Results

Vegetation Classification and Characterization

The vegetation associations of the Delaware Water Gap National Recreation Area were classified using iterative Cluster, TWINSPAN, and NMS analyses. Due to the large size of the dataset, it is impractical to include graphical representations of these analyses in this report. The results of these classification analyses were evaluated against each other and compared to the Terrestrial and Palustrine Plant Communities of Pennsylvania (Fike 1999), Draft New Jersey Ecological Community Crosswalk (Walz et al. 2006), National Vegetation Classification System, vegetation classifications at other Pennsylvania national parks, and the ecologists' field experiences at the Delaware Water Gap National Recreation Area. Based on this evaluation, preliminary vegetation associations were identified and a preliminary vegetation association map was created. These preliminary vegetation associations are listed in Table 4.

Thematic accuracy assessment was then conducted on this preliminary vegetation association map. Based on the data collected during accuracy assessment, the following revisions were made:

- Eastern Red-cedar (Pitch Pine) - Prickly Pear Shale Woodland and Hickory - Eastern Red-cedar Rocky Woodland were determined to be the same association and were lumped into the Hickory - Eastern Red-cedar Rocky Woodland association.
- Dry Oak - Heath Woodland and Dry Oak - Heath Forest were combined into the Dry Oak - Heath Forest association in order to maintain consistency with the other terrestrial forest associations that occur both as forests and woodland.
- Leatherleaf Peatland was split into two associations, Leatherleaf Peatland and Highbush Blueberry - Leatherleaf Wetland to more accurately capture the variation in these unique wetlands.
- Successional Eastern Red-cedar (Eastern White Pine) Woodland was split into two associations to better represent the different successional trajectories based on species dominance. Examples of this preliminary association that were dominated by eastern red-cedar were combined with the Eastern Red-cedar Forest association. Examples of this preliminary association that were dominated by eastern white pine were considered a different association, Successional Eastern White Pine Woodland.
- Successional Mixed Hardwood Forest was eliminated because only two of the 30 thematic accuracy assessment points proved to be correct. The polygons in the preliminary association map labeled as Successional Mixed Hardwood Forest were assigned to other associations, often Northeastern Modified Successional Forest.
- Six additional associations identified during the accuracy assessment were not captured in the preliminary classification. These additional associations were Black Walnut Bottomland Forest, Boulder Vernal Pool Sparse Vegetation, Eastern Woodland Vernal Pool Sparse Vegetation, Cattail Marsh, Hairyfruit Sedge Wetland, and Wooded Successional Old Field.
- Some association names were altered in order to better represent the concept of the association.

The resulting final classification described 69 vegetation associations in the Delaware Water Gap National Recreation Area.

Vegetation Association Descriptions

Detailed local descriptions for 69 vegetation associations were written based on plot data, compositional statistics, photographs of each plot, thematic accuracy assessment data, the ecologists' field observations at the Delaware Water Gap National Recreation Area, and the other research cited in the local descriptions. These vegetation associations were then crosswalked to the National Vegetation Classification System which contains range-wide global descriptions for each association. Since the local expression of an association can differ in various locations throughout its range, the local description provides information on the park-specific expression of the type. The global description provides the broader concept of the association and may include plant species that do not occur in the park, but are typical of the association elsewhere in its range.

One association, Wooded Successional Old Field, is a park-specific local vegetation type that is not represented in the NVCS and therefore is not attributed with a global description. Detailed local and global descriptions of the vegetation associations are contained in Appendix G in Volume 2 of this report; where representative photographs of each vegetation association from the Delaware Water Gap National Recreation Area are provided after each description.

Each association is also crosswalked to the state classifications for Pennsylvania and New Jersey (Fike 1999; Walz et al. 2006). The state conservation rank (S Rank), global conservation rank (G Rank), and classification confidence for state and global classifications are included in the descriptions. Classification confidence refers to the certainty that the association is accurately described, and that the association is distinct from other similar associations. Definitions of the conservation ranks and classification confidence codes are shown in Appendix H.

A dichotomous key was also developed for the vegetation associations of the Delaware Water Gap National Recreation Area (Appendix D). The dichotomous key should be used in conjunction with the detailed vegetation association descriptions to confirm that the association selected with the key is appropriate. This key and the detailed vegetation association descriptions were used in the thematic accuracy assessment and may be used by park resource managers and others to identify vegetation associations in the park

Vegetation Map Production

Based on the accuracy assessment sampling data and the final classification of 69 vegetation associations, the association level map was revised again to correct errors and create more accurate vegetation association polygon boundaries. In this final revision, accuracy assessment data, plot data, field observations, aerial photography signatures, and topographic maps were used to revise polygon boundaries and attributes. Two associations, Calcareous Seep and Water-willow Emergent Bed, were not mapped because they could not be identified on the spring 2002 aerial photography. The Calcareous Seep occurred under forest canopy and was too small in size to be identified through photointerpretation. The Water-willow Emergent Beds were not visible on the photography due to the higher water levels in the Delaware River in April 2002.

The resulting final vegetation association map is shown in Figure 8 and a summary of the vegetation association distribution and abundance is provided in Table 7. In the final map, several polygons were labeled as mosaics of two separate associations. These polygons were labeled as mosaics because both types were present in the polygons and clear boundaries between the two associations could not be delineated. Polygons that were attributed with modified Anderson level II categories retained their attributes in the final map. An aerial photograph interpretation key for the vegetation associations and Anderson level II categories (modified) is located in Appendix A.

Production of FARSITE Data Layers

The fire behavior fuel model map and the canopy cover class map were also revised based on the accuracy assessment data. The ArcView shapefile containing the fire behavior fuel model and the canopy cover class data was then converted into two raster files with 30 meter grid cell size. The Feature to Raster Conversion Tool in the ArcToolbox function of ArcGIS 9 was used to convert the shapefile into raster files. A cell size of 30 meter was selected so that these ratser files will be compatible with the FARSITE simulation model.

The final fire behavior fuel model map is shown in Figure 9. The fuel models associated with ericaceous shrubs (6, 6/7, and 7) that create more intense fires are shown in red and orange. Table 8 provides a summary of the percent of the park covered by each fuel model. The final canopy cover class map is shown in Figure 10. Table 9 provides a summary of the percent of the park covered by each canopy cover class.

In addition to the fire fuel model mapping, the National Park Service fire specialists requested that areas with large concentrations of dead or dying trees be identified. These areas are predominantly dead or dying standing eastern hemlocks (*Tsuga canadensis*) that have suffered mortality as a result of the hemlock woolly adelgid (*Adelges tsugae*). These dead or dying trees pose an increased fire risk. As the dead trees fall and become large downed debris, they potentially could act as Anderson Fuel Model 13, which is currently not mapped within the park. Figure 11 shows the areas that were identified as containing large concentrations of dead or dying trees. These areas cover 1,023.57 hectares, or 3.7% of the total park area (Table 10). The most common associations in these areas are Eastern Hemlock Forest, Dry Eastern Hemlock - Oak Forest, Eastern Hemlock - Mixed Hardwood Palustrine Forest, and Eastern Hemlock - Northern Hardwood Forest. The two deciduous forest associations (Dry Oak - Mixed Hardwood Forest and Red Maple - Sweet Birch Hardwood Forest) were identified in areas that were formerly mixed eastern hemlock-deciduous forests, but in which nearly all of the eastern hemlocks have died. Conifer Plantation, Dry Eastern White Pine - Oak Forest, and Eastern White Pine Forest also contained very rare isolated areas with large concentrations of dead or dying trees (Table 10).

