7	419.4	333.7	387.3	1,695
1932	3,586	5,361	2,862	2,250	1,558	1,682	1,404	1,662	751.0	1,535	1,708	5,134
1933	3,282	5,249	3,389	2,795	2,061	1,367	1,280	750.2	772.0	590.3	893.0	1,223
1934	1,360	1,427	3,792	2,384	1,624	3,571	1,559	1,494	1,298	3,270	1,092	1,594
1935	2,013	1,568	3,994	2,954	1,870	973.9	1,677	1,162	981.5	761.2	1,563	1,145
1936	11,880	8,855	3,736	14,610	2,119	1,406	1,001	3,255	1,481	3,064	1,434	3,750
1937	9,394	7,448	4,755	6,369	4,913	1,919	1,471	1,938	1,733	2,425	1,748	1,646
1938	1,477	1,168	1,851	8,571	1,352	2,098	1,724	1,315	600.5	490.8	665.6	948.6
1939	1,888	5,836	6,527	2,911	1,565	1,810	921.6	2,754	929.0	851.2	954.7	1,049
1940	2,562	3,508	3,450	2,429	1,177	1,309	3,646	1,854	1,065	666.6	1,088	2,061
1941	2,244	1,458	2,280	2,199	1,101	828.7	1,626	915.1	667.7	509.0	517.6	3,220
1942	2,683	3,294	11,020	3,221	1,960	1,355	1,244	1,378	845.9	1,270	1,438	2,815
1943	7,864	3,788	8,260	4,556	2,696	1,597	1,734	1,145	701.7	722.0	1,020	1,213
1944	2,847	4,983	10,650	6,645	2,924	1,312	1,405	952.2	1,323	1,020	828.2	1,259
1945	1,745	4,129	2,773	5,207	2,504	1,346	1,411	1,415	1,006	1,165	1,401	4,781
1946	9,222	4,526	4,409	3,870	3,173	2,420	1,532	1,140	929.2	1,296	1,267	1,181
1947	5,398	2,558	7,046	4,323	2,267	2,830	1,750	1,748	806.7	1,130	5,177	4,593
1948	3,564	7,775	7,876	5,874	2,363	2,061	2,796	1,803	1,140	1,136	9,624	6,742
1949	4,325	5,579	3,856	3,708	4,257	2,522	1,825	2,238	1,802	1,516	1,271	1,423
1950	1,442	1,663	3,496	1,929	1,247	1,548	1,088	1,244	2,049	1,033	1,354	1,557
1951	1,923	1,786	2,328	3,176	1,440	910.5	1,098	731.6	646.5	651.2	944.7	3,173
1952	2,694	3,631	11,720	3,280	2,032	1,440	759.0	893.9	1,019	861.4	795.8	1,292
1953	3,864	4,827	4,463	2,865	6,236	1,490	2,141	880.4	1,904	1,339	882.3	5,071
1954	3,117	2,228	2,505	1,633	1,071	826.8	642.4	551.0	364.9	164.8	186.3	617.5
1955	2,230	2,781	2,251	2,837	1,395	732.0	1,239	903.5	547.8	529.3	679.8	871.4
1956	762.0	3,471	4,493	4,545	1,609	787.6	1,637	603.8	2,065	1,066	884.4	3,179

Table A-1. (Continued).

