National Park Service
U.S. Department of the Interior

Northeast Region
Philadelphia, Pennsylvania

Classification and Mapping of Vegetation and Fire Fuel Models at Delaware Water Gap National Recreation Area: Volume 1 of 2

Technical Report NPS/NER/NRTR—2007/076

ON THE COVER
Hickory - Eastern Red-cedar Rocky Woodland, near Milford, Pennsylvania, in the Delaware Water Gap National Recreation Area.
Photograph by: Gregory Podniesinski.

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U.S. Department of the Interior
National Park Service
Northeast Region
Philadelphia, Pennsylvania

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Executive Summary

Vegetation classification and mapping of vegetation associations, fire behavior fuel models, and canopy cover classes were conducted at the Delaware Water Gap National Recreation Area, creating current digital geospatial databases for the park.

Sixty-nine vegetation associations that occur within the park were identified and described in detail. This wide diversity of vegetation associations is a result of several factors, including differing bedrock geology, variable topographic features, and lengthy land use history. A map showing the locations of vegetation associations in the park was created following the USGS/NPS Vegetation Mapping Program protocols (The Nature Conservancy and Environmental Systems Research Institute 1994a, b, c). These vegetation associations were also crosswalked to the National Vegetation Classification System, as well as the Pennsylvania and New Jersey state classifications, in order to provide a regional and global context for the parks' vegetation. A dichotomous field key was developed for these vegetation associations to assist with field recognition and classification.

The five spatial data inputs required by the FARSITE fire growth simulation model were also developed for the Delaware Water Gap. These data are essential for fire and resource managers to adequate plan for and manage prescribed and wildland fires. Three data layers (elevation, slope, and aspect) were derived using spatial tools in ArcGIS from the existing digital elevation model created by North Carolina State University. The fire behavior fuel model data layer maps 12 fuel models that provide information on fire behavior. The original Anderson (1982) fuel model descriptions, as well as descriptions of the fuels within the park and the relationships between vegetation associations and fire fuel models, are included in this report. A canopy cover data layer was also created for the Delaware Water Gap National Recreation Area using the four cover classes required by the FARSITE program (Finney 1998). In addition, areas of the park with large concentrations of dead or dying trees were identified. These areas, predominantly dead or dying standing eastern hemlocks (*Tsuga canadensis*), pose an increased fire risk.

Keywords: vegetation association, vegetation classification, vegetation mapping, fire behavior fuel model, canopy cover class, FARSITE, Delaware Water Gap National Recreation Area.

Introduction

General Background

One of the goals of the National Park Service's (NPS) Inventory and Monitoring Program and Fire Management Program is to provide current and accurate information for effective, long-term management of the natural resources held in trust (NPS 2003a, b). The Inventory and Monitoring Program recommends that 12 basic natural resource inventories be developed for each park that contains significant natural resources. These park inventories provide crucial baseline information for the proper stewardship of natural and cultural resources. A map of each park's vegetation, based on aerial photography less than five years old, is one of the 12 inventories recommended by the program (NPS 2003a). In addition, the Fire Management Program's Wildland Fire Strategic Plan identifies mapping fire fuel models in collaboration with the Inventory and Monitoring Program's vegetation mapping projects as a core strategy to provide current and accurate data to fire and resource managers (NPS 2003b).

To ensure that vegetation mapping is standardized across the National Park Service (NPS), The Nature Conservancy (TNC), in conjunction with NatureServe, the Federal Geographic Data Committee (FGDC), and the Ecological Society of America Vegetation Subcommittee (ESAVS), developed a protocol for creating vegetation maps in national parks. This protocol was adopted by the United States Geological Survey (USGS)/NPS Vegetation Mapping Program as the standard (TNC and Environmental Systems Research Institute [ESRI] 1994a,b,c) and has been implemented at the Delaware Water Gap National Recreation Area (DEWA) by the Pennsylvania Natural Heritage Program (PANHP).

The goal of the vegetation mapping effort at the Delaware Water Gap National Recreation Area was to produce an up-to-date digital geospatial vegetation database for the park and to provide a vascular plant species list, a dichotomous key for vegetation associations, and descriptions of the vegetation associations in the park. Baseline information on plant community composition and rarity is critical to developing desired conditions and park management goals relating to native plant communities, nonnative plant and insect species, and effects of deer browse and other disturbances. The identification and description of plant communities also provide habitat information important to understanding associated organisms, including animals, protozoans, bacteria, and fungi. A map of vegetation associations may allow inferences about the location and abundance of species that are associated with each community.