In addition, FARSITE requires data layers of elevation, slope, and aspect, in 30 meter grid format. These data layers were created from a digital elevation model with a 10 meter cell size. The digital elevation model of the Delaware Water Gap National Recreation Area and environs was originally created by North Carolina State University for the National Park Service. To create the 30 meter elevation data layer, the Aggregation tool was used in ArcToolbox's Spatial Analyst Tools. The mean aggregation technique was employed with a cell factor of 3. To create

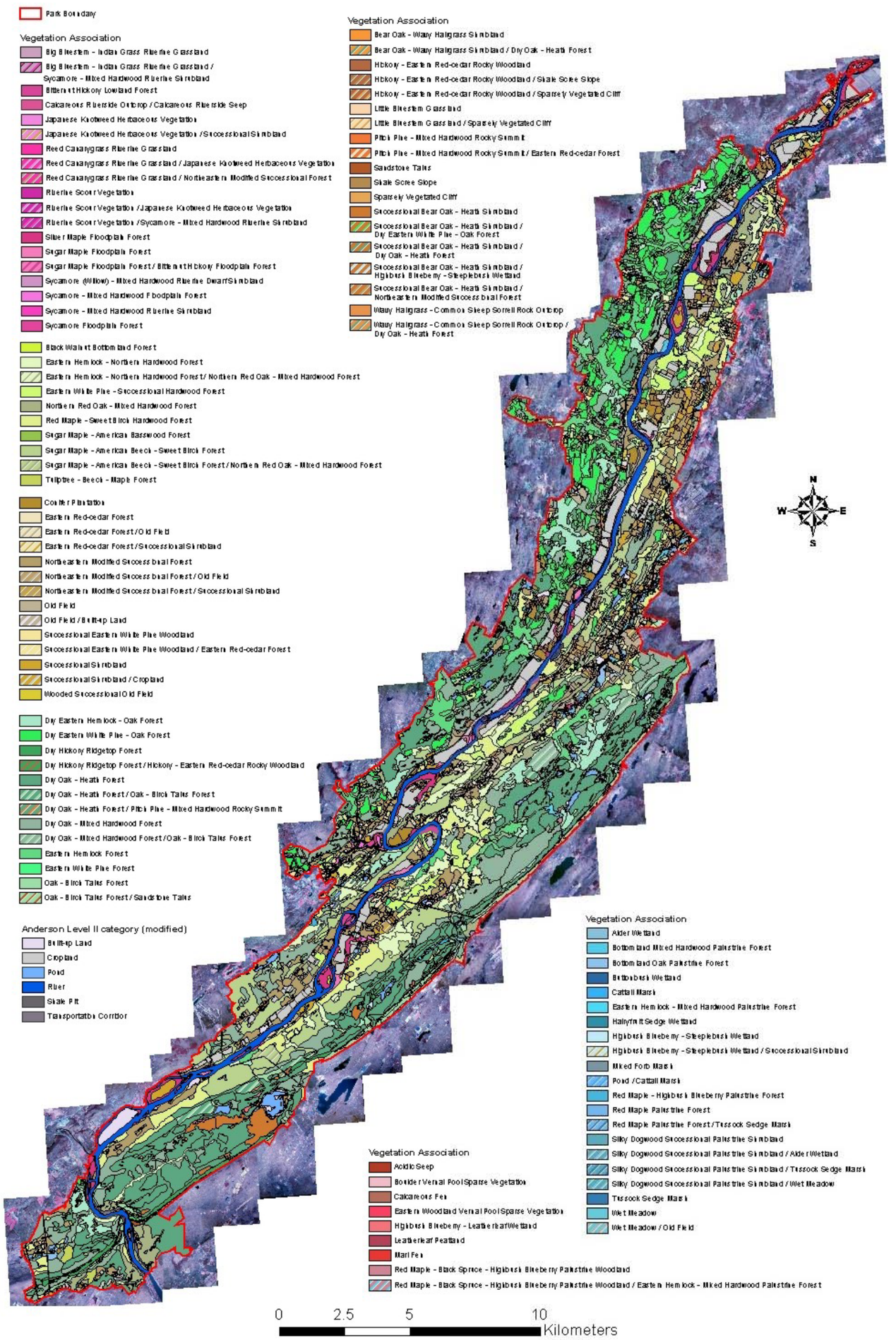

Figure 8. Vegetation associations and Anderson level II categories (modified) in Delaware Water Gap National Recreation Area.

Table 7. Number of polygons and hectares for mapped vegetation associations and Anderson level II categories (modified) in Delaware Water Gap National Recreation Area. Two of the park's associations, Calcareous Seep and Water-willow Emergent Bed, are not listed in this table because they could not be identified on the spring 2002 aerial photography, and thus were not mapped.

Vegetation association or Anderson level II category (modified)	Number of Polygons	Total Mapped Hectares
Acidic Seep	1	0.09
Alder Wetland	2	2.01
Bear Oak - Wavy Hairgrass Shrubland	22	19.28
Bear Oak - Wavy Hairgrass Shrubland / Dry Oak - Heath Forest	2	5.82
Big Bluestem - Indiangrass Riverine Grassland	3	2.78
Big Bluestem - Indiangrass Riverine Grassland / Sycamore - Mixed Hardwood Riverine Shrubland	2	1.65
Bitternut Hickory Lowland Forest	5	24.56
Black Walnut Bottomland Forest	16	34.77
Bottomland Mixed Hardwood Palustrine Forest	20	68.89
Bottomland Oak Palustrine Forest	11	56.21
Boulder Vernal Pool Sparse Vegetation	6	1.50
Built-up Land	136	369.55
Buttonbush Wetland	4	7.12
Calcareous Fen	3	3.53
Calcareous Riverside Outcrop / Calcareous Riverside Seep	4	3.75
Cattail Marsh	2	1.20
Conifer Plantation	206	470.96
Cropland	159	1,268.52
Dry Eastern Hemlock - Oak Forest	107	1,075.41
Dry Eastern White Pine - Oak Forest	252	1,668.61
Dry Hickory Ridgetop Forest	19	152.82
Dry Hickory Ridgetop Forest / Hickory - Eastern Red-cedar Rocky Woodland	1	1.76
Dry Oak - Heath Forest	273	4,416.70
Dry Oak - Heath Forest / Oak - Birch Talus Forest	6	149.94
Dry Oak - Heath Forest / Pitch Pine - Mixed Hardwood Rocky Summit	3	12.59
Dry Oak - Mixed Hardwood Forest	246	2,915.93
Dry Oak - Mixed Hardwood Forest / Oak - Birch Talus Forest	2	118.96
Eastern Hemlock - Mixed Hardwood Palustrine Forest	6	29.82
Eastern Hemlock - Northern Hardwood Forest	149	1,102.80
Eastern Hemlock - Northern Hardwood Forest / Northern Red Oak - Mixed Hardwood Forest	1	12.34
Eastern Hemlock Forest	53	1,013.15
Eastern Red-cedar Forest	36	46.69
Eastern Red-cedar Forest / Old Field	19	31.77
Eastern Red-cedar Forest / Successional Shrubland	14	36.28
Eastern White Pine - Successional Hardwood Forest	76	683.56
Eastern White Pine Forest	98	310.33
Eastern Woodland Vernal Pool Sparse Vegetation	63	7.99
Hairyfruit Sedge Wetland	3	3.91
Hickory - Eastern Red-cedar Rocky Woodland	84	64.86
Hickory - Eastern Red-cedar Rocky Woodland / Shale Scree Slope	1	1.32
Hickory - Eastern Red-cedar Rocky Woodland / Sparsely Vegetated Cliff	29	55.48

Table 7. Number of polygons and hectares for mapped vegetation associations and Anderson level II categories (modified) in Delaware Water Gap National Recreation Area. Two of the park's associations, Calcareous Seep and Water-willow Emergent Bed, are not listed in this table because they could not be identified on the spring 2002 aerial photography, and thus were not mapped (continued).

