



RIPARIAN PLANT COMMUNITIES OF THE DELAWARE RIVER

A framework for identifying and conserving representative riparian communities of the Delaware River from Hancock New York to the Delaware Water Gap.



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ON THE COVER

Sugar Maple Floodplain Forest

Photograph by: Gregory S. Podniesinski, Pennsylvania Natural Heritage Program

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Delaware Water Gap*

FINAL REPORT

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Executive Summary

The riparian corridors that border our freshwater systems possess an unusually diverse mosaic of landforms, communities, and environments (Naiman and Decamps 1997, Committee on Riparian Zone Functioning and Strategies for Management 2002). Floodplains, terraces, active channel bars, interfluvial channels, swales, terraces, and meander belts, provide the geomorphic setting for vegetative communities such as floodplain forests, ice-scour grasslands, mixed-hardwood shrublands, and rock outcrop and seepage communities. Naturally existing in a state of dynamic equilibrium, the interaction of external processes such as climate, hydrology, and geomorphology give rise to spatial and temporal heterogeneity resulting in a shifting mosaic of habitats exhibiting few parallels with other systems and offering a diversity of habitat types unique to themselves (Naiman and Decamps 1997).

Riparian corridors are diverse not only in form, but also in function. By providing shade and cover, these systems help to regulate the light and temperature regimes of adjacent streams thereby maintaining suitable conditions for aquatic species. They naturally retain and recycle nutrients, modify local microclimates, and sustain broadly based food webs that help support a diverse assemblage of fish and wildlife (Committee on Riparian Zone Functioning and Strategies for Management 2002). Shoreline vegetation not only stabilizes stream banks but also traps sediment during over-bank flows. Riparian corridors provide a lateral ecotone between land and water forming a complex gradient between the river channel and nearby uplands (Ward et al. 1999). They also provide a vertical ecotone between surface water and ground water. Longitudinally, riparian corridors form a somewhat linear swath of habitat that frames our waterways and enables the dispersal and movement of flora and fauna both upstream and downstream.

Functional, ecologically intact floodplains, which are one component of riparian areas, help to slow floodwaters allowing increased flood storage, retaining high flows, retaining and recycling nutrients, altering local patterns of scour, sediment transport, and deposition while also providing refugia for aquatic organisms (Committee on Riparian Zone Functioning and Strategies for Management 2002). By augmenting the storage capacity of the riverine system, riparian corridors help to attenuate peak flows thereby reducing the risk of extensive flooding. As the boundary between land and water, the riparian corridor also intercepts, cycles, and accumulates sediment, nutrients, and pollutants being delivered to the riverine environment through overland and subsurface flows. Working both above and below ground, riparian areas filter water coming from the watershed, thereby maintaining the quality of water in our streams and rivers. In addition, by altering local patterns of scour and deposition, the floodplain serves to reduce direct sediment contributions from the floodplain into the river.

The Pennsylvania Natural Heritage Program (PNHP) and The Nature Conservancy (TNC), with support from the Pennsylvania Department of Conservation and Natural Resources, and the National Park Service's Eastern River and Mountains Network, developed this project to identify and evaluate the representative riparian plant

communities in the 100-year floodplain of the mainstem Delaware River between Hancock New York and the Delaware Water Gap. The goals of the project were to

1. Determine the riparian community types that are found and represented in the project area;
2. Develop reference conditions for representative riparian plant communities;
3. Develop conceptual ecological models for these community types; and
4. Provide preliminary insights and discussion into the potential strategies available and needed to conserve this resource.

Study Area

The study area includes the riparian corridor of the mainstem Delaware River extending from the northeastern-most point of Pennsylvania, near the town of Hancock, New York, to immediately downstream of the Delaware Water Gap National Recreation Area in Upper Mount Bethel Township (Figure 1). Due to funding constraints, only the Pennsylvania side of the river was evaluated. This area abounds with opportunities for conservation of biodiversity despite the ever-increasing threats facing the region's natural resources.

Methods

The Pennsylvania Natural Heritage Program and the New York Heritage Program through the support of the National Park Service classified and mapped vegetative alliances for both UPDE and DEWA. Findings from this effort are summarized in two reports entitled, “Classification and Mapping of Vegetative and Fire Fuel Models at Delaware Water Gap National Recreation Area (Perles et al.. 2007)” and “Classification and Mapping of Vegetative at the Upper Delaware Scenic and Recreation River (Perles et al.. in review)”. Individual reports and associated data are currently available for DEWA and can be found at <http://biology.usgs.gov/npsveg/dewa/dewarpt.pdf>. The report and associated data for UPDE are anticipated to be posted for public access within 2009. These studies provided the foundation upon which this project built and are collectively referred to as the two NPS studies in the remainder of this report.

Development of Reference Conditions

Reference conditions for floodplain plant communities were adopted from the two NPS studies. These descriptions represent the best available data regarding the current vegetation types found in the study area. The reference conditions describe spatial distributions, potential invasive plant species pests as well as pristine vegetation structure and species composition for community types. Reference conditions were developed to assist in the assessment of floodplain community condition.

Site Selection

Floodplain sites were initially identified using digital vegetation maps (ESRI shapefile format), developed by Pennsylvania Natural Heritage Program for the two NPS studies. However, due to the severe flooding events that occurred between 2004-2006, the two NPS studies’ riparian vegetative mapping was re-verified. PAMAP imagery (Pennsylvania Spatial Data Access <http://www.pasda.psu.edu> 2005) was used to evaluate

potential changes that occurred in riparian community structure. As necessary, new riparian community boundaries were redelineated or reclassified to represent the vegetation that currently exists.

Floodplain sites included the active floodplain, both low and high terraces, and consisted of plant community types as defined by Fike (1999), Perles et al. (2007) and Perles et al. (in review). Sites were selected to include complexes of riparian community types in order to maximize sampling effort. Focusing on community complexes allowed us to sample communities across successional gradients, thus capturing spatial and temporal heterogeneity across environmental gradients. Our approach was based on the premise that complexes have a greater potential to yield higher quality sites and more functionally intact riparian systems compared to a site consisting of a homogeneous riparian stand.

Sites were restricted to property owned by public and private landowners within the Pennsylvania state border.

Eventually, 261 communities embedded within 23 select riparian floodplain sites were evaluated during the summer of 2007 for a total of 11 field days (approximately 300 person-hours). Based on the two NPS studies' digital vegetation maps, the centroids of all community polygons within a complex were used as sampling points for groundtruthing vegetation community types. The mapping unit for this project was 0.25 hectares. Dominant species composition, percent invasive species cover, hydrologic regime, substrate cover, stand age/successional stage, evidence of disturbance and general site description were recorded for each community. Communities were georeferenced using global positioning systems and stored in an ESRI shape file format (See Appendix A. Community Assessment Field Form).

Based on field surveys and PAMAP aerial imagery, community polygon boundaries were drawn in ArcGIS. Site maps were produced using the updated community polygon boundaries that were modified from the two NPS studies' vegetation maps and areas delineated from aerial photography.

Results

In this project, a total of 17 community types were identified: 12 native community types and 5 developed or degraded community types. Riparian forests were the most dominant community type totaling approximately 45% of the total study area. The two invasive weed communities, Reed Canary Grass Riverine Grassland and Japanese Knotweed Herbaceous Vegetative Communities, were the next in dominance representing approximately 25% of the total area, followed by degraded communities, representing approximately 14% of all sites. The combined total of invasive and degraded community types constitutes approximately 39% or more than a third of the total acreage evaluated.

The least common communities are the unique/rare and shrubland community types. Although only representing a small percentage of the total area, these community types remain a critical component of the overall system. These and other relatively small

habitats with unusual, even extreme, environments are often home to a disproportionate share of Pennsylvania's rarest plant and animal species.

To summarize, native communities within the study sites represent 61% of the total study area. Within these native communities, floodplain forest communities, primarily Silver and Sugar Maple Floodplain Forests, are most common, followed by herbaceous (excluding invasive community types) and shrubland community types. Altered community types, including Agricultural/Old Field, Northeastern Modified Successional Forest, residential lands, and invasive weed community types, represent 39% of the study sites total area.

Conservation Strategies

This project has identified and characterized riparian communities occurring along the Pennsylvania side of the mainstem Delaware River from Hancock, New York to the Delaware Water Gap. While riparian corridor development, the spread and establishment of invasive species, and the alteration of natural ecological processes threaten the future viability of this resource, potential opportunities also abound for its preservation.

Many of the lands occurring within the 100-year floodplain of the study area are retained in private ownership. The protection of these privately owned riparian areas will involve the creative use and integration of a number of different tools ranging from the voluntary conservation of properties and/or their development rights, to regulatory requirements and special incentives.

Land Preservation

Conservation organizations and willing landowners can work together to conserve riparian areas of high biodiversity value. In some circumstances, the landowner voluntarily transfers land ownership to a willing conservation organization through the sale, donation, or some combination thereof of the property. The conservation organization is then bound to protect the property's ecological values. In other situations, landowners protect the property through a conservation easement. A conservation easement is a legal agreement between a landowner and an eligible organization (often a conservation organization) that restricts the activities that may take place on a property in order to protect the land's conservation values. This type of agreement is useful for situations where the landowner wishes to retain ownership of the property, but is also interested in preserving the property's natural values.

The Regulatory Framework

During the last decade, federal, state, and local laws and programs have begun to acknowledge the importance of riparian areas, particularly for preserving stream water quality and maintaining aquatic diversity (Committee on Riparian Zone Functioning and Strategies for Management 2002). However, several challenges still exist within the regulatory framework. The degree of protection, the focus, and the spatial coverage of these regulations and programs are highly variable at all levels of government.

At the federal level, the absence of a national riparian mandate stands in stark contrast to the existence of a federal wetlands law. Without this type of mandate for riparian corridors, the federal regulatory framework lacks the cohesion to guide and influence programs being administered at the state and local levels. Defining state-level riparian protection programs and land use regulations provides another step toward more consistent regulations among basin states. The State of Pennsylvania plans to address the issue of riparian buffer protection in revisions to the Pennsylvania Code, Title 25, Chapter 102, the Soil Erosion and Sedimentation Control Provisions and currently recommends that riparian buffers be 100 feet wide on both sides of the stream. Local governments should also be encouraged to develop consistent protective riparian buffer zoning and ordinances as appropriate. In the study area, all four counties, including Wayne, Pike, Monroe, and Northampton, have consistently adopted Hazard Mitigation Plans (HMP). Although the plans vary and are specific to the needs and environments of each county, some version of floodplain and riparian buffer conservation is frequently recommended to help mitigate flood impact.

Floodplain Mapping

Currently, the 100-year floodplain, as mapped by FEMA, provides the spatial framework and context for identifying regulatory floodways. As the Interstate Flood Mitigation Task Force (2007) states, “A regulatory floodway is defined as the channel of a river or other watercourse and portions of the floodplain adjoining the channel that must be maintained to convey and discharge the base (or 100-year) flood without cumulatively increasing the water surface elevation more than a designated height. The minimum FEMA floodway determination allows for a 1.0-ft rise.” This method for determining the active and functional floodplain has recently been questioned.

The Task Force (2007) urges the basin state regulatory agencies to come together to compare and evaluate the implications of using a newly defined, more stringent standard that defines a larger floodway, thereby requiring development take place farther from the path of damaging floodwaters (Interstate Flood Mitigation Task Force 2007).

Invasive Weeds

Invasive weeds pose yet another serious threat to the riparian corridor of the Delaware River. Numerous invasive weeds were identified during field investigations; noteworthy among them were the significant infestations of reed canarygrass and Japanese knotweed. Weed management efforts to abate this threat begin by viewing the riparian corridor as a functional system and selecting high-quality riparian complexes as areas of concentrated weed management efforts. Ideally, complexes should consist of a mosaic of characteristic riparian communities, some of high biological value, others in varying degrees of degradation by invasive weeds. High biological-value communities serving as core refuges should be defined as relatively weed-free areas while buffer zones surrounding the cores areas serve to protect cores from future invasion by other weedy species.

In these buffer areas, we may need to redefine our management goals. Rather than the restoration of a pre-existing condition or community or the elimination of invasive

weeds, we may wish to strive for the rehabilitation of a portion of the community. Then reconciling ourselves to the fact that not all invaders can be controlled — due to the extent and distribution of the invasive population, limited economic resources, etc. — we may need to define a “new” mixed community of native and non-native species with the most desirable ecosystem functions and properties (Randall PowerPoint presentation 2007).

The above approach provides a starting point for grappling with established invaders, but Prevention, Early Detection and Rapid Response (ED/RR) has become the mantra of invasive species efforts both domestically and internationally. Controlling invasives before they get a foothold and become widespread in the system dramatically increases chances of successful management efforts before it is too late and too expensive.

Prevention is a multi-faceted task that includes actions ranging from education of those who might inadvertently introduce unwanted species, to research identifying pathways and vectors of invasive species spread, to enforcement of laws for inspections and quarantines (The Idaho Invasive Species Council and Technical Committee 2007). Both the UPDE and DEWA Parks plan to implement an early detection/rapid response (ED/RR) protocol in 2009-2010. Although limited to lands owned and managed by the two parks, developing a regional prototype ED/RR Program for 120 miles of high-quality riparian habitat along the mainstem Delaware River has the potential to reach many people and organizations beyond the physical boundaries of Park ownership. The development of the NPS's ED/RR program provides the region with another critical tool for managing invasive weed species.

Alteration of Natural Ecological Processes: Implications of an Altered Flow Regime

As stated in the Conceptual Ecological Models Section of the document, flow regime is a “key” environmental driver of the ecological integrity of riparian communities structuring both the physical and biotic components of aquatic ecosystems (Poff et al. 1997). Riparian communities, adapted to a natural range of flow variability, have developed mechanisms to not only ensure their survival in a disturbance dominated system, but to thrive in these conditions. The introduction of hydrologic alteration may result in riparian corridors becoming disconnected both physically and functionally from riverine processes that ensure riparian plant regeneration and succession (Poff et al. 1997, Zimmerman 2006).

Although the Delaware River remains undammed on its mainstem, 15 dams fragment its tributaries. To advance their goals of sustainable water use, the DRBC and Decree Parties, established a Subcommittee on Ecological Flows (SEF) to assist the DRBC's Regulated Flows Advisory Committee (RFAC). The goal of the subcommittee was to develop scientifically-based ecological flow requirements for the maintenance of self-sustaining aquatic ecosystems, with a focus on fish and freshwater mussel species. The Commission and the Decree Parties committed to participating in a non-binding collaborative process to develop experimental flow management options for the Delaware River and its regulated tributaries.

These and other complimentary efforts have resulted in the "Flexible Flow Management Program (FFMP)," which represents a major step forward in water management in the basin. It is designed to restore natural variability in flows to the upper Delaware and is part of an adaptive management program that will allow for revisions in water management based on biological results (C. Apse, The Nature Conservancy, Portland, ME, personal communication).

The FFMP has been implemented on an interim basis since September 2007 and is expected to be formally incorporated into DRBC's Water Code in the near future. As this proposal sets up a process for improvements to be considered and acted upon, it is a key step forward. However, the ecological flow requirements of a broader array of species and systems, including the riparian corridor, also need to be evaluated and incorporated into water management decisions.

These conservation strategies – land preservation, floodplain regulation, invasive species management and the prevention of new invasions, as well as flow regime restoration – employed individually or collectively, will assist to ameliorate threats at the scale of the individual parcel to the scale of the basin. As each habitat and place is unique, no one strategy will effectively fit every situation. However, working cooperatively these strategies will help to secure the future ecological integrity of riparian corridors at multiple scales.

Summary and Recommendations

This project has identified and described riparian communities along a portion of the mainstem Delaware River, providing us with a biodiversity baseline that can be used in future riparian conservation and restoration efforts. But this is just a piece of the big picture and just the beginning of the work that needs to be done.

Future Inventory

Efforts are needed to expand the geographic scope of this effort to include the entire Delaware River riparian corridor, particularly along the mainstem and along specific high-quality watershed tributaries. Our study, as well as two National Park Service studies, characterize portions of the overall system and although we anticipate communities identified in these project areas to be found elsewhere both across the river as well as upstream and downstream, we also anticipate encountering differences in tributary headwaters and downstream in the middle and lower Delaware. It is essential that we understand and document this spatial variability if we hope to preserve the entire system and not just individual patches within it.

One way to continue the inventory and assessment process is through the continued use and updating of the Natural Area Inventories. The Riparian Plant Community Reference Conditions provides a framework against which the condition of riparian communities can be compared, particularly those occurring within northeastern Pennsylvania, can be compared. Through this process, riparian complexes of high-value as well as those in need of management and restoration can be identified and targeted by individual counties

for future conservation efforts, be that land conservation, floodplain regulations, or invasive species management.

Watershed Management

This project also provides a number of strategies for conservation. Within the proposed strategies, watershed management was not specifically addressed as this project focuses on strategies that relate more directly to riparian corridor conservation. However, the alteration of upstream watershed processes and basin hydrology leads to concomitant changes in channel hydraulics and sedimentation regimes, all of which have immediate implications for the health and vitality of neighboring and downstream riparian corridors as well as aquatic resources. To ensure riparian corridors as well as aquatic resources are not being degraded by increased storm flows laden with pollutants and sediment, land use and watershed management is a critical piece of the puzzle that is often at the root of water quality and quantity degradation issues.

Riparian Management and Restoration

Restoration or the rehabilitation of certain places along the riparian corridor also warrants further investigation. To fully explore the idea of rehabilitation, we need to move beyond inventorying what is currently in place to also assess what has been lost in terms of biodiversity and ecological function.

Riparian Plant Community Reference Conditions provide a basis for developing the future desired conditions for characteristic riparian communities by identifying the environmental conditions, species composition, and structural characteristic for each plant association. Understanding what we're aiming for in terms of community type and composition are critical to ensure the effectiveness of management and restoration efforts.

Outreach and Education

Years to decades will be required before native community types re-establish both in form and function. Commensurate with restoration must be efforts to improve society's understanding of what riparian functions have been lost and what can be recovered.

Preservation of this unique and invaluable resource will take the efforts of many. Individual landowners working alongside conservation organizations can begin by preserving individual yet critical pieces of the riparian corridor. County, regional, state, and national planning and regulatory agencies can complement local efforts by striving for more holistic floodplain delineations, more consistent floodplain and riparian regulations, and more sustainable water resource management.

Continued Funding

We are entering a time when global climate change is commonly recognized and discussed. Newly emerging carbon-based markets are beginning to provide unique and creative economic incentives for the conservation of biological systems, not only recognizing but also ascribing a value to the ecosystem services they provide. This is a time of opportunity, driven by the need for our ecological systems to provide their

intended functional benefits. Directing this and other new funding towards the conservation of riparian corridors and floodplains not only serves to protect places of unique ecological value, but also provides recreational and other ecological services to the human community.

Introduction

*“Natural riparian corridors are the most diverse, dynamic, and complex biophysical habitats on the terrestrial portion of the Earth.”
(Naiman et al. 1993)*

The riparian corridors that border our freshwater systems possess an unusually diverse mosaic of landforms, communities, and environments (Naiman and Decamps 1997, Committee on Riparian Zone Functioning and Strategies for Management 2002). Floodplains, terraces, active channel bars, interfluvial channels, swales, terraces, and meander belts, provide the geomorphic setting for vegetative communities such as floodplain forests, ice-scour grasslands, mixed-hardwood shrublands, and rock outcrop and seepage communities. Naturally existing in a state of dynamic equilibrium, the interaction of external processes such as climate, hydrology, and geomorphology give rise to spatial and temporal heterogeneity resulting in a shifting mosaic of habitats exhibiting few parallels with other systems and offering a diversity of habitat types unique to themselves (Naiman and Decamps 1997).

Riparian corridors are a vital resource providing distinct ecological, recreational, and economic benefit, but a resource that does not quite fit neatly into terrestrial or aquatic conservation efforts. Representing the interface between these system types, riparian corridors provide a transition zone between land and water.

Riparian corridors are diverse not only in form, but also in function. By providing shade and cover, these systems help to regulate the light and temperature regimes of adjacent streams thereby maintaining suitable conditions for aquatic species. They naturally retain and recycle nutrients, modify local microclimates, and sustain broadly based food webs that help support a diverse assemblage of fish and wildlife (Committee on Riparian Zone Functioning and Strategies for Management 2002). Shoreline vegetation not only stabilizes stream banks but also traps sediment during over-bank flows. Riparian corridors provide a lateral ecotone between land and water forming a complex gradient between the river channel and nearby uplands (Ward et al. 1999). They also provide a vertical ecotone between surface water and ground water. Longitudinally, riparian corridors form a somewhat linear swath of habitat that frames our waterways and enables the dispersal and movement of flora and fauna both upstream and downstream.

The function of riparian corridors in terms of natural flood abatement is also an issue of recent interest. Flood waters can damage crops and structures, impair drinking water resources, and tragically result in the loss of human life. In the Delaware River Basin alone, nineteen major flood events have been recorded since 1839 (Waddell 2007). Since 2003, a significant flood has occurred every year in at least some portion of the basin. Property damage in the last decade has ranged from an estimated low of \$35 million to a high of \$200 million. Damage projections for a flood of record, such as the flood of 1995, soar to the billions (Delaware River Basin Commission (DRBC) and DRBC Flood Advisory Committee 2002).

Tragically, economic losses are not the only casualty of floodwaters. Seven people died during Tropical Storm Agnes, and ten residents lost their lives during the most recent floods occurring between 2004 and 2006. The staggering economic costs and loss of human life has heightened public concern and raised organizational awareness of the need to develop effective flood control as well as floodplain management strategies.

Functional, ecologically intact floodplains, which are one component of riparian areas, help to slow floodwaters allowing increased flood storage, retaining high flows, retaining and recycling nutrients, altering local patterns of scour, sediment transport, and deposition while also providing refugia for aquatic organisms (Committee on Riparian Zone Functioning and Strategies for Management 2002). By augmenting the storage capacity of the riverine system, riparian corridors help to attenuate peak flows thereby reducing the risk of extensive flooding. As the boundary between land and water, the riparian corridor also intercepts, cycles, and accumulates sediment, nutrients, and pollutants being delivered to the riverine environment through overland and subsurface flows. Working both above and below ground, riparian areas filter water coming from the watershed, thereby maintaining the quality of water in our streams and rivers. In addition, by altering local patterns of scour and deposition, the floodplain serves to reduce direct sediment contributions from the floodplain into the river.

The Delaware River is one of the last remaining free-flowing mainstem rivers east of the Mississippi. Flowing 330 miles from its headwaters to the Atlantic Ocean (Figure 1), the river is lined by a riparian corridor on both its right and left banks. From the bay to its headwaters, riparian corridors frame the river. However, the corridor's vegetative composition, lateral extent, and condition vary throughout its course. This study, building upon previous research efforts conducted by the National Park Service (NPS), characterizes the representative vegetative communities existing along the upper reaches of the river. Going a step further, the study provides preliminary insights into the external processes which are essential for the formation, maintenance, and potentially the restoration of these systems. Finally, we discuss options for their conservation. These strategies serve to not only preserve the resource's biological value, but by addressing strategies to ensure riparian corridor functional integrity, economic and recreational benefits may also be attained.

The Pennsylvania Natural Heritage Program (PNHP) and The Nature Conservancy (TNC), with support from the Pennsylvania Department of Conservation and Natural Resources, and the National Park Service's Eastern River and Mountains Network, developed this project to identify and evaluate the riparian plant communities in the 100-year floodplain of the mainstem Delaware River between Hancock New York and the Delaware Water Gap. The goals of the project were to

1. Determine the riparian community types that are found and represented in the project area;
2. Develop reference conditions for representative riparian plant communities;
3. Develop conceptual ecological models for these community types; and

4. Provide preliminary insights and discussion into the potential strategies available and needed to conserve this resource.

By identifying the types, distribution, and condition of riparian communities along the Delaware River, conservation strategies can more effectively target the protection of high-quality riparian corridor complexes along the river. Conceptual ecological models provide insights into the formative hydrologic and geomorphologic processes necessary to maintain the successional dynamic of riparian communities. This lends to the identification of strategies effecting change not only on the local scale, but also potentially on the scale of the basin and beyond.

Study Area

The study area includes the riparian corridor of the mainstem Delaware River extending from the northeastern-most point of Pennsylvania, near the town of Hancock, New York, to immediately downstream of the Delaware Water Gap National Recreation Area in Upper Mount Bethel Township (Figure 1). Due to funding constraints, only the Pennsylvania side of the river was evaluated. This area abounds with opportunities for conservation of biodiversity despite the ever-increasing threats facing the region's natural resources.

Today, the Delaware River is the longest remaining undammed mainstem river east of the Mississippi. The small streams of the Delaware's headwaters begin in the Catskill and Pocono Mountains of the Appalachian Plateau. The River's East and West Branches join at Hancock, New York and flow 193.12 scenic km (120 miles) before cutting through the steep ridge of the Kittatinny Mountains at the Delaware Water Gap.

Three reaches of the Delaware River have been included in the National Wild and Scenic Rivers System, two of which are within the study area. One section extends 117.48 km (73 miles) from the confluence of the river's East and West branches at Hancock, New York downstream to Milrift, Pennsylvania; the second is a 64.37 km (40 mile) stretch from just south of Port Jervis, New York downstream to the Delaware Water Gap. Combined, these two parks total 50,557 hectares (124,929 acres), approximately 1,578.27 hectares (3,900 acres) of which are contained within the river's 100-year floodplain (Figure 1).

The upper section of the study area forms the boundary between Pennsylvania and New York and is captured within the boundary of the National Park Service's Upper Delaware Scenic and Recreational River (Figure 1). This is the steepest section of the river, flowing 123.92 km (77 miles) from Hancock to Port Jervis and stepping down the valley in a series of pools and riffles with an average drop of more than 1.83 m per kilometer (6 feet per mile) (Albert and Albert 2002). Moving downstream, the river slows in a 69.2 km (43 mile) stretch between Port Jervis and the Delaware Water Gap and forms the

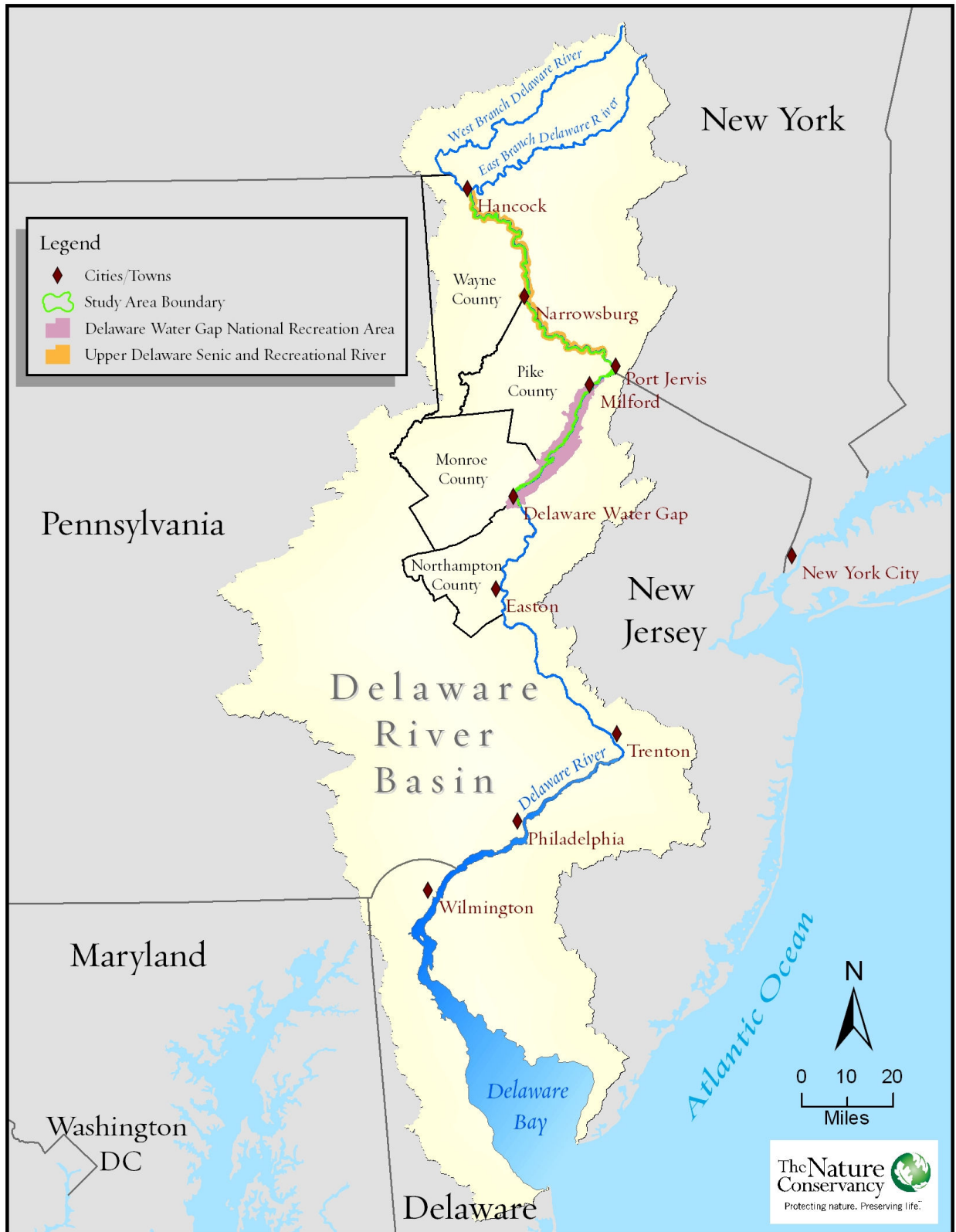


Figure 1. The Study Area includes the Pennsylvania side of the riparian corridor of the mainstem Delaware River from Hancock N.Y. to just below the Delaware Water Gap.

boundary between Pennsylvania and New Jersey. It was within this section of the river that the infamous Tocks Island Dam was proposed, 9.66 km (6 miles) below Walpack Bend. The proposed dam did not survive the environmental movement of the 1970s (Albert and Albert 2002). Instead the NPS's Delaware Water Gap National Recreation Area now extends 64.37 km (40 miles) from the area of Milford to the Water Gap encompassing 27,008.72 ha (66,740 acres) (Delaware Water Gap National Recreation Area and Middle Delaware National Scenic River website).

Nearly 15 million people (approximately five percent of the nation's population) rely on the waters of the Delaware River Basin for drinking and industrial use, but the watershed drains only four-tenths of one percent of the total continental U.S. land area. New York City (NYC) obtains nearly half of its municipal water supply from three Delaware Basin reservoirs—the Cannonsville, Pepacton, and Neversink reservoirs (Figure 22). The basin also supplies drinking water to much of the Philadelphia metropolitan area and major portions of New Jersey.

Recreationally, over the past half century, highly-prized coldwater fisheries have been established in the tailwaters of the Cannonsville, Pepacton, and Neversink reservoirs located on the East and West Branches of the Delaware and the Neversink River, respectively, and in the upper mainstem of the Delaware River (Interstate Flood Mitigation Task Force 2007). In addition, DEWA alone receives more than 5,000,000 recreational visits each year, making it the 8th-most visited unit of the National Park System (Delaware Water Gap National Recreation Area and Middle Delaware National Scenic River website).

Assessment of Representative Riparian Communities

Methods

The Pennsylvania Natural Heritage Program and the New York Heritage Program through the support of the National Park Service classified and mapped vegetative alliances for both UPDE and DEWA. Findings from this effort are summarized in two reports entitled, “Classification and Mapping of Vegetative and Fire Fuel Models at Delaware Water Gap National Recreation Area (Perles et al., 2007)” and “Classification and Mapping of Vegetative at the Upper Delaware Scenic and Recreation River (Perles et al., in review)”. Individual reports and associated data are currently available for DEWA and can be found at <http://biology.usgs.gov/npsveg/dewa/dewarpt.pdf>. The report and associated data for UPDE are anticipated to be posted for public access within 2009. These studies provided the foundation upon which this project built and are collectively referred to as the two NPS studies in the remainder of this report.

Development of Reference Conditions

Reference conditions for floodplain plant communities were adopted from the two NPS studies. These descriptions represent the best available data regarding the current vegetation types found in the study area. The reference conditions describe spatial distributions, potential invasive plant species pests as well as pristine vegetation structure

and species composition for community types. Reference conditions were developed to assist in the assessment of floodplain community condition.