This report also describes the park's vegetation in the context of a national and regional vegetation classification. The Nature Conservancy, in conjunction with NatureServe, the Federal Geographic Data Committee, and the Ecological Society of America Vegetation Subcommittee, developed the National Vegetation Classification System (NVCS) in order to standardize vegetation classification and facilitate the comparison of vegetation types throughout the United States and internationally. The NVCS is a systematic approach to classifying existing natural vegetation using physiognomics and floristics. This classification system has a hierarchical structure (Grossman et al. 1998).

The basic unit of vegetation classification in the NVCS is the association. An association is defined as a plant community type that is relatively homogeneous in composition and structure and occurs in a uniform habitat. For example, Northeastern Dry Oak - Hickory Forest is a common forest type on well-drained, acidic midslopes in the northeastern United States. Associations are also assigned global rarity ranks that indicate their conservation status and relative risk of extirpation (Grossman et al. 1998). Associations from the NVCS are often equivalent to communities in state-specific vegetation classifications, such as the Terrestrial and Palustrine Plant Communities of Pennsylvania (Fike 1999) or the Draft New Jersey Ecological Community Crosswalk (Walz et al. 2006). Therefore, NVCS associations can usually be crosswalked with communities in these state classifications.

Several associations that share one or more dominant or characteristic species can be grouped to form an alliance. Alliances are generally more wide-ranging geographically than associations, covering multiple habitats and broader species composition. For example, the Northeastern Dry Oak - Hickory Forest association mentioned previously is grouped with other similar oak-dominated forest associations into the White Oak - (Northern Red Oak, Hickory species) Forest Alliance. An association with unique species composition or environmental niche can be assigned to its own alliance, such that the alliance only contains one association instead of multiple associations.

One level above alliance is the formation, representing vegetation types that share a common physiognomy within broadly defined environmental factors (Grossman et al. 1998). For example, Lowland or submontane cold-deciduous forest is a common formation that encompasses numerous forest types in the northeastern and midwestern United States, including the White Oak - (Northern Red Oak, Hickory species) Forest Alliance mentioned above.

One of the core strategies identified in the Wildland Fire Strategic Plan is to implement a collaborative vegetation and fuels mapping program between the National Park Service Fire Management Program and the Inventory and Monitoring Program (NPS 2003b). The mission statement of the National Park Service Fire Management Program is to protect lives, property, and resources while restoring and maintaining healthy ecosystems. One of the guiding principles of the NPS Fire Management Program is to provide current and accurate data for fire and resource managers. Spatial databases of fire behavior fuel models, forest condition, and canopy closure are examples of the types of data that are essential for fire and resource managers to adequately protect park and adjacent landowners' resources.

FARSITE is a fire growth simulation model that can be used in fire management and preparedness planning (Finney 1998). It incorporates spatial information on fuels, fire behavior, topography, weather, and wind to predict fire spread under various scenarios. In order for FARSITE to model fire spread in a specific park five spatial data inputs are required: elevation, slope, aspect, fire fuel model, and canopy cover. For the Delaware Water Gap National Recreation Area the first three data layers (elevation, slope, and aspect) can be derived from the existing digital elevation model developed by North Carolina State University for the park in 2005. The two remaining data layers (fire behavior fuel model and canopy cover) have been developed by the Pennsylvania Natural Heritage Program and are presented as part of this report.

The fire behavior fuel models described by Anderson (1982) are the most commonly used standard fuel model inputs for FARSITE. Anderson (1982) described 13 fuel models that are classified into four groups—grasses, brush, timber, and slash. These fuel models are tools to realistically estimate fire behavior. Each fuel model represents certain fire behavior that is related to fuel load, fuel depth, ratio of surface area to volume for fuel particle size classes, and fuel moisture. These variables are critical to predicting whether a fire will ignite in a given vegetation type and to describing its rate of spread and intensity under varying environmental conditions. The 13 fuel models were created for severe conditions when wildfires pose the greatest risk to natural resources (Anderson 1982). Fire resource managers for the Delaware Water Gap National Recreation Area requested that Anderson fuel models be used in the fuel model mapping at this park. The canopy cover map created for the Delaware Water Gap National Recreation Area uses four cover classes that are standard to the FARSITE program (Finney 1998).