1954	3,117	2,228	2,505	1,633	1,071	826.8	642.4	551.0	364.9	164.8	186.3	617.5
1955	2,230	2,781	2,251	2,837	1,395	732.0	1,239	903.5	547.8	529.3	679.8	871.4
1956	762.0	3,471	4,483	4,545	1,609	787.6	1,637	693.8	2,065	1,066	884.4	3,179
1957	3,009	2,919	4,588	4,929	3,822	1,719	1,366	833.6	1,112	1,623	3,837	3,698
1958	3,055	5,611	5,537	5,737	2,330	1,378	2,398	1,127	764.8	728.4	593.8	762.5
1959	1,403	3,994	3,543	2,272	1,691	3,839	1,215	819.6	911.8	1,568	1,142	1,353
1960	4,660	8,244	5,412	5,601	1,748	1,013	790.2	902.9	850.0	861.3	705.5	841.5
1961	981.8	10,220	5,020	7,437	4,315	2,536	1,857	2,008	1,479	798.3	765.3	4,225
1962	4,431	5,472	6,301	6,624	1,614	1,644	1,515	1,036	747.0	1,068	1,546	1,318
1963	5,616	3,436	5,762	2,080	5,454	5,245	3,804	1,317	1,036	979.5	1,082	3,019
1964	7,754	5,801	11,360	11,430	7,305	1,604	3,465	2,041	1,359	3,802	1,933	5,269
1965	2,967	4,714	5,705	4,373	1,536	3,141	1,737	1,083	993.9	2,574	1,197	1,293
1966	5,459	8,494	7,234	3,032	5,024	2,595	1,589	1,589	996.8	1,758	2,639	2,871
1967	4,807	4,266	3,324	1,831	2,300	2,175	2,785	2,922	1,602	1,092	2,621	4,742
1968	5,020	2,198	5,167	2,907	2,779	1,935	1,505	1,029	736.3	905.9	1,847	2,571
1969	2,855	3,405	3,874	5,953	3,435	1,492	899.8	1,567	1,108	876.1	1,157	1,617
1970	1,893	2,374	6,308	2,503	1,395	1,297	1,019	1,021	704.9	876.9	1,413	1,765
1971	3,952	5,278	11,630	4,017	3,109	1,551	2,675	2,741	1,394	711.9	1,065	2,502
1972	6,325	4,588	3,620	2,287	2,178	2,013	1,307	1,501	689.8	551.8	1,288	5,215
1973	6,224	5,145	5,950	8,366	4,434	3,638	2,126	2,134	871.7	1,392	985.3	2,217
1974	6,226	7,068	2,982	5,002	2,221	1,746	1,303	2,192	1,418	573.4	812.8	2,812
1975	5,064	8,147	9,776	7,966	4,381	4,074	2,490	2,773	2,011	2,910	2,027	2,277
1976	3,811	2,850	7,846	2,929	5,625	2,907	2,352	1,258	1,018	1,507	1,945	4,291
1977	3,919	2,212	6,717	4,387	1,610	980.0	894.6	1,569	994.3	1,649	3,272	1,663
1978	7,091	2,908	3,598	2,016	4,216	1,164	791.5	1,970	759.4	589.5	663.3	1,332
1979	3,237	7,525	4,025	8,304	2,325	1,543	1,270	1,102	1,373	1,797	2,322	1,554
1980	3,847	3,449	10,740	5,363	5,194	1,981	978.7	731.8	663.6	833.3	846.1	934.3
1981	749.8	5,218	1,688	2,038	837.2	740.7	453.6	503.1	421.6	391.5	397.7	1,595
1982	4,559	6,213	2,659	3,994	1,960	1,477	1,239	1,293	762.8	1,260	1,299	4,399
1983	3,646	5,551	6,636	7,582	2,189	1,699	894.9	574.6	1,138	897.8	3,006	7,222
1984	4,969	4,729	5,522	5,125	4,318	1,406	2,789	5,050	936.7	971.2	1,305	1,906
1985	2,020	5,960	2,276	1,535	1,943	923.1	1,828	1,779	670.1	1,329	1,179	2,299
1986	1,126	1,698	2,397	971.5	581.2	546.7	405.5	405.5	542.3	582.1	1,815	4,037
1987	4,682	4,127	6,006	2,808	1,499	1,545	950.3	619.6	393.2	243.2	434.8	965.7
1988	2,541	2,924	1,319	2,055	844.7	300.7	214.4	298.6	1,987	939.3	1,283	1,172
1989	1,316	1,309	2,431	4,124	1,940	2,832	3,796	1,121	1,463	5,544	1,961	3,756
1990	6,325	8,704	10,280	3,088	2,220	1,009	1,097	1,232	1,325	1,066	946.0	934.4
1991	3,050	3,583	4,794	4,758	4,646	2,557	2,934	1,551	1,122	694.9	1,081	1,336
1992	3,002	3,490	2,950	1,584	803.9	1,398	1,398	3,608	3,071	2,067	8,387	6,367
1993	5,610	6,400	8,595	5,406	2,410	1,677	897.2	781.0	536.8	1,032	1,748	2,161
1994	3,046	3,787	4,859	3,167	1,216	1,248	12,880	5,054	3,886	4,455	2,191	3,327
1995	3,194	8,593	5,203	2,163	1,343	2,060	1,124	1,219	1,309	4,727	5,433	2,771
1996	5,439	6,827	7,553	3,321	2,262	1,619	775.6	1,232	1,186	945.5	1,190	2,047
1997	3,856	5,150	5,055	2,723	2,604	2,258	1,398	1,030	1,543	2,873	3,553	6,725
1998	6,551	10,640	11,430	6,885	3,927	1,915	1,120	1,782	1,143	1,055	1,042	1,417
1999	1,765	3,449	1,768	1,234	1,341	973.8	1,207	461.7	295.7	779.9	937.4	1,382
2000	2,428	1,945	2,082	1,763	618.2	362.8	323.4	422.3	1,440	537.6	920.6	1,430
2001	1,520	2,224	8,424	3,138	1,437	3,177	1,442	814.1	647.7	425.0	421.8	650.8
2002	1,427	2,008	1,882	2,154	1,382	771.8	565.6	406.5	727.1	1,574	3,265	3,387
2003	2,141	4,261	7,225	3,624	8,050	4,430	6,172	3,008	1,639	1,257	1,965	2,282
2004	2,204	4,653	1,766	1,299	1,207	1,915	1,855	876.7	6,047	2,021	4,190	3,353
2005	2,611	4,840	5,895	6,475	2,295	3,255	8,307	4,885	1,617	2,018	1,423	2,424
2006	2,945	3,740	3,395	1,788	1,367	992.2	567.5	867.8	1,097	727.2	1,558	1,209
2007	2,718	1,655	3,009	1,142	658.9	445.8	630.5	435.6	489.6			
Mean of monthly Discharge	3,530	4,590	5,260	3,980	2,490	1,950	1,990	1,680	1,350	1,460	1,720	2,560

Table A-2. USGS discharge data for Walnut Creek ~4.5 miles upstream from OCMU, in Jones County, GA from 21 August 1962 through 27 July 1976 (NAD27, hydrologic unit 03070103; drainage area 29.0 square miles, 380.36 feet above sea level; latitude 32o58'20", longitude -83o37'08").

00060, Discharge, cubic feet per second,												
YEAR	Monthly mean in cfs (Calculation Period: 1961-10-01 -> 1994-03-30) Period-of-record for statistical calculation restricted by user											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961										0.923	4.56	27.8
1962	60.1	96.2	99.0	93.8	10.3	10.4	6.53	6.73	4.04	6.39	12.6	13.9
1963	126.2	64.6	54.3	19.1	103.1	34.6	24.2	4.93	12.2	5.75	14.8	37.2
1964	106.0	78.4	114.1	156.4	64.0	9.30	46.7	11.2	8.95	57.5	15.4	330.9
1965	24.2	83.9	66.1	37.1	12.1	143.0	87.6	22.6	9.52	12.5	13.3	13.4
1966	89.2	124.1	80.1	26.3	61.7	32.4	13.9	10.9	12.7	16.4	17.8	37.5
1967	48.3	59.8	21.0	11.8	11.3	6.45	5.66	7.13	3.11	4.86	7.28	20.9
1968	35.3	13.3	25.3	12.3	7.18	7.68	7.90	3.11	1.86	2.22	6.63	13.8
1969	23.9	26.9	32.1	37.9	7.29	3.68	10.7	67.0	7.02	3.05	4.84	23.5
1970	19.3	25.0	99.9	31.5	12.6	8.74	9.45	4.22	1.55	4.12	4.82	35.3
1971	73.9	71.9	183.6	45.2	42.1	11.0	14.2	19.9	16.0	7.70	16.2	43.0
1972	50.6	66.5	28.0	15.4	9.20	8.89	6.19	6.41	1.46	1.67	7.22	32.4
1973	83.5	90.6	93.2	96.6	58.3	24.9	16.2	21.0	7.94	5.04	7.88	10.2
1974	67.7	98.3	25.6	69.4	15.0	7.67	6.97	12.2	17.8	4.95	7.51	37.7
1975	97.2	109.7	112.7	129.5	43.0	48.4	21.3	17.2	9.90	24.8	13.8	40.4
1976	57.3	27.1	52.0	18.9	90.6	18.2	14.1	5.26	5.82	9.78	24.6	47.4
1977	52.2	24.2	116.8	19.5	8.01	6.08	4.92	14.6	3.60	5.48	10.5	14.1
1978	118.5	22.2	43.0	23.0	33.9	7.64	4.25	9.67	2.50	2.25	2.68	5.08
1979	24.4	144.5	35.7	67.5	18.0	7.85	8.80	12.1	9.99	7.15	22.0	14.2
1980	43.0	49.6	250.3	49.9	48.5	10.1	4.57	2.98	4.55	3.28	6.57	7.79
1981	7.28	124.3	23.3	40.7	5.93	4.39	0.855	1.19	1.06	1.52	2.54	40.7
1982	42.4	76.7	17.0	68.7	28.0	7.99	5.89	4.86	3.23	5.13	9.07	38.1
1983	46.7	115.0	119.3	81.4	12.6	12.2	5.45	5.75	3.12	2.62	14.4	32.3
1984	62.5	62.9	91.9	30.3	17.8	6.06	29.3	22.0	3.29	6.47	6.07	9.66
1985	13.1	88.3	14.2	9.04	10.2	3.77	5.32	1.81	1.61	2.60	25.0	21.3
1986	12.8	32.0	40.2	8.64	3.23	5.01	0.809	2.25	12.4	5.21	29.0	41.7
1987	87.8	85.4	98.7	28.0	9.84	16.1	3.63	3.86	12.8	3.65	11.3	7.75
1988	34.0	16.7	14.8	27.7	7.88	2.91	1.93	1.41	5.82	3.21	11.0	8.73
1989	17.9	17.8	47.9	64.0	17.6	8.49	30.7	5.16	5.50	35.0	9.87	49.2
1990	51.2	46.8	83.7	14.4	10.2	4.90	2.94	2.40	0.599	3.77	5.24	8.35
1991	59.4	25.9	101.7	98.4	16.9	7.55	24.3	23.5	6.14	3.96	5.75	8.61
1992	39.3	34.4	26.1	16.9	5.27	14.8	5.75	75.3	13.2	10.7	100.0	41.1
1993	70.5	66.9	139.7	42.2	12.8	8.34	4.04	4.02	2.38	8.03	14.3	21.1
1994	26.0	46.4	101.5									
Mean of monthly Discharge	54	64	74	47	25	16	14	13	6.6	8.4	14	34