Vegetation association or Anderson level II category (modified)	Number of Polygons	Total Mapped Hectares
Highbush Blueberry - Leatherleaf Wetland	4	9.31
Highbush Blueberry - Steeplebush Wetland	18	19.01
Highbush Blueberry - Steeplebush Wetland / Successional Shrubland	1	1.98
Japanese Knotweed Herbaceous Vegetation	10	4.26
Japanese Knotweed Herbaceous Vegetation / Successional Shrubland	1	1.98
Leatherleaf Peatland	2	0.82
Little Bluestem Grassland	9	10.28
Little Bluestem Grassland / Sparsely Vegetated Cliff	1	0.34
Marl Fen	1	0.19
Mixed Forb Marsh	14	23.33
Northeastern Modified Successional Forest	523	2,139.29
Northeastern Modified Successional Forest / Old Field	1	1.83
Northeastern Modified Successional Forest / Successional Shrubland	12	49.39
Northern Red Oak - Mixed Hardwood Forest	100	1,076.61
Oak - Birch Talus Forest	42	385.30
Oak - Birch Talus Forest / Sandstone Talus	6	25.97
Old Field	246	532.88
Old Field / Built-up Land	1	0.33
Pitch Pine - Mixed Hardwood Rocky Summit	57	28.55
Pitch Pine - Mixed Hardwood Rocky Summit / Eastern Red-cedar Forest	1	0.55
Pond	207	266.37
Pond / Cattail Marsh	1	3.07
Red Maple - Black Spruce - Highbush Blueberry Palustrine Woodland	7	14.35
Red Maple - Black Spruce - Highbush Blueberry Palustrine Woodland / Eastern Hemlock - Mixed Hardwood Palustrine Forest	1	3.33
Red Maple - Highbush Blueberry Palustrine Forest	39	49.70
Red Maple - Sweet Birch Hardwood Forest	145	1,535.43
Red Maple Palustrine Forest	48	129.40
Red Maple Palustrine Forest / Tussock Sedge Marsh	1	0.47
Reed Canarygrass Riverine Grassland	10	23.00
Reed Canarygrass Riverine Grassland / Japanese Knotweed Herbaceous Vegetation	1	0.64
Reed Canarygrass Riverine Grassland / Northeastern Modified Successional Forest	1	7.16
River	13	1,178.72
Riverine Scour Vegetation	23	15.46
Riverine Scour Vegetation / Japanese Knotweed Herbaceous Vegetation	2	6.03
Riverine Scour Vegetation / Sycamore - Mixed Hardwood Riverine Shrubland	2	5.96
Sandstone Talus	26	18.57
Shale Pit	11	12.19
Shale Scree Slope	21	20.93
Silky Dogwood Successional Palustrine Shrubland	31	50.98
Silky Dogwood Successional Palustrine Shrubland / Alder Wetland	1	6.37
Silky Dogwood Successional Palustrine Shrubland / Tussock Sedge Marsh	1	0.93
Silky Dogwood Successional Palustrine Shrubland / Wet Meadow	4	5.07

Table 7. Number of polygons and hectares for mapped vegetation associations and Anderson level II categories (modified) in Delaware Water Gap National Recreation Area. Two of the park's associations, Calcareous Seep and Water-willow Emergent Bed, are not listed in this table because they could not be identified on the spring 2002 aerial photography, and thus were not mapped (continued).

Vegetation association or Anderson level II category (modified)	Number of Polygons	Total Mapped Hectares
Silver Maple Floodplain Forest	70	509.10
Sparsely Vegetated Cliff	15	18.36
Successional Bear Oak - Heath Shrubland	20	216.69
Successional Bear Oak - Heath Shrubland / Dry Eastern White Pine - Oak Forest	1	0.81
Successional Bear Oak - Heath Shrubland / Dry Oak - Heath Forest	1	1.23
Successional Bear Oak - Heath Shrubland / Highbush Blueberry - Steeplebush Wetland	1	2.15
Successional Bear Oak - Heath Shrubland / Northeastern Modified Successional Forest	1	2.06
Successional Eastern White Pine Woodland	73	108.16
Successional Eastern White Pine Woodland / Eastern Red-cedar Forest	1	4.12
Successional Shrubland	356	858.84
Successional Shrubland / Cropland	1	6.69
Sugar Maple - American Basswood Forest	5	17.10
Sugar Maple - American Beech - Sweet Birch Forest	120	1,706.72
Sugar Maple - American Beech - Sweet Birch Forest / Northern Red Oak Mixed Hardwood Forest	1	42.50
Sugar Maple Floodplain Forest	16	71.35
Sugar Maple Floodplain Forest / Bitternut Hickory Floodplain Forest	1	8.90
Sycamore (Willow) - Mixed Hardwood Riverine Dwarf Shrubland	9	4.43
Sycamore - Mixed Hardwood Floodplain Forest	27	55.08
Sycamore - Mixed Hardwood Riverine Shrubland	20	15.16
Sycamore Floodplain Forest	11	26.43
Transportation Corridor	10	128.89
Tuliptree - Beech - Maple Forest	9	66.05
Tussock Sedge Marsh	20	19.75
Wavy Hairgrass - Common Sheep Sorrell Rock Outcrop	28	9.62
Wavy Hairgrass - Common Sheep Sorrell Rock Outcrop / Dry Oak - Heath Forest	1	0.36
Wet Meadow	53	64.64
Wet Meadow / Old Field	2	5.37
Wooded Successional Old Field	23	52.46
Total	4,687	27,944.52