Park-specific Information

The Delaware Water Gap National Recreation Area was established in 1965 with the intent of providing recreational opportunities in conjunction with the proposed Tocks Island Dam Project and the resulting reservoir (Albert 2002). Authorized by Congress in 1962, the Tocks Island Dam Project had a footprint of approximately 9,300 ha (23,000 ac), with the proposed impoundment stretching 59.5 km (37 mi) upstream and the tail waters reaching above Port Jervis, New York. The creation of the Delaware Water Gap National Recreation Area added another 19,000 ha (47,000ac) to the project area. Opposition to the dam began to grow during the late 1960s and gained momentum during the early 1970s due to private property, and later, environmental issues. Finally, in 1975, the Delaware River Basin Commission (DRBC) voted to stop the dam project with New York, New Jersey, and Delaware voting against the project; only Pennsylvania voted for the project, while the federal government abstained. Subsequently, in 1978, the reach of the river originally proposed for the reservoir was declared by Congress as part of the National Wild and Scenic Rivers System. While the dam project was inactive, it was not formally de-authorized until 1992 (Albert 2002).

Delaware Water Gap National Recreation Area now covers 27,945 ha (69,052 ac) and includes the area authorized for the recreation area in 1965 as well as the area acquired for the now-defunct Tocks Island Dam Project. The park stretches from its southern terminus at the Delaware Water Gap to the town of Milford, Pennsylvania at the northern terminus, a distance of approximately 55 km (34 mi). The majority of the land parcels within the park boundary are owned by the federal government, covering 23,715 ha (58,601 ac) or 84.9% of park. Approximately 2,620 ha (6,474 ac; 9.4% of park) is owned by the Commonwealth of Pennsylvania or the state of New Jersey, and includes Worthington State Forest, Delaware River Joint Toll Bridge Commission property, Walpack Wildlife Management Area, and other miscellaneous land. An additional 310 ha (766 ac; 1.1% of park) is owned by various county, town, and borough governments, typically as watershed lands, roads, rights-of-way, and parks. At present, there are also 1,300 ha (3,212 ac; 4.7% of park) of private property inholdings within the park, including a mix of residences, small businesses, and communication towers. Approximately five million people visit the park each year to enjoy hiking trails, canoeing, fishing, scenic drives, and other activities.

Project Area

Location and Regional Setting

The Delaware Water Gap National Recreation Area is located along the Delaware River and includes portions of Pike, Monroe, and Northampton counties in Pennsylvania, and Sussex and Warren counties in New Jersey (Figure 1). The park covers portions of eleven 1:24,000 USGS topographic quadrangle maps: Portland, Stroudsburg, East Stroudsburg, Bushkill, Flatbrookville, Lake Maskenozha, Culvers Gap, Milford, Edgemere, Newton West, and Port Jervis South (Figure 2).

The park occurs primarily within two sections of two physiographic provinces, the Low Glaciated Plateau Section of the Appalachian Plateau Province and the Appalachian Mountain Section of the Ridge and Valley Province. The extreme southern end of the park (south of the Kittatinny Ridge) lies in a third section, the Great Valley Section of the Ridge and Valley Province (Epstein 2001b) (Figure 3).

The Low Glaciated Plateau Section of the Appalachian Plateau Province is restricted to the western portion of the park, west of the Delaware River Valley. This section extends from approximately Bushkill to Milford within the park (total area approximately 6,000 ha). The east edge of the Glaciated Low Plateau Section is characterized by steep shale and siltstone slopes and cliffs which have been over-steepened by glacial scouring and erosion during the last Pleistocene glaciation (Epstein 2001a; Witte 2001a, 2001b). The terrain of the Low Glaciated Plateau generally consists of relatively straight valleys separated by irregular intervening ridges with moderate and variable relief and numerous small water bodies (Briggs 1999).

The Appalachian Mountain Section of the Ridge and Valley Province is the largest section within the park, covering approximately 21,000 ha (52,000 ac). This section includes the Kittatinny Ridge and extends to the south and east to the western edge of Minisink Valley (more or less the historical floodplain of the Delaware River). This area also includes several smaller ridges to the northwest of the Kittatinny Ridge. The Great Valley Section of the Ridge and Valley Province is limited to a small area of rolling hills south of the Delaware Water Gap on both sides of the Delaware River and is bounded on the north by the Kittatinny Ridge (Epstein 2001a).

Park Environmental Attributes

The vegetation of the region is generally classified as Appalachian Oak Forest, typically dominated by white oak (*Quercus alba*) and northern red oak (*Quercus rubra*), with sugar maple (*Acer saccharum*), sweet birch (Betula lenta), bitternut hickory (*Carya cordiformis*), American beech (*Fagus grandifolia*), and tuliptree (*Liriodendron tulipifera*) as associates (Braun 1950). Many environmental factors, such as geology, topography, soils, hydrology, and fire, affect the types and distribution of vegetation within Delaware Water Gap National Recreation Area.