Appendix B. Limited historic data available (sporadic, in several years during1986 - 1996) for water quality conditions at NPS and GA DNR-EPD stations at or near OCMU

Table B-1. Available data from U.S. EPA STORET; sampling dates per year ranged from 1-20). Red ≡ data in violation of state standard; green ≡ sufficient to support noxious algal blooms – see review in Mallin 2000; purple ≡ data exceeded recommended values to protect aquatic life (U.S. EPA (2000): for TSS, 25 mg/L maximum, and < 10 mg/L increase from a sudden spike; for BOD5 3 mg/L or less – Mallin et al. 2006).

Parameter	Date	n	Mean(range) or single value (sv)	Median	Number of UCs
At or Near OCMU					
NPS OCMU_DNR_CRK (adjacent to OCMU; latitude 32.8394, longitude -83.6154)					
63 chemical contaminants, (pesticides etc.)	10-Aug-95	1 each	Non-detectible except for 3:		
1,2-dichlorobenzene		1	sv 5 µg/L	---	---
Limonene		1	sv 67 µg/L	---	---
m-xylene, p-xylene		1	sv 5 µg/L	---	---
NPS OCMU_MWA_ABS (adjacent to OCMU; latitude 32.8429, longitude -83.6076)					
Temperature (^{o}C)	Apr 95 - Aug 95	15	18.7 (14 - 28)	18	---
DO (mg/L)[a]	Apr 95 - Jun 95	16	6.5 (**4.6** - 8.9)	6.2	**1**
pH	Apr 95 - Aug 95	17	7.0 (6.6 - 7.4)	7.1	---
BOD_5 (mg/L)	Apr 95 - Sep 95	13	2.1 (1 - **7**)	2	**1**
TSS (mg/L)	Apr 95 - Sep 95	19	15.8 (0.4 - **69**)	14	**3**
Fecal coliforms (mpn/100 mL)[b]	Apr 95 - Sep 95	18	**914** (3 - **10,200**)	**315**	**5**
NPS OCMU_MWA_DF (in OCMU; latitude 32.8417, longitude -83.6082)					
Temperature (^{o}C)	Apr 95 - Aug 95	15	18.8 (14 - 28)	18	---
DO (mg/L)[a]	Apr 95 - Jun 95	16	5.97 (**4.0** - 8.8)	5.9	**3**
pH	Apr 95 - Aug 95	17	6.9 (6.2 - 7.2)	6.9	---
BOD_5 (mg/L)	Apr 95 - Sep 95	14	1.3 (0.3 - **4**)	1	**1**
TSS (mg/L)	Apr 95 - Sep 95	20	10.5 (0.3 - **54**)	5.5	**2**
Fecal coliforms (mpn/100 mL)[b]	Apr 95 - Sep 95	19	**1,351** (3 - **8,050**)	124	**6 (6)**

Table B-1. (Continued).