Site Selection

Floodplain sites were initially identified using digital vegetation maps (ESRI shapefile format), developed by Pennsylvania Natural Heritage Program for the two NPS studies. However, due to the severe flooding events that occurred between 2004-2006, the two NPS studies' riparian vegetative mapping was re-verified. PAMAP imagery (Pennsylvania Spatial Data Access <http://www.pasda.psu.edu> 2005) was used to evaluate potential changes that occurred in riparian community structure. As necessary, new riparian community boundaries were redelineated or reclassified to represent the vegetation that currently exists.

Floodplain sites included the active floodplain, both low and high terraces, and consisted of plant community types as defined by Fike (1999), Perles et al. (2007) and Perles et al. (in review). Sites were selected to include complexes of riparian community types in order to maximize sampling effort. Focusing on community complexes allowed us to sample communities across successional gradients, thus capturing spatial and temporal heterogeneity across environmental gradients. Our approach was based on the premise that complexes have a greater potential to yield higher quality sites and more functionally intact riparian systems compared to a site consisting of a homogeneous riparian stand.

Sites were restricted to property owned by public and private landowners within the Pennsylvania state border.

Eventually, 261 communities embedded within 23 select riparian floodplain sites were evaluated during the summer of 2007 for a total of 11 field days (approximately 300 person-hours). Based on the two NPS studies' digital vegetation maps, the centroids of all community polygons within a complex were used as sampling points for groundtruthing vegetation community types. The mapping unit for this project was 0.25 hectares. Dominant species composition, percent invasive species cover, hydrologic regime, substrate cover, stand age/successional stage, evidence of disturbance and general site description were recorded for each community. Communities were georeferenced using global positioning systems and stored in an ESRI shape file format (See Appendix A. Community Assessment Field Form).

Based on field surveys and PAMAP aerial imagery, community polygon boundaries were drawn in ArcGIS. Site maps were produced using the updated community polygon boundaries that were modified from the two NPS studies' vegetation maps and areas delineated from aerial photography.

Results

Identified community types and their total acreages are listed in Table 1. Sites were stratified into three general classes: delta (sites that occur at the mouth of Delaware River tributaries), island (sites that occur mainly on islands within the Delaware River) and riverside (sites occurring on the banks of the river). Table 2 provides summary statistics for these three geomorphic classes. Figures 2-7 illustrate the diversity of riparian communities found throughout the project area. To protect landowner privacy, sites located on privately owned lands are not illustrated.

Table 1. Summary of spatial statistics for community types surveyed at floodplain sites along the Delaware River.

Community Type	# of Sites	# of Patches	Total Combined Area (hectares)	Mean Patch Area (hectares)
*Agriculture/Old Field	5	7	49.16	7.02
**Big Bluestem-Indiangrass Riverine Grassland	16	20	9.09	0.45
**Bitternut Hickory Lowland Forest	5	7	13.18	1.88
**Hairyfruit Sedge Wetland	6	10	7.51	0.75
*Japanese Knotweed Herbaceous Vegetation	13	39	31.10	0.80
*Northeastern Modified Successional Forest	2	7	3.57	0.51
*Reed Canarygrass Riverine Grassland	18	43	66.08	1.54
Residential	1	1	1.06	1.06
River Birch Low Floodplain Forest	1	1	0.73	0.73
Riverine Scour Vegetation	20	37	21.92	0.59
Riverside Rock Outcrop	1	1	0.21	0.21
Silver Maple Floodplain Forest	11	24	69.12	2.88
Sugar Maple Floodplain Forest	9	12	29.81	2.48
Sycamore-(Willow)-Mixed Hardwood Riverine Shrubland	5	6	1.96	0.33
Sycamore-Mixed Hardwood Floodplain Forest	13	25	54.36	2.17
Sycamore-Mixed Hardwood Riverine Shrubland	9	19	15.69	0.83
Water Willow Emergent Bed	2	2	1.16	0.58

* Invasive community types were designated as Japanese Knotweed Vegetation, Reed Canarygrass Riverine Grassland, Modified Successional Forest, Agricultural/Old Field Vegetation or Residential community types.

** Rare community types were based on Pennsylvania state ranks (Pennsylvania Natural Heritage Program) and included community types with a rank of S1, S2 or S3. In this study, the rare communities that occurred included Big-Bluestem-Indiangrass Riverine Grassland, Hairyfruit Sedge Wetland and Bitternut Hickory Lowland Forest.

Table 2. Mean summary statistics of geomorphic classes for the assessment of riparian plant community sites along the Delaware River.

Site Category	Number of Sites	Total Combined Area (hectares)	% Area in Invasive Communities*	Average # of Community Types	Average # of Rare Community Types**
Delta	3	40.3	32.0	6.7	0.7
Island	4	12.8	4.3	6.0	0.8
Riverside	16	13.6	53.2	5.8	1.3

* Invasive community types were designated as Japanese Knotweed Vegetation, Reed Canarygrass Riverine Grassland, Modified Successional Forest, Agricultural/Old Field Vegetation or Residential community types.

** Rare community types were based on Pennsylvania state ranks (Pennsylvania Natural Heritage Program) and included community types with a rank of S1, S2 or S3. In this study, the rare communities that occurred included Big-Bluestem-Indiangrass Riverine Grassland, Hairyfruit Sedge Wetland and Bitternut Hickory Lowland Forest.

Delta Site

Bushkill Creek (Figure 2) - The floodplain surrounding Bushkill Creek is the second largest site surveyed in our efforts. The site tends to be a mosaic of high terrace floodplain forest (Sugar Maple Floodplain Forest and Silver Maple Floodplain Forest) and low terrace floodplain forest (Sycamore-Mixed Hardwood Forest and Bitternut Hickory Lowland Forest) with several large areas of Japanese knotweed vegetation. One rare community, with a state rank of S3, Bitternut Hickory Lowland Forest, occurs at the northern tip of the site. Additionally, there is a fairly large and intact older (over 100 years old) Silver Maple Floodplain Forest stand in the northern portion of the site that is moderately invaded. In general the forests tended to be invaded by several species of exotic plants such as Japanese stilt grass, multiflora rose and Japanese knotweed. The site is threatened by invasion of exotic species possibly dispersed from the surrounding landscape, which consists heavily of agriculture and Japanese knotweed.

Island Sites

Arrow Island (Figure 5) - The site has low community diversity, but does contain a fairly large Big Bluestem-Indiangrass Riverine Grassland. The back half of the island was significantly affected from previous flooding and dominated by sycamore shrubland community. This community contained a substantial amount of blackberry (*Rubus alleghiensis*).

Buck Bar Island (Figure 6) - The site is the smallest island inventoried, moderately invaded in terms of its communities, and represents a classic example of island community succession in the Delaware River system (see Conceptual Ecological Model Figure 14). The tip of the island is riverine scour vegetation and transitions to moderately invaded Sycamore-(Willow)-Mixed Hardwood Dwarf Shrubland and Sycamore-Mixed Hardwood Shrubland communities in the central portion of the island. The tail end of the island, which receives the least amount of impact from flooding events, is a moderately invaded Silver Maple Floodplain Forest. Typical invasive plant species found throughout the shrubland and forest communities are reed canarygrass and Japanese knotweed.

Little Shapnack Island (Figure 3) - Little Shapnack Island was the second largest island sampled in the study. The site contains both the island and adjacent supporting riverside floodplain communities. There are large Silver Maple Floodplain Forest communities that border the river along with Reed Canarygrass Riverine Grassland communities. The silver maple communities are moderately invaded by reed canarygrass. A large area of Sugar Maple Floodplain Forest is located at the southern portion of the site that is fed by a small tributary. This island also contains a classic example of island succession (see Conceptual Ecological Model Figure 14), with shrubland communities occurring at the island head and Silver Maple Floodplain Forests its tail. A large occurrence of Japanese knotweed occurs on the inland central side of the island. There is also a small Big Bluestem-Indiangrass Riverine Grassland toward the central portion of the island.

Shapnack Island (Figure 4) - Shapnack Island was the largest island sampled in the study. The site consists of the island and a thin band of adjacent Silver Maple Floodplain Forest on the mainland. The adjacent Silver Maple Floodplain Forest was moderately invaded by Japanese knotweed. A zone of Riverine Scour Vegetation and Water Willow Emergent Beds occurs between the island and mainland. The island is characterized by a Sycamore-Mixed Hardwood Riverine Shrubland at the island head and dominated by a minimally invaded Sugar Maple Floodplain Forest community. There are small areas of Agricultural/Old Field, Big Bluestem-Indiangrass Riverine Grassland and Reed Canarygrass Riverine Grassland on the island.

Riverside Site

Tom's Creek (Figure 7) - The Tom's Creek site has moderate community diversity; however, the communities found in this site are moderately to heavily invaded containing populations of Japanese knotweed and Japanese stiltgrass. The forested communities within the site are large in size, which makes this site very suitable for restoration efforts. There is a 15 ha (37.1 acre) strip of Silver Maple Floodplain Forest that parallels the Delaware River in the northern portion of the site. A minimally invaded 1.78 ha (4.4 acre) Bitternut Hickory Lowland Forest community type is located in the southern portion of the site. There are also substantial areas of agriculture and residential land use adjacent to the site. The site serves as a mainland buffer for Buck Bar Island.

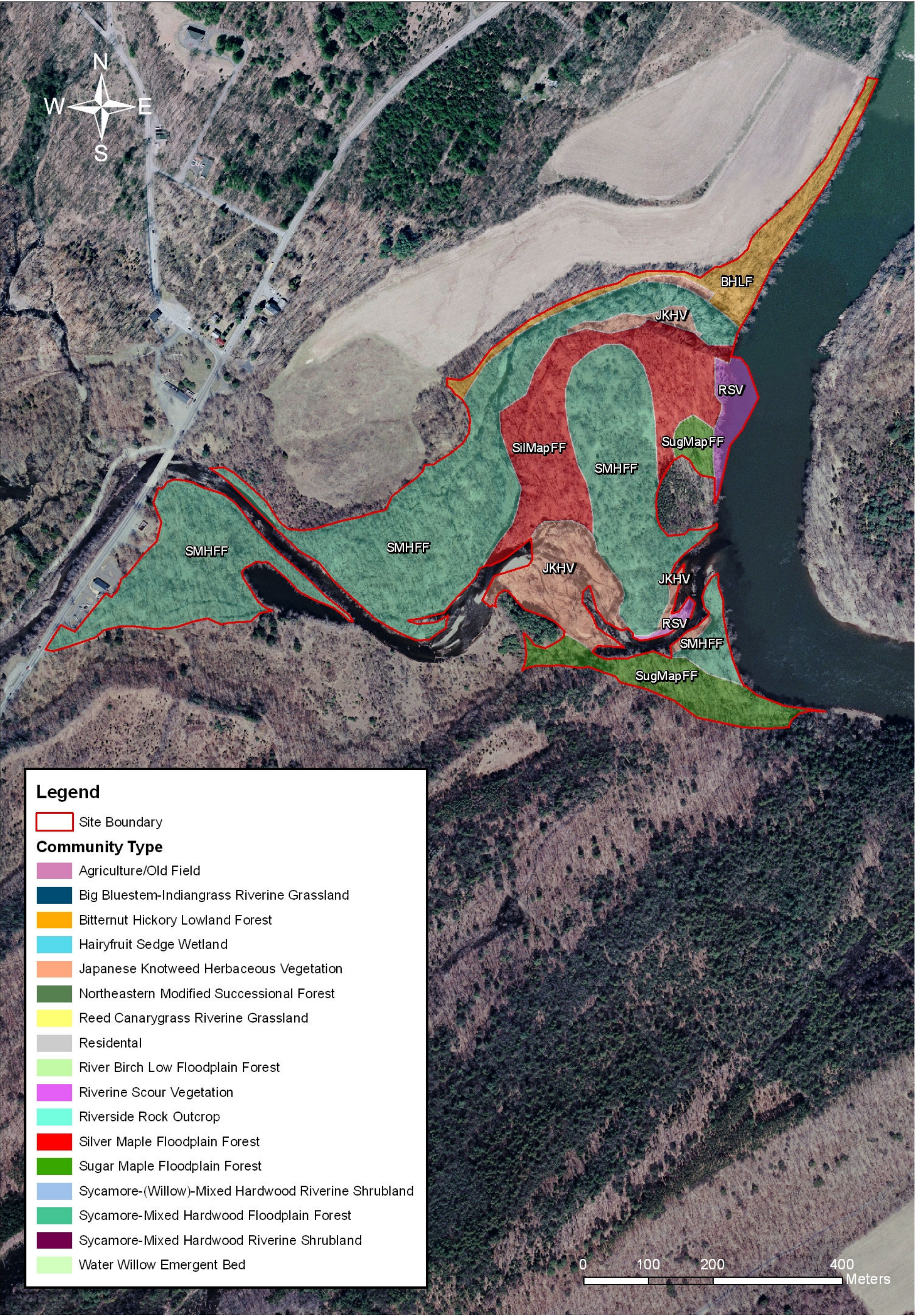


Figure 2. Distribution of floodplain communities at the Bushkill Creek study site (PAMAP 2005 imagery).

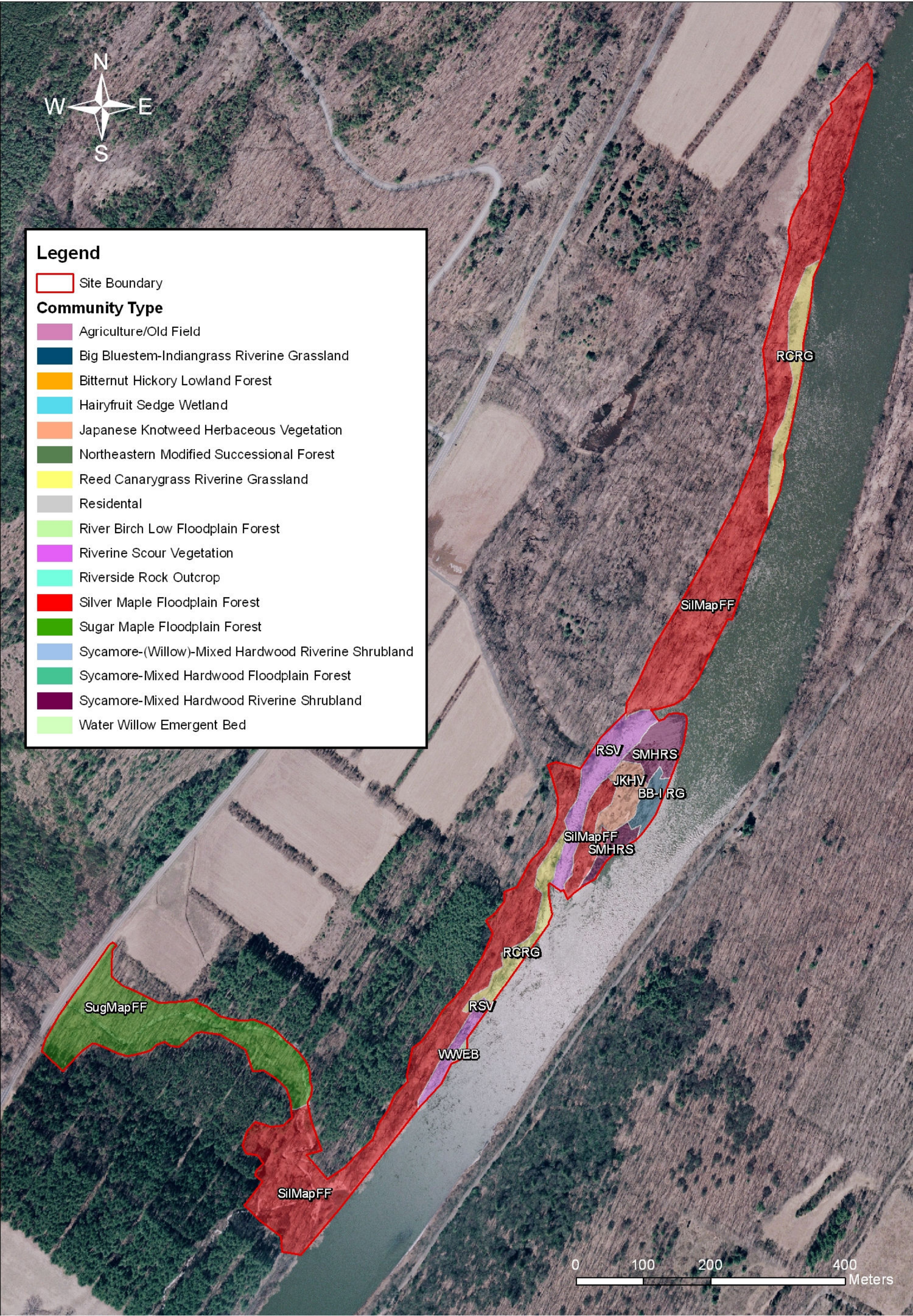


Figure 3. Distribution of floodplain communities at the Little Shapnack Island study site (PAMAP 2005 imagery).



Figure 4. Distribution of floodplain communities at the Shapnack Island study site (PAMAP 2005 imagery).

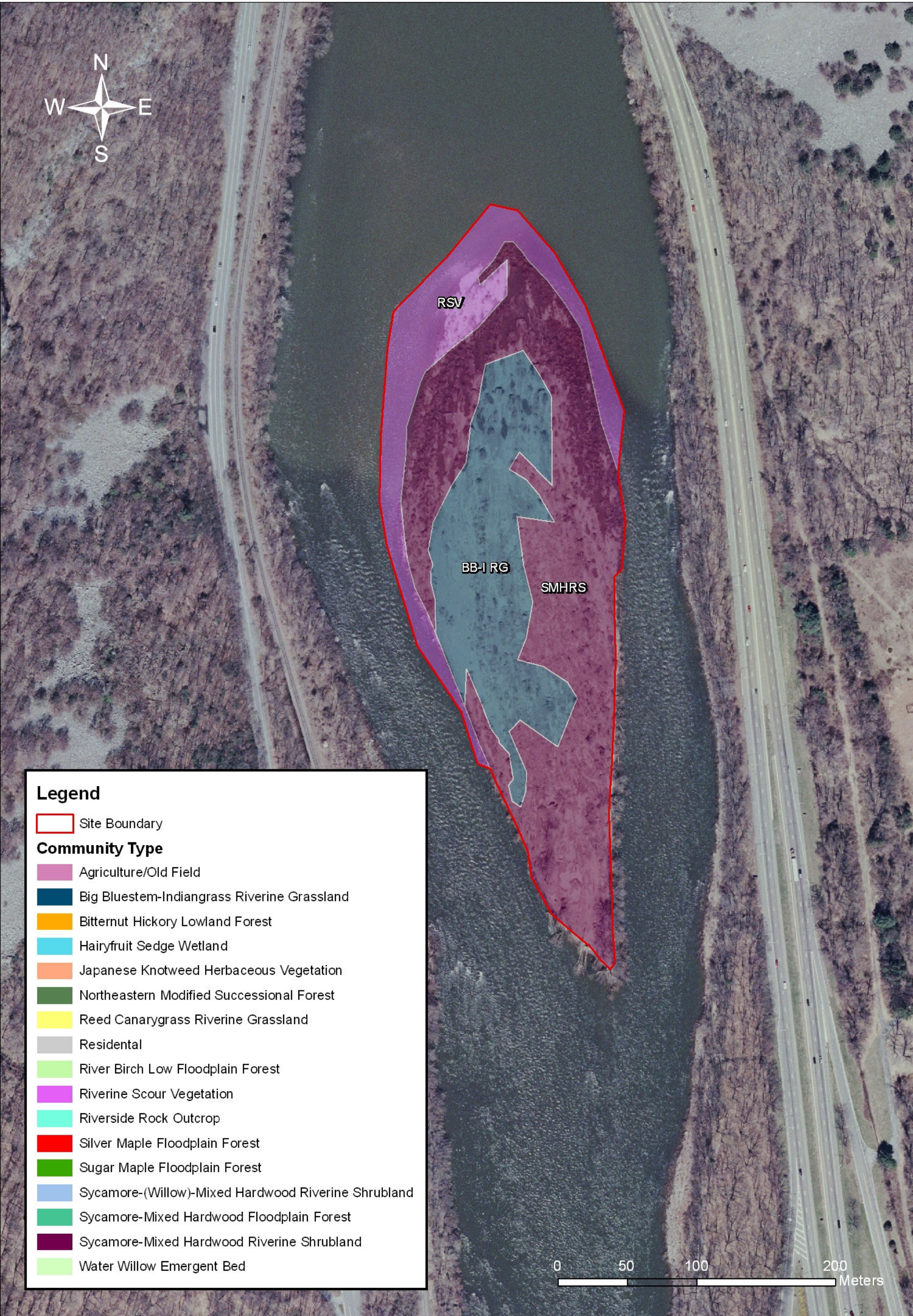


Figure 5. Distribution of floodplain communities at the Arrow Island study site (PAMAP 2005 imagery).

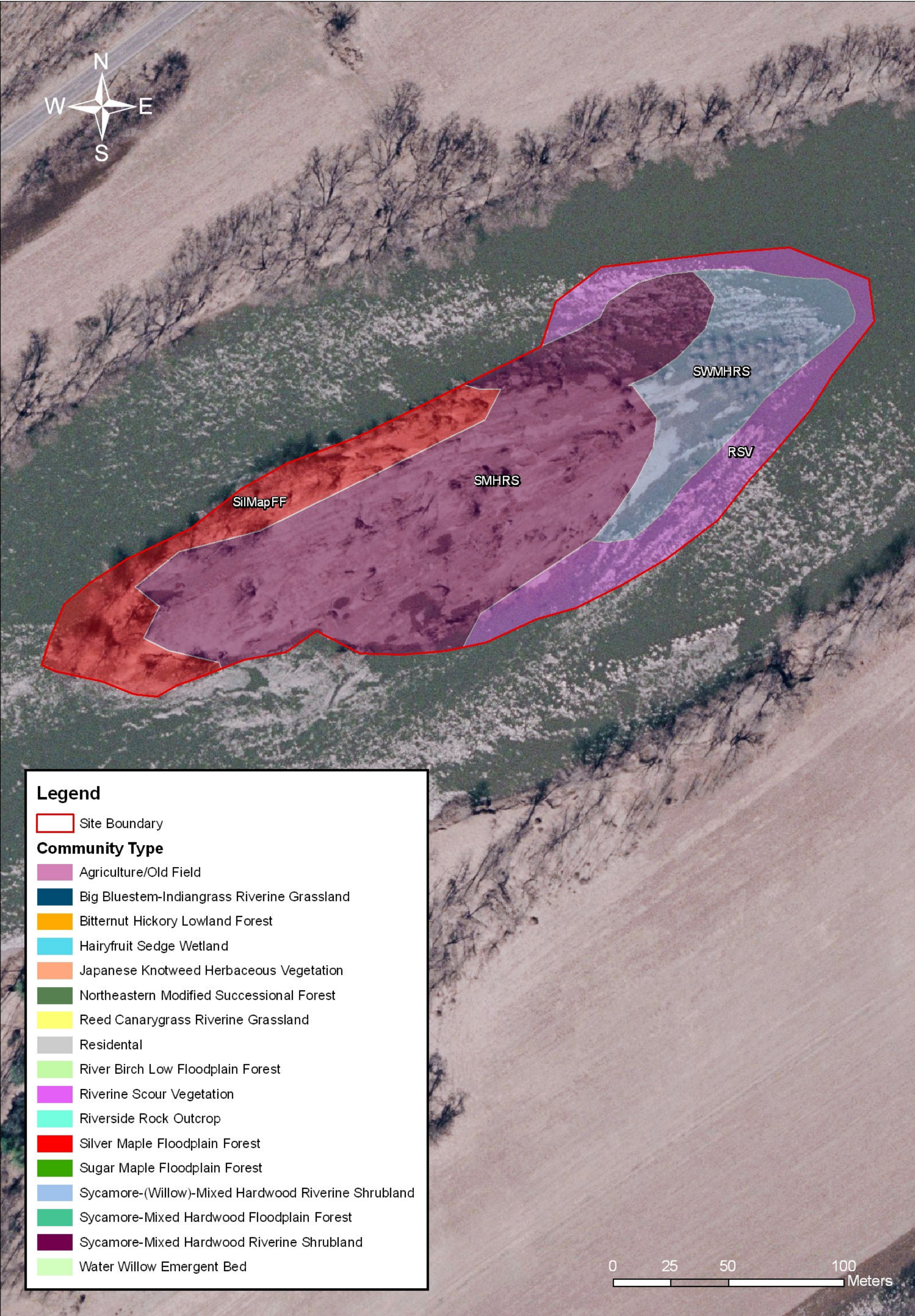


Figure 6. Distribution of floodplain communities at the Buck Bar Island study site (PAMAP 2005 imagery).

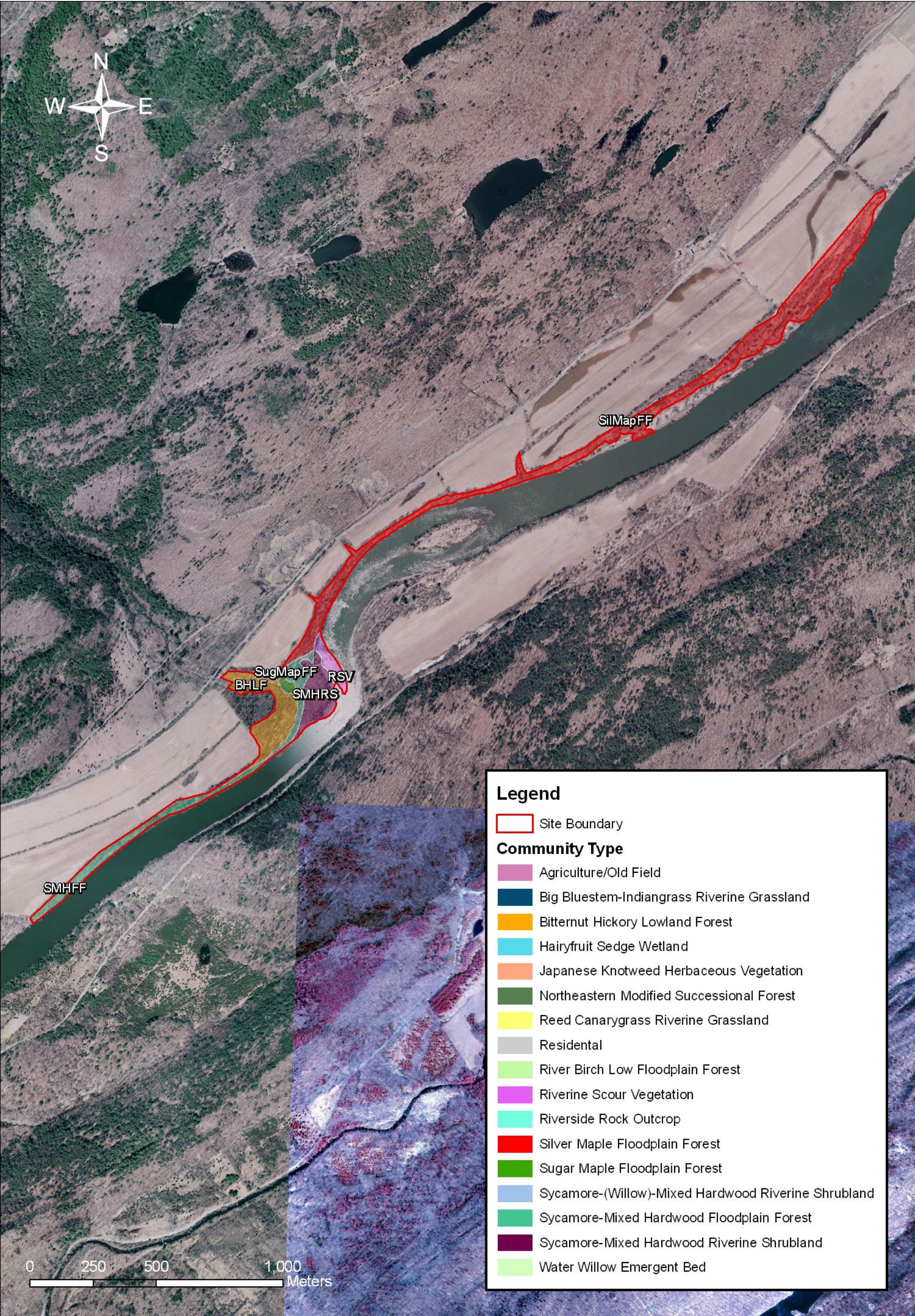


Figure 7. Distribution of floodplain communities at the Tom's Creek study site (PAMAP 2005 imagery).

Discussion

The riparian corridor within our study area supports a diversity of forest, shrubland, herbaceous, and degraded community types (Table 3). See Appendix B, Riparian Plant Community Reference Conditions, for more detail regarding community type spatial distributions, potential invasive plant species pests as well as pristine vegetation structure and species composition.

Riparian Forests

Five riparian forest community types were found during our investigation, with Silver Maple Floodplain Forest being the most common and River Birch Low Floodplain Forest being the least common. All forest communities typically occur on high to low terraces on the mainstem, at tributary mouths, and on islands and bars within the channel. The higher terraces were typically colonized by Silver and Sugar Maple Floodplain Forests as well as Bitternut Hickory Lowland Forest and are primarily impacted by larger, more infrequent flood events. Lower terraces were dominated by Sycamore-Mixed Hardwood Floodplain Forest and River Birch Low Floodplain Forest.

Silver Maple Floodplain Forests became increasingly dominant progressing downstream into DEWA. Below the Hogback Ridge mainstem channel, gradient is reduced resulting in lower velocity flood flows, decreased scour, and finer textured soils and sediment on mid to high terraces. These factors favor the enhanced recruitment and establishment of silver maples (*Acer saccharinum*).

Bitternut Hickory Lowland Forests, a rare community type, typically occur as linear stands several trees wide where the active floodplain transitions to higher terraces, primarily above Port Jervis and only occasionally below. Prior to European settlement, it is possible this community type may have extended onto higher elevation floodplains. Occurrences of Bitternut Hickory Lowland Forest not restricted to narrow, linear stands are rare, with Butternut Island near Callicoon, NY being a good example.

Sycamore-Mixed Hardwood Floodplain Forests typically occur on low to mid terraces of major tributaries to the Delaware River, such as the Bushkill and Flat Brook Creeks as well as on islands and bars. River Birch Low Floodplain Forest occurs on low terrace floodplains of major tributaries to the Delaware River as well as along islands, bars, and low terrace shorelines of the Delaware itself. Documented examples of this association were observed near the southern end of UPDE.

Sugar Maple Floodplain Forest occurs occasionally as small patches on the mainstem, and in most instances appears to be a successional stand on formerly farmed or cleared floodplain terraces. Some occurrences on high floodplain terraces may be attributable to colonization on bare substrate following major floods.

Riparian Shrublands

Only two shrublands were noted and in total comprised <5% of the total combined study area. The Sycamore-Mixed Hardwood Riverine Shrubland Community is distinguished

Table 3. Representative Riparian Communities grouped by community type and listed in order of descending total area occurring in riparian plant community sites along the Delaware River.

Forest Community Types	# of Sites	# of Patches	Total Combined Area (hectares)	Mean Patch Area (hectares)
Silver Maple Floodplain Forest	11	24	69.12	2.88
Sycamore-Mixed Hardwood Floodplain Forest	13	25	54.36	2.17
Sugar Maple Floodplain Forest	9	12	29.81	2.48
**Bitternut Hickory Lowland Forest	5	7	13.18	1.88
River Birch Low Floodplain Forest	1	1	0.73	0.73
Subtotal	39	69	167.2	2.42
Shrubland Community Types	# of Sites	# of Patches	Total Combined Area (hectares)	Mean Patch Area (hectares)
Sycamore-Mixed Hardwood Riverine Shrubland	9	19	15.69	0.83
Sycamore-(Willow)-Mixed Hardwood Riverine Shrubland	5	6	1.96	0.33
Subtotal	14	25	17.65	0.71
Herbaceous Community Types	# of Sites	# of Patches	Total Combined Area (hectares)	Mean Patch Area (hectares)
Reed Canarygrass Riverine Grassland	18	43	66.08	1.54
Japanese Knotweed Herbaceous Vegetation	13	39	31.10	0.80
Riverine Scour Vegetation	20	37	21.92	0.59
**Big Bluestem-Indiangrass Riverine Grassland	16	20	9.09	0.45
**Hairy-Fruit Sedge Wetland	6	10	7.51	0.75
Water Willow Emergent Bed	2	2	1.16	0.58
Riverside Rock Outcrop	1	1	0.21	0.21
Subtotal	76	152	137.07	0.90
Degraded Community Types/Habitats	# of Sites	# of Patches	Total Combined Area (hectares)	Mean Patch Area (hectares)
Agriculture/Old Field	5	7	49.16	7.02
Northeastern Modified Successional Forest	2	7	3.57	0.51
Residential	1	1	1.06	1.06
Subtotal	8	15	53.79	3.59
TOTAL PER STUDY AREA	137	261	375.71	1.44

** Rare community types were based on Pennsylvania state ranks (Pennsylvania Natural Heritage Program) and included community types with a rank of S1, S2 or S3. In this study, the rare communities that occurred included Big-Bluestem-Indiangrass Riverine Grassland, Hairyfruit Sedge Wetland and Bitternut Hickory Lowland Forest.

by the substantial tall-shrub layer of *Platanus occidentalis*, often with *Betula nigra*. The height of the shrubs (2-5 m) differentiates this type from Sycamore-(Willow)-Mixed Hardwood Riverine Dwarf Shrubland in which shrubs are less than 2 m in height. Dwarf shrubs remain stunted because they typically receive more frequent or more intense scour than Sycamore-Mixed Hardwood Riverine Shrubland. These sycamore-dominated

riverine shrublands typically occur on cobble and sand/gravel bars that are adjacent to or contiguous with the shoreline of the Delaware River. This type can also occur on the upstream ends of islands. Both community types are subject to frequent floods, high stream velocity and ice-scour.