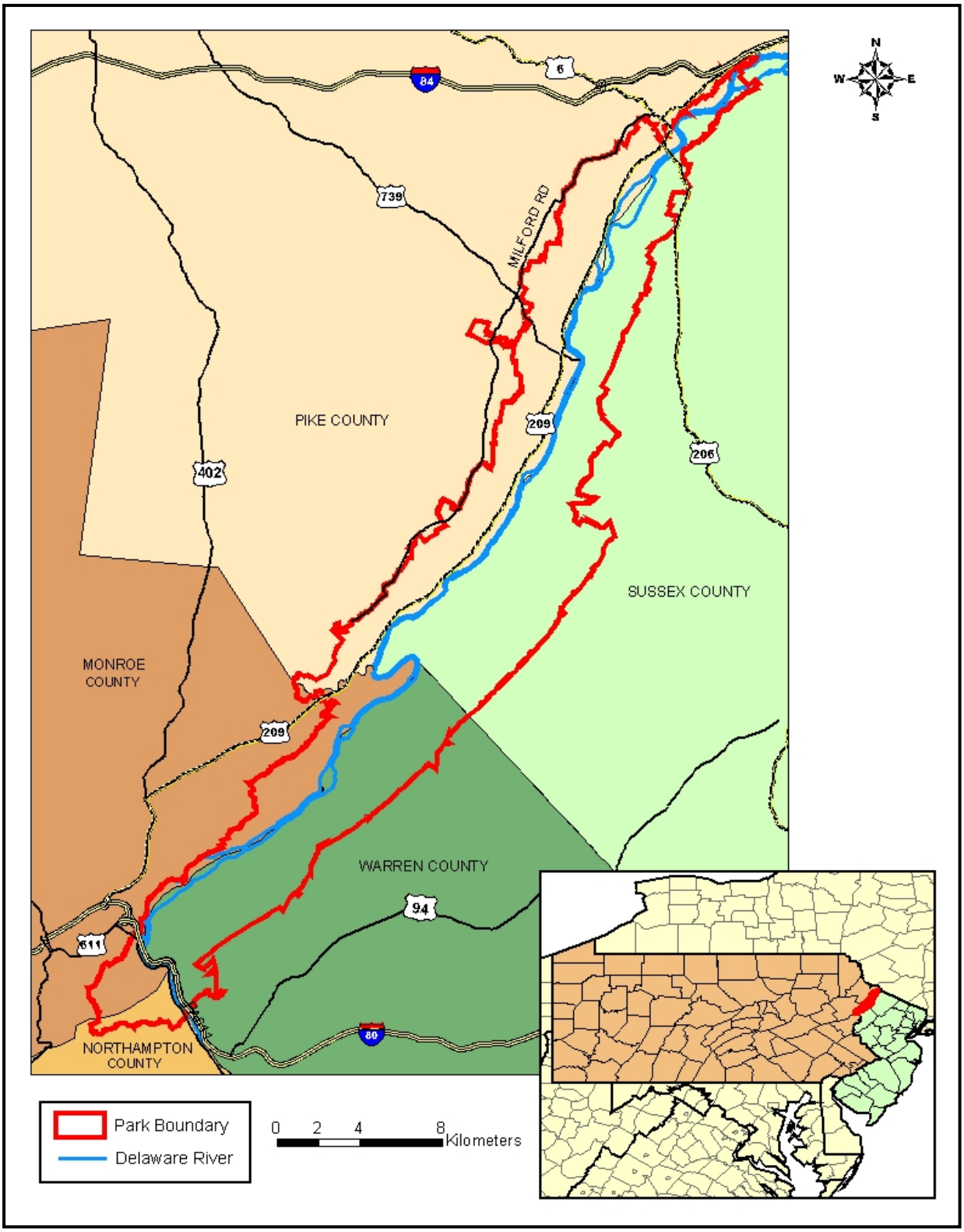

Figure 1. Location of Delaware Water Gap National Recreation Area in Northampton, Monroe, and Pike counties, Pennsylvania, and Warren and Sussex counties, New Jersey.