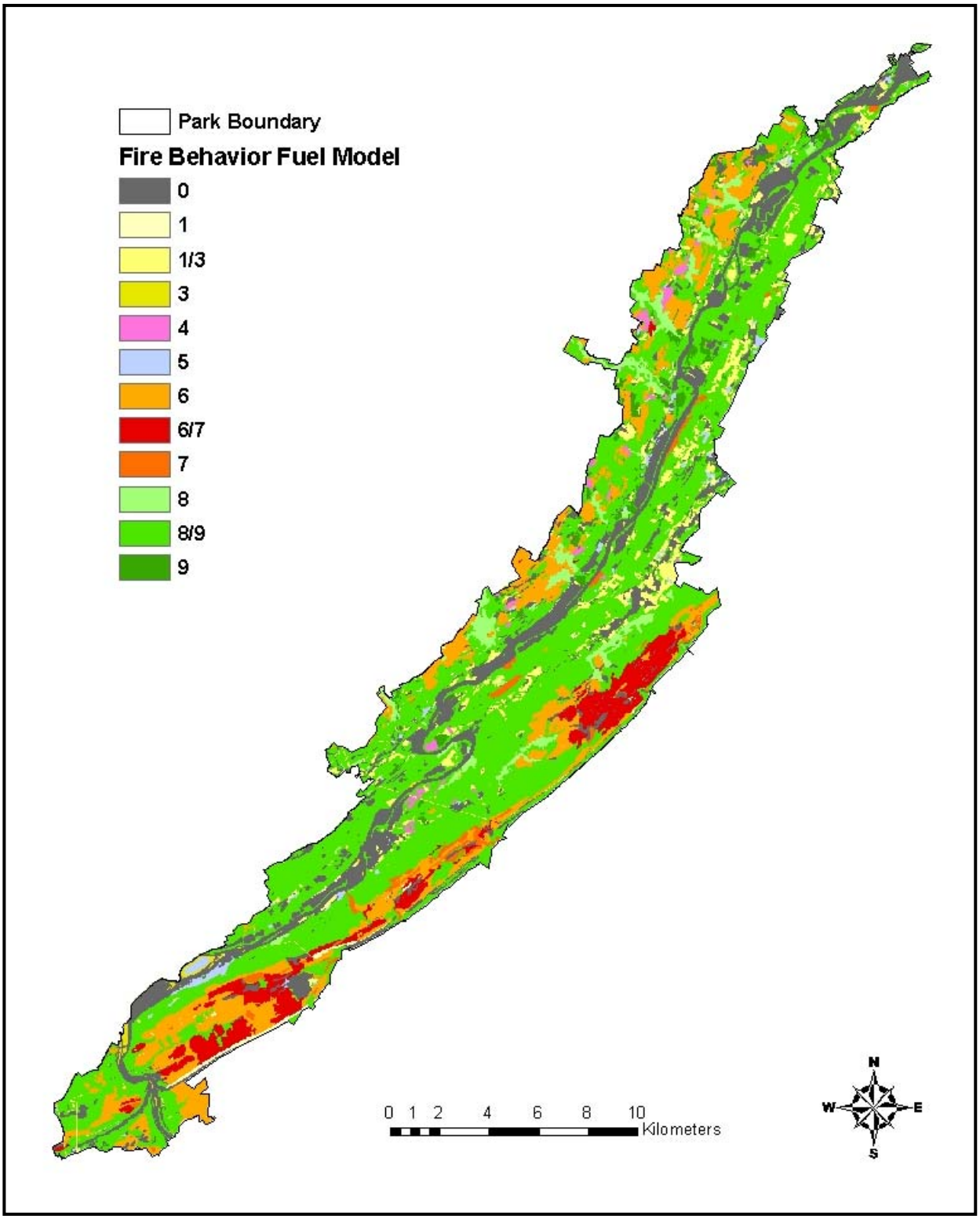

Figure 9. Fire behavior fuel models for Delaware Water Gap National Recreation Area.

Table 8. Summary of the fire behavior fuel model map of Delaware Water Gap National Recreation Area.

Mapped Fuel Model	Total Hectares	Total Acres	Percent of Park
0	4,520.00	11,164.40	16.17%
1	160.02	395.26	0.57%
1/3	1,512.67	3,736.29	5.41%
3	85.95	212.30	0.31%
4	244.45	603.78	0.87%
5	301.33	744.28	1.08%
6	4,015.36	9,917.94	14.37%
6/7	1,462.36	3,612.02	5.23%
7	413.92	1,022.38	1.48%
8	1,036.20	2,559.40	3.71%
8/9	13,553.25	33,476.54	48.50%
9	639.02	1,578.37	2.29%
Total	27,944.52	69,022.96	100.00%

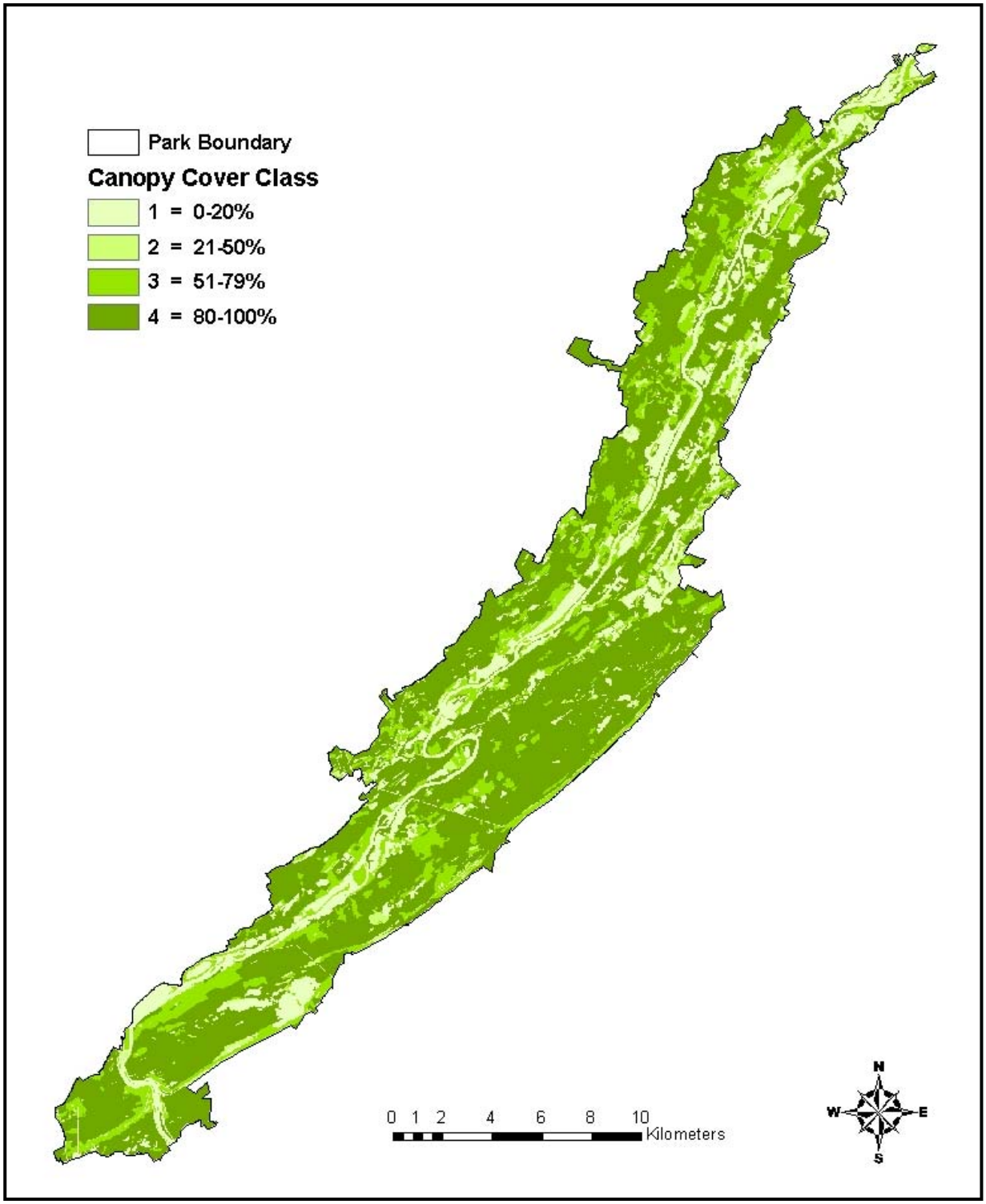

Figure 10. Canopy cover classes in Delaware Water Gap National Recreation Area.

Table 9. Summary of the canopy cover class map of Delaware Water Gap National Recreation Area.