Parameter	Date	n	Mean(range) or single value (sv)	Median	Number of UCs
NPS OCMU_MWA_DWS (at OCMU; latitude 32.8375, longitude -83.6097)					
Temperature (^{o}C)	20-22 May 94	3	23.2 (22.4 - 23.7)	23.4	---
DO (mg/L)	20-22 May 94	3	7.03 (5.2 - 8)	7.9	---
pH	20-22 May 94	3	6.5 (6.3 - 6.6)	6.5	---
BOD_5 (mg/L)	22-May-94	1	sv **7**	---	**1**
Fecal coliforms (mpn/100 mL)[b]	20-21 May 94	2	**1,105** (**600** - **1,610**)	---	**2** (2)
NPS OCMU_MWA_PR (at OCMU; latitude 32.8381, longitude -83.6094)					
Temperature (^{o}C)	25-28 Apr 95	4	17.5 (15 - 22)	16.5	---
DO (mg/L)	23-28 Apr 95	6	5.77 (**3.8** - 7.1)	6.3	**2**
pH	23-28 Apr 95	5	6.8 (6.6 - 7.1)	6.9	---
BOD_5 (mg/L)	27-28 Apr 95	2	2.5 (2 - 3)	2.5	---
TSS (mg/L)	23-28 Apr 95	5	10.6 (2 - 23)	3	---
Fecal coliforms (mpn/100 mL)	23-28 Apr 95	5	**3,403** (6 - **12,961**)	**653**	**2 (3)**
NPS OCMU_MWA_S1 (adjacent to OCMU; latitude 32.8424, longitude -83.6079)					
Temperature (^{o}C)	20-22 May 94	3	23.2 (22.3 - 23.7)	23.6	---
DO (mg/L)	20-22 May 94	3	8.3 (7.8 - 8.6)	8.6	---
pH	20-22 May 94	3	6.6 (6.5 - 6.7)	6.6	---
BOD (mg/L)	22-May-94	1	sv **6**	---	**1**
Fecal coliforms (mpn/100 mL)[b]	20-21 May 94	2	**705** (**600** - **810**)	---	**2 (2)**
NPS OCMU_MWA_S2 (at OCMU; latitude 32.8381, longitude -83.6093)					
Temperature (^{o}C)	Apr 95 - Aug 95	15	18.6 (14 - 28)	18	---
DO (mg/L)[a]	Apr 95 - Jun 96	16	5.99 (**4.2** - 8.6)	8.6	**3**
pH	Apr 95 - Aug 95	17	6.8 (**6.3** - 7.3)	6.9	---
BOD_5 (mg/L)	Apr 95 - Sep 95	13	1.5 (0.7 - **5**)	1	**1**
TSS (mg/L)	Apr 95 - Jun 96	19	10.4 (2 - **35**)	8	**2**
Fecal coliforms (mpn/100 mL)	Apr 95 - Jun 96	18	**1,531** (1 - **9,500**)	84	**6 (5)**
NPS OCMU_MWA_STO (at OCMU; latitude 32.8353, longitude -83.6078)					
Temperature (^{o}C)	22-May-94	1	sv 20.8	---	---
DO (mg/L)	22-May-94	1	sv 6.4	---	---
pH	22-May-94	1	sv 6.2	---	---
BOD_5 (mg/L)	22-May-94	1	sv 2	---	---

Table B-1. (Continued).

Parameter	Date	n	Mean(range) or single value (sv)	Median	Number of UCs
NPS OCMU_MWA_SWP (at OCMU; latitude 32.8361, longitude -83.6101)					
Temperature (^oC)	20-22 May 94	3	23 (21.9 - 23.6)	23.5	---
DO (mg/L)	20-22 May 94	3	6.73 (5.4 - 7.5)	7.3	---
pH	20-22 May 94	3	6.5 (6.4 - 6.7)	6.5	---
BOD_5 (mg/L)	22-May-94	1	sv **10**	---	**1**
Fecal coliforms (mpn/100 mL)[b]	20-21 May 94	2	**600** (**600** - **600**)	---	**2 (2)**
NPS OCMU_MWA_UPS (at OCMU; latitude 32.8387, longitude -83.6091)					
Temperature (^oC)	20-22 May 94	3	22.3 (22.1 - 22.6)	22.2	---
DO (mg/L)	20-22 May 94	3	8.7 (8.6 - 8.8)	8.7	---
pH	20-22 May 94	3	6.7 (6.3 - 6.9)	6.8	---
BOD_5 (mg/L)	22-May-94	1	sv **8**	---	**1**
Fecal coliforms (mpn/100 mL)	20-21 May 94	2	172.5 (95 - **250**)	---	**1(---)**
Upstream from OCMU – Ocmulgee River					
NPS OCMU_FRUS_1 (5.8 miles upstream; latitude 32.8962, longitude -83.6623)					
Temperature (^oC)	13, 14, 20 July 88	3	34.3 (32 - 37)	34	---
Turbidity (NTU)	14, 20 July 88	2	7.5 (5 - 10)	---	---
Spec. cond. (µmhos/cm, field)	13, 14, 20 July 88	3	114 (105 - 126)	111	---
DO (mg/L)	13, 14, 20 July 88	3	6.97 (5.4 - 7.9)	7.6	---
pH	14, 20 July 88	2	7.65 (7.4 - 7.9)	---	---
$NO_2^-N + NO_3^-N$ (µg/L)	13, 14, 20 July 88	3	86.7 (60 - **130**)	70	**1**
TP (µg/L)	13, 14, 20 July 88	3	33.3 (20 - 40)	40	---
TOC (mg/L)	14, 20 July 88	2	3.1 (2.3 - 3.9)	---	---
BOD_5 (mg/L)	13,14, 20 Jul 88	3	0.8 (0.7 - 1)	0.8	---
TSS (mg/L)	14, 20 July 88	2	4.5 (1 - 8)	---	---
Fecal coliforms (mpn/100 mL)	13, 14, 20 July 88	3	56.7 (40 - 80)	50	---
Metals, chemical elements	14, 26 July 88		(see *Table 10*)		

Table B-1. (Continued).