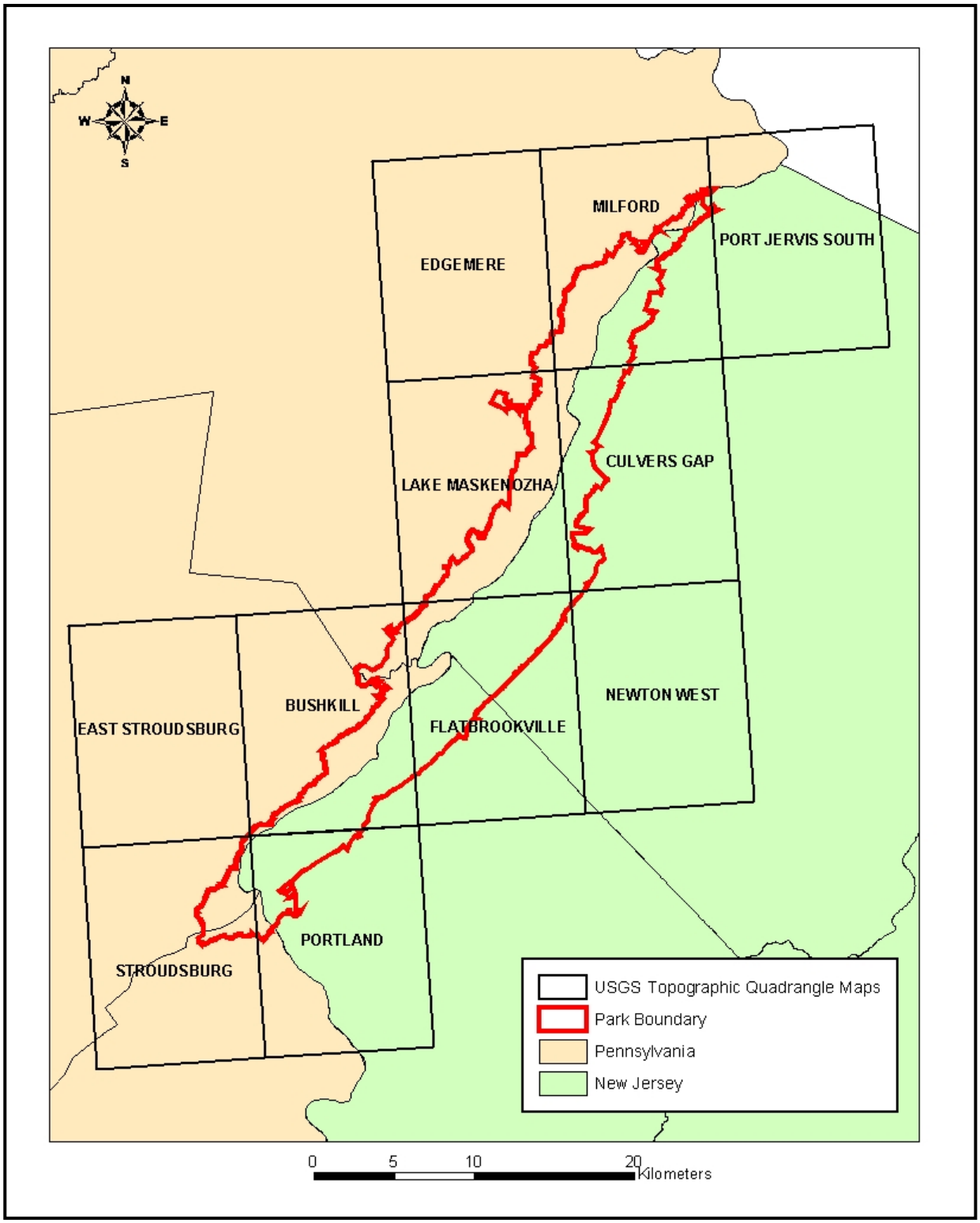

Figure 2. Location of Delaware Water Gap National Recreation Area on eleven 1:24,000 USGS topographic quadrangle maps.