Riparian Herbaceous Communities

There are six herbaceous community types within the study area with two invasive weed communities being the most common and significantly more abundant than the native communities. Approximately 71% of the total herbaceous area was Reed Canary Grass Riverine Grassland and Japanese Knotweed Herbaceous Vegetation community types. These two invasive weed communities were abundant throughout the study sites, ranging from smaller to larger patches. They occur as monocultures in some environments, yet in other situations were found interspersed with other native communities. Japanese knotweed was found in the understory of several floodplain forest communities, while Reed Canarygrass Riverine Grassland was often found interspersed with the Hairy-Fruit Sedge Wetland community, another rare community type. Hairy-Fruit Sedge Wetlands are typically found in low-lying mesic floodplains. This community is routinely flooded during most high-water events and commonly occurs on low flats associated with the active floodplain, either directly adjacent to the channel or associated with backwater depressions and sloughs.

The Big Bluestem-Indiangrass Riverine Grassland was the final unique/rare community identified within the study sites. This community type can be distinguished from other riparian types by the dominance of *Andropogon gerardi*, *Sorghastrum nutans*, *Panicum virgatum*, and *Schizachyrium scoparium* that form tall prairie-like grasslands. In the upper reaches of the Delaware, the community may be sparser, especially when the substrate is coarse cobbles. This rare community tended to be moderately distributed along the Delaware River but occurred in small patches. It typically occurs along shorelines and on islands at slightly higher elevations than Reed Canarygrass Riverine Grasslands and Hairy-Fruit Sedge Wetlands and can also be associated with or surrounded by Sycamore-Mixed Hardwood Riverine Shrubland.

Big Bluestem-Indiangrass Riverine Grasslands are subject to flooding and ice-scour that removes woody vegetation and maintains a graminoid- and herbaceous-dominated vegetation. The coarse substrate may experience drought conditions in mid-to-late summer, as river stage falls. The deep-rooted nature of most of the characteristic vegetation in this type allows them to reach sufficient moisture to avoid drought impacts.

Riverine Scour Vegetation occurs in a wide variety of riverine settings. The unifying factor that bridges the differences in environmental factors and species composition is the frequent scour that these sites experience. This vegetation type establishes itself in areas of the active channel that are underwater for the majority of the year and are exposed only at low water or in drought years. Therefore, these areas are subjected to high water velocities, floods, and ice-scour more frequently than the other riparian communities (with the exception of emergent beds).

Water Willow Emergent Bed communities were common throughout the study sites and are found at the heads of islands, along the edges of bars, banks, terraces, and spits, and in shallow sections of the river channel. The lower portions of the plants' stems are under water for most of the year, with the tops of the plants emerging above flowing water. These beds are entirely submerged by most flood events.

Riverside Rock Outcrop occurs along the river's shoreline where winter ice-scouring, shale bedrock outcrops, and natural seepage co-occur. The substrate consists of open, flood-scoured flat to nearly-flat bedrock exposures that extend for variable lengths from the woodland edge to the river edge. Species are distributed in patches due to microsite conditions that range from dry to moist (seepage areas). The sparse vegetation, when present, establishes itself crevices and in thin soil over bedrock. It is also susceptible to severe drought periods that may stress or kill some vegetation.

Unique/Rare Riparian Communities

In this study, the rare communities that occurred along the Delaware River included Big-Bluestem-Indiangrass Riverine Grassland, Hairyfruit Sedge Wetland and Bitternut Hickory Lowland Forest. All three communities have a PA state rank of S3. The rare communities tended to be moderately distributed along the Delaware River occurring in small patches.

Summary

In this project, a total of 17 community types were identified: 12 native community types and 5 developed or degraded community types. Riparian forests were the most dominant community type totaling approximately 45% of the total study area. The two invasive weed communities, Reed Canary Grass Riverine Grassland and Japanese Knotweed Herbaceous Vegetative Communities, were next in dominance representing approximately 25% of the total area, followed by degraded communities, representing approximately 14% of all sites. The combined total of invasive and degraded community types constitutes approximately 39% or more than a third of the total acreage evaluated.

The least common communities are the unique/rare and shrubland community types. Although only representing a small percentage of the total area, these community types remain a critical component of the overall system. These and other relatively small habitats with unusual, even extreme, environments are often home to a disproportionate share of Pennsylvania's rarest plant and animal species.

Delta sites contained the most Japanese knotweed vegetation community patches; however riverside sites also contained a large number. Reed Canarygrass Riverine Grasslands occurred most frequently on riverside sites with some community polygons occurring on islands and one on a delta site. In general, riverside communities had the highest invasive community cover at the site level while islands had the lowest. Delta sites had larger area and overall community complexity and the second highest in invasive cover (Table 2).

To summarize, native communities within the study sites represent 61% of the total study area. Within these native communities, floodplain forest communities, primarily Silver

and Sugar Maple Floodplain Forests, are most common, followed by herbaceous (excluding invasive community types) and shrubland community types. Altered community types, including Agricultural/Old Field, Northeastern Modified Successional Forest, residential lands, and invasive weed community types, represent 39% of the study sites total area.

Reference Conditions

Reference conditions or descriptions of the riparian plant communities are provided in Appendix B. These descriptions describe the environmental conditions if known and if specific to that community type and may include information regarding soils, geology, hydrology, chemistry, hydrology, and disturbance. Most importantly, the descriptions provide information on species composition, and relative abundance, while noting those species and community characteristics that distinguish one community type from another.

Reference conditions provide a framework against which the condition of riparian communities can be compared. They can also provide the basis for developing future desired conditions by identifying the environmental conditions, species composition and structural characteristic for each plant association.

Following is an example of a community type description or reference condition. Full descriptions for the remaining community types can be found in Appendix B.

Example: Silver Maple Floodplain Forest

COMMON NAME: SILVER MAPLE FLOODPLAIN FOREST

SYNONYMS

NVC English Name: *Silver Maple - American Elm Forest*

NVC Scientific Name: *Acer saccharinum - Ulmus americana Forest*

NVC Identifier: *CEGL002586*

LOCAL INFORMATION

Environmental Description: This floodplain forest occurs on the downstream ends of islands and on high terraces along the shoreline of the Delaware River. The substrate is typically silt loam or sandy loam, as in Delaware fine sandy loam or Pope fine sandy loam. The forest floor frequently has numerous parallel swales created by flood scour. Floods leave river-deposited debris on the forest floor, with large debris piles common. Winter flooding indicated by numerous ice scars on older trees. These forests are inundated only during larger flood events.

Vegetation Description: This floodplain forest is dominated by silver maple (*Acer saccharinum*), covering 40-75% of the canopy. Sugar maple (*Acer saccharum*) can be a canopy codominant, with sycamore (*Platanus occidentalis*), willows (*Salix* spp.) and river birch (*Betula nigra*) as occasional associates. Other occasional canopy associates include: red maple (*Acer rubrum*), aspen (*Populus* spp.), ash (*Fraxinus* spp.), walnut (*Juglans* spp.), and bitternut hickory (*Carya cordiformis*). The canopy trees typically extend 20-30 m in height, while subcanopy trees range in height from 5-10 m. The sparse subcanopy can contain sugar maple, bitternut hickory (*Carya cordiformis*), silver maple,

boxelder (*Acer negundo*), white ash (*Fraxinus americana*), eastern hop-hornbeam (*Ostrya virginiana*), black cherry (*Prunus serotina*), and black walnut (*Juglans nigra*). The sparse short-shrub layer includes black raspberry (*Rubus occidentalis*), spice bush (*Lindera benzoin*) and seedlings of the canopy species. The dense herbaceous layer contains reed canarygrass (*Phalaris arundinacea*), whitegrass (*Leersia virginica*), ostrich fern (*Matteuccia struthiopteris*), hedge false bindweed (*Calystegia sepium ssp. sepium*), dogtooth violet (*Erythronium americanum*), Jack-in-the-pulpit (*Arisaema triphyllum*), giant goldenrod (*Solidago gigantea*), sensitive fern (*Onoclea sensibilis*), marsh pepper weed (*Polygonum hydropiper*), Pennsylvania smartweed (*Polygonum pensylvanicum*), deer-tongue (*Dichanthelium clandestinum*), upland bentgrass (*Agrostis perennans*), small-spike nettle (*Boehmeria cylindrica*), sensitive fern (*Onoclea sensibilis*), Canada clearweed (*Pilea pumila*), swamp smartweed (*Polygonum hydropiperoides*) and sweet woodreed (*Cinna arundinacea*). Vines such as eastern poison ivy (*Toxicodendron radicans*) and Virginia creeper (*Parthenocissus quinquefolia*) can also be common.

Most Abundant Native Species:

<u>Stratum</u>	<u>Lifeform</u>	<u>Species</u>
Tree canopy	Broad-leaved deciduous tree	<i>Acer saccharinum</i>
Tree subcanopy	Broad-leaved deciduous tree	<i>Acer saccharum</i>
Tall shrub/sapling	Broad-leaved deciduous shrub	<i>Acer saccharinum</i> <i>Acer saccharum</i> <i>Carya cordiformis</i>
Herb (field)	Vine/Liana	<i>Parthenocissus quinquefolia</i> , <i>Toxicodendron radicans</i>
Herb (field)	Forb	<i>Calystegia sepium ssp. sepium</i> , <i>Arisaema triphyllum</i> , <i>Erythronium americanum</i> , <i>Solidago gigantea</i> , <i>Polygonum hydropiper</i> , <i>Boehmeria cylindrica</i> , <i>Pilea pumila</i> , <i>Polygonum hydropiperoides</i>
Herb (field)	Graminoid	<i>Leersia virginica</i> , <i>Phalaris arundinacea</i> , <i>Agrostis perennans</i> , <i>Cinna arundinacea</i>
Herb (field)	Fern or fern ally	<i>Matteuccia struthiopteris</i> , <i>Onoclea sensibilis</i>

Characteristic Species: *Acer saccharinum*, *Acer saccharum*, *Matteuccia struthiopteris*,

Typical Invasive/non-native plant species:

Trees:

Robinia pseudoacacia

Shrubs:

Berberis thunbergii

Rosa multiflora

Lonicera morrowii

Herbs:

Alliaria petiolata

Glechoma hederacea

Microstegium viminium

Polygonum cuspidatum

Polygonum persicaria

The invasive species Japanese knotweed (*Polygonum cuspidatum*) can form dense thickets on the forest floor. Garlic mustard (*Alliaria petiolata*), spotted lady's thumb (*Polygonum persicaria*), ground ivy (*Glechoma hederacea*) and Japanese stiltgrass (*Microstegium vimineum*) are other common herbaceous invasive species in this forest.

Other Noteworthy Species: Information not available.

Subnational Distribution with Crosswalk data:

State	State Rank	Confidence	State Name	Reference
NJ	SNR	1	Silver Maple – American Elm Floodplain Forest	Walz et al. 2006
NY	SNA	1	Floodplain Forest	Edinger et al. 2002
PA	S5	1	Silver Maple Floodplain Forest	Fike 1999

Local Range: This forest occurs on larger islands with higher terraces and terrace shorelines associated with the Delaware River from Hancock to the Delaware Water Gap.

Classification Comments: Silver Maple Floodplain Forest can be distinguished from other floodplain forests by the dominance of *Acer saccharinum* (40-75% cover), often with *Acer saccharum* as codominant in the canopy or subcanopy. In other drainages, such as the Susquehanna River, in the few instances where *Polygonum cuspidatum* is not dominant in this community, the understory may have a higher cover of tall herbs such as *Impatiens capensis*, *I. pallida*, *Laportea canadensis*, *Lysimachia ciliata*, *Verbena urticifolia*, *Lycopus* spp. and *Arisaema draconitum*.

Other Comments: None.

USFWS Wetland System: Palustrine

Local Description Authors: S.J. Perles (PNHP)

Plots and Data Sources: Podniesinski et al. 2007; Perles et al. 2007. Fike 1999, Podniesinski and Wagner 2002.

References: Anderson 1996, CAP pers. comm. 1998, Eyre 1980, Fike 1999, INAI unpubl. data, MNNHP 1993, Midwestern Ecology Working Group n.d., Podniesinski and Wagner 2002, TDNH unpubl. data, WINHIP unpubl. Data.



**Figure 8. Silver Maple Floodplain Forest in Delaware Water Gap National Recreation Area.
Photograph by: Gregory Podniesinski, Pennsylvania Natural Heritage Program.**

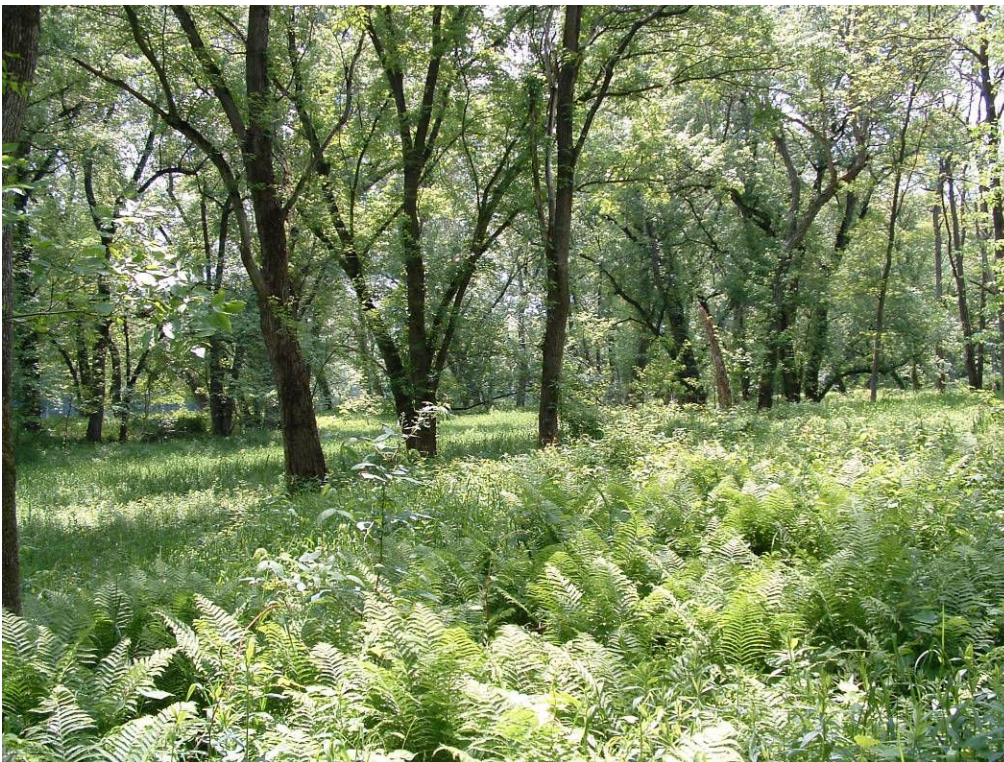


**Figure 9. Silver Maple Floodplain Forest in Delaware Water Gap National Recreation Area.
Photograph by: Gregory Podniesinski, Pennsylvania Natural Heritage Program.**

Conceptual Ecological Models

"This "ecological" diversity is related to variable flood regimes, geomorphic channel processes, altitudinal climate shifts, and upland influences on the fluvial corridor. This dynamic environment results in a variety of life history strategies, and a diversity of biogeochemical cycles and rates, as organisms adapt to disturbance regimes over broad spatio-temporal scales." (Naiman et al. 1993)

These conceptual ecological models will first describe the setting of the Delaware River and general principles affecting riparian communities on the Delaware River and then present ecological models of plant community development and succession in different geomorphic settings.

Environmental Setting and Controls

Climate

The Delaware River basin experiences a humid continental climate characterized by large annual ranges in temperature and an even distribution of precipitation. Proximity to the Atlantic Ocean provides some additional moisture and increases precipitation (Rossi, 1999). Annual precipitation generally exceeds 114 cm in the study area. The mean maximum January temperature for UPDE is 0° C or less and only slightly above 0° C for DEWA, which allows for significant accumulations of river ice in most years (U.S. National Oceanic and Atmospheric Administration 1984). Average snowfall in the UPDE section is generally over 200 cm and varies from about 130 to 170 cm in DEWA. The accumulation of a snow pack, especially in the UPDE watershed, allows for late winter-early spring flooding due to sudden snowmelt combined with warm rain events. The Delaware River basin is also subject to extreme precipitation events associated with intense summer storm systems as well as tropical storm systems moving along the Atlantic coast.

UPDE Geology

The bedrock geology underlying the Delaware River within UPDE and DEWA includes two different physiographic provinces, the Glaciated Low Plateau Section of the Appalachian Plateau and the Ridge and Valley (Figure 10). The UPDE portion (from Hancock, NY to Port Jervis, NY) lies entirely within the Glaciated Low Plateau Section of the Appalachian Plateau and is characterized by nearly horizontally bedded sandstone, siltstone and shale of Upper Devonian age (Harrell through Spechty Kopf Formation). The formation gently dips to the northwest with occasional folds and little variation between the Pennsylvania and New York sides of the river. The plateau has been uplifted and subsequently dissected by the Delaware River and its tributaries. Bedrock jointing may contribute to north-south flowing streams having relatively straight, laterally offset segments (e.g., Lackawaxen Creek, perhaps the Delaware mainstem). Very limited bedrock geology information is available for this portion of the river, as the region has not received much attention from either PA or NY geologists.

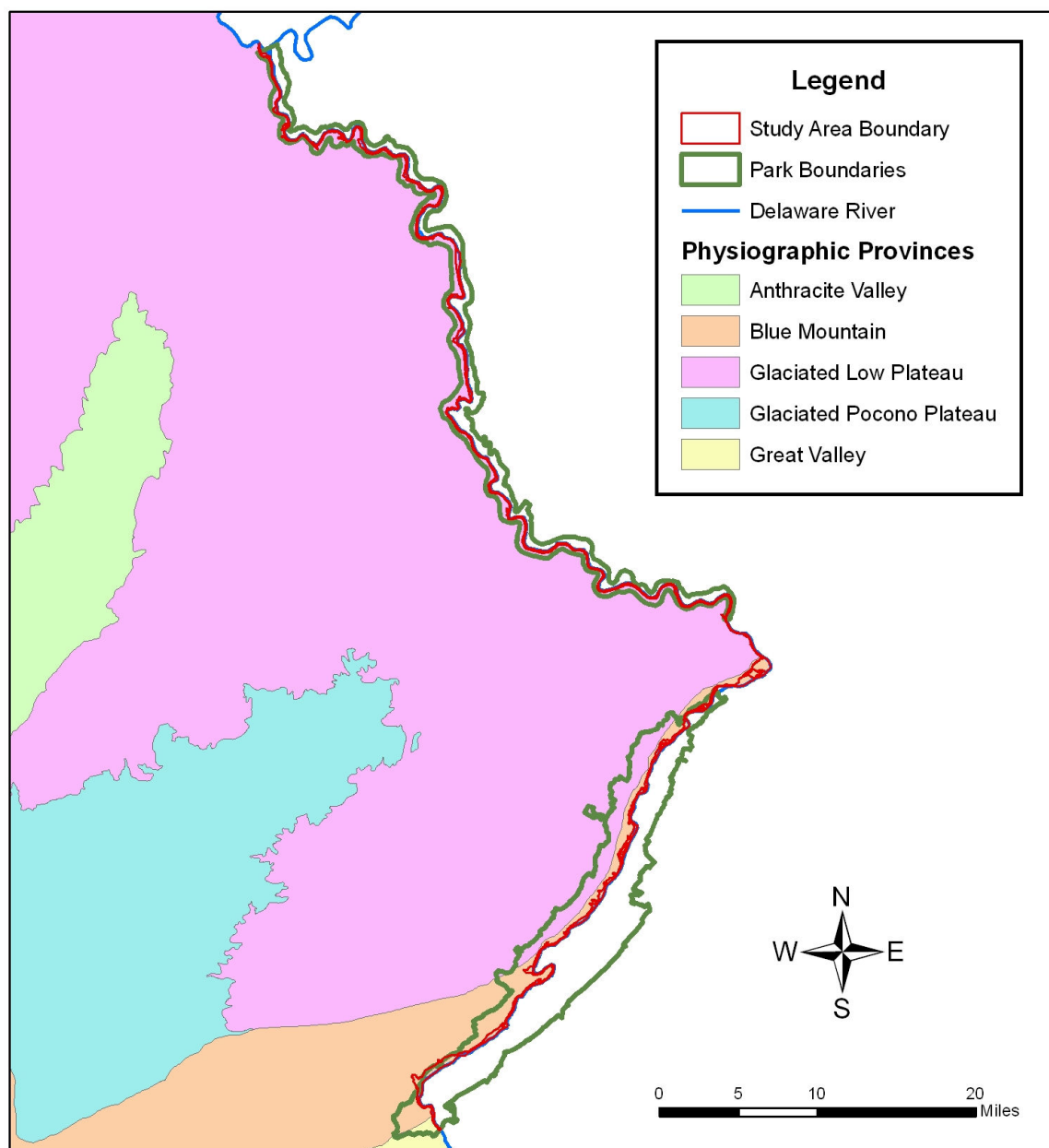


Figure 10. Physiographic provinces of UPDE and DEWA park units.

DEWA Geology

The structural geology of DEWA differs greatly among the sections of the physiographic provinces (Epstein 2001) (Figure 11). 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 Ordovician, Silurian, and Devonian age strata. The Ordovician 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 Kittatinny 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, 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 Kittatinny Ridge.

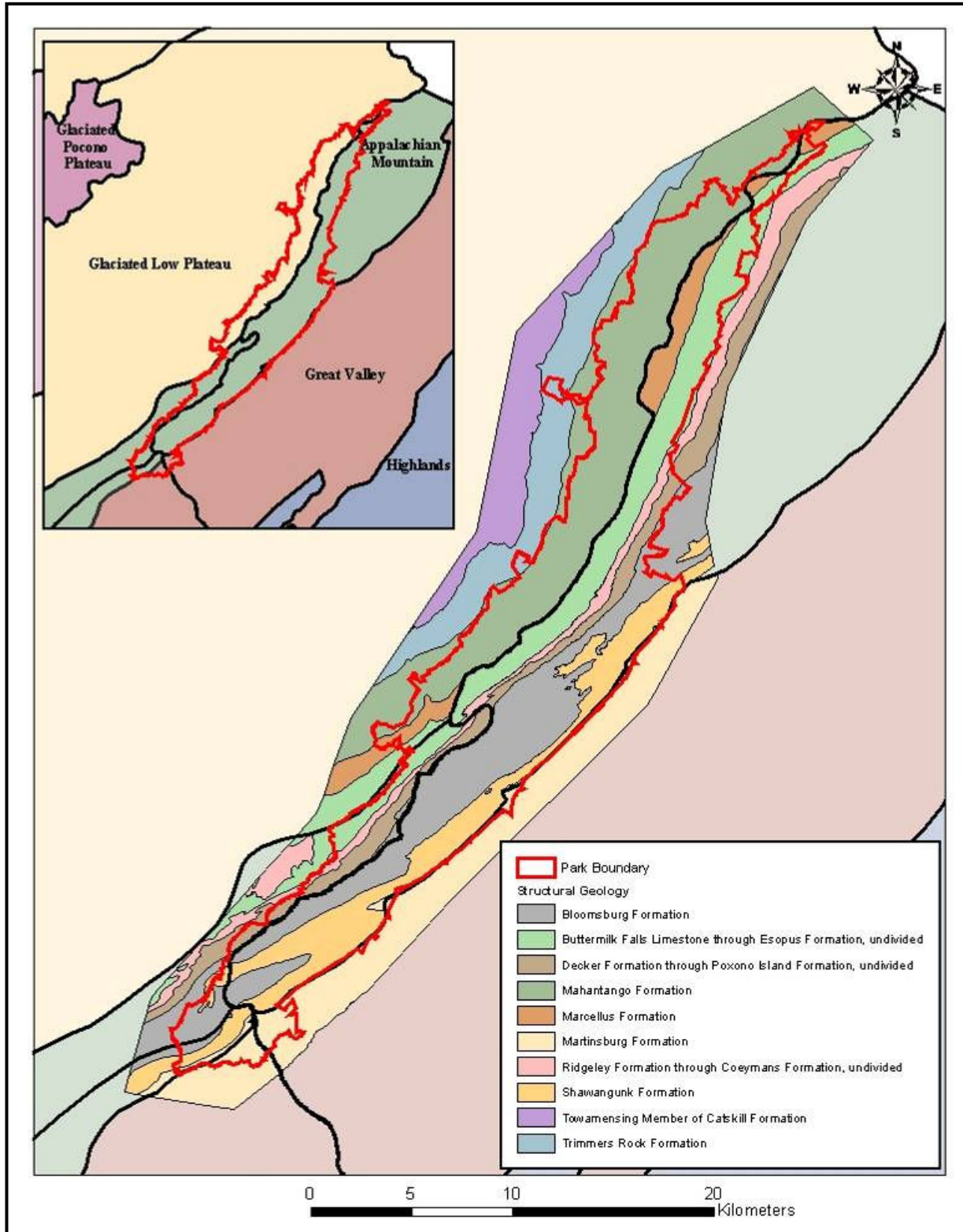


Figure 11. Physiographic province sections and structural geology of the Delaware Water Gap National Recreation Area.

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 (Ridgely through Coeymans Formations), in Figure 11. 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 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. 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 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 Ordovician Age Martinsburg Shale, which occurs as relatively flat to gently rolling terrain.

Topography

The topography of the UPDE section of the Delaware River reflects down cutting into the Glaciated Low Plateau Section of the Appalachian Plateau, resulting in low mountains with steep tributary drainages flowing to the river. While the bedrock dips to the northwest, the elevation of the plateau decreases to the southeast. Plateau elevation near Hancock is approximately 560 m, 455 m near Callicoon and 335 m near Milrift (southern terminus of UPDE). The Delaware River at Hancock lies at 274 m, 225 m at Callicoon, and 134 m at Milrift. The average gradient is approximately 1.2 m/km.

Topography varies widely within DEWA. This is illustrated most dramatically at the Delaware Water Gap where the Delaware River (elevation 90 m) cuts through the Kittatinny Ridge creating spectacular views from Mt. Tammany (470 m) and Mt. Minsi (445 m). The elevation of the Delaware River floodplain decreases as the river runs through the park, from approximately 120 m at Mashipacong Island at the park's northern boundary to approximately 90 m at Arrow Island, just south of the Delaware Water Gap. The average gradient is approximately 0.5 m/km. The height of Kittatinny Ridge varies between 425 m and 487 m with one of the highest points occurring north of Crater Lake at 490 m. The Hogback and Walpack Ridge run through the central portion of the park with height varying from 210 m to 365 m. The plateau of the Low Glaciated Plateau sits at approximately 245 m to 290 m, although elevation along the plateau can vary from 210 m to 320 m. The northeast portion of the park in New Jersey gently rises from the Delaware River floodplain at 120 m to approximately 245 m at the park's eastern

boundary. The valleys surrounding Flat Brook and Bushkill Creek occur at approximately 245 m in elevation.

Hydrology

The Delaware River is the longest free-flowing river east of the Mississippi, extending 330 miles from the confluence of its East and West branches at Hancock, NY to the mouth of the Delaware Bay and is fed by over 200 tributaries. The drainage basin covers 35,065.9 square kilometers (13,539 square miles), draining parts of Pennsylvania (16,632.9 square kilometers (6,422 square miles) or 50.3 percent of the basin's total land area); New Jersey (7,689.7 square kilometers (2,969 square miles), 23.3%); New York (6,117.6 square kilometers (2,362 square miles), 18.5%); and Delaware (2,600.3 square kilometers (1,004 square miles), 7.9%).

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 important of these streams are, from north to south, Equinunk Creek, Lackawaxen River, Raymondskill Creek, Adams Creek, Dingmans Creek, and Tom's 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, Brodhead Creek, Cherry Creek, and Caledonia Creek, enter the Delaware River just upstream from the Delaware Water Gap.

In New York, important tributaries include the East and West branches of the Delaware River at Hancock and the Neversink River, just below Port Jervis. In New Jersey, from Port Jervis to the Delaware Water Gap, significant tributaries include the Flat Brook (entering at the Hogback) and the Vancampens Brook (entering near Poxono Island).

Dams

While the mainstem is free-flowing, there are a number of dams in the drainage, with the most important being the three dams on the tributaries to the upper Delaware River: Cannonsville Dam on the West Branch (1175.6 km² (290,497.1 acres) watershed, capacity 369.1 million m³ (97.5 billion gallons)), Pepacton Reservoir (963.5 km² (238,086.1 acres) watershed, capacity 530.7 million m³ (140.2 billion gallons)) and the Neversink Reservoir (239.6 km² (59,206.5 acres) watershed, capacity 132.1 million m³ (34.9 billion gallons)). The dams were installed and became operational over a period of ten years (Neversink 1953, Pepacton 1954, Cannonsville 1963). These dams were constructed primarily to provide water to the New York City region, and in conjunction with other smaller reservoirs in the basin, provide drinking water to 5 percent of the United States population (despite a watershed that covers less than 0.4% of the continental U.S.) (DRBC). The general effect of regulated dams on riparian vegetation is to attenuate flood flows, with decreased flow velocity and scouring and increased flood duration (but at lower river stage). Related geomorphic processes, including the erosion, transport and deposition of sediment, are consequently altered.

Geomorphology

The close link between geomorphology and the distribution and structure of riparian vegetation requires a review of the geomorphic features common to the study area. The Upper Delaware River (from Hancock, NY to the Delaware Water Gap) is an alluvial upland river system of straightened-confined meandering character with a pluvio-nival flow regime (i.e. high flows related to rain and snow melt in the fall and spring, and low flow in the summer (Parde 1968)) (Parasiewicz 2001). The valley is U-shaped, with the river generally flowing over glacial deposits.

Longitudinally, the section of the river from Hancock to Port Jervis is confined in a very narrow valley with very limited capacity for meandering and the formation of geomorphic features such as point bars. The overall width of the valley bottom (including the river) is seldom much wider than 500 meters. Aside from some channel braiding near Hancock where the East and West Branches meet and near Callicoon, the rest of the river down to Port Jervis (about 122 km) contains about ten large islands (roughly 300 to 1000 m long, 80 to 200 m wide) and twenty low cobble-gravel islands/bars. Islands over 500 m long tended to have elevated sections that supported riparian forest. Islands less than 500 m long and cobble-gravel bars supported riparian shrubland and herbaceous vegetation. The channel bed is primarily freestone cobbles and boulders, and typically confined on one or both sides by bedrock. Sand and finer deposits are limited in extent and occur below bends and constrictions in the river along slackwater sections of shore line. Sand and sandy loam deposits may also occur on the higher elevations of islands and downstream from obstructions (e.g., coarse woody debris) where the flood currents were slower. Instream sand bars were very rare. The shoreline in confined reaches is very narrow (often less than 30-50 meters wide) and characterized by scoured cobbles, gravel, and a concave slope that terminated abruptly into upland forest. Where the valley bottom is wider, one or both sides of the river are bounded by glacial deposits, forming high terraces that appear to seldom flood. Between the river and this terrace, the riparian zone may consist of a gently sloping gravel, cobble and sand flat, with an abrupt bank where it meets the glacial fill terrace.

At several locations on the UPDE section, bedrock is exposed in the riparian zone, with notable examples at Skinner's Falls, and near Narrowsburg. At Skinner's Falls, the exposed bedrock zone is 10 to 20 meters wide, while near Narrowsburg the bedrock presents a more vertical rock face with the occasional narrow ledge (generally less than 5 m wide) that dips to the north or northwest. Rock outcrops also occur periodically downstream below Narrowsburg. Rock outcrops in UPDE are typically resistant sandstones.