Mapped Canopy Cover Class	Total Hectares	Total Acres	Percent of Park
1	5,286.82	13,058.45	18.92%
2	583.39	1,440.98	2.09%
3	4,766.34	11,772.85	17.06%
4	17,307.97	42,750.68	61.94%
Total	27,944.52	69,022.96	100.00%

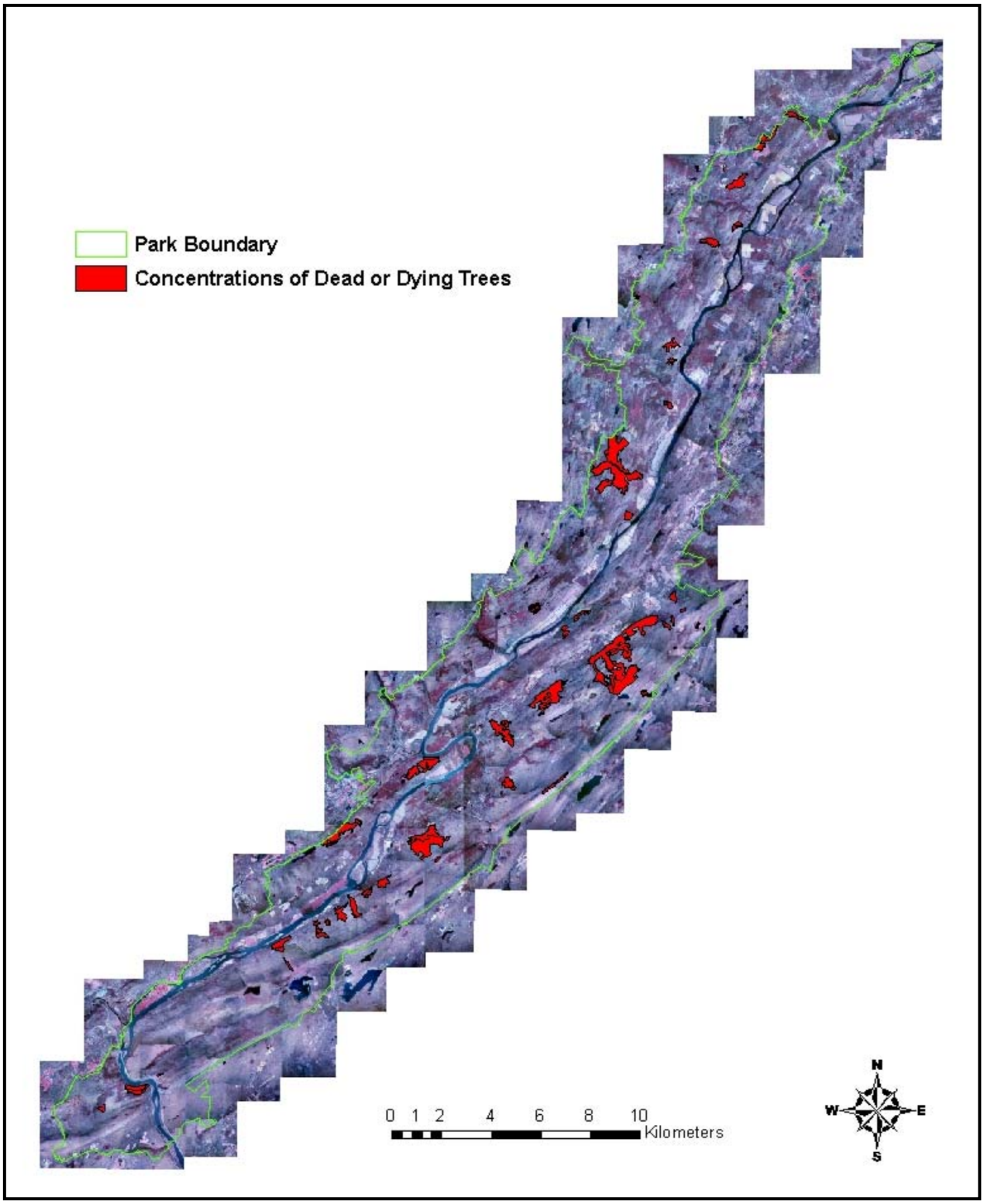

Figure 11. Areas of Delaware Water Gap National Recreation Area characterized by large concentrations of dead or dying trees, typically eastern hemlocks (*Tsuga canadensis*).

Table 10. Summary information for the areas of Delaware Water Gap National Recreation Area containing large concentrations of dead or dying trees, typically eastern hemlocks (*Tsuga canadensis*).

Vegetation Association	Number of Polygons	Total Mapped Hectares	Total Mapped Acres
Conifer Plantation	1	1.66	4.10
Dry Eastern Hemlock - Oak Forest	21	455.01	1,123.87
Dry Eastern White Pine - Oak Forest	2	11.28	27.86
Dry Oak - Mixed Hardwood Forest	3	17.65	43.60
Eastern Hemlock - Mixed Hardwood Palustrine Forest	1	2.71	6.69
Eastern Hemlock - Northern Hardwood Forest	22	308.65	762.37
Eastern Hemlock Forest	9	217.45	537.10
Eastern White Pine Forest	1	5.76	14.23
Red Maple - Sweet Birch Hardwood Forest	1	3.41	8.42
Total	61	1,023.57	2,528.22

the slope data layer, the Slope function in Spatial Analyst's Surface Analysis tool was employed. The output cell size was specified at 30 and degrees was selected as the output measurement. To create the aspect data layer, the Aspect function in Spatial Analyst's Surface Analysis tool was employed, with the cell size specified as 30.

Accuracy Assessment

Positional Accuracy

The horizontal positional accuracy of the mosaic is 2.448 meters which meets Class 1 National Map Accuracy Standards (FGDC 1998b). A copy of the spreadsheet containing the x and y coordinates for each ground control point and the accuracy calculation formula is included in the air photo archive.

Thematic Accuracy

Thematic accuracy assessment for the vegetation association map was calculated with a contingency matrix (Table 11). The final vegetation association classification was used in the contingency table to simplify the record keeping of correct and incorrect sampling points. Errors of omission were calculated for 59 of the 60 mapped vegetation associations. The error of omission could not be calculated for Successional Mixed Hardwood Forest because this type was eliminated in the final classification. Errors of commission were calculated for 60 of the 67 vegetation associations observed during accuracy assessment. The remaining seven vegetation associations were new to the classification and were not included in the preliminary vegetation association map. Therefore, the errors of commission could not be calculated for these associations. One Anderson level II category (modified) was also observed during the accuracy assessment due to errors in mapping.

Based on the contingency matrix (Table 11), the Kappa index for the preliminary vegetation association map was 55.0% ± 2.5%, with the overall percent accuracy calculated as 56.1%. This falls below the USGS/NPS vegetation mapping protocol requirement of 80%. The errors of omission for 11 of the 59 mapped vegetation associations exceeded the USGS/NPS vegetation mapping protocol requirement of 80%, with six associations attaining 100% correct. Twenty-two of the 59 vegetation associations had errors of omission below 50%. The errors of commission for 22 of the 60 vegetation associations observed during the accuracy assessment exceeded the USGS/NPS vegetation mapping protocol requirement of 80%, with 11 vegetation associations attaining 100% correct. Nineteen of the 60 vegetation associations had errors of commission below 50%.

The contingency matrix (Table 11) identifies some common trends in photointerpretation and mapping errors. First, in mixed coniferous - deciduous forest stands, the conifer species were often identified correctly; however, the associated hardwoods were occasionally incorrectly identified. For example, 13 of the 31 accuracy assessment points that were mapped as Eastern Hemlock - Northern Hardwood Forest were actually Dry Eastern Hemlock - Oak Forest. Second, percent cover of conifer trees was often over estimated during aerial photointrepretation. Since the bright pink conifers are obvious on the aerial photography, polygons were often considered to contain more cover of conifers relative to their deciduous associates.