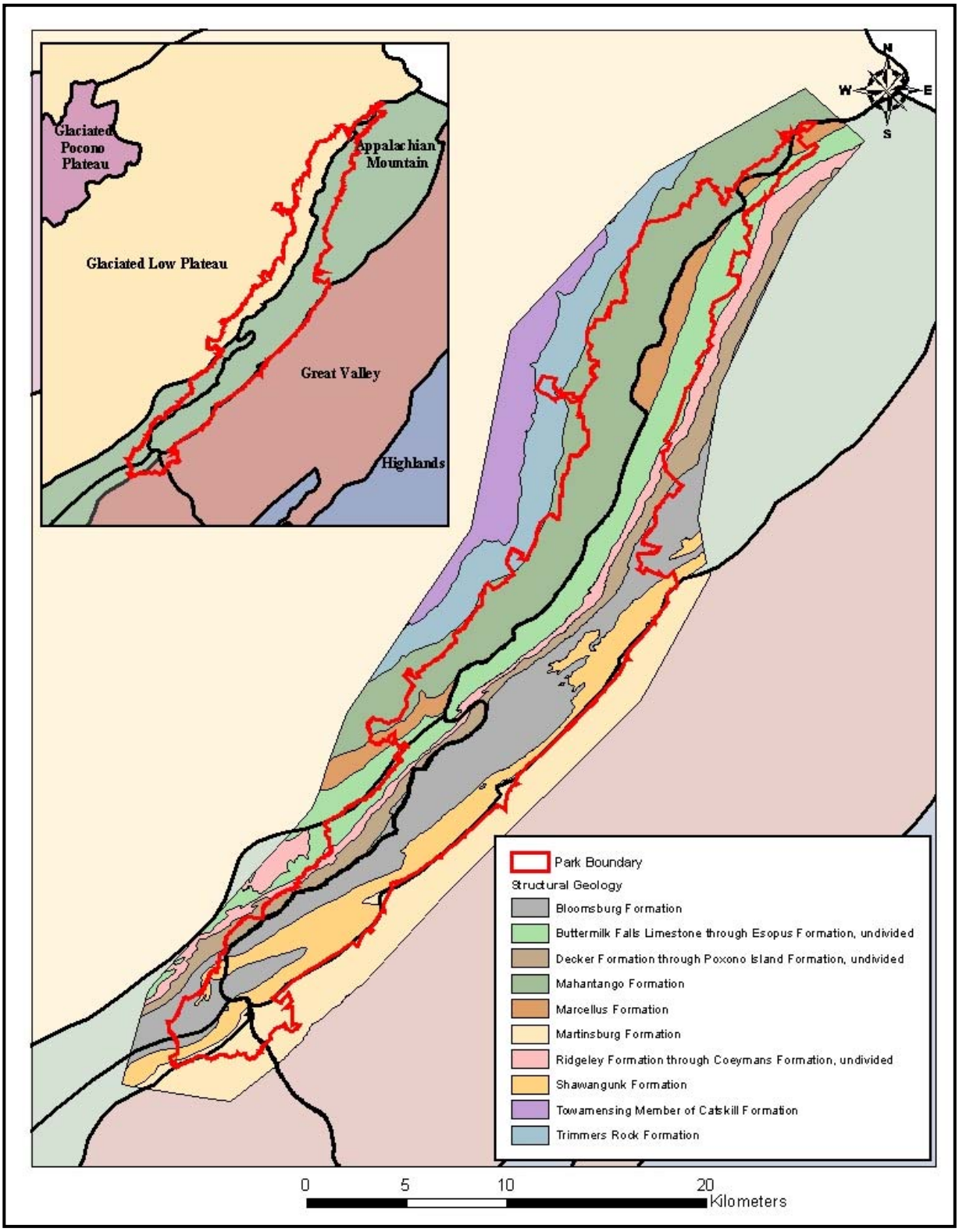

Figure 3. Physiographic province sections and structural geology of Delaware Water Gap National Recreation Area.

Geology

The structural geology of the park differs greatly among the sections of the physiographic provinces (Epstein 2001b) (Figure 3). The bedrock of the Low Glaciated Plateau Section of the Appalachian Plateau Province dips gently to the northwest with occasional gentle folds. The bedrock consists of Middle and Upper Devonian age strata, including the Marcellus Formation (shale and shaly limestone), the Mahantango Formation (siltstone and silty shale), and the Trimmers Rock Formation (siltstone, shale, and fine-grained sandstone). The Marcellus Formation is limited to a narrow band near Bushkill Creek. The Mahantango Formation is the dominant formation within the Low Glaciated Plateau Section of the park and forms the rolling uplands as well as the steep cliffs and escarpments along the western edge of the Delaware River valley. The Trimmers Rock Formation is limited to the extreme western portion of the park and includes the upper portion of Dingmans Creek near Fulmers Falls.

Within the park, the Appalachian Mountain Section of the Ridge and Valley Province consists of strongly folded Ordivician, Silurian, and Devonian age strata. The Ordivician stratum consists of slate and sandstone of the Martinsburg formation. This stratum is limited to the southwestern portion of the park near the Delaware Water Gap where it forms the lowest portion of the southeast facing slope of Kittatinny Mountain. Directly above and to the northwest of the Martinsburg Formation lies the Silurian Shawangunk Formation consisting of (from oldest to youngest): the Minsi Member (quartzite, conglomerate quartzite, and conglomerate), the Lizard Creek Member (thin to thick interbedded quartzite and argillite shale), and the Tammany Member (conglomerate and quartzite). The weather-resistant quartzite beds of the Shawangunk Formation form the ridge and cliffs associated with the Kittatiny Ridge and the Delaware Water Gap. Northwest of the Shawangunk Formation lies the Silurian Bloomsburg Red Beds which lie in the center of the Dunnfield Syncline (along Dunnfield Creek) near the Delaware Water Gap and along the northwest facing slope of most of the Kittatinny Ridge.