Parameter	Date	n	Mean(range) or single value (sv)	Median	Number of UCs
Upstream of OCMU – Walnut Creek					
NPS OCMU_WNC_JVR (0.4 mile upstream; latitude 32.8521, longitude - 83.5934)					
Temperature (^{o}C)	16 July, 27 Aug 86	2	27 (26 - 28)	---	---
Turbidity (NTU)	16 July, 27 Aug 86	2	8 (8 - 8)	---	---
Spec. cond. (µmhos/cm, field)	16 July, 27 Aug 86	2	127.5 (120 - 135)	---	---
DO (mg/L)	16 July, 27 Aug 86	2	6.5 (6.5 - 6.5)	---	---
pH	16 July, 27 Aug 86	2	7.25 (7.2 - 7.3)	---	---
$NO_3^-N + NO_2^-N$ (µg/L)	16 July, 27 Aug 86	2	**240** (**220** - **260**)	---	**2**
TP (µg/L)	16 July, 27 Aug 86	2	30 (*nd - 30)	---	---
TOC (mg/L)	16 July, 27 Aug 86	2	4.4 (3.2 - 5.5)	---	---
BOD_5 (mg/L)	16 July, 27 Aug 86	2	0.65 (0.6 - 0.7)	---	---
TSS (mg/L)	16 July, 27 Aug 86	2	2 (*nd - 2)	---	---
Fecal coliforms (mpn/100 mL)	16 July, 27 Aug 86	2	**640** (**490** - **790**)	640	**2** (2)
Metals, chemicals detected	16 July, 27 Aug 86		(see *Table 9*)		
NPS OCMU_WNC_H11 (2.9 miles upstream; latitude 32.8772, longitude -83.6094)					
Temperature (^{o}C)	16 July, 27 Aug 86	2	28 (26 - 30)	---	---
Turbidity (NTU)	16 July, 27 Aug 86	2	4 (3 - 5)	---	---
Spec. cond. (µmhos/cm, field)	16 July, 27 Aug 86	2	131.5 (123 - 140)	---	---
DO (mg/L)	16 July, 27 Aug 86	2	6.2 (5.2 - 7.2)	---	---
pH	16 July, 27 Aug 86	2	7.6 (7.6 - 7.6)	---	---
$NO_3^-N + NO_2^-N$ (µg/L)	16 July, 27 Aug 86	2	**465** (**420** - **510**)	---	**2**
TP (µg/L)	16 July, 27 Aug 86	2	35 (30 - 40)	---	---
TOC (mg/L)	16 July, 27 Aug 86	2	4.1 (3.6 - 4.6)	---	---
BOD_5 (mg/L)	16 July, 27 Aug 86	2	0.7 (0.4 - 1)	---	---
TSS (mg/L)	16 July, 27 Aug 86	2	3 (*nd - 3)	---	---
Fecal coliforms (mpn/100 mL)	16 July, 27 Aug 86	2	**273** (110 - **435**)	---	**1 (1)**
NPS OCMU_WNC_H18 (10 miles upstream; latitude 32.9733, longitude -83.6192)					
Temperature (^{o}C)	16 July, 27 Aug 86	2	26.5 (24.5 - 28.5)	---	---
Turbidity (NTU)	16 July, 27 Aug 86	2	4 (*nd - 4)	---	---
Spec. cond. (µmhos/cm, field)	16 July, 27 Aug 86	2	111.5 (104 - 119)	---	---
DO (mg/L)	16 July, 27 Aug 86	2	6.1 (5.3 - 6.9)	---	---
pH	16 July, 27 Aug 86	2	7.5 (7.4 - 7.6)	---	---
$NO_3^-N + NO_2^-N$ (µg/L)	16 July, 27 Aug 86	2	**275** (**170** - **380**)	---	**2**
TP (µg/L)	16 July, 27 Aug 86	2	30 (*nd - 30)	---	---
TOC (mg/L)	16 July, 27 Aug 86	2	5.3 (4.9 - 5.6)	---	---
BOD (mg/L)	16 July, 27 Aug 86	2	0.7 (0.6 - 0.8)	---	---
TSS (mg/L)	16 July, 27 Aug 86	2	(*nd)	---	---
Fecal coliforms (mpn/100 mL)	16 July, 27 Aug 86	2	**1,015** (**330** - **1,700**)	---	**2 (1)**

Table B-1. (Continued).

Parameter	Date	n	Mean(range) or single value (sv)	Median	Number of UCs
Downstream of OCMU on Walnut Creek					
NPS OCMU_WNC_I16 (0.1 mile downstream; latitude 32.8291, longitude -83.6046)					
Temperature (^{o}C)	16 July, 27 Aug 86	2	27.5 (27 - 28)	---	---
Turbidity (NTU)	16 July, 27 Aug 86	2	36 (16 - 56)	---	---
Spec. cond. (µmhos/cm, field)	16 July, 27 Aug 86	2	141 (129 - 153)	---	---
DO (mg/L)	16 July, 27 Aug 86	2	**4.7** (**4.2** - 5.2)	---	**1**
pH	16 July, 27 Aug 86	2	7.3 (7.2 - 7.4)	---	---
$NO_2^-N + NO_3^-N$ (µg/L)	16 July, 27 Aug 86	2	**125** (70 - **180**)	---	**1**
TP (µg/L)	16 July, 27 Aug 86	2	35 (30 - 40)	---	---
TOC (mg/L)	16 July, 27 Aug 86	2	7.9 (6.9 - 8.9)	---	---
BOD_5 (mg/L)	16 July, 27 Aug 86	2	1.15 (1.1 - 1.2)	---	---
TSS (mg/L)	16 July, 27 Aug 86	2	2 (2 - 2)	---	---
Fecal coliforms (mpn/100 mL)	16 July, 27 Aug 86	2	**945** (**790** - **1,100**)	---	**2 (2)**

[a] The original value of 0 on one date (1 Jun 95) was reported in STORET as "non-detect". This sample was omitted from statistical analysis because sensor performance was suspect.

[b] The sample value in STORET was noted as "*present > QL", with the upper quantification limit equal to 600. The 600 value was used in the statistical analysis as a conservative estimate.

Table B-2. Available STORET data (sparse, 1-3 dates each in 1986, 1988, or 1999-2000) for metal concentrations in the water and/or sediments at four stations upstream from OCMU or on the upper OCMU boundary.

Parameter	Concentration	Parameter	Concentration
Station NPS OCMU_FRUS_1 (Ocmulgee R., 5.8 miles upstream from OCMU; lat. 32.8962, long. -83.6623)			
16 July 1986 – Water (µg/L)		16 July 1986 – Sediment (mg/kg)	
Aluminum	**360 µg/L**	Aluminum	---
Barium	50 µg/L	Barium	---
Calcium	720 µg/L	Calcium	---
Iron	570 µg/L	Iron	---
Magnesium	3,200 µg/L	Magnesium	---
Manganese	840 µg/L	Manganese	---
Sodium	5,100 µg/L	Sodium	2.2 mg/kg
14 July 1988 – Water		26 July 1988 – Sediment	
Aluminum	**800 µg/L**	Aluminum	17,000 mg/kg
Barium	21 µg/L	Barium	90 mg/kg
Calcium	7,600 µg/L	Calcium	1,100 mg/kg
Iron	400 µg/L	Iron	21,000 mg/kg
Magnesium	2,400 µg/L	Magnesium	2,400 mg/kg
Manganese	84 µg/L	Manganese	1,300 mg/kg
Nickel	20 µg/L	Nickel	7.7 mg/kg
Potassium	2,600 µg/L	Potassium	2,000 mg/kg
Sodium	9,200 µg/L	Sodium	130 mg/kg
Titanium	31 µg/L	Titanium	900 mg/kg
Zinc	**200 µg/L**	Zinc	54 mg/kg
Chromium	*nd = 10 µg/L	Chromium	23 mg/kg
Cobalt	*nd = 10 µg/L	Cobalt	7.9 mg/kg
Copper	*nd = 20 µg/L	Copper	24 mg/kg
Lead	*nd = 25 µg/L	Lead	4.5 mg/kg
Vanadium	*nd = 10 µg/L	Vanadium	42 mg/kg

Table B-2. (Continued).