The DEWA portion of the study area has distinct geomorphic sections. From approximately Milford to the Hogback (near Bushkill), the river runs through the Minisink Valley. The Delaware River valley is at its widest here, varying from 1000 to nearly 1400 m wide. The river valley becomes constricted (approximately 200 m wide) as it runs through the Hogback Ridge. From Hogback Ridge to the Delaware Water Gap, the river valley widens again to about 600 to 900 m with a number of large islands. At the Water Gap, the river constricts again, with a width of 100-200m and very little

riparian vegetation. The park terminates just below the Water Gap at Arrow Island. The DEWA section contains approximately 19 large islands (roughly 300 to 2700 m long, 70 to 750 m wide) and 16-20 low cobble-gravel bars. Between Milford and the Hogback, the islands are similar in appearance to those in UPDE as described above. Below the Hogback, the river gradient decreases to about 0.3 m/km, and a number of the larger islands typically have one or two terraces with loamy to sandy loam alluvial soils. These terraces tend to support larger and more mature Silver Maple Floodplain Forests than islands above the Hogback. Presumably the lower gradient in this reach has allowed the accumulation of fines (sand, silt and clay) on the island floodplain terraces. Many of the larger islands also have one or more cross channels.

As in UPDE, the DEWA portion of the river appears to lack well-developed point bar features. Although the Minisink Valley portion is up to 1400 meters wide and lies over glacial deposits, archeological evidence suggests that the river's course has shifted little in the past 6000 years (Ritter et al., 1973). Below the Minisink Valley, from the Hogback to the Delaware Water Gap, the river is confined by the geologic formations of the Ridge and Valley Province with little opportunity for meander development.

Bedrock outcrops in the DEWA section include limestone outcrops near Montague and sandstone outcrops near the Delaware Water Gap. The bedrock typically dips steeply to the northwest, with the bedrock exposures also being steeply angled toward the river and having limited lateral extent before transitioning into upland vegetation (generally less than 5 to 10 m wide).

General Ecological Principles of Riparian Communities

Life History Strategies

Life history strategies are the means by which organisms carry out the functions necessary for survival and reproduction. In riparian communities, the temporal and spatial heterogeneity of available habitat allows for nearly every conceivable variation in life history strategies (Toner and Keddy 1997, Decocq 2002, Lamb and Mallik 2003, Turner et al., 2004, Karaus et al., 2005). Spatial heterogeneity reflects a wide variation of habitat present on the Delaware River, including scoured bedrock outcrops, point bars, island heads and riffle zones, quiet floodplain pools and back channels, low and mid-elevation floodplain terraces and levees. Temporal heterogeneity includes seasonal variations in flow and water quality, storm events, and vegetation succession (from seasonal to decadal time frames). Life history strategies also reflect adaptation to habitat predictability (or lack thereof). In general, the interaction of spatial and temporal variability controls the degree of predictability in site conditions. For example, Water Willow (*Justicia americana*) beds are typically the lowest elevation riparian community and are routinely and predictably subjected to high velocity flows and ice scouring in winter. At the opposite end of the elevation gradient, the Sugar Maple Floodplain Forest is “predictably” subject to infrequent, short-duration flood events.

Physiological adaptations of riparian plants

Life history strategies of riparian plants typically include adaptations to the riparian environment. Riparian plants can be assigned to one of four general classes reflecting functional adaptations for colonization and establishment (after Naiman et al., 1998):

- **Invader:** Produces large numbers of wind and water-dispersed propagules that colonize alluvial substrates (e.g., sycamore, river birch, silver maple, willow, sedges and grasses).
- **Endurer:** Resprouts after breakage or burial of either the stem or roots from floods or after being partially eaten.
- **Resister:** Withstands flooding for weeks during the growing season; also withstands moderate fires or disease epidemics.
- **Avoider:** lacks adaptations to specific disturbance types; individuals germinating in an unfavorable habitat are due not to survive.

On the Delaware River, woody plants typical of the lower active riparian zone often exhibit more than one of the above life history strategies. For example, river birch (*Betula nigra*) produces large numbers of seeds that are dispersed by the wind or carried by water to bare alluvial soils (invader); it typically occurs on island heads and scoured shorelines where it may be subjected to regular ice and flood scour (endurer) and can tolerate flooding for extended periods during the growing season (resister). In contrast, woody plants typical of the higher terraces, near the edge of the floodplain, occur in microhabitats where stresses are limited (avoiders). Sugar maple (*Acer saccharum*) and bitternut hickory (*Carya cordiformis*) are examples of this. These two trees tend to occur on the higher floodplain terraces or higher portions of islands where physical stress (e.g., scour, breakage, burial in sediments) and flood stress (anaerobic soil conditions) are limited. The life history strategies exhibited at any one site will be influenced by local site conditions.

Morphological adaptations of riparian plants

Morphological adaptations of plants to the riparian environment reflect responses to anaerobic soil conditions and unstable substrate. Flooded soils have a greatly reduced availability of oxygen, which is rapidly depleted by the metabolic demand of soil flora and fauna. Many riparian plants (e.g., many sedges and rushes) have adaptations to anoxic soil conditions including aerenchyma tissue with airspaces for the diffusion of oxygen from upper (aerated) to lower (anoxic) portions of the plant. Plants may also form adventitious roots to enhance oxygen diffusion above the anoxic zone. However, flooding of well-drained alluvial soils during the late-fall to early spring months on the Delaware river may not result in anoxic soil conditions, due in part to the low metabolic activity in the soil at low temperatures and the coarse nature of many alluvial soils that allows water to move in and out of riparian soils (rhizotrophic flow) before becoming anoxic.

The abrasion of plants by suspended sediment and debris and the erosion of soils during flood events also create important stresses on riparian vegetation. Plant species occurring in the active flood zone of the Delaware River typically experience wide variation in flow. An important factor in survival, particularly in woody plants, is stem flexibility. Flood flows can produce tremendous shear stress on woody plants, and plants with inflexible stems are likely to experience catastrophic stem failure and mortality. The three most common woody plants on the heads of islands and scoured shorelines of the Delaware River are shrubby black willow (*Salix nigra*), river birch (*Betula nigra*) and sycamore (*Platanus occidentalis*). All of these species can withstand tremendous stream flows, with larger individuals on the island often exhibiting a downstream-bent form (Figure 12). This environment is also prone to the erosion and deposition of a significant amount of sediment, which may alternately expose and bury the stem and roots of woody plants and subject them to damaging abrasion by moving debris and sediment. Each of the above species is strongly rooted to the substrate and can re-establish vertical growth, even when bent over at nearly a 90° angle and partially buried. In addition, woody vegetation that occurs in linear stands (parallel to the direction of flow) improves their survival by reducing the flow velocity to which downstream individuals are exposed.



Figure 12. Sycamore-Mixed Hardwood Riverine Shrubland showing battered and bent boles of river birch (*Betula nigra*). Photograph by: Gregory Podniesinski, Pennsylvania Natural Heritage Program.

Reproductive strategies

Reproductive strategies observed in riparian plants usually reflect the pattern of disturbance that makes habitat available for colonization and establishment. The majority riparian woody plant species on the Delaware River are shade intolerant, both as

seedlings and adults, and require microhabitats with limited competition, especially for light. Therefore, many of these species time the dispersal of seeds to correspond with spring floods in order to take advantage of newly scoured substrate and sediment deposits. The window of opportunity is often limited to several weeks or less, as the seeds of many species remain viable for only a short period. Cottonwood and willow seeds are generally viable for only one to two weeks. Seed dispersal is typically wind (anemochory) and/or water (hydrochory) dependent. It is not uncommon for stands of willow, cottonwood, river birch, or sycamore to establish themselves as narrow bands on point bars and scoured shorelines, reflecting the deposition of water-borne seeds in strand lines by receding flood waters. Once deposited, the seeds usually germinate quickly and survival is dependent on substrate type, soil moisture and the hydrology of the micro-site. The seasonal timing for herbaceous vegetation may be less important, especially for annual herbs that can run through their lifecycle even in a flood-shortened growing season.

Asexual or clonal growth is also an important strategy for survival and spread in riparian habitats. Dwarf shrub willow, *Carex trichocarpa*, water willow (*Justicia americana*) and reed canarygrass (*Phalaris arundinacea*) stands exhibit examples of clonal reproduction on the Delaware River, particularly where frequent inundation, scour, and sediment deposition may make sexual reproduction unpredictable or impossible. Willows can also reproduce via broken branches, which produce adventitious roots on moist substrate that grow into new trees. Clonal growth often allows species to persist in habitats where larger individuals can utilize resources, but where conditions prevent successful germination and establishment. For example, many island heads with coarse gravel and cobble deposits may be too droughty in the upper portion of the substrate to allow successful willow colonization in most years, but already established individuals can reach deeper for soil moisture and therefore spread laterally across an island head. In general, clonal growth is favored in open habitat, where vertical competition for light is limited.

General Distribution of Riparian Communities

Riparian vegetation tends to demonstrate predictable patterns in spatial and temporal heterogeneity. Heterogeneity in the riparian environment reflects the underlying geology, climate, hydrology, natural disturbances, and life history traits of riparian species (Naiman et al.. 2005).

Riparian zones based on soils and vegetation type

The local distribution of riparian vegetation is strongly influenced by the pattern and distribution of alluvial soils. Recurring erosion and deposition events that move and redistribute organic and mineral material create a complex mosaic of soil conditions (Oliver and Larson 1996) within floodplain geomorphic features. As a result, soil properties (e.g., soil moisture, texture, nutrient availability, organic matter content, hydroperiod) influencing plant germination, establishment, and growth can vary greatly over short distance. In addition, variation in soil properties such as texture can modify the impacts of flooding, with fine textured soils with low permeability becoming anoxic

much faster than coarse textured soils (e.g., gravel and cobbles), which allow greater subsurface water flow and better oxygenation.

Organic matter (OM) in riparian soils can influence the rate of nitrogen mineralization, nutrient cycling and soil moisture. The presence of OM can influence the size of pore spaces, and increase the surface area available for denitrifying bacteria as well as energy in the form of adsorbed dissolved OM. Fine particulate OM and the attendant microbial community tend to “hold on” to mineralized N as well as mineralized C, and make it available for a short period of time to floodplain vegetation. High rates of N mineralization in fine soils are strongly correlated with enhanced primary productivity (Pastor et al. 1984, Reich et al. 1997).

Riparian soil and sediment moisture also greatly affects the distribution of vegetation. Riparian soils vary in their ability to hold water and are influenced by tributary and subsurface groundwater flows (Hupp and Osterkamp 1985, Brinson 1990). Soil moisture is also influenced by the distance from the river, microtopographic variation, and soil hydraulic conductivity. The lag time between rising river stage and inundation of a riparian site will vary with the above parameters, and the duration of flooded or saturated soils will depend on soil texture and OM content and the composition of underlying alluvial sediments (and evapotranspiration during the growing season) as well as the annual hydrograph. The highly variable nature of the factors controlling riparian soil moisture results in soil moisture gradients that can be steep and often discontinuous, and may result in abrupt transitions between plant community types.

An example of potential soil moisture control on vegetation patterns can be seen on Shapnack Island, where a sycamore-dominated shrubland growing in coarse cobbles, gravel and sand transitions abruptly into a riparian prairie where there is a slight topographic rise and the substrate changes to small cobbles and a higher fraction of sand and small gravel. The sycamore vegetation is at a lower elevation and adjacent to the river, facilitating the roots obtaining moisture from the water table. Presumably, the higher elevation and droughty prairie soil lacks sufficient moisture long enough for sycamore seedlings to establish. Adjacent to the prairie, near the middle of the island is a terrace dominated by reed canarygrass and old-field herbs. Although this terrace is at a higher elevation, soil moisture here is higher due to a finer, sandy-loam texture and possibly greater OM content and a resulting higher water-holding capacity.

The pattern of riparian vegetation is influenced by the interaction of soil moisture and an individual plant's means of water uptake and water demand (Naiman et al. 2005). Factors influencing this interaction include root architecture, ability of soil to hold moisture, root growth to access water at greater depth, physiological and morphological adaptation to changing moisture conditions, and plant size and age.

Lateral zonation

Lateral zonation of riparian plant communities has been attributed to the combination of hydroperiods, landforms, sediment types, competition and species life history traits. Hydroperiods, fluvial landforms and sediment types are a consequence of distinct

hydrogeomorphic processes. Common fluvial landforms on the Delaware River include active channel bars, interfluvial channels, swales, and terraces. These landforms vary in elevation above a given river stage and therefore represent variation in flood frequency, duration, and often, flow velocity. Often, the variability in landform type and elevation can explain much of the pattern seen in riparian communities, but not in all cases. On the Delaware River, the zone closest to the active channel is characterized by early successional plants adapted to disturbed habitats and low nutrient levels while requiring high light levels. At higher elevations, woody plant cover increases with vegetation demonstrating a general increase in shade tolerance and decreasing flood tolerance. Communities at the edge of the active plain are typically long-lived, shade-tolerant species that can tolerate only brief periods of saturated or flooded soils, or terrestrial species (on the Delaware River this is often sugar maple, *Acer saccharum*, and bitternut hickory, *Carya cordiformis*). Plant communities may be distinct where the landforms have clear breaks in slope or abrupt changes in elevation (e.g., terraces and steep channel banks). In situations where landforms change gradually (e.g., large islands and bars with a gradual rise from head to tail), plant community boundaries can become blurred with considerable overlap. In general, the elevation gradient of a landform can dictate hydroperiod, but as mentioned earlier, the effective hydroperiod can be modified by soil and sediment heterogeneity, with some micro-sites being drier or wetter than expected.

Longitudinal zonation

Longitudinal variation in riparian vegetation can result from variations in climate, geology, channel gradient, elevation, geomorphic processes, and sediment and litter loads, as well as sea level change and the length of time substrate has been available for colonization (Nilsson et al. 1991, Rot et al. 2000, Catterall et al. 2001). Many of these factors co-vary along the length of rivers. On the Delaware River, one of the more obvious longitudinal differences is the increasing dominance of silver maple on shoreline and island terraces in DEWA versus UPDE, especially below the Hogback Ridge. This coincides with a decreasing channel gradient, lower velocity flood flows, decreased scour, and finer textured soils and sediment on mid to high terraces in DEWA, conditions which tend to favor silver maple recruitment and establishment. Silver maple is relatively rare in UPDE and is limited to a few locations where the channel geometry allows fine sediments to accumulate on mid to high terraces, and where flooding occurs periodically but scouring is limited. Another longitudinal vegetation difference on the Delaware River is the distribution of bitternut hickory, which is ubiquitous on high terraces along the channel bank and occasional islands in UPDE, but is nearly absent on the floodplain below Milford in DEWA. The reason for this pattern is unclear.

Successional and Seasonal Community Patterns

Vegetation succession

Vegetation succession in the riparian environment is typically a complex combination of primary and secondary succession. Major floods that scour and transport sediments can create and reshape fluvial landforms that are devoid of vegetation and open to

colonization. At the same time, many existing landforms are only partially scoured or partially buried in sediments, with remnants of the existing vegetation persisting to recolonize. In addition, many riparian plants survive and colonize through flood-dispersed propagules, and plant fragments. Vegetation succession can also reflect the legacy of other disturbances such as drought, wind, fire, disease, litter accumulation, herbivory, etc. Succession in riparian communities involves a complex interaction of species life history traits with the pattern of disturbance, geomorphology and climate.

Oliver and Larson (1996) present vegetation succession as occurring in four stages:

- Establishment: Following a disturbance, plants colonize open, unoccupied space. In riparian systems this would be recently deposited sediment or newly scoured, exposed bare substrate.
- Stem Exclusion Stage: Plants fill-in and occupy all available habitat. New recruitment is prevented by competition from previously established individuals. Competition for resources (space, light, nutrients) results in elimination of less well adapted species or individuals. In riparian communities this is often seen as a dense even-aged shrubland or low forest.
- Understory Initiation Stage: Increasing height of canopy with some overstory mortality allows development of understory vegetation. Shade tolerant herbs and shrubs and trees become established. Multiple understory layers may develop.
- Mature Stage: Individual trees die as stand ages, canopy gaps open and release understory vegetation from low light conditions. As mature trees die, the forest begins to accumulate large, coarse woody debris and takes on an old-growth character. Further changes in the biota are driven by autogenic processes (driven by biological interactions). Allogenic processes (environment driven) may still shape the forest stand through disturbance events. Mature riparian forests are characterized by large old trees, large dead standing snags, large downed trees, open canopies with multiple foliage layers, and a diverse understory.

Succession in riparian systems seldom occurs as orderly as described above. The interplay of autogenic and allogenic processes (especially floods) results in a quasi-stable state, somewhere between the first and last successional stage. In general, riparian vegetation undergoes a pattern of alternating disturbance (flood scouring, deposition, landform creation and destruction) and succession. The disturbance event may abruptly alter sediment grain size, degree of soil development as well as patch size and landform shape and position. Over time autogenic processes will alter soil development, increase surface sediment texture and increase nutrient availability. Inevitably another disturbance event (i.e., flood) will reset the community to an earlier successional stage and the process will repeat. Many of the shrub communities on the Delaware River demonstrate this pattern, where vegetation is held in check between the establishment and stem exclusion stages by flood and ice scouring, which break and remove stems before competitive exclusion becomes the dominant process. Thus, quasi-stable states can

persist for decades to centuries (Schumm 1977), with succession never advancing to the “Mature Stage.” It should also be noted that different lag times exist for physical and biological elements of riparian communities, so that contemporary vegetation is always adjusting to one or more past disturbance events.

In general, allogenic processes dominate on low elevation land forms, where disturbance intervals are short and successional processes have little opportunity to modify the local environment. Examples of this on the Delaware River include Riverine Scour Vegetation and the Sycamore-(Willow) Riverine Dwarf Shrubland communities, where frequent flood and ice scour prevent the development of vertical growth and vegetation is routinely damaged or removed, leaving open bare substrate. In contrast, autogenic processes dominate in mature Silver Maple Floodplain Forests, typical of the lower DEWA section, which display old-growth characteristics such as large trees, multiple-layered canopies, large logs, and often a diverse understory (where Japanese knotweed and reed canarygrass have not invaded the herb layer).

The Role of Disturbance

Anthropogenic disturbances

Anthropogenic disturbances are human-mediated events or activities almost unknown in natural systems in terms of type, frequency, intensity, duration, spatial extent or predictability (Naiman et al. 2005). In riparian systems, disturbance acts as a restructuring agent that can maintain ecological integrity, as with natural disturbances, or alter and degrade ecological systems, as is often the case with anthropogenic disturbances. Human-mediated suppression or reduction in natural disturbance can also lead to ecological degradation by removing environmental drivers that maintain system integrity.

Under natural disturbance regimes, the natural hydrogeomorphic processes shape the patterns and process of the riparian zone. These are a function of the interaction of climate and geology, which determine discharge patterns and sediment bed loads. These, together with the character of the riparian corridor and the available species pool, shape the biophysical properties of riparia on intact, natural landscapes (Naiman et al. 2005.).

While the same factors influence modern riparian vegetation and landforms, human-mediated changes have altered the climate as well as the frequency and intensity of natural geomorphic processes. Some natural disturbances have been reduced or eliminated (e.g., nutrient pulses from large spawning migrations of shad and Atlantic salmon), while novel disturbances have been introduced (e.g., chronic high nutrient input, air pollution). These alterations to the riparian disturbance regime affect current vegetation through legacies, lag times and cumulative effects.

Legacies include long-term or permanent human-mediated changes to the physical environment. The construction of large reservoirs on the East and West branches of the Delaware and the Neversink River represent legacies that have altered the flow regime, water temperature, sediment transport, and other properties of the Upper Delaware River

for at least the next several decades or longer. Lag times reflect biophysical processes acting in the past (or legacies) whose biotic expression may take place now or in the future. Altered riparian community succession due to historic river management and past land use in Europe has been documented for several rivers. (Decamps et al. 1988, Johnson 1994, Tremolieres et al. 1998, Harding et al. 1998). On the Delaware River, tributary reservoirs have attenuated flood flows and may be responsible for a reduction in flood frequency and flow velocity. This may be responsible for an increase in woody plant cover over the past fifty years on many low islands and gravel bars as the intensity of flood scour, woody plant damage and mortality decreased.

Riparian systems are often affected by more than one human-mediated disturbance, requiring the examination of cumulative effects. The Upper Delaware River, as an example, is impacted in several ways by the tributary reservoirs, but it is also impacted by invasive species (e.g., Japanese knotweed, reed canarygrass), point and non-point-source pollution, acid rain, floodplain and channel alterations from roads, railroads, and bridges, and climate change. Prediction of how the combined effect of these stresses will affect riparian systems is daunting, especially since many biotic responses may be non-linear.

Riparia are subject to four general types of anthropogenic environmental change or stress: flow regulation, pollution, climate change and land use. As opposed to natural disturbances which may revitalize and maintain natural systems, these stresses can degrade and impair riparian systems. The result can be a “distress syndrome”, where the ecological system is characterized by reduced biodiversity, altered productivity, increased disease outbreaks, reduced efficiency of nutrient cycling, and increased dominance of exotic species and smaller, short-lived opportunistic species (McIntyre et al. 1999, Rood et al. 2003).

Ecological consequences of flow regulation

The response of riparian vegetation to flow regulation depends on the degree of variance from natural flows and the local geology and climate. The resulting change in flow variability and sediment load will in turn modify local fluvial processes to which riparian vegetation responds.

Effects on native species and processes

Flow regulation impacts sediment transport and reduces flood peaks, flood frequency and channel forming flows. The results of these impacts are lower water tables, reduced lateral fluxes of water, sediment and organic matter, accelerated and modified successional processes and the cessation of new habitat formation (Ward and Stanford 1995). The reduced frequency and extent of flooding combined with a lower water table allows riparian species to be replaced by upland species that are able to invade the floodplain under artificially stable and “terrestrialized” conditions (Decamps 1984). The net effect of flow regulation is to reduce the amplitude of the primary disturbance mechanism (flooding), creating equilibrium conditions on plant communities adapted to a non-equilibrium environment. The resulting maladapted communities may be subject to

greater unanticipated amounts of damage when exposed to catastrophic flows (Naiman et al. 2005).

Alterations to seasonal flow patterns may put life cycles of riparian species out of synchronization with their environment. As an example, many plant species time reproduction to correspond with spring flooding on the Delaware River, but low spring flows would strand many water-dispersed propagules close to the active channel. This zone often has coarse substrate unsuitable for seedling establishment, and could be drowned during altered higher summer flows and then exposed to severe ice scour during altered low winter flows. The net result may be changes in the spatial distribution of new plants as well as reduced reproductive success for many native species. This may also partially explain why the Riverine Scour Vegetation community that lies adjacent to the active channel is dominated by annual exotic species.

Basic principles related to flow regimes

Flow regime is the “key” environmental driver of the ecological integrity of riparian communities. Flow alteration is the single most important threat to riparian systems (Nilsson and Svedmark 2002). Guiding principles to consider when evaluating natural and modified flow regimes are (Naiman et al. 2005):

- The flow regime determines the successional evolution of riparian plant communities and ecological processes
- The river serves as a pathway for redistribution of organic and inorganic material that influences plant communities along rivers.
- Every river has a characteristic flow regime and associated riparian communities.
- Riparian zones are topographically unique in occupying nearly the lowest position in the landscape, thereby integrating catchment-scale processes.

As noted earlier, riparian systems are subject to multiple stresses in addition to altered flow regime. The difficult task for ecologists and resource managers is teasing out the role and importance of altered flow regime when trying to manage for the health of riparian communities.

Consequences of global climate change

Anthropogenic climate change has become a well-documented phenomenon (Schneider and Root 1998). Consequences for riparian systems in North America, including the Delaware River drainage, may include changes in precipitation and run-off patterns. Mean monthly flow in cool season months (November-April) has increased in the last half of the 20th century. In the eastern United States, extreme, heavy precipitation events have occurred with greater frequency resulting in an increased frequency of high stream flows. This increases the impact of catastrophic flood flows on riparian communities and increases the likelihood for abrupt shifts in riparian community composition and distribution.

Other aspects of climate change may also impact riparian plant species. Shorter and milder winters may allow the northward migration of southern species and provide an opportunity for less cold-tolerant exotic species to spread (e.g., kudzu, *Pueraria lobata*). Native species may also flower and fruit early, and become out of sync with other environmental cues. Milder winters could reduce or eliminate ice formation and remove an important factor in the distribution and structure of woody vegetation on the Delaware River. Similarly snow melt could occur earlier and the available snow pack volume may decrease, possibly reducing springtime flood flows.

The response of Delaware River riparian vegetation to climate change will depend on how changes in temperature and water availability manifest themselves. While increasing temperatures are expected, future conditions and their effect on the hydrology of the Delaware River watershed remain uncertain.

Land use change

The land use changes described above can impact riparian communities through their effects on temperature regimes, nutrient enrichment and invasive species. Riparian vegetation affects the temperature regime of streams while stream temperatures modify riparian air and soil temperatures. Variations in temperature regimes can influence a number of physical and biological processes, including metabolism, growth, solubility of gases and the timing of life history traits. The effect of riparian forest removal on stream temperature has been well documented, with higher summer temperatures due to increased insolation and lower winter temperatures due to increased short-wave radiation of heat. Lack of a canopy and increased heat radiation is thought to also promote the formation of anchor ice in some situations.

The Delaware River valley has been occupied over six thousand years (Ritter and Kinsey 1973), with the Munsee and Lenape present at the time of European colonization, and later, the Shawnee for a brief period (e.g., at Shawnee Island). Settlements were typically on the higher floodplain terraces and islands where crops could be raised and in close proximity to water and fisheries (Wallace 2005). The cultivation of corn exhausted the soil in a few years, requiring relocation of settlements. This may have resulted in much of the arable land on the Delaware River being cleared and planted for crops repeatedly prior to the appearance of European settlers in the early 1700's. After European settlement, much of the river valley bottom and higher floodplain terraces were put into cultivation and remain so to the present. Some areas have been abandoned, especially in the DEWA portion, and are now reverting to successional upland forests. In the UPDE portion, some reaches of the river have been subject to moderate to high density development of riverfront residences, many with mowed lawns and vegetation down to the riverside. UPDE and DEWA also have a number of small towns that are directly adjacent to the river, as well as transportation infrastructure (roads and railroads) usually on or adjacent the floodplain on both sides of the river.

Nutrient enrichment

Human activity has greatly increased the amount of nutrients entering and cycling in the environment. Nitrogen in particular is rapidly increasing in the land-based nitrogen cycle

with potentially significant impacts on the species composition, productivity, dynamics, and diversity of natural systems (Galloway and Cowling 2002, Vitousek et al. 2002). Similarly, phosphorous (another important element in fertilizer) is being mined and applied to farmland and entering the world nutrient cycle. The addition of large quantities of both of these elements can result in saturated systems and affect the chemistry and availability of other elements. Riparian systems are especially susceptible to nutrient loading due to their position at the bottom of the watershed. Once saturated with anthropogenic N and P, these elements will pass through riparian zones and result in nutrient pollution in the receiving water bodies.

The impact of nutrient loading on riparian communities is not well documented. Some studies suggest that increased nutrient loading leads to less diverse, impoverished plant communities (van den Brink et al. 1996).

Invasive species

Riparian zones are particularly vulnerable to invasive species, and many riparian systems are dominated by invasive species. In general, riparian zones have a higher percentage of non-native species than the adjacent uplands (Deferrari and Naiman 1994, Pysek and Prach 1994). On the Delaware River there are two plant community types characterized by nearly monotypic species stands (Japanese Knotweed Vegetation, and the Reed Canarygrass Riverine Grassland). These two species have so completely filled their preferred habitat that it is uncertain what vegetation type occupied the same habitat prior to invasion, or if native species have been eliminated from the system. Unfortunately, the same processes that support high species diversity in riparian communities also favor invasion by exotic species including transport of propagules, flooding disturbance, and water availability (Naiman et al. 2005). In general, the scour zone adjacent to the active channel has the highest percentage of exotic species and this concept is definitely true for the Delaware River.

Conceptual Ecological Models

Conceptual ecological models have been developed to elucidate the processes affecting the development of riparian plant communities on the Delaware River. In general, each model represents a geomorphic setting typically found on the Delaware River within UPDE and DEWA, including: low islands/cobble-gravel bars, large islands with one or more terraces, sloping scour shorelines adjacent to steep upland slopes, scour shorelines adjacent to high terraces and riverside rock outcrops. These models are focused primarily on native plant communities, although invasive communities are included in some models. Two invasive species communities common on the Delaware River are also discussed individually. The models have several general patterns. Decreased flood and ice scouring will tend to favor succession to shrubland and forest. Decreased water levels will also favor succession and terrestrialization with a narrowing of the riparian zone. Increased flooding and scouring will tend to reset riparian zones to early successional communities.

Invasive Communities

Reed Canarygrass Riverine Grassland

Reed canarygrass (*Phalaris arundinacea*) is a cosmopolitan species and was present in North America prior to European settlement. However, it is believed that the introduction of European cultivars led to reed canarygrass becoming an aggressive invader of wetland and riparian habitats (Lavergne and Molofsky 2004). Factors such as disturbance, changes in hydrologic regime, and nutrient run-off can enhance reed canarygrass establishment and spread. Reed canarygrass can be outcompeted by native vegetation under natural nutrient conditions, but with the nutrient enrichment typical of agricultural run-off (especially elevated nitrate concentrations), reed canarygrass quickly outcompetes and displaces native species (Green and Galatowitsch 2002, Perry et al. 2004).

This community is included in the two shoreline conceptual models as it was nearly always present and it was difficult in many cases to determine which community it had displaced. The distribution of reed canarygrass appears to be restricted to landforms with ample moisture, either through fine-textured soils with adequate water holding capacity or proximity to the water table. In the case of sloping scour shorelines, the proximity of steep upland slopes likely results in groundwater discharge (seepage) within the narrow floodplain. In the high floodplain terrace scour shorelines, reed canarygrass occurs on low terraces with fine-textured moist soils. On the Delaware River, reed canarygrass may also occur on higher terraces (often under forest and woodland canopies) with finer textured soils that are not subject to drought. It appears to be less successful in invading severely scoured habitats and/or habitats that experience drought.

Japanese Knotweed Vegetation

Japanese knotweed (*Polygonum cuspidatum*) is a very aggressive species in Delaware River floodplain communities. Japanese knotweed is a creeping perennial that forms an extensive network of rhizomes that may spread 7 to 20 meters from the parent plant and to a depth of 2 meters (McHugh 2006). Propagation can be from seed or root and stem fragments as small as 1 cm. On floodplains, propagules germinate or root quickly on bare soil and will soon begin to form a colony. Japanese knotweed grows to a height of approximately 3 meters and forms very dense stands. Native herb flora are quickly outshaded and soon extirpated, resulting in a monoculture. Field observations on the Delaware River also suggest tree and shrub regeneration is non-existent under knotweed canopies. As knotweed often dominates under many mature silver maple and sycamore stands, this may have implications for future floodplain forest regeneration.

Like reed canarygrass, Japanese knotweed prefers habitats with ample available moisture and often dominates the herb and shrub layer on floodplain terraces throughout the study area, particularly where fine-textured floodplain soils are present. Knotweed tends not to persist or grows poorly in severely scoured habitats or habitats that experience drought conditions.

Low Island (Gravel-Cobble Bar)

Low islands and small gravel-cobble bars are high energy environments where the flood and ice scour hold woody plant succession in check through frequent removal, breakage and abrasion of vegetation. These islands tend to lack terraces and the entire island may frequently flood. The substrate tends to be coarse and soil formation is absent. During low water periods, slightly elevated portions of the island may experience drought conditions. Figure 13 shows the general pattern of vegetation for this geomorphic setting; with low vegetation present in the high scour areas at the island head and lateral edges, and taller shrubs at the downstream end of the island. Many of these islands have open grassland behind the leading edge of tall shrub vegetation.

Figure 14 is a conceptual model of the relationship between the plant communities characteristic of low islands on the Delaware River. Some islands have Water Willow Emergent Bed communities at the island head, which normally are partially exposed during low summer flows, though the substrate often remains flooded or saturated. The near constant inundation of this vegetation, along with severe flooding and ice scour, prevents colonization by woody plants. This community is often absent from many islands, perhaps due to flow regulation impacts noted earlier. Abnormally low late summer and fall flows may drought stress water willow (*Justicia americana*). Conversely, low winter flows may expose the beds, causing the rhizomes to freeze, leading to mortality.