Northeast of the Walpack Ridge, the Bloomsburg Red Beds Formation extend from the toeslope of the Flat Brook floodplain to just below the summit of the Kittatinny Ridge (capped by the Shawangunk Formation). The Bloomsburg Red Beds Formation varies in composition from relatively weather-resistant silica-cemented sandstone and sandstone conglomerate to more easily weathered clayey sandstone, siltstone, and shale. Adjacent to the Bloomsburg Red Beds to the northwest are a series of Upper Silurian Formations, mapped as one unit (Decker, Bossardville Limestone, and Poxono Island Formations), which consists of limestone, dolomite, calcareous sandstones and shales, and sandstone, siltstone and sandstone conglomerate. South of Walpack Bend, these formations form the southeast facing slope of the Delaware River valley (including The Hogback) until approximately Shawnee-on-Delaware. North of Walpack Bend these formations trend to the northeast, forming the bottom of the Flat Brook valley and low rolling hills at the foot of the Kittatiny Ridge.

Parallel and to the northeast of the Upper Silurian Formations lie Lower Devonian bedrock consisting of six formations (Ridgely, Shriver Chert, Port Ewen Shale, Minisink Limestone, New Scotland, and Coeymans formations), mapped as one unit (Ridgeley through Coeysmans Formations), in Figure 3. This unit is characterized by numerous alternating beds of limestone, calcareous shale, calcareous sandstone, and sandstone conglomerate. This unit extends approximately from north of Depue Island to the northeast through the ridge of the Hogback at

Walpack Bend, eventually exiting the park near Peters Valley. The topography associated with the formation is low ridges and rolling hills. North of Walpack Bend this formation forms the northwest slope of the Flat Brook valley. The furthest western unit of the the Appalachian Mountain Section of the Ridge and Valley Province consists of Lower to Middle Devonian bedrock of the Esopus (silty shale and siltstone), Schoharie (calcareous siltstone), and Buttermilk Falls (limestone) Formations. The Buttermilk Falls formation is of particular interest as it appears to be associated with several rare calcareous plant communities within the park (Arnot and Montague Fens, Montague Calcareous Riverside Seep, and Calcareous Riverside Outcrop). Northwest of this unit is the transition to the Low Glaciated Plateau Section of the Appalachian Plateau Province, as indicated by the Devonian Age Marcellus Formation as discussed above.

The Great Valley Section of the Ridge and Valley Province occurs at the extreme southern tip of the park, south of Kittatinny Ridge and the Delaware Water Gap. The only geologic unit within the park portion of the Great Valley Section is the Ordivician Age Martinsburg Shale which occurs as relatively flat to gently rolling terrain.

Topography

Topography varies widely within the park. This is illustrated most dramatically at the Delaware Water Gap where the Delaware River (elevation 90 m [300 ft]) cuts through the Kittatinny Ridge creating spectacular views from Mt. Tammany (470 m [1,549 ft]) and Mt. Minsi (445 m [1,461 ft]). The elevation of the Delaware River floodplain decreases as the river runs through the park, from approximately 120 m (400 ft) at Mashipacong Island at the park's northern boundary to approximately 90 m (300 ft) at Arrow Island just south of the Delaware Water Gap. The height of the Kittatinny Ridge varies between 425 m and 487 m (1,400–1,600 ft) with one of the highest points occurring north of Crater Lake at 490 m (1,606 ft). The Hogback and Walpack Ridge run through the central portion of the park with height varying from 210 m to 365 m (700–1,200 ft). The plateau of the Low Glaciated Plateau sits at approximately 245 m to 290 m (800–950 ft), although elevation along the plateau can vary from 210 m to 320 m (700–1,055 ft). The northeast portion of the park in New Jersey gently rises from the Delaware River floodplain at 120 m to approximately 245 m (400–800 ft) at the park's eastern boundary. The valleys surrounding Flat Brook and Bushkill Creek occur at approximately 245 m (400 ft) in elevation.

Soils

Soils in the park vary by topographic position. Typical floodplain soils are fine sandy loams, including Delaware, Pope, Colonie, Barbour, Wallpack, Wyalusing, Philo, and Udifluvent soil series. Lower slopes and valleys tend to contain silt loams and sandy loams, typically Alden silt loam, Chenango gravelly fine sandy loam, Lordstown-Wallpack complex, Scio silt loam, Venango silt loam, Wallpack silt loam, Wellsboro silt loam, and Wyoming gravelly sandy loam. The soils of the Kittatiny Ridge tend to be complexes of rocky loams, silt loams, and sandy loams. Arnot, Benson, DeKalb, Hazen, Hoosic, Lackawanna, Lordstown, Manlius, Mardin, Morris, Nassau, Oquaga, and Otisville are typical soil series found in soil complexes on the ridge. Wetlands that occur at high elevations on the ridge tend to contain Alden mucky silt loam or Catden mucky peat. Soils typical of the Low Glaciated Plateau are rocky loams or soil complexes, primarily Arnot, Manlius, and Mardin, and less commonly, Oquaga, Lordstown,

Benson, Lackawanna, Edgemere, and Shohola series. Wetlands on the Low Glaciated Plateau tend to contain Paupack mucky peat.