Table 11. Contingency matrix and calculated errors for the thematic accuracy assessment of the vegetation association map of Delaware Water Gap National Recreation Area. The cells highlighted in green show the number of sampling points that were correct. Errors of commission and omission could not be calculated for the associations highlighted in orange because either the association was not included in the preliminary association map, or the association was removed from the final classification. The one modified Anderson level II category that was observed during accuracy assessment is highlighted in blue.

	Mapped Vegetation Association																														
Accuracy Assessment Observation	Acidic Seep	Alder Wetland	Bear Oak - Wavy Hairgrass Shrubland	Big Bluestem - Indiangrass Riverine Grassland	Bitternut Hickory Lowland Forest	Bottomland Hardwood Palustrine Forest	Bottomland Oak Palustrine Forest	Buttonbush Wetland	Calcareous Fen	Calcareous Riverside Outcrop / Calcareous Riverside Seep	Conifer Plantation	Dry Eastern Hemlock - Oak Forest	Dry Eastern White Pine - Oak Forest	Dry Hickory Ridgetop Forest	Dry Oak - Heath Forest	Dry Oak - Mixed Hardwood Forest	Eastern Hemlock - Mixed Hardwood Palustrine Forest	Eastern Hemlock - Northern Hardwood Forest	Eastern Hemlock Forest	Eastern Red-cedar Forest	Eastern White Pine - Successional Hardwood Forest	Eastern White Pine Forest	Hickory - Eastern Red-cedar Rocky Woodland	Highbush Blueberry - Steeplebush Wetland	Japanese Knotweed Herbaceous Vegetation	Leatherleaf Peatland	Little Bluestem Grassland	Mud Fen	Mixed Forb Marsh	Northeastern Modified Successional Forest	Northern Red Oak - Mixed Hardwood Forest
Acidic Seep	1																														
Alder Wetland		2																													
Bear Oak - Wavy Hairgrass Shrubland			1												1								3				1				
Big Bluestem - Indian Grass Riverine Grassland				3																											
Bitternut Hickory Lowland Forest					2																										
Black Walnut Bottomland Forest						1																								1	
Bottomland Hardwood Palustrine Forest						7	1																								1
Bottomland Oak Palustrine Forest						2	2																								
Boulder Vernal Pool Sparse Vegetation																													4		
Buttonbush Wetland								4																							
Calcareous Fen									3																						
Calcareous Riverside Outcrop										2																					
Calcareous Riverside Seep										1																					
Cattail Marsh																													1		
Conifer Plantation											27		1								4	1									
Dry Eastern Hemlock - Oak Forest												12			1			13	11			3									
Dry Eastern White Pine - Oak Forest												1	20					1			2	5								1	
Dry Hickory Ridgetop Forest			1											13	3								2								
Dry Oak - Heath Forest												4	1	2	42	3															
Dry Oak - Mixed Hardwood Forest												8	1	4	10	23		1													4
Eastern Hemlock - Mixed Hardwood Palustrine Forest																	2	2													
Eastern Hemlock - Northern Hardwood Forest												1					1	11	2												
Eastern Hemlock Forest																			14		1	1									
Eastern Red-cedar Forest																				12										1	
Eastern White Pine - Successional Hardwood Forest											1	1	6					1	1		17	1								1	
Eastern White Pine Forest											1		1						2	1		19									
Eastern Woodland Vernal Pool Sparse Vegetation																															
Harryfruit Sedge Wetland																															
Hickory - Eastern Red-cedar Rocky Woodland			1																				35								
Highbush Blueberry - Leatherleaf Wetland																										1					
Highbush Blueberry - Steeplebush Wetland																								2					2		
Japanese Knotweed Herbaceous Vegetation																									2						
Leatherleaf Peatland																										1					
Little Bluestem Grassland																											2				
Mud Fen																												1			
Mixed Forb Marsh																								1					9		
Northeastern Modified Successional Forest						1					1				1			1		3	4		1							20	2
Northern Red Oak - Mixed Hardwood Forest												2				4		1												1	11
Oak Talus Forest														1	1																1
Old Field																											1			1	
Pitch Pine - Mixed Hardwood Rocky Summit																														1	
Pond																													3		
Red Maple - Black Spruce - Highbush Blueberry Palustrine Woodland																															
Red Maple - Highbush Blueberry Palustrine Forest						2																		1							
Red Maple - Sweet Birch Hardwood Forest															2															1	3
Red Maple Palustrine Forest						2															1									1	3
Reed Canarygrass Riverine Grassland																															
Riverine Scour Vegetation				1						1															1						
Sandstone Talus																															
Shale Scree Slope																							8								
Silky Dogwood Successional Palustrine Shrubland																													1		
Silver Maple Floodplain Forest																													1		
Sparsely Vegetated Cliff																															
Successional Bear Oak - Heath Shrubland			1												2																
Successional Eastern White Pine Woodland																														1	
Successional Shrubland						1									1								1								
Sugar Maple - American Basswood Forest																															
Sugar Maple - American Beech - Sweet Birch Forest							1									1					1										4
Sugar Maple Floodplain Forest						2																									1
Sycamore - Mixed Hardwood Floodplain Forest						1	1																								
Sycamore - Mixed Hardwood Riverine Shrubland																															
Sycamore (Willow) - Mixed Hardwood Riverine Dwarf Shrubland				1																											
Sycamore Floodplain Forest																									2						
Tulptree - Beech - Maple Forest					1																										
Tussock Sedge Marsh																								1					4		
Wavy Hairgrass - Common Sheep Sorrell Rock Outcrop			1																												
Wet Meadow																													4		
Wooded Successional Old Field																															
Total	1	2	5	5	3	19	5	4	3	4	30	29	30	20	64	31	3	31	30	16	30	30	50	5	5	2	4	1	29	30	30
Producer's Accuracy (Percent Correct)	100.00%	100.00%	20.00%	60.00%	66.67%	36.84%	40.00%	100.00%	100.00%	75.00%	90.00%	41.38%	66.67%	65.00%	65.63%	74.19%	66.67%	35.48%	46.67%	75.00%	56.67%	63.33%	70.00%	40.00%	40.00%	50.00%	50.00%	100.00%	31.03%	66.67%	36.67%
Error of Omission (1 - Producer's Accuracy)	0.00%	0.00%	80.00%	40.00%	33.33%	63.16%	60.00%	0.00%	0.00%	25.00%	10.00%	58.62%	33.33%	35.00%	34.38%	25.81%	33.33%	64.52%	53.33%	25.00%	43.33%	36.67%	30.00%	60.00%	60.00%	50.00%	50.00%	0.00%	68.97%	33.33%	63.33%

Table 11 Contingency matrix and calculated errors for the thematic accuracy assessment of the vegetation association map of Delaware Water Gap National Recreation Area. The cells highlighted in green show the number of sampling points that were correct. Errors of commission and omission could not be calculated for the associations highlighted in orange because either the association was not included in the preliminary association map, or the association was removed from the final classification. The one modified Anderson level II category that was observed during accuracy assessment is highlighted in blue (continued).