Riverine Scour Vegetation occurs just above the Water Willow Emergent Bed community and may be quite extensive on islands and bars with a low elevation gradient. The substrate varies from coarse cobbles and gravel to sand. The environment is very stressful due to fluctuating water levels any time of the year, including drought conditions in summer and ice scour in winter. This community may be under water for weeks at a time during the early growing season under current flow regulation. During cold winters, large ice deposits may also remain in this zone through early spring, delaying plant growth. As a result of the unpredictable environment, annual grasses and herbs dominate the vegetation in this zone, completing their life cycle in between disturbance events. The majority of plant species in this zone are exotics, with many being agricultural weeds. Widespread agriculture within the Delaware River valley is likely the source of many weed propagules.

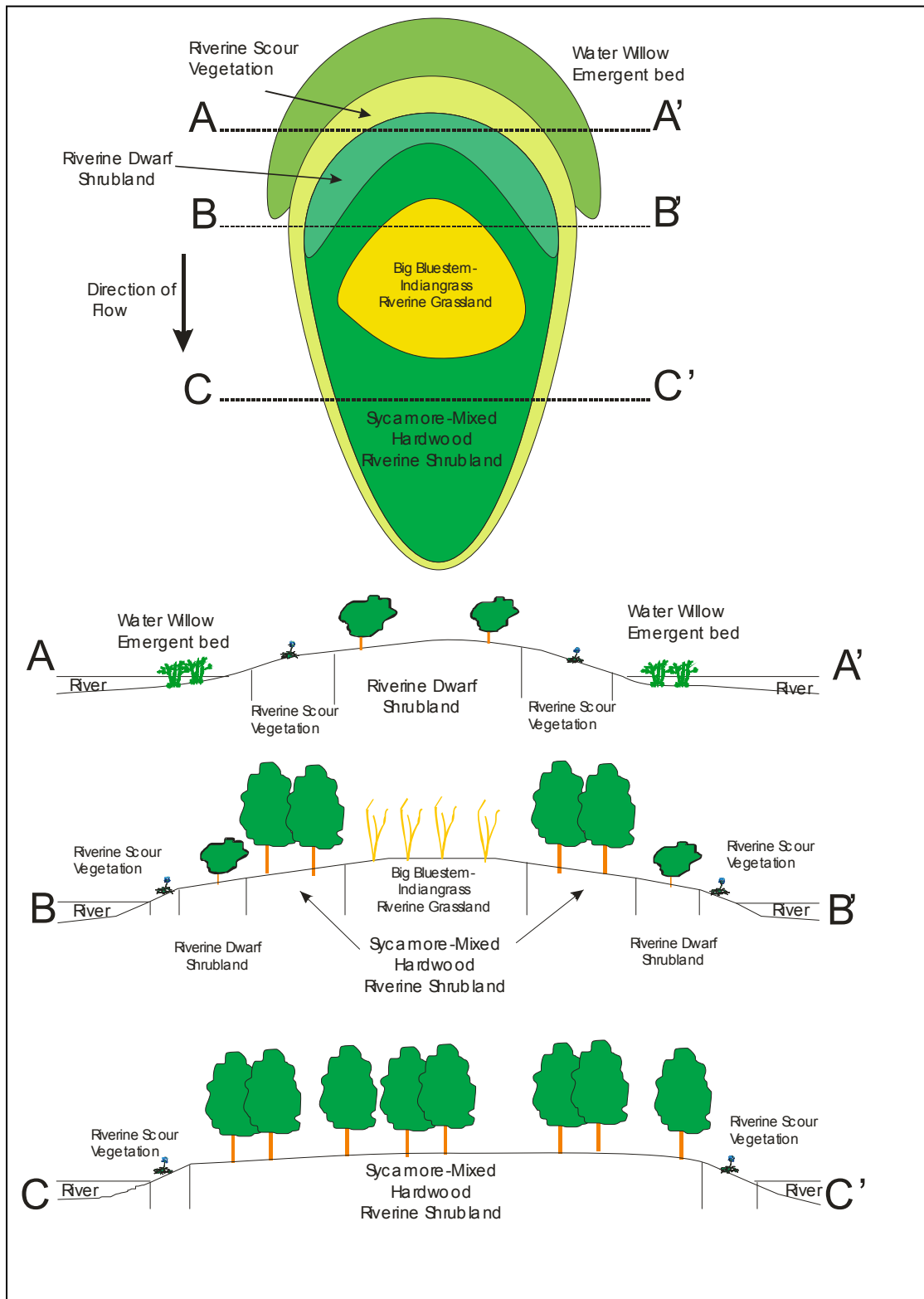


Figure 13. Generalized pattern of vegetation on low islands and cobble gravel bars on the Delaware River.

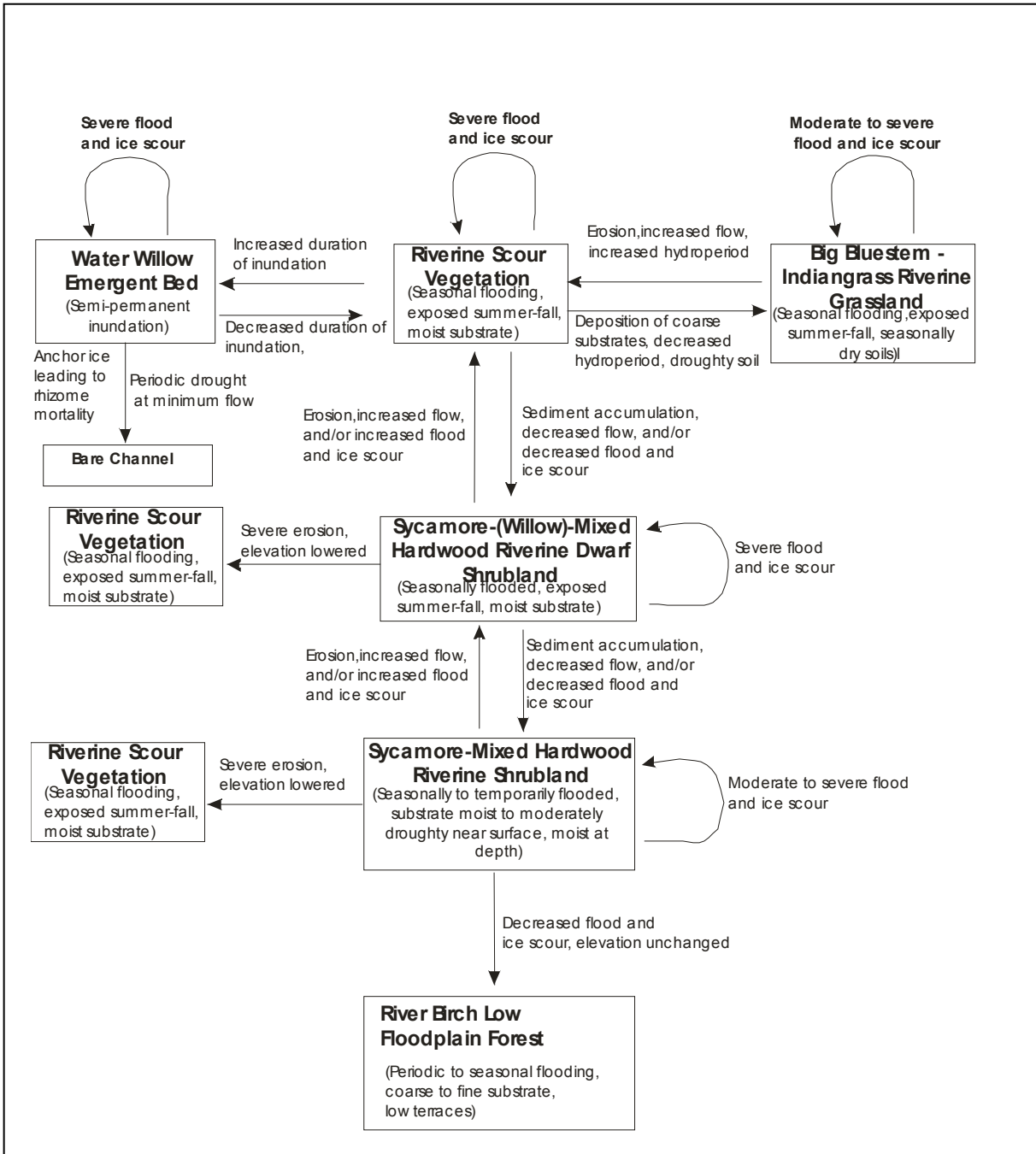


Figure 14. Ecological model of plant community dynamics on low islands and cobble-gravel bars on the Delaware River.

Most of the other communities in this model will revert to Riverine Scour Vegetation following severe floods and erosion that removes existing vegetation. Succession to another community type will depend on the post-flood elevation of the site.

The Big Bluestem-Indiangrass Riverine Grassland community occurs on low islands and bars. As Figure 13 shows, many low islands have open grassland behind the Sycamore-Mixed Hardwood Riverine Shrubland. Whether this area was Riverine Scour Vegetation at some point in time is unclear, however the general lack of woody vegetation suggests it was heavily scoured and coarse sand, gravel and cobbles deposited. The substrate appears to lack silt and clay and is often droughty. It is often at higher elevation than either of the shrubland communities. Since it appears to receive less scour than the shrubland community, it appears that summertime drought may prevent the establishment of woody vegetation. Elements of this community may mix with Sycamore-Mixed Hardwood Riverine Shrubland along the lateral edges of islands.

Sycamore-(Willow)-Mixed Hardwood Riverine Dwarf Shrubland is generally restricted to the heads of islands. The substrate is typically coarse cobbles and gravel and may be flooded for extended periods throughout the year. The vegetation is a mix of annual herbs (similar to Riverine Scour Vegetation), stunted willows (*Salix* spp.) and sycamore (*Platanus occidentalis*). Woody vegetation cover is often low. This community may receive some of the most intense flooding and ice scouring, with woody vegetation being constantly bent, broken and abraded. Black willow (*Salix nigra*) is the most common willow on island heads but rarely attains a height greater than 1-2 m, and was not observed in flower or fruit. Colonization and establishment likely relies on rooting of broken stem and branch fragments and deposition of seeds by wind and water. Mature black willows are occasional along the shoreline of the Delaware and are the likely seed source. This community grades into the taller Sycamore-Mixed Hardwood Riverine Shrubland as the substrate increases in elevation and exposure to severe flood and ice scour lessens.

Sycamore-Mixed Hardwood Riverine Shrubland occurs behind the Sycamore-(Willow)-Mixed Hardwood Riverine Dwarf Shrubland on island heads, and often forms an irregular ring around low islands. It is subject to less intense, routine flood and ice scour than the Sycamore-(Willow)-Mixed Hardwood Riverine Dwarf Shrubland, but is prevented from succeeding into mature forest by less frequent and severe flood and scour events. Evidence of this is the relatively straight vertical boles of new growth, several years old, growing from strongly bent and abraded lower stems. As noted above, this community is often adjacent to the Big Bluestem-Indiangrass Riverine Grassland, but appears to be prevented from colonizing the grassland by droughty soil conditions.

The River Birch Low Floodplain Forest is not common on the Delaware River and represents stands of the Sycamore-Mixed Hardwood Riverine Shrubland that have managed to succeed to forest stature, usually with river birch (*Betula nigra*) as the dominant and sycamore only occasional. Many of the trees are battered and bent, but greater than 5 m in height (the general size limit for classification as tall shrub). The

substrate and environmental conditions appear similar to the Sycamore-Mixed Hardwood Riverine Shrubland, but with possibly minor shifts in local geomorphology and channel bed, flood flow velocity and decreased scouring. These stands survived the major floods that occurred between 2004 and 2006 and appear to be stable.

Other communities that may occasionally occur on low islands include Reed Canarygrass Riverine Grassland, Hairy-Fruit Sedge Wetland, and Japanese Knotweed Vegetation. When present, these communities occupy small patches, presumably in microhabitats where river scour may be less severe, soil texture is finer and soil moisture is abundant. There was also one large low island in the UPDE section of the river where the soils were loamier and the river much wider, which presumably experienced lower flood flow velocities. On this island woody plant cover was low with a mix of Hairy-Fruit Sedge Wetland, Reed Canarygrass Riverine Grassland, and Japanese Knotweed Vegetation, with small patches of Big Bluestem-Indiangrass Grassland. The abundance of terrestrial agricultural weeds suggested it may have been recently cultivated.

Large Island with Terraces

This model is similar to the Low Island (Cobble-Gravel Bar) described above, with the addition of communities that occur on higher terraces and are subject to decreased flood and ice scour. This model would also apply to the islands and shoreline terraces associated with tributary mouth bars at Brodhead Creek. The description here will be limited to the forests associated with the terraces. Figure 15 shows the general pattern of vegetation for this geomorphic setting, with the forested communities generally limited to the terraces on the downstream end of the island. Figure 16 is a conceptual model of the relationship between the plant communities characteristic of large island with terraces on the Delaware River.

Silver Maple Floodplain Forest occurs on higher terraces where flow velocities are lower and fine sediments are deposited. Whether this community represents succession from the Sycamore-Mixed Hardwood Riverine Shrubland is debatable, as young silver maples tend to form even-aged stands at slightly higher elevations and downriver from the sycamore-dominated shrublands, where finer substrates are likely to accumulate. It may be that silver maple stands represent single recruitment events on bare sand and silt substrate with little canopy cover. This community may develop old-growth characteristics over time, with many large (possibly old) trees, large dead trees and layered foliage. Another characteristic of old growth is a diverse ground layer; however, most of the Silver Maple Floodplain Forest stands in the study area have been invaded by Japanese knotweed and reed canarygrass. In the few places where this has not occurred, the understory vegetation is reasonably diverse with forest grass, herb and fern species, especially ostrich fern (*Matteuccia struthiopteris*). Silver maple seedlings are fairly shade intolerant and while some silver maple regeneration may occur under open silver maple forests, the high cover of invasive species (especially Japanese knotweed) may preclude seedling survival. An example of possible regeneration failure may be occurring at the mouth of Brodhead Creek, where recent catastrophic flooding scoured under and tipped a large number of mature silver maples. Prior to the flood, the understory was dense knotweed, after the flood the knotweed is nearly as dense,

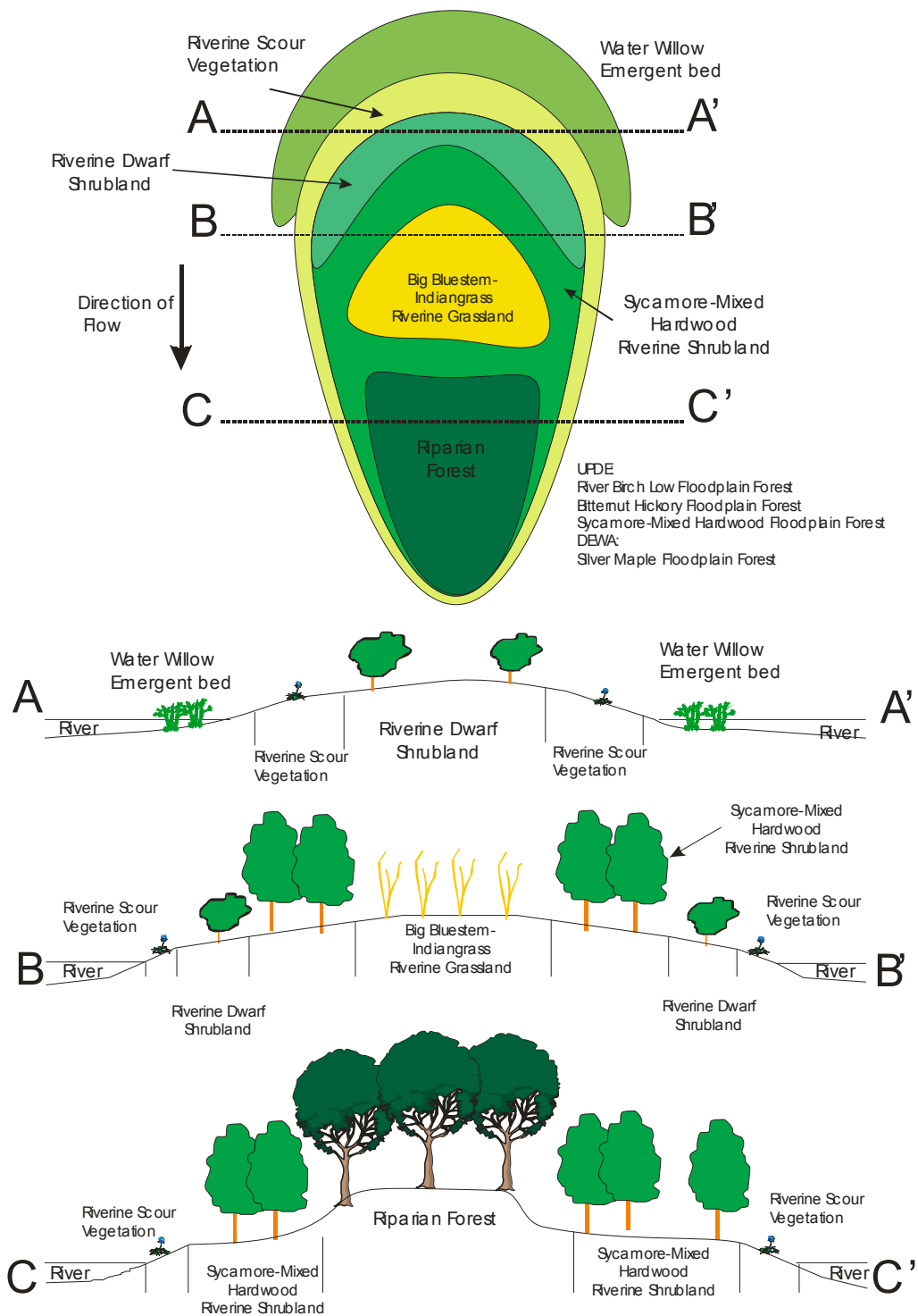


Figure 15. Generalized pattern of vegetation on large islands with terraces on the Delaware River.

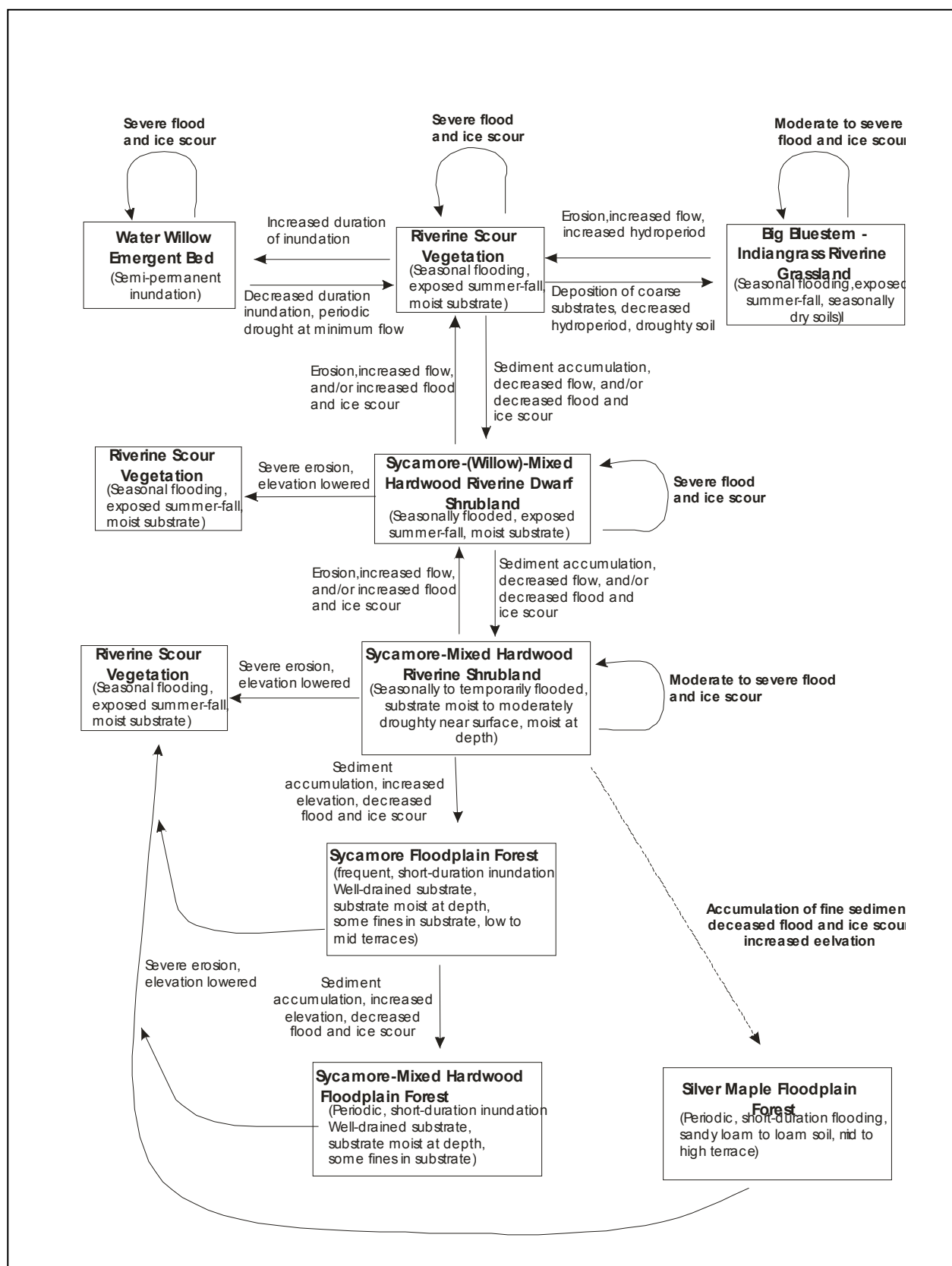


Figure 16. Ecological model of plant community dynamics on large islands with terraces on the Delaware River.

despite the deposition of over a meter of cobbles, gravel and sand in many places. It appears unlikely that any tree regeneration will occur in this area without elimination of the knotweed.

Sycamore Floodplain Forest is uncommon on the mainstem Delaware River and is more often associated with the alluvial deposits at the mouths of larger tributaries such as the Brodhead and Bushkill Creeks. Transport and deposition of sediments to tributary mouths increases the elevation of terraces and bars and allows Sycamore-Mixed Hardwood Riverine Shrubland vegetation to succeed to forest. In mature stands, early associates, such as river birch, may eventually be eliminated through shading from the taller sycamore. Continued sediment accumulation and terrace building will allow the invasion of shade tolerant trees that could not persist in the lower, more frequently flooded Sycamore Floodplain Forest. At this point the stand would more properly be classified as a Sycamore-Mixed Hardwood Floodplain Forest. As with the Silver Maple Floodplain Forest, these two communities are susceptible to invasion by Japanese knotweed. However, younger stands occasionally have a denser canopy and lower light conditions in the understory, which appears to limit knotweed colonization.

Other communities that may occur here (besides the invasive communities) include the Sugar Maple Floodplain Forest, the Bitternut Hickory Floodplain Forest, and the Hairy-Fruit Sedge Wetland. The Sugar Maple Floodplain Forest is occasional as small patches on the mainstem, and in most instances appears to be a successional stand on formerly farmed or cleared floodplain terraces. Some occurrences on high floodplain terraces may be attributable to colonization on bare substrate following major floods. In general, sugar maple (*Acer saccharum*) is not very flood tolerant and is limited to the higher floodplain terraces. It is a common understory species in some Silver Maple Floodplain Forests, possibly an artifact of flow regulation and reduced peak flows during flood events. Bitternut Hickory Floodplain Forest is rare on islands, with the best example on Butternut Island, near Callicoon, NY. It appears to occur in similar habitat as the Sugar Maple Floodplain Forest, but may tolerate more flooding. The Hairy-Fruit Sedge Wetland occurs occasionally on islands in UPDE, with Butternut Island as one of the better examples. This community occurs behind the island heads but where the substrate has sufficient fines or organic matter to hold more moisture. In DEWA, several of the large islands below the Hogback have large stands of this community, typically under an open Silver Maple Floodplain Forest, on a mid to high terrace with a moist sandy loam soil.

Sloping Shoreline Adjacent to Steep Uplands

This geomorphic setting occurs in UPDE where the channel is confined and the floodplain narrow. Figure 17 shows the general pattern of vegetation for this geomorphic setting. Figure 18 is a conceptual model of the relationship between the plant communities characteristic of sloping shoreline adjacent to steep uplands on the Delaware River.

These areas are subject to intense flood and ice scour and may have stranded ice blocks for prolonged periods in winter and early spring. Riparian woody vegetation is rare or absent, presumably the result of the intense scouring. The vegetation appears to be

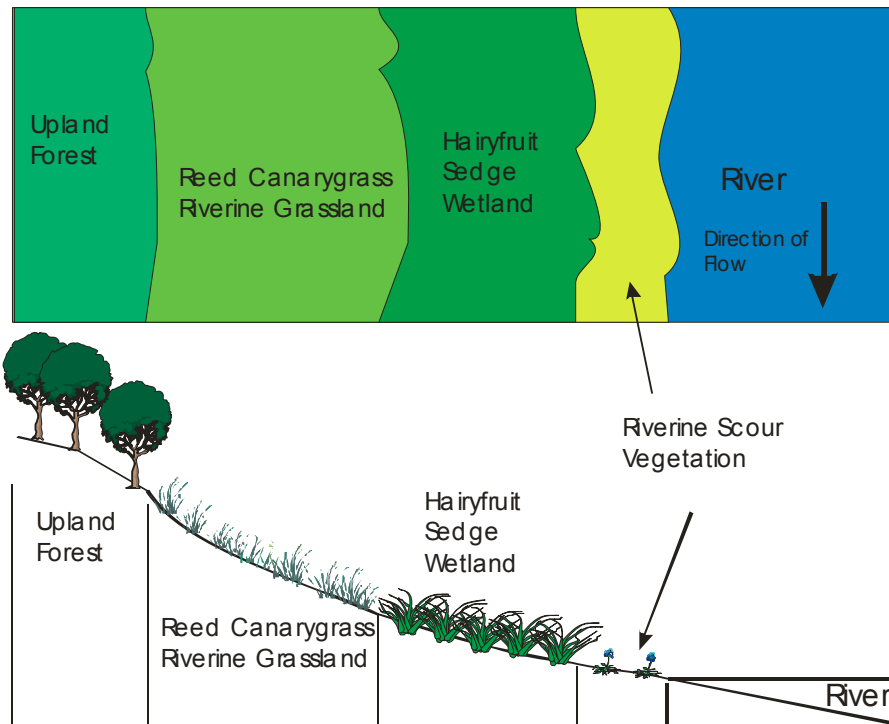
organized into three discrete zones: Riverine Scour Vegetation adjacent to the active channel, dominated by exotic annual herbs and grasses as described above; Hairy-Fruit Sedge Wetland; and Reed Canarygrass Riverine Grassland. The hairy-fruit sedge (*Carex trichocarpa*) usually dominates the zone just above the Riverine Scour Vegetation and may tolerate prolonged inundation better than reed canarygrass. However both species show considerable overlap in their vertical distribution from river channel to upland edge. Reed canarygrass is the clear dominant in the upper third of the shoreline, with hairy-fruit sedge absent. This zone does not appear to be droughty, and many areas have groundwater seepage, which may allow the reed canarygrass to persist well above the river's normal flow. Japanese knotweed is rare in this setting.

Scour Shorelines Adjacent to High Terraces

This geomorphic setting occurs in UPDE and DEWA where low gravel bars and terraces are adjacent to high terraces of glacial deposits. These geomorphic settings can be complex with a number of communities occurring within close proximity in response to patchy substrate variation, elevation and moisture availability. Figure 17 shows a general pattern of zonation. Figure 19 is a conceptual model of the relationship between the plant communities characteristic of scour shoreline adjacent to high terraces on the Delaware River.

As with the geomorphic settings above, the active channel is bordered by Riverine Scour Vegetation. Above the Riverine Scour Vegetation, the community composition can vary, with Hairy-Fruit Sedge Wetland or sometimes Reed Canarygrass Riverine Grassland present if the substrate is only slightly elevated above the scour zone or the substrate is fine-textured. In many cases there is an abrupt rise of a meter or more where Big Bluestem-Indiangrass Riverine Grassland occurs on coarse sand, gravel and cobble deposits. Above this zone there is usually a Sycamore-Mixed Hardwood Riverine Shrubland or a Sycamore-Mixed Hardwood Floodplain Forest, depending on the age of the shoreline deposits and the degree of scour activity. As with the low islands, the Sycamore-Mixed Hardwood Riverine Shrubland community can be held in a state of arrested succession by repeated flood and ice scour. Above this zone in UPDE, usually on the slope of the adjacent high terrace is a narrow band of Bitternut Hickory Lowland Forest or, less often, either Sugar Maple Floodplain Forest or Silver Maple Floodplain Forest. In DEWA this zone is nearly always dominated by Silver Maple Floodplain Forest and the sycamore-dominated forest and shrubland may be absent. In UPDE the terrace slope is characterized by fine-textured soils and decreased flood and ice scour, and shorter duration of flooding. DEWA is similar, but the silver maple-dominated terraces may be subject to longer periods of inundation, favoring the more flood-tolerant silver maple. Japanese knotweed can occur in this setting in more mesic soil on low terraces and in the forest communities along the terrace slope.

Sloping shoreline, adjacent steep uplands



Scour shoreline, adjacent high terrace

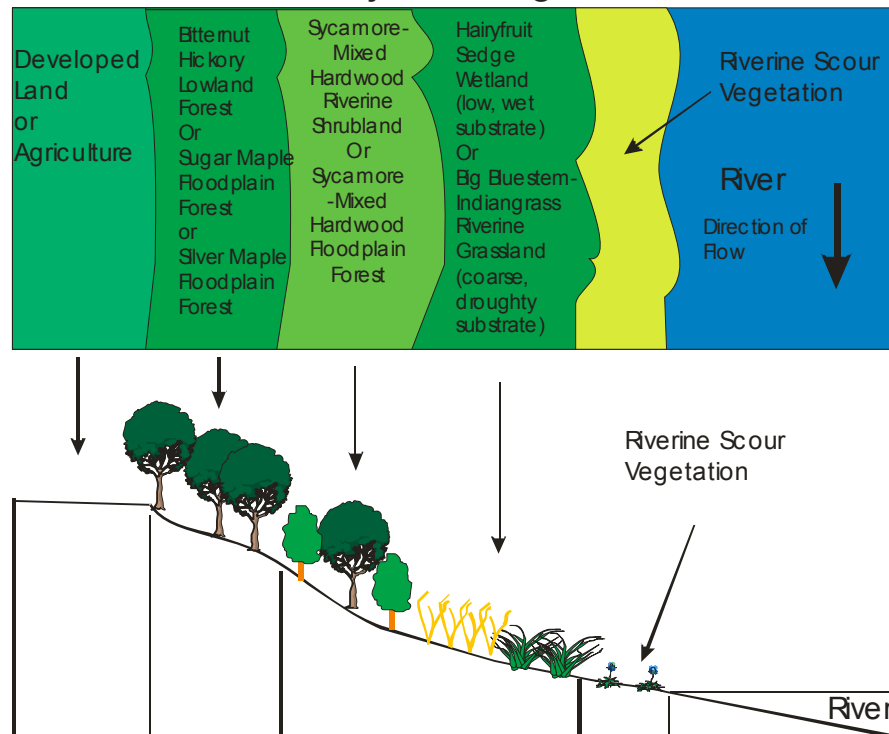


Figure 17. Generalized patterns of vegetation along shorelines of the Delaware River.