Hydrology

The Delaware River, one of the last large free-flowing rivers left in the eastern United States, is the major hydrologic feature around which the park is centered. Nearly 70 km (42 mi) of the 530 km (330 mi) long Delaware River occurs within the park. Several major tributaries and smaller streams flow through the park into the Delaware River. In New Jersey, the Flat Brook is a significant major tributary, running through a valley between the Walpack Ridge and the Kittatiny Ridge from the eastern park boundary to the Delaware River. Buttermilk Falls Brook and Fuller Brook drain from the Kittatiny Ridge into the Flat Brook. Several small tributaries drain directly into the Delaware River from park land in New Jersey; however, Shimer's Brook and White Brook are the only two named streams. Van Campen Brook and Dunnfield Creek are two other major tributaries that originate on top of the Kittatiny Ridge and drain into the Delaware River.

In Pennsylvania, many of the tributaries flow off of the Glaciated Low Plateau through steep ravines that are often dominated by eastern hemlocks (*Tsuga canadensis*) and contain waterfalls of various heights. The larger and most visited of these streams are Raymondskill Creek, Adams Creek, Dingmans Creek, and Toms Creek. Smaller tributaries that flow from the Glaciated Low Plateau into the Delaware River include Conashaugh Creek, Dry Brook, Hornbecks Creek, Spackmans Creek, Alicia's Creek, Broadhead-Heller Creek, Mill Creek, Denmark Creek, VanCampen Creek, and Randall Creek. The Big Bushkill Creek, a major Pennsylvania tributary, is joined by Little Bushkill Creek before it enters the Delaware River just upstream of the Hogback. Three additional tributaries, Broadhead Creek, Cherry Creek, and Caledonia Creek, enter the Delaware River just upstream from the Delaware Water Gap.

Numerous ponds and small lakes are scattered throughout the park, many of which are recreational attractions. The waterbodies on the top of Kittatiny Ridge are either depressions carved by glacial activity, such as Sunfish Pond and Crater Lake, or impoundments created by damming a stream, such as Catfish Pond and Blue Mountain Lake. Most other waterbodies that do not occur on Kittatiny Ridge are impoundments created either by man, such as Egypt Mills Pond and Hidden Lake, or by beaver. Some smaller ponds lie in naturally occurring depressions.

Fire

Historically, fire has been an important influence on the Appalachian forests of the eastern United States. Low-intensity fires were ignited by lightning, as well as by Native Americans and Europeans settlers, who used fire to aid in hunting, to clear land, to maintain open grasslands and woodlands, and to encourage the growth of forage or food plants (Day 1953; Waldrop and Van Lear 1989; Delcourt and Delcourt 1998). The majority of the hardwood forests in the Delaware Water Gap National Recreation Area are adapted to this natural fire regime of frequent, low-intensity, low-severity surface fires that are generally non-lethal to the canopy trees but lethal to the understory vegetation. This fire regime is classified as Natural Fire Regime 1B (Heinselman 1981) or Historic Natural Fire Regime I (Schmidt et al. 2002) and has a return interval of more than 25 years, on average 35 years, between fires (Heinselman 1981; Schmidt et al. 2002). This

historic fire regime is not necessarily representative of the current condition of the park's vegetation.

During the industrial revolution around the turn of the 20th century, high-intensity, catastrophic fires became much more common due to intensive timber harvesting and steam locomotives. The destruction caused by these fires led to the fire suppression and control strategies enforced throughout the 20th century (Waldrop and Van Lear 1989; Shumway et al. 2001; Schuler and McClain 2003). Due to this fire suppression the historic fire regime has been altered. Schmidt et al. (2002) classified the forests in the region around the Delaware Water Gap National Recreation Area as Current Condition Class 2 to 3, indicating that historic fire regimes have been moderately to severely altered, posing a risk to the native ecosystems, and requiring varied levels of restoration treatments. Restoration and maintenance methods could include prescribed fire and hand or mechanical treatments. In general, in the Delaware Water Gap region, fires under "normal" non-drought conditions were determined to be of relatively low risk to homes and other flammable structures for most, but not all, of the fuel models represented (Schmidt et al. 2002).