Parameter	Concentration	Parameter	Concentration
Station OCMU_WNC_JVR (Walnut Cr. Bridge, Jeffersonville Rd., 0.4 mile upstream from OCMU on Walnut Cr.; lat. 32.8521, long. - 83.5934)			
16 July 1986 – Water (µg/L)		16 July 1986 – Sediment (mg/kg)	
Aluminum	**360 µg/L**	Aluminum	---
Barium	50 µg/L	Barium	---
Calcium	720 µg/L	Calcium	---
Iron	570 µg/L	Iron	---
Magnesium	3,200 µg/L	Magnesium	---
Manganese	840 µg/L	Manganese	---
Sodium	5,100 µg/L	Sodium	2.2 mg/kg
27 July 1986 – Sediment			
TCPH (Trichlorophenol)	0.2 mg/kg	Lead	14 mg/kg
Aluminum	2,740 mg/kg	Magnesium	560 mg/kg
Arsenic	3.1 mg/kg	Manganese	1,970 mg/kg
Barium	160 mg/kg	Nickel	3 mg/kg
Beryllium	1.1 mg/kg	Potassium	390 mg/kg
Calcium	725 mg/kg	Sodium	65 mg/kg
Chromium	6.3 mg/kg	Titanium	165 mg/kg
Cobalt	7.7 mg/kg	Vanadium	19 mg/kg
Copper	7.7 mg/kg	Zinc	26 mg/kg
Iron	8,890 mg/kg		

Appendix C. Water quality standards in Georgia for toxic substances – streams and lakes (GA DNR 2008c).

TABLE 3-3
GEORGIA INSTREAM WATER QUALITY STANDARDS FOR ALL WATERS: TOXIC SUBSTANCES

(Excerpt from Georgia's Rules and Regulations for Water Quality Control Chapter 391-3-6-.03 - Water Use Classifications and Water Quality Standards)

(i) Instream concentrations of the following chemical constituents which are considered to be other toxic pollutants of concern in the State of Georgia shall not exceed the criteria indicated below under 7-day, 10-year minimum flow (7Q10) or higher stream flow conditions except within established mixing zones:

1. 2,4-Dichlorophenoxyacetic acid (2,4-D)	70 µg/l
2. Methoxychlor	0.03 µg/l*
3. 2,4,5-Trichlorophenoxy propionic acid (TP Silvex)	50 µg/l

(ii) Instream concentrations of the following chemical constituents listed by the U.S. Environmental Protection Agency as toxic priority pollutants pursuant to Section 307(a)(1) of the Federal Clean Water Act (as amended) shall not exceed the acute criteria indicated below under 1-day, 10-year minimum flow (1Q10) or higher stream flow conditions and shall not exceed the chronic criteria indicated below under 7-day, 10-year minimum flow (7Q10) or higher stream flow conditions except within established mixing zones or in accordance with site specific effluent limitations developed in accordance with procedures presented in 391-3-6-.06. Unless otherwise specified, the criteria below are listed in their total recoverable form. Because most of the numeric criteria for the metals below are listed as the dissolved form, total recoverable concentrations of metals that are measured instream will need to be translated to the dissolved form in order to compare the instream data with the numeric criteria. This translation will be performed using guidance found in "Guidance Document of Dynamic Modeling and Translators August 1993" found in Appendix J of EPA's Water Quality Standards Handbook: Second Edition, EPA-823-B-94-005a or by using other appropriate guidance from EPA.

		Acute	Chronic
1.	Arsenic		
	(a) Freshwater	340 µg/l [1]	150 µg/l [1]
	(b) Coastal and Marine Estuarine Waters	69 µg/l [1]	36 µg/l [1]
2.	Cadmium		
	(a) Freshwater	2.0 µg/l [1,3]	1.3 µg/l [1,3]
	(b) Coastal and Marine Estuarine Waters	42 µg/l [1]	9.3 µg/l [1]
3.	Chromium III		
	(a) Freshwater	320 µg/l [1,3]	42 µg/l [1,3]
	(b) Coastal and Marine Estuarine Waters	--	--
4.	Chromium VI		
	(a) Freshwater	16 µg/l [1]	11 µg/l [1]
	(b) Coastal and Marine Estuarine Waters	1,100 µg/l [1]	50 µg/l [1]
5.	Copper		
	(a) Freshwater	7.0 µg/l [1,2*,3]	5.0 µg/l [1,2*,3]
	(b) Coastal and Marine Estuarine Waters	4.8 µg/l [1,2]	3.1 µg/l [1,2]
6.	Lead		
	(a) Freshwater	30 µg/l [1,3]	1.2 µg/l [1,2*,3]
	(b) Coastal and Marine Estuarine Waters	210 µg/l [1]	8.1 µg/l [1]
7.	Mercury		
	(a) Freshwater	1.4 µg/l	0.012 µg/l [2]
	(b) Coastal and Marine Estuarine Waters	1.8 µg/l	0.025 µg/l [2]
8.	Nickel		
	(a) Freshwater	260 µg/l [1,3]	29 µg/l [1,3]
	(b) Coastal and Marine Estuarine Waters	74 µg/l [1]	8.2 µg/l [1]
9.	Selenium		
	(a) Freshwater	–	5.0 µg/l
	(b) Coastal and Marine Estuarine Waters	290µg/l [1]	71 µg/l [1]

10.	Silver	– [4]	-- [4]
11.	Zinc		
	(a) Freshwater	65 µg/l [1,3]	65 µg/l [1,3]
	(b) Coastal and Marine Estuarine Waters	90 µg/l [1]	81 µg/l [1]
12.	Lindane [Hexachlorocyclohexane (g-BHC-Gamma)]		
	(a) Freshwater	0.95 µg/l	
	(b) Coastal and Marine Estuarine Waters	0.16 µg/l	

[1] The in-stream criterion is expressed in terms of the dissolved fraction in the water column. Conversion factors used to calculate dissolved criteria are found in the EPA document – National Recommended Water Quality Criteria – Correction, EPA 822-Z-99-001, April 1999.

[2] The in-stream criterion is lower than the EPD laboratory detection limits (A "*" indicates that the criterion may be higher than or lower than EPD laboratory detection limits depending upon the hardness of the water).

[3] The aquatic life criteria for these metals are expressed as a function of total hardness (mg/l) in a water body. Values in the table above assume a hardness of 50 mg/l CaCO3. For other hardness values, the following equations from the EPA document – National Recommended Water Quality Criteria – Correction; EPA 822-Z-99-001, April 1999 should be used. The minimum hardness allowed for use in these equations shall not be less than 25 mg/l, as calcium carbonate and the maximum shall not be greater than 400 mg/l as calcium carbonate.