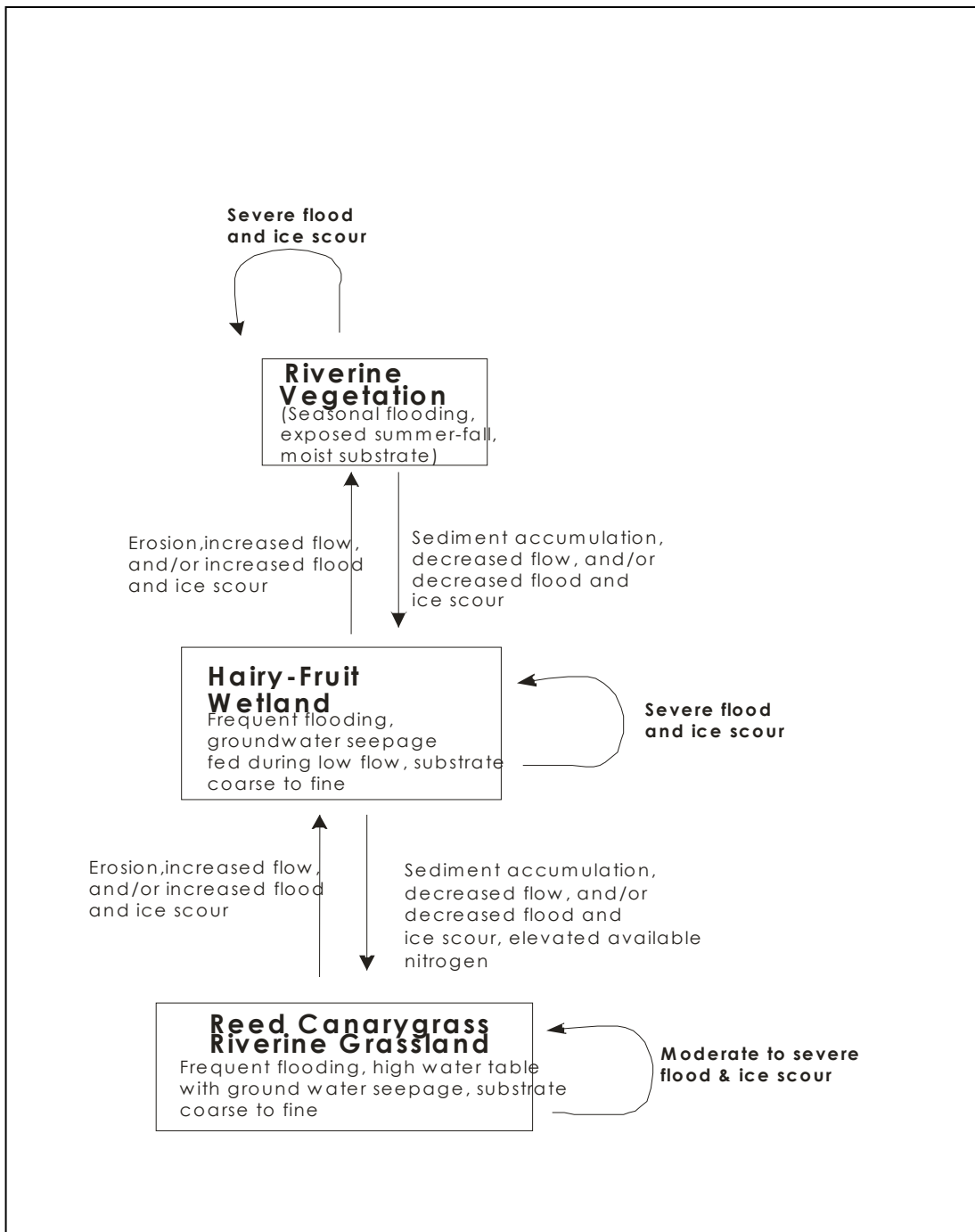


Figure 18. Ecological model of plant community dynamics on sloping shorelines adjacent to steep uplands on the Delaware River.

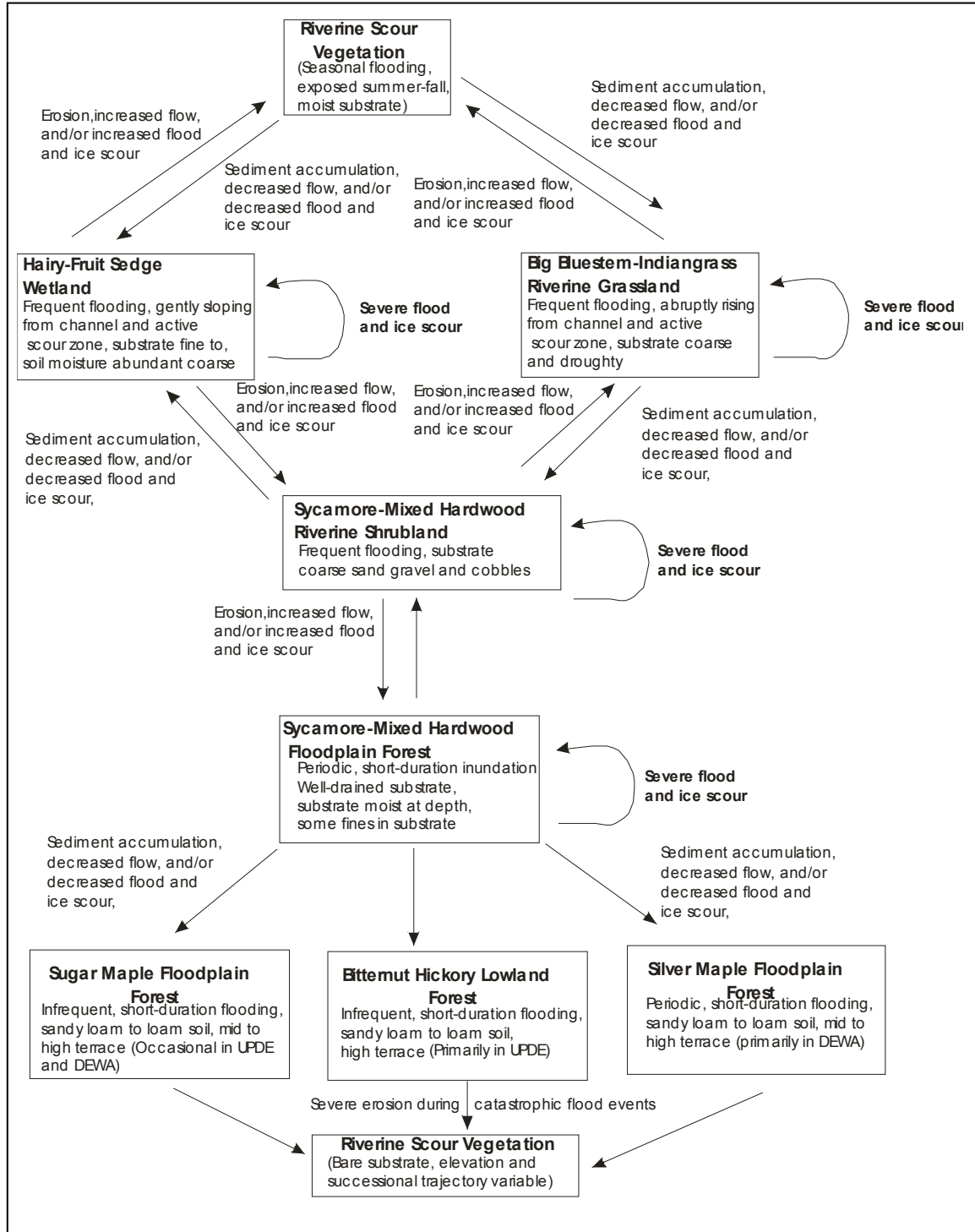


Figure 19. Ecological model of plant community dynamics on scour shorelines adjacent to high terraces on the Delaware River.

Riverside Rock Outcrops

The riverside rock outcrop communities are simple systems where bedrock lies in and adjacent to the active channel, with a high frequency of flood and ice scouring. There is little opportunity for soil development and most vegetation is limited to cracks and crevices in the bedrock surface. In UPDE, these bedrock outcrops are primarily sandstone, are gently sloping to the north or northwest, and are covered with sparse vegetation of the Northern Riverside Rock Outcrop community. Plant species present tend to be perennial herbs and some shrubs, possibly reflecting the stable nature of the substrate. Moisture availability does not appear to be a limiting factor as the Northern Riverside Rock Outcrop tends to lie at or just above the normal flow and many areas receive groundwater seepage. This community appears to be very stable, but does rely on scouring events to maintain an early successional state.

In DEWA, most of the bedrock outcrops are limestone belonging to the Buttermilk Falls Formation, which dip steeply to the west along the eastern shore of the Delaware River near Montague, New Jersey. The physical processes here are similar to the sandstone outcrops in UPDE, but the vegetation has a high number of calciphilic species not found elsewhere on the Delaware River. Outcrops with significant groundwater seepage are characterized by the Calcareous Riverside Seep community, while areas lacking significant seepage are characterized by the Calcareous Riverside Rock Outcrop community. As in UPDE, succession appears to be arrested by frequent flood and ice scouring, while the stable substrate appears to favor perennial over annual herbaceous species.

Conservation Strategies

This project has identified and characterized representative riparian communities occurring along the Pennsylvania side of the mainstem Delaware River from Hancock, New York to the Delaware Water Gap. While riparian corridor development, the spread and establishment of invasive species, and the alteration of natural ecological processes threaten the future viability of this resource, potential opportunities also abound for its preservation.

Many of the lands occurring within the 100-year floodplain of the study area are retained in private ownership. The protection of these privately owned riparian areas will involve the creative use and integration of a number of different tools ranging from the voluntary conservation of properties and/or their development rights, to regulatory requirements and special incentives.

To protect and preserve wildlife, maintain essential ecological functions, as well as to provide recreational opportunities for communities, riparian corridors are increasingly being identified as conservation priorities through hazard mitigation, open space, and greenway plans. For instance, many of the greenways identified in the Pike County Open Space, Greenway, and Recreation Plan (2008) extend along streams and rivers encompassing important riparian areas such as the Delaware River Corridor, the Shohola Greenway, and the Bushkill Greenway.

Land Preservation

Conservation organizations and willing landowners can work together to conserve riparian areas of high biodiversity value. In some circumstances, the landowner voluntarily transfers land ownership to a willing conservation organization through the sale, donation, or some combination thereof of the property. The conservation organization is then bound to protect the property's ecological values. In other situations, landowners protect the property through a conservation easement. A conservation easement is a legal agreement between a landowner and an eligible organization (often a conservation organization) that restricts the activities that may take place on a property in order to protect the land's conservation values. This type of agreement is useful for situations where the landowner wishes to retain ownership of the property, but is also interested in preserving the property's natural values.

While often used to protect properties with high biological value, conservation easements can also target riparian properties providing specific functional benefits. Several comprehensive plans throughout the study area recommend this tool. The state of Vermont has also applied this concept. Vermont's Agency of Natural Resources River Management Program has developed a conservation easement program aimed to purchase development and channel management rights within the river corridor at key sediment attenuation areas within a watershed (Smith et al. 2008). Floodplain management approaches aimed at maintaining or enhancing the functional value of intact riparian areas offer non-structural alternatives for reducing the risk and impacts of floodwaters.

The Regulatory Framework

During the last decade, federal, state, and local laws and programs have begun to acknowledge the importance of riparian areas, particularly for preserving stream water quality and maintaining aquatic diversity (Committee on Riparian Zone Functioning and Strategies for Management 2002). However, several challenges still exist within the regulatory framework. The degree of protection, the focus, and the spatial coverage of these regulations and programs are highly variable at all levels of government.

This lack of consistency is emphasized by the Delaware River Basin Interstate Flood Mitigation Task Force in their July 2007 Action Agenda, which states, “There is no consistent set of floodplain regulations basinwide to uniformly manage development within the floodplain areas of the basin. Currently, floodplain regulations vary widely from state to state and often from community to community. As a result, development may be occurring in the floodplain of one state or community that may be adversely affecting other states and communities.” (Interstate Flood Mitigation Task Force 2007)

Understanding the challenges of working in a basin that crosses four state lines, 25 congressional districts, two Federal Emergency Management Agency regions, two Environmental Protection Agency (EPA) regions, five U.S. Geological Survey (USGS) offices, four Natural Resources Conservation Service (NRCS) state offices, two National Weather Service (NWS) local forecast offices, 42 counties, and 838 municipalities, the Task Force still maintained that “a consistent set of comprehensive floodplain regulations beyond minimum National Flood Insurance Program (NFIP) standards needs to be implemented across the entire Delaware River Basin, which responsibly reflects the conditions and needs of the various watershed regions within the basin.”

At the federal level, the absence of a national riparian mandate stands in stark contrast to the existence of a federal wetlands law. The federal Clean Water Act requires that wetlands be protected from degradation because of their multiple, important ecological roles. Yet few, if any, federal statutes refer explicitly to riparian area values, despite the fact that these areas provide a disproportionate number of biological and physical functions per unit area (Committee on Riparian Zone Functioning and Strategies for Management 2002). Without this type of mandate for riparian corridors, the federal regulatory framework lacks the cohesion to guide and influence programs being administered at the state and local levels.

Defining state-level riparian protection programs and land use regulations provides another step toward more consistent regulations among basin states. In 2004, the State of New Jersey adopted stormwater regulations which included a 300-foot buffer on either side of Category 1 streams or their drainage area. The State of Pennsylvania plans to address the issue of riparian buffer protection in revisions to the Pennsylvania Code, Title 25, Chapter 102, the Soil Erosion and Sedimentation Control Provisions and currently recommends that riparian buffers be 100 feet wide on both sides of the stream. Another example of a state program is the Massachusetts Riverfront Protection Act, which treats all riparian landowners equally in providing these important public benefits.

Other states, such as Ohio, are using riparian buffers to meet Total Maximum Daily Load (TMDL) standards, coupling federal and state regulatory needs. TMDL programs do not explicitly require the protection of riparian areas; however, the restoration of riparian areas is typically one of the required management measures for achieving reductions in nonpoint source pollutant loadings. Therefore, although not a stated goal of the program, TMDL implementation may provide another tool for protecting and restoring the function of riparian areas (Committee on Riparian Zone Functioning and Strategies for Management 2002).

Local governments should also be encouraged to develop consistent protective riparian buffer zoning and ordinances as appropriate. In the study area, all four counties, including Wayne, Pike, Monroe, and Northampton, have consistently adopted Hazard Mitigation Plans (HMP). Although the plans vary and are specific to the needs and environments of each county, some version of floodplain and riparian buffer conservation is frequently recommended to help mitigate flood impact. Pike County's HMP recommends the use of riparian buffers and stream corridor zoning to develop standards that protect natural drainage patterns and strengthen hazard prevention measures, including restrictions on development on floodplains. The State of Vermont is using a similar approach to protect their riparian corridors.

Vermont's River Management Program has developed the Fluvial Erosion Hazard (FEH) zoning tool which is beginning to be applied at the municipal level. The tool goes beyond existing federal regulations to limit risks to the public, protect natural processes, and reduce the cost of managing rivers (VTDEC 2007). The FEH zoning overlay is based on the meander belt width of 4-8 bankfull channel widths, the likelihood of channel adjustment, and geomorphic sensitivity. Similar to the NFIP, incentives are recommended to encourage towns to participate in the program, with anticipated savings for the state with the reduction of risks and less need for disaster recovery (Kline et al. 2006) (excerpted from Smith et al. 2008).

Other counties such as Monroe and Northampton have or are looking to develop riparian buffer recommendations that exceed NFIP standards and provide guidance for municipalities looking to establish riparian setbacks and buffers. Regulatory approaches such as these are particularly appropriate to situations in which the development and use of land and natural resources causes unacceptable public loss. In these situations, the negative consequences of the land use activity largely fall on the public, thereby justifying programs and regulations aimed to serve the public good (Committee on Riparian Zone Functioning and Strategies for Management 2002).

We also need to better understand the functional relationship between riparian corridors and flooding impacts while being able to more accurately identify those areas providing ecological services in terms of flood mitigation. This is echoed by the Delaware River Basin Interstate Flood Mitigation Task Force, stating, "Standardized Riparian Corridors should be considered along all basin streams, rivers, and estuary waters and a study to identify and prioritize certain riparian corridors throughout the basin that can provide areas for efficient floodplain restoration and increased floodplain storage should be

performed.” They further recommend that “disturbance to existing vegetation within the corridors should be highly discouraged, while incentives should be developed to encourage revegetation and enhancement of previously disturbed areas with native trees, shrubs and herbaceous plants.” (Interstate Flood Mitigation Task Force 2007)

The Nature Conservancy and the United States Army Corps of Engineers (USACE) are working cooperatively to develop a spatially explicit decision-support system that will identify the best sites to reconnect the river and its tributaries to their floodplains, restoring ecosystem function, reversing historic habitat losses, and helping fish and wildlife to recover. The decision-support tool will enable users to model the hydraulic conditions at a site, including flood extent, water depth, velocity, etc., under differing climatic and flood frequency scenarios as well as under differing infrastructure or development scenarios (Figure 20). The tool will identify areas of potential conflict between flood processes and human infrastructure. It will prioritize floodplain management alternatives and is intended to help assess the impacts of infrastructure management, planned development, flood mitigation, and environmental restoration (Schuler 2008). Studies such as this enable us to better understand the intricacies and impacts of various land use, management, and environmental actions and are essential for integrating planning and conservation efforts.



Figure 20. Floodplain Reconnection Tool Scenario Analysis. Under the predefined options and user defined parameters, how flood extent, depth and relative velocity distribute across the landscape, especially with respect to vital social, economic and cultural resources (Reprinted with permission from Schuler 2008).

Floodplain Mapping

Currently, the 100-year floodplain, as mapped by FEMA, provides the spatial framework and context for identifying regulatory floodways. As the Interstate Flood Mitigation Task Force (2007) states, “A regulatory floodway is defined as the channel of a river or other watercourse and portions of the floodplain adjoining the channel that must be maintained to convey and discharge the base (or 100-year) flood without cumulatively increasing the water surface elevation more than a designated height. The minimum FEMA floodway determination allows for a 1.0-ft rise.” This method for determining the active and functional floodplain has recently been questioned.

According to The Delaware River Basin Interstate Flood Mitigation Task Force Action Agenda (2007), “The existing flood hazard area maps greatly underestimate the limit of the floodway along the mainstem Delaware River and other waterways within the

Delaware River Basin.” The existing maps identify the inner floodway, but do not encompass areas adjacent to the floodway that are also often subject to the impacts of floodwaters. New construction is generally prohibited in regulatory floodways, but remains a permitted use in the areas adjacent to the floodway (Interstate Flood Mitigation Task Force 2007).

Currently, the New Jersey State floodway standard allows for a more conservative 0.2-ft. rise in flood depths, resulting in the identification of a larger regulatory floodway. However, to maintain consistency between state programs, the less stringent 1.0-ft rise standards being used by Pennsylvania and New York have been used to map the floodway of the mainstem Delaware River. This results in narrow, more confined floodways being identified for the river and more areas available for new development (Interstate Flood Mitigation Task Force 2007).

The Task Force (2007) urges the basin state regulatory agencies to come together to compare and evaluate the implications of using a newly defined, more stringent standard that defines a larger floodway, thereby requiring development take place farther from the path of damaging floodwaters (Interstate Flood Mitigation Task Force 2007).

Identifying the regulatory floodway can also provide additional regulatory benefits to the conservation of the riparian corridor. The Nature Conservancy is developing of a spatially explicit framework for identifying a functional riverine network referred to as the “Active River Area” (Smith et al. 2008).

The *active river area* is a spatially explicit yet process-based framework for defining areas of interaction between flowing waters and land. Spatially, the framework identifies both the channels and the riparian lands which are critical components of a riverine system and necessary to accommodate both the physical structure and ecological processes associated with river systems (Figure 21). It goes beyond the conventional 100-year floodplain delineation approach, which relies on a specified rise in water stage to delineate a floodplain, to identify a number of distinct components of the river system, including material contribution areas, meander belts, floodplains, terraces, and riparian wetlands which are primarily defined by the type and frequency of interaction with the river (Smith et al. 2008).

The *active river area* framework informs river conservation by providing an approach to account for the areas and processes that form, change and maintain a wide array of habitat types and conditions in and along rivers and streams. By applying this tool to the development of regulatory floodways, a process-based component would be added to the procedure, which has the potential to identify additional areas of floodway that are not only important conservation targets but also locations where valuable ecosystem services originate (Smith et al. 2008).

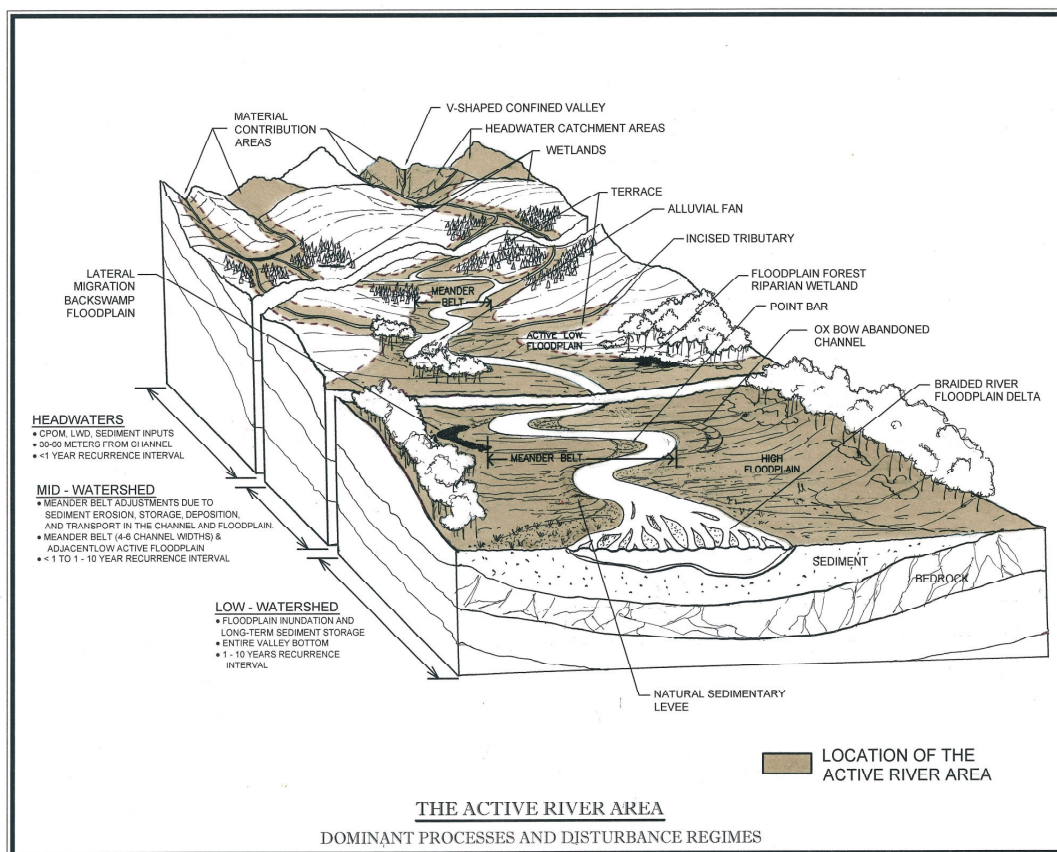


Figure 21. The dominant processes and disturbance regimes of the *Active River Area* (Reprinted with permission from Smith et al. 2008).

In addition, floodplain mapping and delineation efforts need to look beyond today to incorporate anticipated hydrologic responses to changing land use patterns and climate change. According to the Interstate Flood Mitigation Task Force (2007), Delaware, Pennsylvania, New York, and local communities within New Jersey currently use the 100-year flood event for planning purposes without consideration for future build-out. This results in a lack of safety factors being incorporated into floodway delineations.

Numerous flood mapping efforts involving state resource agencies and federal partners are underway in the basin. FEMA is currently working cooperatively with the New Jersey Department of Environmental Protection (NJDEP), the Pennsylvania Department of Community and Economic Development (PADCED), and the New York State Department of Environmental Conservation (NYSDEC) to complete a five-year digital map modernization effort which will incorporate local, county-wide information and update flood maps from paper to digital format. NYSDEC is also working with FEMA and the New York City Department of Environmental Protection (NYCDEP) on county-wide Digital Flood Insurance Rate Maps (DFIRM) in Delaware, Sullivan, and Ulster counties while NJDEP is coordinating with the United States Geological Survey (USGS), the USACE, and FEMA on the development of updated hydrologic information for the Delaware River which will be used during hydraulic modeling for the new mapping.

Finally, Pennsylvania, coordinating with the Delaware Valley Regional Planning Commission (DVRPC), is currently preparing Light Detection and Ranging (LiDAR) data for various counties within the basin that will be used by FEMA. The Flood

Insurance Rate Maps (FIRM) are also being revised. High-water marks from the June 2006 flood have been surveyed and will be used to assess the accuracy of 100-year flood levels. Peak flow regression equations and flood-frequency data are also being updated by PADCED, FEMA, and the USGS. Coordination between all modeling and mapping efforts is imperative to the individual and cumulative success of these basin initiatives. Ensuring current funding levels are maintained and increased where necessary is also crucial.

Invasive Weeds

Invasive weeds pose yet another serious threat to the riparian corridor of the Delaware River. Numerous invasive weeds were identified during field investigations; noteworthy among them were the significant infestations of reed canarygrass and Japanese knotweed. Weed management efforts to abate this threat begin by viewing the riparian corridor as a functional system and selecting high-quality riparian complexes as areas of concentrated weed management efforts. Ideally, complexes should consist of a mosaic of characteristic riparian communities, some of high biological value, others in varying degrees of degradation by invasive weeds. High biological-value communities serving as core refuges should be defined as relatively weed-free areas. Buffer zones surrounding the cores areas serve to protect cores from future invasion by other weedy species.

Site management and rehabilitation efforts in buffers will vary depending upon the ecological value of the existing habitats. In general, those buffers most proximate to core areas should strive to maintain the ecological value of the existing communities while minimizing (not always eliminating) the amount of invasive weeds present at the site. The further one moves away from core areas, the higher the degree of invasive weed tolerance.

In these buffer areas, we may need to redefine our management goals. Rather than the restoration of a pre-existing condition or community or the elimination of invasive weeds, we may wish to strive for the rehabilitation of a portion of the community. Then reconciling ourselves to the fact that not all invaders can be controlled — due to the extent and distribution of the invasive population, limited economic resources, etc. — we may need to define a “new” mixed community of native and non-native species with the most desirable ecosystem functions and properties (Randall PowerPoint presentation 2007).

Where the threshold between invasive and native species' coexistence and balance lies is an excellent question and one that should be kept in mind as this approach is applied. Site specificity, species life history strategies and physiology play a role in determining that balance between invasive and native species. This approach depends on a context of adaptive management that includes monitoring to inform decision-making and further management.

This picturesque vision of weed-free core areas surrounded by protective buffers may be difficult to find or create in a natural setting, particularly one as highly dynamic and changeable as the riparian corridor. Riparian corridors exist in a state of dynamic

equilibrium where a natural balance is maintained within some range of natural variability (Schumm 1977). Subject to impacts of flooding, riparian communities are disturbance dominated ecosystems and do not always follow a linear successional pathway (Ward et al. 1999). Instead, they are punctuated by ecological processes, such as hydrologic and sediment transport regimes that can restart the clock without warning. As a result, riparian complexes are constantly being created, changed, destroyed, and maintained (Smith et al. 2008). Each time the clock is reset, invasive weeds have yet another opportunity to colonize a site perhaps previously dominated by native species. Ecological management must therefore be able to respond to both the spatial and temporary variability that are typical of a riparian setting.

The outlined management strategy is not meant to be restrictive. On the contrary, the goal is to provide a flexible and adaptive framework for managing invasive weeds within a larger site or complex. Although simplistically described, the complexities and sometimes stochastic nature of natural systems will most often preclude the ideal, but keeping the overarching goal in mind allows flexibility to respond to the dynamic nature of a riparian corridor.

Employing this type of approach has the potential to build riparian complexes with relatively weed-free areas surrounded by ecologically viable buffers of new mixed-type communities. It advances the conservation of the ecological integrity of our riparian corridor while also funneling limited resources toward targeted areas for more effective conservation and collaboration. This approach will probably happen parcel by parcel, piece by piece, but it is hoped that by identifying complexes consisting of several or more parcels, in the end the pieces will fit together to form a more holistic, ecologically connected system: the riparian corridor.

The above approach provides a starting point for grappling with established invaders, but what about those that are anticipated? Prevention, Early Detection and Rapid Response (ED/RR) has become the mantra of invasive species efforts both domestically and internationally. Controlling invasives before they get a foothold and become widespread in the system dramatically increases chances of successful management efforts before it is too late and too expensive. According to the Idaho Aquatic Nuisance Species Plan (The Idaho Invasive Species Council and Technical Committee 2007), it is more desirable and cost effective to prevent new invasions of unwanted species than to attempt to eradicate or control them once they become established. The Pennsylvania Invasive Species Council's Aquatic Invasive Species Plan (2006) cites prevention as a key management objective and enumerates the complexities associated with effective prevention.

Prevention is a multi-faceted task that includes actions ranging from education of those who might inadvertently introduce unwanted species, to research identifying pathways and vectors of invasive species spread, to enforcement of laws for inspections and quarantines (The Idaho Invasive Species Council and Technical Committee 2007). An example of this type of research in the project area is being conducted by the National Park Service's ERMN. They are currently researching ways to prevent future infestations

of invasive weeds in one project resulting in two reports entitled, “Determining the Status and Trends of Key Invasive Plant Species” and “Invasive Plant Species Distribution Analysis and Predictive Modeling in the Upper Delaware Scenic and Recreational River and the Delaware Water Gap National Recreation Area.” These studies will evaluate the status of established and encroaching invasive plants, while also conducting predictive modeling of invasive weeds to determine their anticipated park-wide distribution.

The Pennsylvania Invasive Species Council further identifies the implementation of a coordinated system for rapid response efforts to contain or eradicate newly detected aquatic invasive species as well as the development of specific rapid response plans for priority organisms as key strategies (Commonwealth of Pennsylvania 2006). The fundamental premise of effective rapid response efforts is that there is usually a window of opportunity to eradicate small pioneering populations before they become large, widespread populations. Unfortunately, often invasive populations are not detected until large populations are established. By initiating an effective early detection, rapid response and monitoring program, it is hoped that pioneering infestations will be discovered and managed at a point when the species can be eradicated in a cost effective manner.

Pennsylvania's plan enumerates five key strategies for developing and implementing an effective Early Detection Program:

1. Identify gaps in existing efforts;
2. Increase the knowledge and expertise available to enhance early detection efforts;
3. Prioritize early detection efforts by location and species;
4. Establish simple, coordinated reporting system(s) for detection and monitoring in Pennsylvania; and
5. Facilitate regional cooperation for early detection efforts.

Although meant to guide the development and implementation of regional or statewide rapid response efforts, these same guiding principles are found in the National Park Service ERMN's emerging surveillance monitoring and rapid response protocol.

Both the UPDE and DEWA Parks are part of the ERMN network and implementation of the early detection/rapid response (ED/RR) protocol began in 2008. Although limited to lands owned and managed by the two parks, developing a regional prototype ED/RR Program for 120 miles of high-quality riparian habitat along the mainstem Delaware River has the potential to reach many people and organizations beyond the physical boundaries of Park ownership. As a leader in the field of invasive species management, UPDE has offered and assisted many landowners, watershed, and conservation organizations with invasive weed management efforts. Through their expertise, education, and field support, they continue to build a coalition of individuals, communities, and organizations who are committed to preservation of the Delaware River including its riparian corridor. The development of the NPS's ED/RR program provides the region with another critical tool for managing invasive weed species.

Alteration of Natural Ecological Processes: Implications of an Altered Flow Regime

As stated in the Conceptual Ecological Models Section of the document, flow regime is a “key” environmental driver of the ecological integrity of riparian communities structuring both the physical and biotic components of aquatic ecosystems (Poff et al. 1997). Riparian communities, adapted to a natural range of flow variability, have developed mechanisms to not only ensure their survival in a disturbance dominated system, but to thrive in these conditions. The introduction of hydrologic alteration may result in riparian corridors becoming disconnected both physically and functionally from riverine processes that ensure riparian plant regeneration and succession (Poff et al. 1997, Zimmerman 2006).

As cited in Postel and Richter (2003), Bunn and Arthington explain why flow alteration has been so devastating to river species and ecosystems: “First, river flows particularly floods shape the physical habitat of rivers and their floodplains, changes in these flows strongly affect the spatial distribution and abundance of plants and animals and can completely eliminate species that are dependent upon habitats no longer available after flow alteration. Second, species have evolved survival and reproductive strategies that are tied to natural flow condition. Third, many species require adequate water depth at critical times of the year to facilitate longitudinal and lateral movement as well as dispersal. Finally, altered flow conditions often favor nonnative species introduced into river systems, placing greater competition pressures on native species.”

In the Delaware River Basin, Dr. Rebecca Brown of Eastern Washington University initiated a study to determine how hydrologic alteration, caused by dams, affected exotic species invasion, specifically invasion by Japanese knotweed, within the riparian corridor. She found that there were some distinct differences in the size and frequency of knotweed patches among reaches operating under differing hydrologic regimes. Smaller more frequent patches of Japanese knotweed occurred on undammed reaches of the Beaverkill and upper reaches of the East and West Branches of the Delaware, whereas fewer, yet larger patches occurred on dam-influenced reaches of the West Branch and mainstem of the upper Delaware. The largest patches of knotweed were in reaches affected by damming, particularly on the mainstem. This suggests that flow regime may affect knotweed dispersal and its ability to develop into large dominant patches (Brown 2005). This study provides preliminary insights into the relationship between flow regime and riparian plant community dominance and distribution, specifically invasive species such as Japanese knotweed. Further research is necessary to enable the development of more prescriptive flow regime recommendations enhancing native species biodiversity while minimizing invasive weed establishment and dominance.