	Mapped Vegetation Association																																
Accuracy Assessment Observation	Oak Talus Forest	Old Field	Pitch Pine - Mixed Hardwood Rocky Summit	Red Maple - Black Spruce - Highbush Blueberry Woodland	Red Maple - Highbush Blueberry Palustrine Forest	Red Maple - Sweet Birch Hardwood Forest	Red Maple Palustrine Forest	Reed Canarygrass Riverine Grassland	Riverine Scour Vegetation	Sandstone Talus	Shale Scree Slope	Silky Dogwood Successional Palustrine Shrubland	Silver Maple Floodplain Forest	Sparsely Vegetated Cliff	Successional Bear Oak - Heath Shrubland	Successional Eastern White Pine Woodland	Successional Mixed Hardwood Forest	Successional Shrubland	Sugar Maple - American Basswood Forest	Sugar Maple - American Beech - Sweet Birch Forest	Sugar Maple Floodplain Forest	Sycamore - Mixed Hardwood Floodplain Forest	Sycamore - Mixed Hardwood Riverine Shrubland	Sycamore (Willow) - Mixed Hardwood Riverine Dwarf Shrubland	Sycamore Floodplain Forest	Tulipitree - Beech - Maple Forest	Tussock Sedge Marsh	Wavy Hairgrass - Common Sheep Sorrell Rock Outcrop	Wet Meadow	Grand Total	User's Accuracy (Percent Correct)	Error of Commission (1 - User's Accuracy)
Acidic Seep																															1	100.00%	0.00%
Alder Wetland																													1	3	66.67%	33.33%
Bear Oak - Wavy Hairgrass Shrubland			1												1															8	12.50%	87.50%
Big Bluestem - Indiangrass Riverine Grassland																														3	100.00%	0.00%
Bitternut Hickory Lowland Forest													2								1									5	40.00%	60.00%
Black Walnut Bottomland Forest		2																	1		1									6	N/A	N/A
Bottomland Hardwood Palustrine Forest						1						1	1																1	13	53.85%	46.15%
Bottomland Oak Palustrine Forest							1					2																		7	28.57%	71.43%
Boulder Vernal Pool Sparse Vegetation																														4	N/A	N/A
Buttonbush Wetland																														4	100.00%	0.00%
Calcareous Fen																														3	100.00%	0.00%
Calcareous Riverside Outcrop																														2	100.00%	0.00%
Calcareous Riverside Seep																														1	100.00%	0.00%
Cattail Marsh																														1	N/A	N/A
Conifer Plantation																														33	81.82%	18.18%
Dry Eastern Hemlock - Oak Forest	2																			1										43	27.91%	72.09%
Dry Eastern White Pine - Oak Forest						1																								31	64.52%	35.48%
Dry Hickory Ridgetop Forest	2		1												1															23	56.52%	43.48%
Dry Oak - Heath Forest	3		4			1									7		1			1										69	60.87%	39.13%
Dry Oak - Mixed Hardwood Forest						3									3		2			4						2				65	35.38%	64.62%
Eastern Hemlock - Mixed Hardwood Palustrine Forest				1																1										6	33.33%	66.67%
Eastern Hemlock - Northern Hardwood Forest																				1										16	68.75%	31.25%
Eastern Hemlock Forest																														16	87.50%	12.50%
Eastern Red-cedar Forest																														13	92.31%	7.69%
Eastern White Pine - Successional Hardwood Forest																														29	58.62%	41.38%
Eastern White Pine Forest																1		1												26	73.08%	26.92%
Eastern Woodland Vernal Pool Sparse Vegetation							1																							1	N/A	N/A
Hairyfruit Sedge Wetland									1																				2	3	N/A	N/A
Hickory - Eastern Red-cedar Rocky Woodland											1																			37	94.59%	5.41%
Highbush Blueberry - Leatherleaf Wetland				2																										3	N/A	N/A
Highbush Blueberry - Steeplebush Wetland							2					1			2														1	10	20.00%	80.00%
Japanese Knotweed Herbaceous Vegetation								1	2																					5	40.00%	60.00%
Leatherleaf Peatland																														1	100.00%	0.00%
Little Bluestem Grassland														2																4	50.00%	50.00%
Marl Fen																														1	100.00%	0.00%
Mixed Forb Marsh																														10	90.00%	10.00%
Northeastern Modified Successional Forest		1				6	2						1		1		13	6		1	3								1	69	28.99%	71.01%
Northern Red Oak - Mixed Hardwood Forest	4					3	1						2				1		7	8	3					4				52	21.15%	78.85%
Oak Talus Forest	18																													21	85.71%	14.29%
Old Field		21						1										2										1		27	77.78%	22.22%
Pitch Pine - Mixed Hardwood Rocky Summit			22											1																24	91.67%	8.33%
Pond							1																						1	5	N/A	N/A
Red Maple - Black Spruce - Highbush Blueberry Palustrine Woodland				2																										2	100.00%	0.00%
Red Maple - Highbush Blueberry Palustrine Forest				1	4		7																							15	26.67%	73.33%
Red Maple - Sweet Birch Hardwood Forest	1					6											6			2						3				24	25.00%	75.00%
Red Maple Palustrine Forest							12					1					2										1			23	52.17%	47.83%
Reed Canarygrass Riverine Grassland								2	2																				2	6	33.33%	66.67%
Riverine Scour Vegetation									9													1	1							14	64.29%	35.71%
Sandstone Talus										27																				27	100.00%	0.00%
Shale Scree Slope											4																			12	33.33%	66.67%
Silky Dogwood Successional Palustrine Shrubland					1							20										1								23	86.96%	13.04%
Silver Maple Floodplain Forest													20				1				2	2								26	76.92%	23.08%
Sparsely Vegetated Cliff														9														1		10	90.00%	10.00%
Successional Bear Oak - Heath Shrubland			1											1	14															19	73.68%	26.32%
Successional Eastern White Pine Woodland		1														16														18	88.89%	11.11%
Successional Shrubland		6										3				1		21											1	35	60.00%	40.00%
Sugar Maple - American Basswood Forest																			7											7	100.00%	0.00%
Sugar Maple - American Beech - Sweet Birch Forest						8	2										2		5	10	2					3				39	25.64%	74.36%
Sugar Maple Floodplain Forest												1	3				1				7	1								16	43.75%	56.25%
Sycamore - Mixed Hardwood Floodplain Forest																					1	20			3					26	76.92%	23.08%
Sycamore - Mixed Hardwood Riverine Shrubland									5														4	4						13	38.77%	69.23%
Sycamore (Willow) - Mixed Hardwood Riverine Dwarf Shrubland																								1						2	50.00%	50.00%
Sycamore Floodplain Forest													1									5			2					10	20.00%	80.00%
Tulipitree - Beech - Maple Forest	1					1	1													1						8				13	61.54%	38.46%
Tussock Sedge Marsh																											3		2	10	30.00%	70.00%
Wavy Hairgrass - Common Sheep Sorrell Rock Outcrop														1	1													3		6	50.00%	50.00%
Wet Meadow								1	1			1															1		19	27	70.37%	29.63%
Wooded Successional Old Field		1														1	1													3	N/A	N/A
Total	31	32	29	6	5	30	30	5	20	27	5	30	30	14	30	19	30	30	20	30	20	30	5	5	5	20	5	5	31	1130		
Producer's Accuracy (Percent Correct)	58.06%	65.63%	75.86%	33.33%	80.00%	20.00%	40.00%	40.00%	45.00%	100.00%	80.00%	66.67%	66.67%	64.29%	46.67%	84.21%	N/A	70.00%	35.00%	33.33%	35.00%	66.67%	80.00%	20.00%	40.00%	40.00%	60.00%	60.00%	61.29%			
Error of Commission (1 - Producer's Accuracy)	41.94%	34.38%	24.14%	66.67%	20.00%	80.00%	60.00%	60.00%	55.00%	0.00%	20.00%	33.33%	33.33%	35.71%	53.33%	15.79%	N/A	30.00%	65.00%	66.67%	65.00%	33.33%	20.00%	80.00%	60.00%	60.00%	40.00%	40.00%	38.71%			