Cadmium

acute criteria = $(e^{(1.128[\ln(hardness)] - 3.6867)})(1.136672-[(\ln hardness)(0.041838)]$ µg/l

chronic criteria = $(e^{(0.7852[\ln(hardness)] - 2.715)})(1.101672-[(\ln hardness)(0.041838)]$ µg/l

Chromium III

acute criteria = $(e^{(0.8190[\ln(hardness)] + 3.7256)})(0.316)$ µg/l

chronic criteria = $(e^{(0.8190[\ln(hardness)] + 0.6848)})(0.860)$ µg/l

Copper

acute criteria = $(e^{(0.9422[\ln(hardness)] - 1.700)})(0.96)$ µg/l

chronic criteria = $(e^{(0.8545[\ln(hardness)] - 1.702)})(0.96)$ µg/l

Lead

acute criteria = $(e^{(1.273[\ln(hardness) - 1.460)})(1.46203 - [(\ln hardness)(0.145712)])$ µg/l

chronic criteria = $(e^{(1.273[\ln(hardness) - 4.705)})(1.46203 - [(\ln hardness)(0.145712)])$ µg/l

Nickel

acute criteria = $(e^{(0.8460[\ln(hardness)] + 2.255)})(.998)$ µg/l

chronic criteria = $(e^{(0.8460[\ln(hardness)] + 0.0584)})(.997)$ µg/l

Zinc

acute criteria = $(e^{(0.8473[\ln(hardness)] + 0.884)})(0.978)$ µg/l

chronic criteria = $(e^{(0.8473[\ln(hardness)] + 0.884)})(0.986)$ µg/l

[4] This pollutant is addressed in 391-3-6-.06.

(iii) Instream concentrations of the following chemical constituents listed by the U.S. Environmental Protection Agency as toxic priority pollutants pursuant to Section 307(a)(1) of the Federal Clean Water Act (as amended) shall not exceed criteria indicated below under 7-day, 10-year minimum flow (7Q10) or higher stream flow conditions except within established mixing zones or in accordance with site specific effluent limitations developed in accordance with procedures presented in 391-3-6-.06.

1.	Chlordane	
	(a) Freshwater	0.0043 µg/l*
	(b) Coastal and Marine Estuarine Waters	0.004 µg/l*
2.	Cyanide	
	(a) Freshwater	5.2 µg/l*
	(b) Coastal and Marine Estuarine Waters	1.0 µg/l*
3.	Dieldrin	
	(a) Freshwater	0.056 µg/l*
	(b) Coastal and Marine Estuarine Waters	0.0019 µg/l*
4.	4,4'-DDT	0.001 µg/l*
5.	a-Endosulfan	
	(a) Freshwater	0.056 µg/l*
	(b) Coastal and Marine Estuarine Waters	0.0087 µg/l*
6.	b-Endosulfan	
	(a) Freshwater	0.056 µg/l*
	(b) Coastal and Marine Estuarine Waters	0.0087 µg/l*

7.	Endrin	
	(a) Freshwater	0.036 µg/l*
	(b) Coastal and Marine Estuarine Waters	0.0023 µg/l*
8.	Heptachlor	
	(a) Freshwater	0.0038 µg/l*
	(b) Coastal and Marine Estuarine Waters	0.0036µg/l*
9.	Heptachlor Epoxide	
	(a) Freshwater	0.0038 µg/l*
	(b) Coastal and Marine Estuarine Waters	0.0036 µg/l*
10	Pentachlorophenol	
	(a) Freshwater	2.1 µg/l*
	(b) Coastal and Marine Estuarine Waters	7.9 µg/l*
11.	PCBs	
	(a) Freshwater	0.014 µg/l*
	(b) Coastal and Marine Estuarine Waters	0.03 µg/l*
12.	Phenol	300 µg/l
13.	Toxaphene	0.0002 µg/l*

*The in-stream criterion is lower than the EPD laboratory detection limits.

(iv) Instream concentrations of the following chemical constituents listed by the U. S. Environmental Protection Agency as toxic priority pollutants pursuant to Section 307(a)(1) of the Federal Clean Water Act (as amended) shall not exceed criteria indicated below under annual average or higher stream flow conditions:

1.	Acenaphthene	2700 µg/l
2.	Acenaphthylene	**
3.	Acrolein	780 µg/l
4.	Acrylonitrile	0.66 µg/l
5.	Aldrin	0.00014 µg/l
6.	Anthracene	110000 µg/l
7.	Antimony	4300 µg/l
8.	Arsenic	50 µg/l
9.	Benzidine	0.00054 µg/l
10.	Benzo(a)Anthracene	0.049µg/l
11.	Benzo(a)Pyrene	0.049µg/l
12.	3,4-Benzofluoranthene	0.049µg/l
13.	Benzene	71 µg/l
14.	Benzo(ghi)Perylene	**
15.	Benzo(k)Fluoranthene	0.049µg/l
16.	Beryllium	**
17.	a-BHC-Alpha	0.013 µg/l
18.	b-BHC-Beta	0.046 µg/l
19.	Bis(2-Chloroethyl)Ether	1.4 µg/l
20.	Bis(2-Chloroisopropyl)Ether	170000 µg/l
21.	Bis(2-Ethylhexyl)Phthalate	5.9 µg/l
22.	Bromoform (Tribromomethane)	360 µg/l
23.	Butylbenzyl Phthalate	5200
24.	Carbon Tetrachloride	4.4 µg/l
25.	Chlorobenzene	21000 µg/l
26.	Chlorodibromomethane	34 µg/l
27.	2-Chloroethylvinyl Ether	**
28.	Chlordane	0.0022 µg/l
29.	Chloroform (Trichloromethane)	470 µg/l
30.	2-Chloronaphthalene	4300 µg/l
31.	2-Chlorophenol	400 µg/l
32.	Chrysene	0.049 µg/l
33.	Dibenzo(a,h)Anthracene	0.049 µg/l
34.	Dichlorobromomethane	46 µg/l
35.	1,2-Dichloroethane	99 µg/l
36.	1,1-Dichloroethylene	3.2 µg/l
37	1,2 – Dichloropropane	39 µg/l
38.	1,3-Dichloropropylene	1700 µg/l
39.	2,4-Dichlorophenol	790 µg/l
40.	1,2-Dichlorobenzene	17000 µg/l
41.	1,3-Dichlorobenzene	2600 µg/l