Within the last century, particularly the last 50 years, a growing demand for irrigation, water supply, and hydroelectric power has led to an unprecedented boom in dam and reservoir construction (Postel and Richter 2003). Yet as stated by Schuler (2003) “modern scientific methods can allow for the design and implementation of new flow management regimes that change reservoir release schedules, provide for the water supply needs of cities and municipalities, while greatly enhancing the ecological health

and recreational use of our rivers. Achieving an improved balance between human uses and ecological health is the essence of ecologically sustainable water management.”

The Delaware River Basin Commission advanced such an effort to move toward a more sustainable and equitable management of water resources within the basin. Several of the guiding principles of this effort are captured in the 2004 Water Resource Plan for the Delaware River Basin which states, “Prudent water management requires a commitment to ecological integrity and biologic diversity to ensure a healthy environment; to a dynamic economy, and to social equity for present and future generations.” Specifically two goals of the plan relate to this guiding principle:

Goal 1.1 Equitably balance the multiple demands on the limited water resources of the Basin, while preserving and enhancing conditions in watersheds to maintain or achieve ecological integrity.

Goal 1.2 Ensure an adequate supply of suitable quality water to restore, protect and enhance aquatic ecosystems and wildlife resources.

Understanding the types of human as well as ecological demands on the hydrologic system is essential to moving towards the sustainable management of our water resources while also ensuring a more equitable balance between sometimes competing demands for water supply (DRBC 2004).

Although the Delaware River remains undammed on its mainstem, 15 dams fragment its tributaries. These dams range in size from a minimum of 15.1 million m³ (4.0 billion gallons) of total storage capacity to a maximum of 529.9 million m³ (140 billion gallons) (Figure 22). There are two major exportations of water from the basin: the largest of approximately 650 mgd is to New York City, which obtains around half of its water supply from a system of upper basin reservoirs including the Cannonsville, the Pepacton, and the Neversink Reservoirs. The other major export (approximately 90 mgd) carries water to northeastern New Jersey via the Delaware and Raritan Canal. The largest water using sectors are power generation, industrial use, and public water supply with power generation showing a marked increase in recent years (DRBC 2004). So although the mainstem is undammed, flows in the mainstem are certainly altered. This results in a river that flows according to the management of a regulated network of reservoirs.

To further advance their goals of sustainable water use, the DRBC and Decree Parties, established a Subcommittee on Ecological Flows (SEF) to assist the DRBC's Regulated Flows Advisory Committee (RFAC). The goal of the subcommittee was to develop scientifically-based ecological flow requirements for the maintenance of self-sustaining aquatic ecosystems, with a focus on fish and freshwater mussel species. The Commission and the Decree Parties committed to participating in a non-binding collaborative process to develop experimental flow management options for the Delaware River and its regulated tributaries.

Delaware River Basin Reservoirs

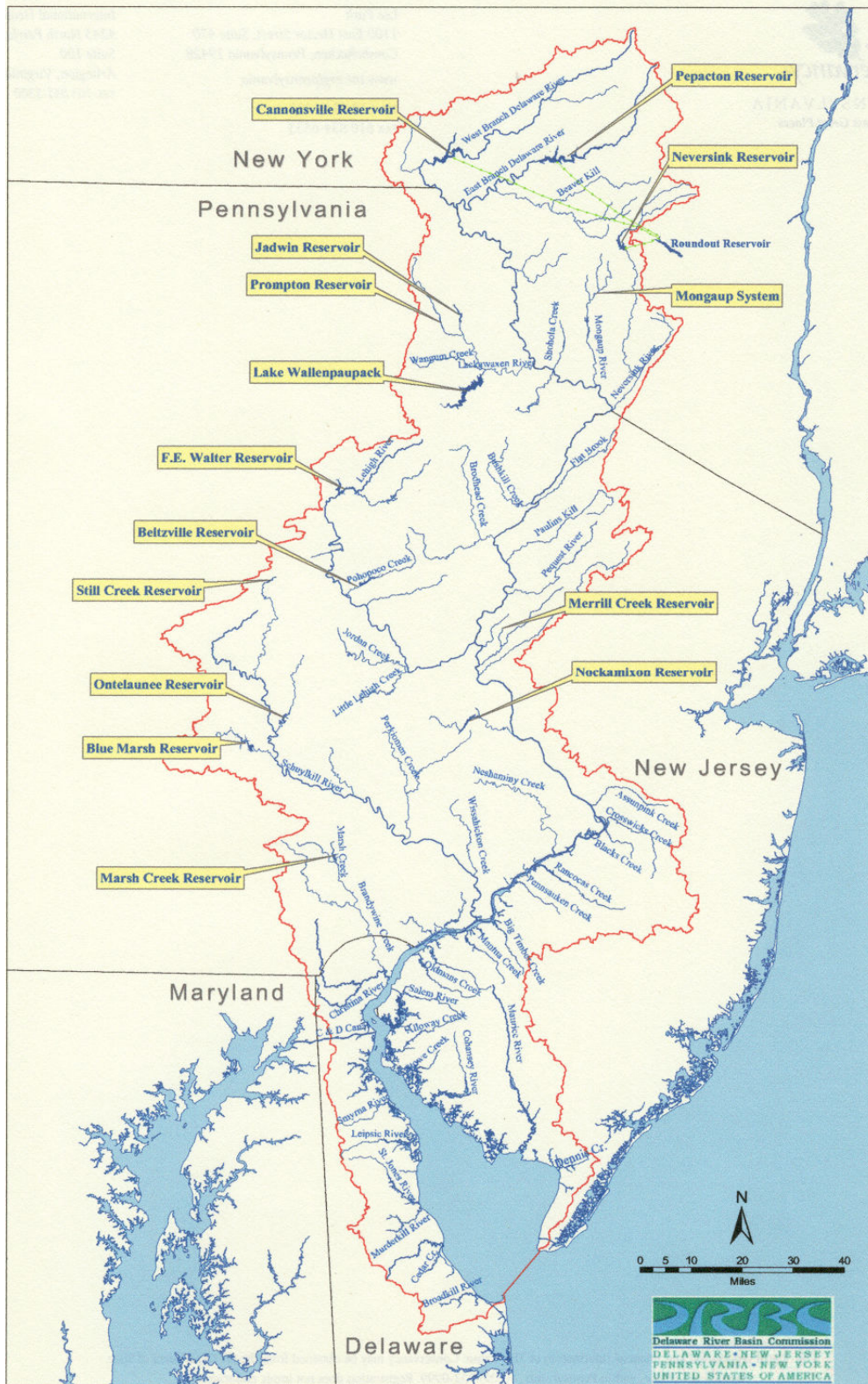


Figure 22. Reservoirs located within the Delaware River Basin (Reprinted with permission from the Delaware River Basin Commission 2008).

These and other complimentary efforts have resulted in the "Flexible Flow Management Program (FFMP)," which represents a major step forward in water management in the basin. It is designed to restore natural variability in flows to the upper Delaware and is part of an adaptive management program that will allow for revisions in water management based on biological results (C. Apse, The Nature Conservancy, Portland, ME, personal communication).

The FFMP has been implemented on an interim basis since September 2007 and is expected to be formally incorporated into DRBC's Water Code in the near future. As this proposal sets up a process for improvements to be considered and acted upon, it is a key step forward. However, the ecological flow requirements of a broader array of species and systems, including the riparian corridor, also need to be evaluated and incorporated into water management decisions.

General hypotheses regarding riparian response to altered flow regime do exist, yet most of the studies to date have been conducted for western river systems (Zimmerman 2006). The results of these investigations cannot be unilaterally applied across basins operating in different climatic regimes, with differing geologies and ultimately with different hydrologic regimes. The uniqueness of each basin drives a somewhat individual response of each riverine system to hydrologic alteration which underscores the need for a site specific or Delaware River Basin assessment of the ecological impacts of altered flow regime on the river's riparian communities.

Although ecological response to flow varies between basins and regions, in nearly every case altered flow regime results in a loss of ecological integrity and a decline in river health (Postel and Richter 2003). As stated by Postel and Richter (2003), "The loss of ecological integrity is of concern in of itself, but this loss results in further losses in the services and goods these systems provide to people and communities. Floodplains disconnected from river systems have a greatly diminished capacity to purify and store water, a very valuable ecosystem service."

These conservation strategies – land preservation, floodplain regulation, invasive species management and the prevention of new invasions, as well as flow regime restoration – employed individually or collectively, will assist to ameliorate threats at the scale of the individual parcel to the scale of the basin. As each habitat and place is unique, no one strategy will effectively fit every situation. However, working cooperatively these strategies will help to secure the future ecological integrity of riparian corridors at multiple scales.

Summary and Recommendations

“Although many riparian areas can be restored and managed to provide many of their natural functions, they are not immune to the effects of poor management in adjacent uplands. In other words, riparian area management must be a component of good watershed management.” (Committee on Riparian Zone Functioning and Strategies for Management 2002)

This project has identified and described riparian communities along a portion of the mainstem Delaware River, providing us with a biodiversity baseline that can be used in future riparian conservation and restoration efforts. But this is just a piece of the big picture and just the beginning of the work that needs to be done.

Future Inventory

Efforts are needed to expand the geographic scope of this effort to include the entire Delaware River riparian corridor, particularly along the mainstem and along specific high-quality watershed tributaries. The National Park Service has been a leader in characterizing large regions of the riparian corridor in both UPDE and DEWA Parks. These efforts provide an excellent and absolutely necessary baseline for future conservation efforts, but we need to extend these efforts to the entire watershed. Our study, as well as those of the two National Park Service studies, characterize portions of the overall system and although we anticipate communities identified in these project areas to be found elsewhere both across the river as well as upstream and downstream, we also anticipate encountering differences in tributary headwaters and downstream in the middle and lower Delaware. The riverine system is connected laterally to its floodplain and longitudinally to upstream and downstream river reaches. It is essential that we understand and document this spatial variability if we hope to preserve the entire system and not just individual patches within it.

One way to continue the inventory and assessment process is through the continued use and updating of the Natural Area Inventories. The Riparian Plant Community Reference Conditions provides a framework against which the condition of riparian communities, particularly those occurring within northeast Pennsylvania, can be compared. Through this process, riparian complexes of high-value as well as those in need of management and restoration can be identified and targeted by individual counties for future conservation efforts, be that land conservation, floodplain regulations, or invasive species management.

Watershed Management

This project also provides a number of strategies for conservation. Within the proposed strategies, watershed management was not specifically addressed as this project focuses on strategies that relate more directly to riparian corridor conservation. However, the alteration of upstream watershed processes and basin hydrology leads to concomitant changes in channel hydraulics and sedimentation regimes, all of which have immediate implications for the health and vitality of neighboring and downstream riparian corridors as well as aquatic resources. To ensure riparian corridors as well as aquatic resources are

not being degraded by increased storm flows laden with pollutants and sediment, land use and watershed management is a critical piece of the puzzle that is often at the root of water quality and quantity degradation issues.

According to the Interstate Flood Mitigation Task Force (2007) little of the Delaware Basin Watershed is currently under approved stormwater management plans due to inadequate funding mechanisms and yet there is much that could be done. More holistic and comprehensive approaches to watershed management including tributary-based stormwater plans are one mechanism for providing more effective means for managing stormwater issues. Implementation of these plans is critical to minimizing the volume and peak rate of runoff while also addressing water quality issues (Interstate Flood Mitigation Task Force 2007).

Riparian Management and Restoration

Restoration or the rehabilitation of certain places along the riparian corridor also warrants further investigation. Studies such as those being pioneered by The Nature Conservancy and the Army Corps of Engineers are beginning to provide quantitative insights into the trade-offs between infrastructure management, planned development, floodplain mitigation, and environmental restoration. However, to fully explore the idea of rehabilitation, we need to move beyond inventorying what is currently in place to also assess what has been lost in terms of biodiversity and ecological function. How much of the mainstem riparian corridor has been converted from native riparian community types to residential, commercial, agricultural, transportation and utility infrastructure uses? How much of the corridor is currently in invasive weed cover? What do these changes or conversions mean in terms of lost biodiversity value as well as floodplain and riparian corridor functionality? One also needs to determine the appropriate balance or the new mixed community types we are striving for in light of extensive alterations, global climate change, invasive species, etc.

The rehabilitation of our riparian corridors will take the patience and endurance of individuals and organizations alike. The current degraded status of many riparian areas throughout the country represents the cumulative, long-term effects of numerous, persistent, and often incremental impacts from a wide variety of land uses and human alterations. Rehabilitation efforts re-establishing native species and managing non-native species competition may be necessary to ensure communities succeed to native or mixed community types typical and/or desirable for riparian corridors of the region.

Riparian Plant Community Reference Conditions provide a basis for developing the future desired conditions for characteristic riparian communities by identifying the environmental conditions, species composition, and structural characteristic for each plant association. Understanding what we're aiming for in terms of community type and composition are critical to ensure the effectiveness of management and restoration efforts.

Outreach and Education

Rehabilitation of these and other degraded sites will take time. Years to decades will be required before native community types re-establish both in form and function. Commensurate with restoration must be efforts to improve society's understanding of what riparian functions have been lost and what can be recovered.

Preservation of this unique and invaluable resource will take the efforts of many. Individual landowners working alongside conservation organizations can begin by preserving individual yet critical pieces of the riparian corridor. County, regional, state, and national planning and regulatory agencies can complement local efforts by striving for more holistic floodplain delineations, more consistent floodplain and riparian regulations, and more sustainable water resource management.

Some efforts will come to an end, but other efforts will be initiated in their place—perhaps at different scales, in different locales within the basin, and with a slightly different focus—but all efforts will cumulatively advance the conservation of these important places. Over the past ten years, invasive efforts in the basin have ranged from local efforts to manage invasive weeds at a community park, to the development of watershed invasive weed plans, to a regional effort to bring together partners in the advancement of our understanding and management of invasive weeds, specifically Japanese knotweed. Some efforts have faded, partially or entirely due to the ever-fluctuating availability of funding, staff resources, and/or volunteer interest, while others persist. Yet, in the midst of one effort's decline, others are beginning and building upon the foundation previously laid. Continued funding is vital to support these efforts.

Continued Funding

We are entering a time when global climate change is commonly recognized and discussed. Newly emerging carbon-based markets are beginning to provide unique and creative economic incentives for the conservation of biological systems, not only recognizing but also ascribing a value to the ecosystem services they provide. This is a time of opportunity, driven by the need for our ecological systems to provide their intended functional benefits. In Pennsylvania, increased funds may be available through Senate Bill No. 2, the H₂O PA Act, which proposes to direct substantial funding toward updating water and sewer projects, stormwater projects, flood control projects, and high hazard/unsafe dam projects. Directing this and other new funding towards the conservation of riparian corridors and floodplains not only serves to protect places of unique ecological value, but also provides recreational and other ecological services to the human community.

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Appendix A: Field Form for Community Assessment

Form 1: TNC Riparian Site Survey

A. General Information

Sheet: _____ of _____

Site Number: _____ Site Name: _____ County _____
 Survey date: _____ Surveyors: _____
 Easting: _____ E Northing: _____ N Elev: _____ DOP: _____ Map datum: _____ Zone: _____

B. Topography

Annotated Reconnaissance diagram/comments:

C. Vegetation / Habitat

Observation point 1

Community name:

Easting: _____ E Northing: _____ N Elev: _____
 DOP: _____ Map datum: _____ Zone: _____

Stand age/successional stage:

Debris Piles/CWD Present:

Photo #:

Dominant/characteristic Vegetation by strata

“*” Dominant, “*” abundant, sub-dominant, “ “ characteristic

% Invasive cover: _____

Dominant Invasives:

Hydrologic regime:

____ Permanently flooded ____ Saturated ____ Intermittently exposed
 ____ Temporarily flooded ____ Semi-permanently ____ Intermittently flooded
 flooded

____ Seasonally flooded ____ Artificially flooded

Unvegetated surface:

____ % Bedrock ____ % Wood (> 1 cm)
 ____ % Large rocks ____ % Litter, duff
 (cobbles, boulders > 10 cm)
 ____ % Small rocks (gravel, 0.2-10 cm) ____ % Water
 ____ % Sand (0.1-2 mm) ____ % Other:
 ____ % Bare soil

Evidence of Disturbance (anthropogenic disturbance, alteration to natural processes, etc):

General description and comments (known/inferred land use history; context, etc)

Condition Rank and rationale(1- pristine, 2- moderately impacted, 3 -significantly impacted, potential for restoration, 4- severely degraded, restoration value questionable):

Appendix B: Riparian Plant Community Reference Conditions listed alphabetically

Big Bluestem-Indiangrass Riverine Grassland

COMMON NAME: BIG BLUESTEM-INDIANGRASS RIVERINE GRASSLAND

SYNONYMS

NVC English Name: *Sand Cherry / Big Bluestem - Yellow Indian grass*
Herbaceous Vegetation

NVC Scientific Name: *Prunus pumila / Andropogon gerardi -*
Sorghastrum nutans Herbaceous Vegetation

NVC Identifier: *CEGL006518*

LOCAL INFORMATION

Environmental Description: This community type occurs on sand, gravel and/or coarse cobble deposits along shorelines and on islands in the Delaware River. These sites are subject to flooding and ice-scour that removes woody vegetation and maintains a graminoid- and herbaceous-dominated vegetation. The coarse substrate may experience drought conditions in mid-late summer, as river stage falls. The-deep rooted nature of most of the characteristic vegetation in this type allows them to reach sufficient moisture to avoid drought impacts.

Vegetation Description: The typical aspect is that of a tall prairie-like grassland. In the upper reaches of the Delaware, the community may be more sparse, especially when the substrate is coarse cobbles. The dominant species are big bluestem (*Andropogon gerardi*), Indian grass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), and little bluestem (*Schizachyrium scoparium*). Other herbaceous species include Indian-hemp (*Apocynum cannabinum*), hairy lespedeza (*Lespedeza hirta*), reed canarygrass (*Phalaris arundinacea*), wrinkleleaf goldenrod (*Solidago rugosa*), giant goldenrod (*Solidago gigantea*), early goldenrod (*Solidago juncea*), Canada goldenrod (*Solidago canadensis*), prairie fleabane (*Erigeron strigosus*), and horseflyweed (*Baptisia tinctoria*) and eastern marsh fern (*Thelypteris palustris*) among many others. Woody species may become established within the grassland matrix. Common species include willows (*Salix* spp.), sycamore (*Platanus occidentalis*), ashes (*Fraxinus* spp.), boxelder (*Acer negundo*), river birch (*Betula nigra*), sandcherry (*Prunus pumila*), bear oak (*Quercus ilicifolia*), Carolina rose (*Rosa carolina*), Blue Ridge blueberry (*Vaccinium pallidum*) and common winterberry (*Ilex verticillata*). Vines may also be present, including Virginia creeper (*Parthenocissus quinquefolia*), eastern poison ivy (*Toxicodendron radicans*), fox grape (*Vitis labrusca*), and riverbank grape (*Vitis riparia*).

Most Abundant Native Species:

Stratum

Tall/Short Shrub
Herb (field)

Lifeform

Broad-leaved deciduous shrub
Forb

Species

Betula nigra, *Prunus pumila*
Apocynum cannabinum,
Lespedeza hirta

Herb (field)

Graminoid

Andropogon gerardi,
Panicum virgatum,
Schizachyrium scoparium,
Sorghastrum nutans

Characteristic Species: *Andropogon gerardi*, *Sorghastrum nutans*, *Panicum virgatum*,
Schizachyrium scoparium, *Prunus pumila* var. *depressa*

Invasive/non-native plant species:

Trees:

Shrubs:

Herbs:

Achillea millefolium
Centaurea biebersteinii
Thlaspi arvense

Grasses:

Phalaris arundinacea

The invasive species spotted knapweed (*Centaurea biebersteinii*), along with exotics like field pennycress (*Thlaspi arvense*), reed canary-grass (*Phalaris arundinacea*) and common yarrow (*Achillea millefolium*) can also be present.

Other Noteworthy Species: *Prunus pumila* var. *depressa*

Subnational Distribution with Crosswalk data:

State	State Rank	Confidence	State Name	Reference
NJ	S2?	2	Riverside Prairie Grassland	Walz et al. 2006
PA	S3	1	Big bluestem - Indian grass river grassland	Fike 1999
NY	SNA	1	Floodplain grassland	Edinger et al. 2002

Local Range: This vegetation is found occasionally along the upper Delaware River. Large (>1 ha), high quality examples are rare.

Classification Comments: This type can be distinguished from other riparian types by the dominance of *Andropogon gerardi*, *Sorghastrum nutans*, *Panicum virgatum*, and *Schizachyrium scoparium* that form a tall prairie-like grassland. This association typically occurs at a slightly higher elevation than Reed Canarygrass Eastern Marsh and Hairy-fruit Sedge Wetland; it can be associated with or surrounded by Sycamore-Mixed Hardwood Riverine Shrubland.

Other Comments: None.

USFWS Wetland System: Palustrine

Local Description Authors: S.J. Perles (PNHP), Feldmann, A.L. (NYNHP)

Plots and Data Sources: DEWA.107, UPDE.96, UPDE.97, UPDE.121, UPDE.123, UPDE.145, UPDE.146, UPDE.152, UPDE.153, UPDE.193, UPDE.219, Fike 1999.

References: Eastern Ecology Working Group n.d., Edinger et al. 2002, Fike 1999, Metzler and Barrett 2001, Nichols et al. 2001, Perles et al .2004,



Figure 1b. Big Bluestem – Indian grass Riverine Grassland in Upper Delaware Scenic and Recreational River. Photograph by: Stephanie Perles, Pennsylvania Natural Heritage Program.



Figure 2b. Big Bluestem – Indian grass Riverine Grassland in Delaware Water Gap National Recreation Area. Photograph by: Gregory Podniesinski, Pennsylvania Natural Heritage Program.

Bitternut Hickory Lowland Forest

COMMON NAME: BITTERNUT HICKORY LOWLAND FOREST

SYNONYMS

NVC English Name: *Bitternut Hickory - Black Cherry / White Snakeroot Forest*

NVC Scientific Name: *Carya cordiformis - Prunus serotina / Ageratina altissima Forest*

NVC Identifier: *CEGL006445*

LOCAL INFORMATION

Environmental Description: This association typically occurs on mid to high floodplain terraces of the Delaware River, typically as a linear stand several trees wide where the active floodplain transitions to higher terraces, primarily on the Upper Delaware River above Port Jervis and only occasionally below Port Jervis. It typically occurs in sections where there are broader, abandoned floodplains that are now mostly developed into residential housing or agriculture. Prior to settlement it is possible this community may have extended onto these higher elevation floodplains. Occurrences of Bitternut Hickory Lowland Forest not restricted to narrow, linear stands are rare, with Butternut Island near Callicoon, New York being a good example. Flood frequency is unknown, but it is likely flooded less often than sycamore- (*Platanus occidentalis*) and silver maple- (*Acer saccharinum*) dominated forests found on lower floodplain terraces. Soils are derived from alluvial deposits and consist of fine sandy loams and loamy fine sand.

Vegetation Description: This association is characterized by the dominance or codominance of bitternut hickory (*Carya cordiformis*) with at least 25% relative canopy cover. Other potential codominant or associate canopy species include pin oak (*Quercus palustris*), northern red oak (*Quercus rubra*), black oak (*Quercus velutina*), American basswood (*Tilia americana*) butternut (*Juglans cinerea*), black cherry (*Prunus serotina*), American elm (*Ulmus americana*), white ash (*Fraxinus americana*), sugar maple (*Acer saccharum*) and silver maple (*Acer saccharinum*). American sycamore (*Platanus occidentalis*) can occur sporadically but is more common on lower terrace steps, closer to the river. The canopy is usually somewhat open to closed (total cover 70 to 90%) and 20 to 25 m in height. The subcanopy height ranges from 5 to 18 m with total cover of about 20 to 30%. Composition of the subcanopy is similar to the canopy layer and may also include red maple (*Acer rubrum*) and sugar maple (*Acer saccharum*). The tall-shrub and short-shrub layers are usually sparse and may include occasional saplings of canopy and subcanopy species as well as American hornbeam (*Carpinus caroliniana*), hawthorn (*Crataegus* sp.) and slippery elm (*Ulmus rubra*) as well as black raspberry (*Rubus occidentalis*), and northern dewberry (*Rubus flagellaris*). Ostrich fern (*Matteuccia struthiopteris*) is a characteristic herb that grows in association with a mix of graminoids and ferns that vary according to microtopographic setting. Common native species

include white snakeroot (*Ageratina altissima* var. *altissima*), Shawnee salad (*Hydrophyllum virginianum*), white avens (*Geum canadense*), rough avens (*G. laciniatum*), rough-leaved goldenrod (*Solidago rugosa*), Christmas fern (*Polystichum acrostichoides*), smooth goldenrod (*Solidago gigantea*), white wood aster (*Eurybia divaricata*), cleavers (*Galium aparine*), Lady fern (*Athyrium filix-femina*) and sedges (*Carex* spp.). Vine cover is variable and occasionally abundant, characterized by poison ivy (*Toxicodendron radicans*) and Virginia creeper (*Parthenocissus radicans*).

Most Abundant Native Species:

<u>Stratum</u>	<u>Lifeform</u>	<u>Species</u>
Tree canopy	Broad-leaved deciduous tree	<i>Carya cordiformis</i> , <i>Prunus serotina</i>
Tree subcanopy	Broad-leaved deciduous tree	<i>Acer saccharum</i> , <i>Ulmus americana</i> , <i>Carya cordiformis</i> , <i>Prunus serotina</i>
Tall shrub/sapling	Broad-leaved deciduous shrub	<i>Carya cordiformis</i> , <i>Carpinus caroliniana</i> , <i>Prunus serotina</i>
Short shrub/sapling	Broad-leaved deciduous shrub	
Herb (field)	Forb	<i>Ageratina altissima</i> var. <i>altissima</i> , <i>Hydrophyllum virginianum</i> , <i>Carex</i> spp.
Herb (field)	Graminoid	
Herb (field)	Fern or fern ally	<i>Matteuccia struthiopteris</i> , <i>Polystichum acrostichoides</i> , <i>Athyrium filix-femina</i>
Herb (field)	Vine/Liana	<i>Parthenocissus quinquefolia</i> , <i>Toxicodendron radicans</i> .

Characteristic Species: *Carya cordiformis*, *Prunus serotina*, *Ulmus americana*, *Acer saccharum*, *Carpinus caroliniana*, *Ageratina altissima* var. *altissima*

Invasive/non-native plant species:

Trees:

Shrubs:

Berberis thunbergii

Rosa multiflora

Lonicera morrowi

Lonicera maackii

Herbs:

Alliaria petiolata
Glechoma hederacea
Microstegium vimineum
Polygonum persicaria

Other Noteworthy Species: Information not available.

USFWS Wetland System: Palustrine

Subnational Distribution with Crosswalk data:

State	State Rank	Confidence	State Name	Reference
NJ	SNR	2	Bitternut Hickory Floodplain Forest Terrace	Walz et al. 2006
PA	S3?	2	no crosswalk	Fike 1999

Local Range: This association likely occurs throughout the Delaware River on mid to high floodplain terraces of the Delaware River. It appears to be restricted to small patches of well-drained loamy fine sand to fine sandy loam.

Classification Comments: This association differs from other mesic forest types in the dominance or codominance of *Carya cordiformis* in the canopy.

Other Comments: None.

USFWS Wetland System: Palustrine

Local Description Authors: G.S. Podniesinski (PNHP), Feldmann, A.L. (NYNHP)

Plots and Data Sources: DEWA.79, DEWA.126, DEWA.243, UPDE.22, UPDE.222

Most Abundant Species:

References: Eastern Ecology Working Group n.d.



Figure 3b. Bitternut Hickory Lowland Forest in Delaware Water Gap National Recreation Area. Photograph by: Stephanie Perles, Pennsylvania Natural Heritage Program.



Figure 4b. Bitternut Hickory Lowland Forest in Delaware Water Gap National Recreation Area. Photograph by: Gregory Podniesinski, Pennsylvania Natural Heritage Program.

Hairy-Fruit Sedge Wetland

COMMON NAME: HAIRY-FRUIT SEDGE WETLAND

SYNONYMS

NVC English Name: *Hairy-fruit Sedge - Bulrush species - Giant Goldenrod Herbaceous Vegetation*

NVC Scientific Name: *Carex trichocarpa - Scirpus spp. - Solidago gigantea Herbaceous Vegetation [Provisional]*

NVC Identifier: *CEGL006447*

LOCAL INFORMATION

Environmental Description: This association is found occasionally in small patches on mainstem islands in the Delaware River, as well as on the floodplains of major tributaries where tree canopy is lacking. Typical soils include the coarse loamy to sandy Fredon-Halsey complex, which are somewhat poorly to very poorly drained glacio-fluvial deposits. This community is routinely flooded during most high-water events and commonly occurs on low flats associated with the active floodplain, either directly adjacent to the channel or in association with backwater depressions and sloughs. In the Upper Delaware, above Matamoras, this community often occurs in bedrock-confined stretches of the river between the water's edge and the adjacent upland forest. Some of the linear patches can be extensive, 10 to 20 meters wide and several hundred meters long or more.

Vegetation Description: Hairyfruit sedge (*Carex trichocarpa*) is the dominant species in this association. Shrubs may be present but at less than 25% cover, including silky dogwood (*Cornus amomum*), and Allegheny blackberry (*Rubus allegheniensis*). Other woody species include bitternut hickory (*Carya cordiformis*), with northern dewberry (*Rubus flagellaris*) occasionally present. Shrubby St. Johnswort (*Hypericum prolificum*) is a common short shrub. Other common herbaceous species include giant goldenrod (*Solidago gigantea*), small-spike false nettle (*Boehmeria cylindrica*), deertongue (*Dichanthelium clandestinum*), reed canarygrass (*Phalaris arundinacea*), Emory's sedge (*Carex emoryi*), stinging nettle (*Urtica dioica*), knotweeds (*Polygonum* spp.), prairie cordgrass (*Spartina pectinata*), flat-top goldentop (*Euthamia graminifolia*), jewelweed (*Impatiens capensis*), Canada germander (*Teucrium canadense*), common milkweed (*Asclepias syriaca*), eastern hayscented fern (*Dennstaedtia punctilobula*), and common ladyfern (*Athyrium filix-femina*) and woolgrass (*Scirpus cyperinus*). Vines may be present at low cover including virgin's bower (*Clematis virginiana*).

Most Abundant Native Species:

<u>Stratum</u>	<u>Lifeform</u>	<u>Species</u>
Tall shrub/sapling	Broad-leaved deciduous shrub	<i>Cornus amomum</i> ,
Herb (field)	Forb	<i>Boehmeria cylindrica</i> ,
		<i>Solidago gigantea</i>
Herb (field)	Graminoid	<i>Carex trichocarpa</i> ,
		<i>Dichanthelium clandestinum</i>

Characteristic Species: *Carex trichocarpa*, *Boehmeria cylindrica*, *Solidago gigantea*, *Cornus amomum*, *Teucrium canadense*, *Hypericum prolificum*

Invasive/non-native plant species:

Trees:

Shrubs:

Rosa multiflora
Berberis thunbergii

Herbs:

Phalaris arundinacea
Persicaria nepalensis
Polygonum convolvulus
Polygonum cilinode

Fringed black bindweed (*Polygonum cilinode*), a herbaceous vine can be abundant at some sites. Reed canary-grass (*Phalaris arundinacea*) often co-occurs with hairy-fruit sedge and may be displacing it throughout the Delaware River floodplain.

Other Noteworthy Species: *Dennstaedtia punctilobula*, *Spartina pecinata*, *Euthamia graminifolia*.

Subnational Distribution with Crosswalk data:

State	State Rank	Confidence	State Name	Reference
NJ	SNR	2	Riverside Hairy-fruit Sedge Flat	Walz et al. 2006
PA	S3	1	no crosswalk	Fike 1999
NY	SNA	1	Shallow emergent marsh	Edinger et al. 2002

Local Range: This vegetation type is occasional throughout on the floodplain of the upper Delaware River and its major tributaries.