Total Points Correct	634
Overall Accuracy	56.1%
Kappa Index	55.0%
90% Confidence Interval	2.5%

For example, 11 of the 30 accuracy assessment points that were mapped as Eastern Hemlock Forest were actually Dry Eastern Hemlock - Oak Forest. Third, mapping errors tended to occur between associations within the same vegetation cover type or ecological group. Within palustrine herbaceous vegetation occurrences of Wet Meadow and Tussock Sedge Marsh were often incorrrectly mapped as Mixed Forb Marsh. The most widespread example of this type of error was within the mesic terrestrial hardwood forests. Deciduous tree species can be very difficult to distinguish from each other in aerial photointerpretation. Thus, types such as Red Maple - Sweet Birch Hardwood Forest, Sugar Maple - American Beech - Sweet Birch Forest, and Northern Red Oak - Mixed Hardwood Forest that occur in similar mesic environmental settings were often incorrectly mapped as another mesic terrestrial hardwood forest type.

There are several reasons that the vegetation on the ground at an accuracy assessment sampling point is different than the mapped vegetation type. The inaccuracy can be attributed to one or more of the following reasons:

- The polygon is attributed with the incorrect association because of aerial photointerpretation error.
- The polygon boundary was incorrectly drawn due to aerial photointerpretation error.
- The sampling area around the point is an inclusion - a small patch of one association embedded within another association.
- The vegetation key is incorrect or incomplete leading to the misclassification of the sampling area.
- The classification is incorrect or incomplete and does not include the vegetation in the sampling area.

To address these multiple sources of error, revisions were made to several project products based on the thematic accuracy assessment data. Revisions were made to the classification itself (see Vegetation Classification and Charaterization section), the vegetation key (see Appendix D), and the preliminary vegetation association map (see Vegetation Map Production section). Because the vegetation association map was revised after thematic accuracy asssement, the accuracy of the final vegetation association map (Figure 8) is greater than that reported above for the preliminary vegetation association map. However, re-assessing the thematic accuracy of the final vegetation association map would require another round of intensive field sampling. The costs of a second round of sampling do not seem justified simply to quantify the level of increased accuracy in the final map.

The thematic accuracy of the fire behavior fuel model map was also calculated with a contingency table (Table 12). The Kappa index for the fuel model map was 68.1% ± 2.3%, with the overall percent accuracy calculated as 76.4%. This falls below the USGS/NPS vegetation mapping protocol requirement of 80%. The errors of omission for three of the 12 mapped fuel models exceeded the USGS/NPS vegetation mapping protocol requirement of 80%, while five fuel models had errors of omission below 50%. The errors of commission for only one of the 12 fuel models observed during the accuracy assessment exceeded the USGS/NPS vegetation mapping protocol requirement of 80%. Five fuel models had errors of commission below 50%.

Table 12. Contingency matrix and calculated errors for the thematic accuracy assessment of the fire behavior fuel model map of Delaware Water Gap National Recreation Area. The cells highlighted in green show the number of sampling points that were correct.

Accuracy Assessment Observation	Mapped Fire Behavior Fuel Model												Total	Error of Commission (Percent Correct)
	0	1	1/3	3	4	5	6	6/7	7	8	8/9	9		
0	323	1	5	8		1		1		8	30		377	86.21%
1	17	15	11	1			8				3		55	47.27%
1/3	5	4	45	2		3					1		60	75.00%
3	2		2	9		1							14	78.57%
4					1				1			5	7	14.29%
5	4		6			5					1		16	31.25%
6	9	1	1				39	6			13		69	65.22%
6/7	2	1					2	2	6		1		14	14.29%
7	1						3	7	7		1		19	73.68%
8		1	2		1					11	9	1	25	44.00%
8/9	21		8		5	2	24		10	7	337	8	422	79.86%
9			1		3		1				6	41	52	78.85%
Total	383	23	81	20	10	12	77	17	24	26	402	55	1130	
Error of Omission (Percent Correct)	84.20%	65.22%	73.42%	45.00%	10.00%	41.67%	50.65%	93.75%	29.17%	42.31%	83.83%	74.55%		

Total Points Correct	863
Overall Accuracy	76.4%
Kappa Index	68.1%
90% Confidence Interval for Kappa Index	2.3%

For the canopy cover class map, a contingency table (Table 13) calculated the Kappa index as 59.9%±2.4%, with the overall percent accuracy calculated as 71.9%. This falls below the USGS/NPS vegetation mapping protocol requirement of 80%. The errors of omission for one of the four mapped cover classes exceeded the USGS/NPS vegetation mapping protocol requirement of 80%; however, all four fuel models had errors of omission above 50%. The errors of commission for two of the four cover classes observed during the accuracy assessment exceeded the USGS/NPS vegetation mapping protocol requirement of 80%. One of the cover classes had an error of commission below 50%, while the error of commission for the remaining cover class was just above 50%.

Project Deliverables

Final products of the vegetation mapping project are shown in Table 14. All products will be delivered to the National Park Service by the Pennsylvania Natural Heritage Program with this report.

Table 13. Contingency matrix and calculated errors for the thematic accuracy assessment of the canopy cover class map of Delaware Water Gap National Recreation Area. The cells highlighted in green show the number of sampling points that were correct.

Accuracy Assessment Observation	Mapped Canopy Cover Class				Total	Error of Commission (Percent Correct)
	1	2	3	4		
1	267	19	6	0	292	91.44%
2	58	48	25	2	133	36.09%
3	17	23	119	74	233	51.07%
4	2	4	87	379	472	80.30%
Total	344	94	237	455	1,130	
Error of Omission (Percent Correct)	77.62%	51.06%	50.21%	83.30%		

Total Points Correct	813
Overall Accuracy	71.9%
Kappa Index	59.9%
90% Confidence Interval for Kappa Index	2.4%

Table 14. Summary of products resulting from the vegetation classification and mapping of vegetation and fire fuel models at Delaware Water Gap National Recreation Area.

Product	FGCD-complaint spatial metadata
Aerial photos, including flight line map and photoindex	Yes
Photomosaic as paper copy and in digital format	Yes
Annotated field forms with vegetation plot sampling data	Not applicable
Vegetation plot sampling data in the PLOTS 2.0 database	Not applicable
Differentially corrected GPS locations of vegetation plots	Yes
Annotated field forms with thematic accuracy assessment Data	Not applicable
Thematic accuracy assessment data in the PLOTS 2.0 Database	Not applicable
Differentially corrected GPS locations of thematic accuracy assessment sampling points	Yes
Digital photos representative of all vegetation types	Not applicable
Final map of vegetation associations as paper copy and in digital format	Yes
Final map of fire behavior fuel models as paper copy and in digital format	Yes
Final map of canopy cover class as paper copy and in digital format	Yes
Final map of large concentration of dead or dying trees as paper copy and in digital format	Yes
Digital raster data of elevation in 30-m grid cells	Yes
Digital raster data of slope in 30-m grid cells	Yes
Digital raster data of aspect in 30-m grid cells	Yes
Final report as paper copy and in digital format	Not applicable