42.	1,4-Dichlorobenzene	2600 µg/l
43.	3,3'-Dichlorobenzidine	0.077 µg/l
44.	4,4'-DDT	0.00059 µg/l
45.	4,4'-DDD	0.00084 µg/l
46.	4,4'-DDE	0.00059 µg/l
47.	Dieldrin	0.00014 µg/l
48.	Diethyl Phthalate	120000 µg/l
49.	Dimethyl Phthalate	2900000 µg/l
50.	2,4-Dimethylphenol	2300 µg/l
51.	2,4-Dinitrophenol	14000 µg/l
52.	Di-n-Butyl Phthalate	12000 µg/l
53.	2,4-Dinitrotoluene	9.1 µg/l
54.	1,2-Diphenylhydrazine	0.54 µg/l
55.	Endrin	0.81 µg/l
56.	Endrin Aldehyde	0.81 µg/l
57.	alpha – Endosulfan	240 µg/l
58.	beta – Endosulfan	240 µg/l
59.	Endosulfan Sulfate	240 µg/l
60.	Ethylbenzene	29000 µg/l
61.	Fluoranthene	370 µg/l
62.	Fluorene	14000 µg/l
63.	Heptachlor	0.00021 µg/l
64.	Heptachlor Epoxide	0.00011 µg/l
65.	Hexachlorobenzene	0.00077 µg/l
66.	Hexachlorobutadiene	50 µg/l
67.	Hexachlorocyclopentadiene	17000 µg/l
68.	Hexachloroethane	8.9 µg/l
69.	Indeno(1,2,3-cd)Pyrene	0.049 µg/l
70.	Isophorone	2600 µg/l
71.	Lindane [Hexachlorocyclohexane (g-BHC-Gamma)]	0.063 µg/l
72.	Methyl Bromide (Bromomethane)	4000 µg/l
73.	Methyl Chloride (Chloromethane)	**
74.	Methylene Chloride	1600 µg/l
75.	2-Methyl-4,6-Dinitrophenol	765 µg/l
76.	3-Methyl-4-Chlorophenol	**
77.	Nitrobenzene	1900 µg/l
78.	N-Nitrosodimethylamine	8.1 µg/l
79.	N-Nitrosodi-n-Propylamine	1.4 µg/l
80.	N-Nitrosodiphenylamine	16 µg/l
81.	PCBs	0.00017 µg/l
82.	Pentachlorophenol	8.2 µg/l
83.	Phenanthrene	**
84.	Phenol	4,600,000 µg/l
85.	Pyrene	11,000 µg/l
86.	1,1,2,2-Tetrachloroethane	11 µg/l
87.	Tetrachloroethylene	8.85 µg/l
88.	Thallium	6.3 µg/l
89.	Toluene	200000 µg/l
90.	Toxaphene	0.00075 µg/l
91.	1,2-Trans-Dichloroethylene	140000
92.	1,1,2-Trichloroethane	42 µg/l
93.	Trichloroethylene	81 µg/l
94.	2,4,6-Trichlorophenol	6.5 µg/l
95.	1,2,4-Trichlorobenzene	940 µg/l
96.	Vinyl Chloride	525 µg/l

**These pollutants are addressed in 391-3-6-.06.

(v) Site specific criteria for the following chemical constituents will be developed on an as-needed basis through toxic pollutant monitoring efforts at new or existing discharges that are suspected to be a source of the pollutant at levels sufficient to interfere with designated uses:

1. Asbestos

(vi) instream concentrations of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) must not exceed 0.0000012 µg/l under long-term average stream flow conditions.

(f) Applicable State and Federal requirements and regulations for the discharge of radioactive substances shall be met at all times.

Appendix D. Criteria for classification of surface waters as meeting or not meeting their designated use(s) (GA DNR 2008b).

Substantial changes have been made to the format of Georgia's 2008 305(b)/303(d) List of Waters assessed from earlier listing years. The USEPA has required States to move to a five-part categorization of their waters. The GAEPD adopted the five-part categorization method with the 2008 305(b)/303(d) report. Assessed waters were placed into the five categories as described below:

Category 1 – Data indicate that waters are meeting their designated use(s). The placement of a water body in Category 1 is comparable to a water body having been on the "supporting" list in previous 305(b)/303(d) lists.

Category 2 – A water has more than one designated use and data indicate that at least one designated use is being met, but there is insufficient evidence to determine that all uses are being met. GAEPD did not have a designation similar to Category 2 on previous 305(b)/303(d) lists.

Category 3 – There is insufficient data or other information to make a determination as to whether or not the designated use(s) is being met.

Category 4a – Data indicate that at least one designated use is not being met, but TMDL(s) have been completed for the parameter(s) that are causing a water not to meet its use(s). In GAEPD's previous 305(b)/303(d) lists, a water body that was determined not to be supporting its use, but a TMDL had been completed for the parameter of concern would have been indicated by the presence of the number "3" in the 303(d) column of the report.

Category 4b - Data indicate that at least one designated use is not being met, but there are actions in place (other than a TMDL) that are predicted to lead to compliance with water quality standards. In previous 305(b)/303(d) lists, waters meeting this condition would have been indicated by the presence of the number "2" in the 303(d) column of the report.

Category 4c - Data indicate that at least one designated use is not being met, but a pollutant does not cause the impairment. The Clean Water Act (502(6)) defines a pollutant as dredged spoil, solid waste, incinerator residue, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, salt, cellar dirt, and industrial, municipal, and agricultural waste discharged into water. An example of a situation that may call for a water to be placed in Category 4c is the case of a highly modified stream (such as a stream that has been channelized) and therefore has insufficient habitat to support an acceptable biological community.

Category 5 - Data indicate that at least one designated use is not being met and TMDL(s) need to be completed for one or more pollutants. In previous 305(b)/ 303(d) lists, a water body that was determined not to be supporting its use and for which a TMDL still needed to be completed was indicated by the presence of an "x" in the 303(d) column of the report.

In accordance with Section 303(d) of the Clean Water Act, the 303(d) list is a list of waters not meeting their uses and for which TMDL(s) have not been completed for the parameter(s) of concern. Once the TMDL is completed, the water may still not be supporting its use; however, it is no longer on the 303(d) list. In the new 5-part categorization method, waters that are assessed as "not supporting" their uses will either be placed in Category 4a, 4b, 4c or 5. Only those waters in Category 5 make up the federally mandated 303(d) list.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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