Classification Comments: This type is distinguished by the clear dominance of *Carex trichocarpa* and low shrub cover (<25%). At three sites, (UPDE.AA.484, UPDE.AA.516, UPDE.AA.524) Emoryi's sedge (*Carex emoryi*) was dominant, with greater cover than hairy-fruit sedge. However, the environmental setting and associated species at these sites were very similar to that described above for this association. Because the dominant sedge could not be conclusively identified and there is no current association in the NVCS describing riparian herbaceous vegetation strongly dominated by Emoryi's sedge, these sites were classified as Hairy-fruit Sedge Wetlands until further information is gathered on these areas.

Other Comments: None.

USFWS Wetland System: Palustrine

Local Description Authors: G.S. Podniesinski (PNHP), Feldmann, A.L. (NYNHP)

Plots and Data Sources: DEWA.50, UPDE.24, UPDE.25, UPDE. 28, UPDE.92;
Accuracy Assessment Observation Points DEWA.178, DEWA.591, DEWA.551,
UPDE.AA.484, UPDE.AA.516, UPDE.AA.524.

References: Eastern Ecology Working Group n.d.



Figure 5b. Hairyfruit Sedge Wetland in Delaware Water Gap National Recreation Area.
Photograph by: Gregory Podniesinski, Pennsylvania Natural Heritage Program.



Figure 6b. Hairyfruit Sedge Wetland in Upper Delaware Scenic and Recreational River.
Photograph by: Gregory Podniesinski, Pennsylvania Natural Heritage Program.

Japanese Knotweed Herbaceous Vegetation

COMMON NAME: JAPANESE KNOTWEED HERBACEOUS VEGETATION

SYNONYMS

NVC English Name: *Japanese Knotweed Temporarily Flooded Herbaceous Vegetation*

NVC Scientific Name: *Polygonum cuspidatum Temporarily Flooded Herbaceous Vegetation*

NVC Identifier: *CEGL008472*

LOCAL INFORMATION

Environmental Description: This vegetation type occurs on islands and along the shoreline of the Delaware River. The substrate is typically silt loam or sandy loam that is a well-drained, moist alluvium - as in Delaware fine sandy loam or Pope fine sandy loam. These sites are subject to frequent floods and scour.

Vegetation Description: This vegetation type is typically a near monoculture of the invasive species Japanese knotweed (*Polygonum cuspidatum*), covering 50-100% of the area. Other typical riparian species can persist beneath and around the knotweed, including touch-me-nots (*Impatiens* spp.), reed canarygrass (*Phalaris arundinacea*), whitegrass (*Leersia virginica*), marshpepper knotweed (*Polygonum hydropiper*), swamp smartweed (*Polygonum hydropiperoides*), Jack-in-the-pulpit (*Arisaema triphyllum*), spotted ladythumb (*Polygonum persicaria*), and small-spike false nettle (*Boehmeria cylindrica*).

Most Abundant Species:

Stratum

Herb (field)

Lifeform

Forb

Species

Polygonum cuspidatum

Characteristic Species: *Polygonum cuspidatum*

Invasive/non-native plant species:

Trees:

Shrubs:

Herbs:

Polygonum cuspidatum

Polygonum persicaria

Polygonum sachalinense

Alliaria petiolata

Microstegium vimineum

Along with Japanese knotweed are other exotics, including garlic mustard (*Alliaria petiolata*), Japanese stiltgrass (*Microstegium vimineum*), spotted ladysthumb (*Polygonum persicaria*), giant knotweed (*Polygonum sachalinense*) or a hybrid of Japanese knotweed and giant knotweed may also be present.

Other Noteworthy Species: Information not available.

Subnational Distribution with Crosswalk data:

State	State Rank	Confidence	State Name	Reference
NJ	SNA	2	Japanese Knotweed Rivershore	Walz et al. 2006
PA	SNA	1	no crosswalk	Fike 1999
NY	SNA	1	Shallow emergent marsh	Edinger et al. 2002

Local Range: This vegetation type occurs throughout on islands and along the shoreline of the Delaware River.

Classification Comments: This type is distinguished by the extremely high cover of *Polygonum cuspidatum*, covering greater than 50% of the area in a non-forested riparian setting.

Other Comments: None.

USFWS Wetland System: Palustrine

Local Description Authors: S.J. Perles (PNHP)

Plots and Data Sources: Accuracy Assessment Observation Points DEWA.155, DEWA.177, DEWA.993, UPDE.26; Podniesinski and Wagner 2002, Perles et al. 2004.

References: Brown pers. comm., Evans pers. comm., Schafale pers. comm., Schotz pers. comm., Southeastern Ecology Working Group n.d., TDNH unpubl. data, Perles et al. 2004, Podniesinski and Wagner 2002



Figure 7b. Japanese Knotweed Herbaceous Vegetation in Upper Delaware Scenic and Recreational River. Photograph by: Stephanie Perles, Pennsylvania Natural Heritage Program.

Northern Riverside Rock Outcrop

COMMON NAME: NORTHERN RIVERSIDE ROCK OUTCROP

SYNONYMS

NVC English Name: *Big Bluestem - Bluebell Bellflower - Sticky Goldenrod Sparse Vegetation*

NVC Scientific Name: *Andropogon gerardi - Campanula rotundifolia - Solidago simplex Sparse Vegetation*

NVC Identifier: *CEGL006284*

LOCAL DESCRIPTION

Environmental Description: This vegetation type occurs along the shoreline of the Upper Delaware River where winter ice-scouring, shale bedrock outcrops, and natural seepage co-occur. The substrate consists of open, flood-scoured flat to nearly flat bedrock exposures that extend for variable lengths from the woodland edge to the river edge. Species are distributed patchily due to microsite conditions that range from dry to moist (seepage areas) and the sparse vegetation, when present, establishes in crevices and in thin soil over bedrock. It is also prone to severe drought periods that may stress or kill some vegetation.

Vegetation Description: Herbaceous species typically dominate this association, but shrubs can be present in areas with somewhat good soil development. Gray alder (*Alnus incana*), silky dogwood (*Cornus amomum*), white meadowsweet (*Spiraea alba*), and river birch (*Betula nigra*) are most common; sandcherry (*Prunus pumila*), American sycamore (*Platanus occidentalis*), Carolina rose (*Rosa carolina*), and others can also be present. Big bluestem (*Andropogon gerardi*) is the most abundant native herb. Many herbs can be present sparsely in the thin soil of crevices, including white panicle aster (*Symphyotrichum lanceolatum*), eastern marsh fern (*Thelypteris palustris*), flat-top goldentop (*Euthamia graminifolia*), flaxleaf whitetop aster (*Ionactis linariifolius*), weak rush (*Juncus debilis*), American water-willow (*Justicia americana*), brownish beaksedge (*Rhynchospora capitellata*), switchgrass (*Panicum virgatum*), strawcolored flatsedge (*Cyperus strigosus*), toothed flatsedge (*Cyperus dentatus*), early goldenrod (*Solidago juncea*), golden hedgehyssop (*Gratiola aurea*), slender fimbry (*Fimbristylis autumnalis*), purpleleaf willowherb (*Epilobium coloratum*), and Allegheny monkeyflower (*Mimulus ringens*).

Purple loosestrife (*Lythrum salicaria*) and sweet clover (*Melilotus officinalis* (= *Melilotus alba*) are common invasive exotic species.

Most Abundant Native Species

<u>Stratum</u>	<u>Lifeform</u>	<u>Species</u>
Short Shrub	Broad-leaved deciduous shrub	<i>Spiraea alba</i>
Herb	Graminoid	<i>Andropogon gerardi</i>

Characteristic Species: *Andropogon gerardi*

Invasive/non-native plant species:

Trees:

Shrubs:

Herbs:

Lythrum salicaria

Melilotus officinalis (= *Melilotus alba*)

Polygonum cuspidatum

Purple loosestrife (*Lythrum salicaria*) and sweet clover (*Melilotus officinalis* (= *Melilotus alba*) are common invasive exotic species.

Other Noteworthy Species: *Spiraea alba*, *Euthamia graminifolia*, *Montia chamissoi*

Subnational Distribution with Crosswalk data:

State	State Rank	Confidence	State Name	Reference
NY	SNA	1	Shoreline outcrop	Edinger et al. 2002
NJ	S1	2	Northern Riverside	Walz et al. 2006
			Rock Outcrop	
PA	SNA	1	Riverside Ice Scour	Fike 1999
			Community	

Local Range: These outcrops can occur on the shores of the Upper Delaware River throughout UPDE, but they are more common in the southern part of the park.

Classification Comments: None

Other Comments: None

USFWS Wetland System: Palustrine

Local Description Authors: Feldmann, A.L. (NYNHP)

Plots: UPDE.117, UPDE.122, UPDE.154, UPDE.155

References: Breden 1989, Cowardin et al. 1979, Eastern Ecology Working Group n.d., Gawler 2002, Grossman et al. 1994, Metzler and Barrett 2001, Rawinski 1984, Shank and Shreiner 1999, Sperduto 1992, Swain and Kearsley 2001, Thompson 1996, Thompson and Sorenson 2000



Figure 8b. Northern Riverside Rock Outcrop in Upper Delaware Scenic and Recreational River. Photograph by: Aissa Feldmann, New York Natural Heritage Program.



Figure 9b. Northern Riverside Rock Outcrop in Upper Delaware Scenic and Recreational River. Photograph by: Aissa Feldmann, New York Natural Heritage Program.

Reed Canary Grass Riverine Grassland

COMMON NAME: REED CANARYGRASS RIVERINE GRASSLAND

SYNONYMS

NVC English Name: *Reed Canarygrass Eastern Herbaceous Vegetation*

NVC Scientific Name: *Phalaris arundinacea Eastern Herbaceous Vegetation*

NVC Identifier: *CEGL006044*

LOCAL INFORMATION

Environmental Description: This association is typically found on bars, shorelines, or islands in the Delaware River and smaller tributaries. These grasslands may have small, winding drainages running through them and are exposed to frequent floods, high stream velocity and ice-scour. The substrate is typically coarse, composed of sand, gravel, and cobbles underlain by bedrock of Devonian age sandstone, siltstone, shale in the Catskill Formation. These occurrences above Matamoras are often 10-20 meters wide and up to several hundred meters long. They are often interspersed with the Hairy-Fruit Sedge Wetland.

Vegetation Description: This association is characterized by thick herbaceous and graminoid vegetation dominated by invasive reed canarygrass (*Phalaris arundinacea*). A diverse mix of other herbaceous and graminoid species also persists. Some common species are hairy-fruit sedge (*Carex trichocarpa*) marshpepper knotweed (*Polygonum hydropiper*), stinging nettle (*Urtica dioica*), Canadian clearweed (*Pilea pumila*), whitegrass (*Leersia virginica*), small-spike false nettle (*Boehmeria cylindrica*), fowl bluegrass (*Poa palustris*), wild mint (*Mentha arvensis*), and wingstem (*Verbesina alternifolia*). Other common associates found in the northern part of the river drainage, present at variable abundances, include big bluestem (*Andropogon gerardi*), flat-top goldentop (*Euthamia graminifolia*), sensitive fern (*Onoclea sensibilis*), common milkweed (*Asclepias syriaca*), prairie cordgrass (*Spartina pectinata*), spreading dogbane (*Apocynum androsaemifolium*), giant goldenrod (*Solidago gigantea*), spotted joe-pye weed (*Eupatorium maculatum*), and eastern marsh fern (*Thelypteris palustris*). A few scattered willows (*Salix* spp.), sycamore (*Platanus occidentalis*), river birch (*Betula nigra*), and silky dogwood (*Cornus amomum*) may be present as short shrubs; however, their relative cover does not exceed 25%. Vines may also be present; common species include Virginia creeper (*Parthenocissus quinquefolia*), eastern poison ivy (*Toxicodendron radicans*), fox grape (*Vitis labrusca*), and riverbank grape (*Vitis riparia*).

Most Abundant Native Species:

<u>Stratum</u>	<u>Lifeform</u>	<u>Species</u>
Short shrub/sapling	Broad-leaved deciduous shrub	<i>Rubus allegheniensis</i> , <i>Spiraea tomentosa</i>

Herb (field)	Vine/Liana	<i>Toxicodendron radicans</i> , <i>Vitis riparia</i>
Herb (field)	Forb	<i>Pilea pumila</i> , <i>Polygonum</i> <i>hydropiper</i> , <i>Urtica dioica</i>
Herb (field)	Graminoid	<i>Phalaris arundinacea</i> , <i>Carex</i> <i>trichocarpa</i>

Characteristic Species: *Phalaris arundinacea*

Invasive/non-native plant species:

Trees:

Shrubs:

Herbs:

Phalaris arundinacea (Native status of this species is unclear)
Rorippa nasturtium-aquaticum

Other Noteworthy Species: *Andropogon gerardi*, *Euthamia graminifolia*

Subnational Distribution with Crosswalk data:

State	State Rank	Confidence	State Name	Reference
NJ	SNR	1	Reed Canarygrass Eastern Marsh	Walz et al. 2006
PA	S5	1	Bluejoint - reed canarygrass marsh	Fike 1999

Local Range: This association is typically found on bars, shorelines, or islands throughout the Delaware River and smaller tributaries of the river.

Classification Comments: Reed Canarygrass Riverine Grassland is distinguished from other riparian types by the clear dominance of *Phalaris arundinacea*.

Other Comments: None.

USFWS Wetland System: Palustrine

Local Description Authors: S.J. Perles (PNHP), Feldmann, A.L. (NYNHP)

Plots and Data Sources: DEWA.109, DEWA.111; UPDE.21, UPDE.65, UPDE.90, UPDE.91; Fike 1999, Perles et al. 2004.

References: Apfelbaum and Sams 1987, Barnes 1999, Cowardin et al. 1979, Edinger et al. 2002, Fike 1999, Metzler and Barrett 2001, Midwestern Ecology Working Group n.d., Perles et al. 2004, Podniesinski et al. 2006, Rawinski 1984, Sperduto 2000a, Swain and Kearsley 2001, TDNH unpubl. data, TNC and WPC 2004, Thompson 1996, Thompson and Sorenson 2000



Figure 10b. Reed Canarygrass Riverine Grassland in Delaware Water Gap National Recreation Area. Photograph by: Gregory Podniesinski, Pennsylvania Natural Heritage Program.

River Birch Low Floodplain Forest

COMMON NAME: RIVER BIRCH LOW FLOODPLAIN FOREST

SYNONYMS

NVC English Name: River Birch - Sycamore / Orange Jewelweed Forest

NVC Scientific Name: *Betula nigra* - *Platanus occidentalis* / *Impatiens capensis* Forest

NVC Identifier: CEG006184

LOCAL DESCRIPTION

Environmental Description: This riparian woodland association typically occurs on low terrace floodplains of major tributaries to the Upper Delaware River. It also can occur on islands, bars, and low terrace shorelines of the Upper Delaware itself. The low terraces are usually immediately adjacent to the river channel and subject to frequent flooding. The substrate is typically moderately well-drained, stony, recent alluvium typically consisting of gravel and cobbles or occasionally sand and silt.. This woodland may be subjected to periodic battering and canopy damage during severe flood events, resulting in bent and broken limbs and tree boles.

Vegetation Description: The open woodland canopy of this community is characterized by river birch (*Betula nigra*) dominance (this species is important in all woody strata) with American sycamore (*Platanus occidentalis*), silver maple (*Acer saccharinum*), black walnut (*Juglans nigra*), bitternut hickory (*Carya cordiformis*), and green ash (*Fraxinus pennsylvanica*) as occasional associates. Box elder (*Acer negundo*) is somewhat common in the subcanopy and tall shrub strata. Dogwoods (red osier dogwood, *Cornus sericea*; gray dogwood, *Cornus racemosa*; silky dogwood, *Cornus amomum*), blackberries (Allegheny blackberry, *Rubus allegheniensis*; dwarf red blackberry, *Rubus pubescens*), and multiflora rose (*Rosa multiflora*) make up the short shrub layer. Eastern poison ivy (*Toxicodendron radicans*) and Virginia creeper (*Parthenocissus quinquefolia*) are common woody vines. There can be a dense herbaceous layer dominated by graminoids; the most common species are Wiegand's wildrye (*Elymus wiegandii*), and reed canarygrass (*Phalaris arundinacea*), and less often deer-tongue (*Dichanthelium clandestinum*). Forbs are variable, but may include Canada germander (*Teucrium canadense*), sensitive fern (*Onoclea sensibilis*), and rough goldenrod (*Solidago rugosa*).

Most Abundant Native Species

<u>Stratum</u>	<u>Lifeform</u>	<u>Species</u>
Tree Canopy/Subcanopy	Broad-leaved deciduous tree	<i>Betula nigra</i>
Short Shrub	Broad-leaved deciduous shrub	<i>Cornus sericea</i>
Vine	Woody vine	<i>Toxicodendron radicans</i>
Herb	Forb	<i>Teucrium canadense</i> , <i>Onoclea sensibilis</i> , <i>Solidago rugosa</i>
Herb	Graminoid	<i>Elymus wiegandii</i> , <i>Phalaris</i>

arundinacea, Dichanthelium clandestinum

Characteristic Species: *Betula nigra, Phalaris arundinacea*

Invasive/non-native plant species:

Trees:

Shrubs:

Rosa multiflora

Herbs:

Phalaris arundinacea (native/non-native status unclear)

Poa trivialis

Polygonum cuspidatum

Microstegium vimineum

Other Noteworthy Species:

Subnational Distribution with Crosswalk data:

State	State Rank	Confidence	State Name	Reference
NY	SNA	1	Floodplain forest	Edinger et al. 2002
PA	SNA	1	Sycamore – (river birch) – box-elder floodplain forest	Fike 1999

Local Range: This type can occur throughout the upper Delaware River on low terrace floodplains and island heads adjacent to the river or its tributaries. Documented examples of this association were observed near the southern end of the Upper Delaware Scenic and Recreational River.

Classification Comments: A floodplain woodland strongly dominated by river birch.

Other Comments: None

USFWS Wetland System: Palustrine

Local Description Authors: Feldmann, A.L. (NYNHP), G. S. Podniesinski (PNHP)

Plots and Data Sources: UPDE.124, UPDE.134, UPDE.143, UPDE.AA.32, UPDE.AA.48, UPDE.AA.202, UPDE.AA.514.

References: Bartgis 1986, Bowman 2000, CAP pers. comm. 1998, Eastern Ecology Working Group n.d., Edinger et al. 2002, Fike 1999, Harrison 2004, Podniesinski and Wagner 2002, Thomson et al. 1999



Figure 11b. River Birch Low Floodplain Forest in Upper Delaware Scenic and Recreational River. Photograph by: Gregory Podniesinski, Pennsylvania Natural Heritage Program.



Figure 12b. River Birch Low Floodplain Forest in Upper Delaware Scenic and Recreational River. Photograph by: Stephanie Perles, Pennsylvania Natural Heritage Program.

Riverine Scour Vegetation

COMMON NAME: RIVERINE SCOUR VEGETATION

SYNONYMS

NVC English Name: ***Fringed Loosestrife - Indian-hemp Sparse Vegetation***

NVC Scientific Name: ***Lysimachia ciliata - Apocynum cannabinum Sparse Vegetation***

NVC Identifier: ***CEGL006554***

LOCAL INFORMATION

Environmental Description: This type is associated with the Delaware River in a wide variety of riverine settings. Island heads, bars, spits, low terraces, and shorelines can support this broadly defined vegetation type. The underlying substrate varies greatly, although it is often cobbles and sand, with thin deposits of silt, muck, or organic matter. Species composition also varies greatly from site to site. The unifying factor that bridges the differences in environmental factors and species composition is the frequent scour that these sites experience. This vegetation type establishes in areas of the active channel that are underwater for the majority of the year and are exposed only at low water or in drought years. Therefore, these areas are subjected to high water velocities, floods, and ice-scour more frequently than the other riparian communities (with the exception of emergent beds). The constant scour removes established vegetation and maintains or creates exposed sediments or cobbles. Water, air, and animals are constantly dispersing new seeds and plant propagules to these areas. This causes the continual flux in species composition that is characteristic of this community.

Vegetation Description: Frequent disturbance of these areas creates conditions that promote continual colonization by a wide variety of plants. After a disturbance, herbaceous and graminoid species may establish sparsely across bare substrate. As more time elapses between disturbance events, vegetation can become dense, completely covering the area but some tall and short shrubs may be present in low abundance. Such species can include American sycamore (*Platanus occidentalis*), black locust (*Robinia pseudoacacia*), willow species (*Salix* spp.), and staghorn sumac (*Rhus hirta*). The species composition of the community varies depending upon the available seedbank, surrounding vegetation, type of substrate, ecoregion, and hydrologic conditions. Some common species include water knotweed (*Polygonum amphibium*), spikerushes (*Eleocharis* spp.), sensitive fern (*Onoclea sensibilis*), American water-willow (*Justicia americana*), Virginia marsh St. Johnswort (*Triadenum virginicum*), tussock sedge (*Carex stricta*), spotted joe-pyeweed (*Eupatorium maculatum*), eastern marsh fern (*Thelypteris palustris*), chufa flatsedge (*Cyperus esculentus*), Indian-hemp (*Apocynum cannabinum*), fringed loosestrife (*Lysimachia ciliata*), smallspike false nettle (*Boehmeria cylindrica*), common marsh bedstraw (*Galium palustre*), whitegrass (*Leersia virginica*), marshpepper knotweed (*Polygonum hydropiper*), swamp smartweed (*Polygonum hydropiperoides*), reed canarygrass (*Phalaris arundinacea*), poverty rush (*Juncus tenuis*), common threesquare (*Schoenoplectus pungens*), wild mint (*Mentha arvensis*), groundnut (*Apios americana*), flat-top goldentop (*Euthamia graminifolia*), American hogpeanut

(*Amphicarpaea bracteata*), big bluestem (*Andropogon gerardi*), switchgrass (*Panicum virgatum*), and common sneezeweed (*Helenium autumnale*). Numerous other species can be present. In the Delaware River above Matamoras, smartweeds (Pennsylvania smartweed, *Polygonum pensylvanicum*; arrowleaf tearthumb, *Polygonum sagittatum*; dotted smartweed, *Polygonum punctatum*) are often dominant with spreading dogbane (*Apocynum androsaemifolium*) commonly sub-dominant. Many diverse associates can be present in varying amounts, including reed canarygrass (*Phalaris arundinacea*), rough bluegrass (*Poa trivialis*), big bluestem (*Andropogon gerardi*), rice cutgrass (*Leersia oryzoides*), eastern marsh fern (*Thelypteris palustris*), strawcolored flatsedge (*Cyperus strigosus*), hairyfruit sedge (*Carex trichocarpa*), Carolina horsenettle (*Solanum carolinense*), blunt spikerush (*Eleocharis obtusa*), swamp verbena (*Verbena hastata*), common milkweed (*Asclepias syriaca*), and marsh seedbox (*Ludwigia palustris*), among many others. Scattered short and tall shrubs may be present, including river birch (*Betula nigra*), silver maple (*Acer saccharinum*), sycamore (*Platanus occidentalis*), willows (*Salix* spp.), and/or red maple (*Acer rubrum*).

Most Abundant Native Species:

<u>Stratum</u>	<u>Lifeform</u>	<u>Species</u>
Short shrub/sapling	Broad-leaved deciduous shrub	<i>Betula nigra</i> , <i>Platanus occidentalis</i>
Herb (field)	Forb	<i>Mentha arvensis</i> , <i>Polygonum amphibium</i> , <i>Polygonum pensylvanicum</i> , <i>Apocynum androsaemifolium</i>
Herb (field)	Graminoid	<i>Carex stricta</i> , <i>Eleocharis</i> spp.
Herb (field)	Fern or fern ally	<i>Onoclea sensibilis</i>

Characteristic Species: This vegetation type characteristically includes wide variation in species composition between sites. See the Vegetation Description above for common species.

Invasive/non-native plant species:

Trees:

Shrubs:

Herbs:

Lythrum salicaria
Cyperus esculentus
Persicaria nepalensis
Phalaris arundinacea
Polygonum cuspidatum

The invasive exotic purple loosestrife (*Lythrum salicaria*) can be abundant in this community type.

Other Noteworthy Species: Information not available.

Subnational Distribution with Crosswalk data:

State	State Rank	Confidence	State Name	Reference
NJ	SNR	2	Loosestrife - Dogbane Scoured Rivershore	Walz et al. 2006
PA	S4	2	no crosswalk	Fike 1999

Local Range: This type is common within the Delaware River.

Classification Comments: Calcareous Riverside Outcrop and Calcareous Riverside Seep is distinguished from Riverine Scour Vegetation by the presence of exposed calcareous bedrock along the shoreline of the river that often provides habitat for rare species. Riverine Scour Vegetation occurs in a wide variety of riverine settings and on various substrates, although not bedrock.

Other Comments: None.

Local Description Authors: S.J. Perles (PNHP)

Plots and Data Sources: DEWA.99, DEWA.100, DEWA.102, DEWA.218, UPDE.93, UPDE.95, UPDE.99, UPDE.100, UPDE.116, UPDE.132, UPDE.144, UPDE.147, UPDE.149, UPDE.150, UPDE.151, UPDE.156, UPDE.157, UPDE.159; Perles et al. 2004, Feldmann, A.L. (NYNHP).

Delaware Water Gap National Recreation Area Inventory Notes: Information not available.

USFWS Wetland System: Palustrine

References: Eastern Ecology Working Group n.d., Fike 1999, Perles et al. 2004, Bowman 2000, Edinger et al. 2002, Metzler and Barrett 2001, Nichols et al. 2001, Sperduto and Nichols 2004, Swain and Kearsley 2000, Thompson 1996, Thompson and Sorenson 2000



Figure 13b. Riverine Scour Vegetation in Delaware Water Gap National Recreation Area. Photograph by: Stephanie Perles, Pennsylvania Natural Heritage Program.



Figure 14b. Riverine Scour Vegetation in Upper Delaware Scenic and Recreational River. Photograph by: Aissa Feldmann, New York Natural Heritage Program.

Silver Maple Floodplain Forest

COMMON NAME: SILVER MAPLE FLOODPLAIN FOREST

SYNONYMS

NVC English Name: *Silver Maple - American Elm Forest*

NVC Scientific Name: *Acer saccharinum - Ulmus americana Forest*

NVC Identifier: *CEGL002586*

LOCAL INFORMATION

Environmental Description: This floodplain forest occurs on the downstream ends of islands and on high terraces along the shoreline of the Delaware River. The substrate is typically silt loam or sandy loam, as in Delaware fine sandy loam or Pope fine sandy loam. The forest floor frequently has numerous parallel swales created by flood scour. Floods leave river-deposited debris on the forest floor, with large debris piles common. Winter flooding indicated by numerous ice scars on older trees. These forests are inundated only during larger flood events.

Vegetation Description: This floodplain forest is dominated by silver maple (*Acer saccharinum*), covering 40-75% of the canopy. Sugar maple (*Acer saccharum*) can be a canopy codominant, with sycamore (*Platanus occidentalis*), willows (*Salix* spp.) and river birch (*Betula nigra*) as occasional associates. Other occasional canopy associates include: red maple (*Acer rubrum*), aspen (*Populus* spp.), ash (*Fraxinus* spp.), walnut (*Juglans* spp.), and bitternut hickory (*Carya cordiformis*). The canopy trees typically extend 20-30 m in height, while subcanopy trees range in height from 5-10 m. The sparse subcanopy can contain sugar maple, bitternut hickory (*Carya cordiformis*), silver maple, boxelder (*Acer negundo*), white ash (*Fraxinus americana*), eastern hop-hornbeam (*Ostrya virginiana*), black cherry (*Prunus serotina*), and black walnut (*Juglans nigra*). The sparse short-shrub layer includes black raspberry (*Rubus occidentalis*), spice bush (*Lindera benzoin*) and seedlings of the canopy species. The dense herbaceous layer contains reed canarygrass (*Phalaris arundinacea*), whitegrass (*Leersia virginica*), ostrich fern (*Matteuccia struthiopteris*), hedge false bindweed (*Calystegia sepium* ssp. *sepium*), dogtooth violet (*Erythronium americanum*), Jack-in-the-pulpit (*Arisaema triphyllum*), giant goldenrod (*Solidago gigantea*), sensitive fern (*Onoclea sensibilis*), marsh pepper weed (*Polygonum hydropiper*), Pennsylvania smartweed (*Polygonum pennsylvanicum*), deer-tongue (*Dichanthelium clandestinum*), upland bentgrass (*Agrostis perennans*), small-spike nettle (*Boehmeria cylindrica*), sensitive fern (*Onoclea sensibilis*), Canada clearweed (*Pilea pumila*), swamp smartweed (*Polygonum hydropiperoides*) and sweet woodreed (*Cinna arundinacea*). Vines such as eastern poison ivy (*Toxicodendron radicans*) and Virginia creeper (*Parthenocissus quinquefolia*) can also be common.

Most Abundant Native Species:

<u>Stratum</u>	<u>Lifeform</u>	<u>Species</u>
Tree canopy	Broad-leaved deciduous tree	<i>Acer saccharinum</i>

Tree subcanopy	Broad-leaved deciduous tree	<i>Acer saccharum</i>
Tall shrub/sapling	Broad-leaved deciduous shrub	<i>Acer saccharinum</i> <i>Acer saccharum</i> <i>Carya cordiformis</i>
Herb (field)	Vine/Liana	<i>Parthenocissus quinquefolia</i> , <i>Toxicodendron radicans</i>
Herb (field)	Forb	<i>Calystegia sepium</i> ssp. <i>sepium</i> , <i>Arisaema triphyllum</i> , <i>Erythronium americanum</i> , <i>Solidago gigantea</i> , <i>Polygonum hydropiper</i> , <i>Boehmeria cylindrica</i> , <i>Pilea</i> <i>pumila</i> , <i>Polygonum</i> <i>hydropiperoides</i>
Herb (field)	Graminoid	<i>Leersia virginica</i> , <i>Phalaris</i> <i>arundinacea</i> , <i>Agrostis</i> <i>perennans</i> , <i>Cinna</i> <i>arundinacea</i>
Herb (field)	Fern or fern ally	<i>Matteuccia struthiopteris</i> , <i>Onoclea sensibilis</i>

Characteristic Species: *Acer saccharinum*, *Acer saccharum*, *Matteuccia struthiopteris*,

Typical Invasive/non-native plant species:

Trees:

Robinia pseudoacacia

Shrubs:

Berberis thunbergii

Rosa multiflora

Lonicera morrowii

Herbs:

Alliaria petiolata

Glechoma hederacea

Microstegium viminium

Polygonum cuspidatum

Polygonum persicaria

The invasive species Japanese knotweed (*Polygonum cuspidatum*) can form dense thickets on the forest floor. Garlic mustard (*Alliaria petiolata*), spotted lady's thumb (*Polygonum persicaria*), ground ivy (*Glechoma hederacea*) and Japanese stiltgrass (*Microstegium vimineum*) are other common herbaceous invasive species in this forest.

Other Noteworthy Species: Information not available.

Subnational Distribution with Crosswalk data:

State	State Rank	Confidence	State Name	Reference
NJ	SNR	1	Silver Maple – American Elm Floodplain Forest	Walz et al. 2006
NY	SNA	1	Floodplain Forest	Edinger et al. 2002
PA	S5	1	Silver Maple Floodplain Forest	Fike 1999

Local Range: This forest occurs on larger islands with higher terraces and terrace shorelines associated with the Delaware River from Hancock to the Delaware Water Gap.

Classification Comments: Silver Maple Floodplain Forest can be distinguished from other floodplain forests by the dominance of *Acer saccharinum* (40-75% cover), often with *Acer saccharum* as codominant in the canopy or subcanopy. In other drainages, such as the Susquehanna River, in the few instances where *Polygonum cuspidatum* is not dominant in this community, the understory may have a higher cover of tall herbs such as *Impatiens capensis*, *I. pallida*, *Laportea canadensis*, *Lysimachia ciliata*, *Verbena urticifolia*, *Lycopus* spp. and *Arisaema dracocitum*.

Other Comments: None.

USFWS Wetland System: Palustrine

Local Description Authors: S.J. Perles (PNHP)

Plots and Data Sources: Podniesinski et al. 2007; Perles et al. 2007. Fike 1999, Podniesinski and Wagner 2002.

References: Anderson 1996, CAP pers. comm. 1998, Eyre 1980, Fike 1999, INAI unpubl. data, MNNHP 1993, Midwestern Ecology Working Group n.d., Podniesinski and Wagner 2002, TDNH unpubl. data, WINHIP unpubl. Data.



Figure 17b. Silver Maple Floodplain Forest in Delaware Water Gap National Recreation Area. Photograph by: Gregory Podniesinski, Pennsylvania Natural Heritage Program.

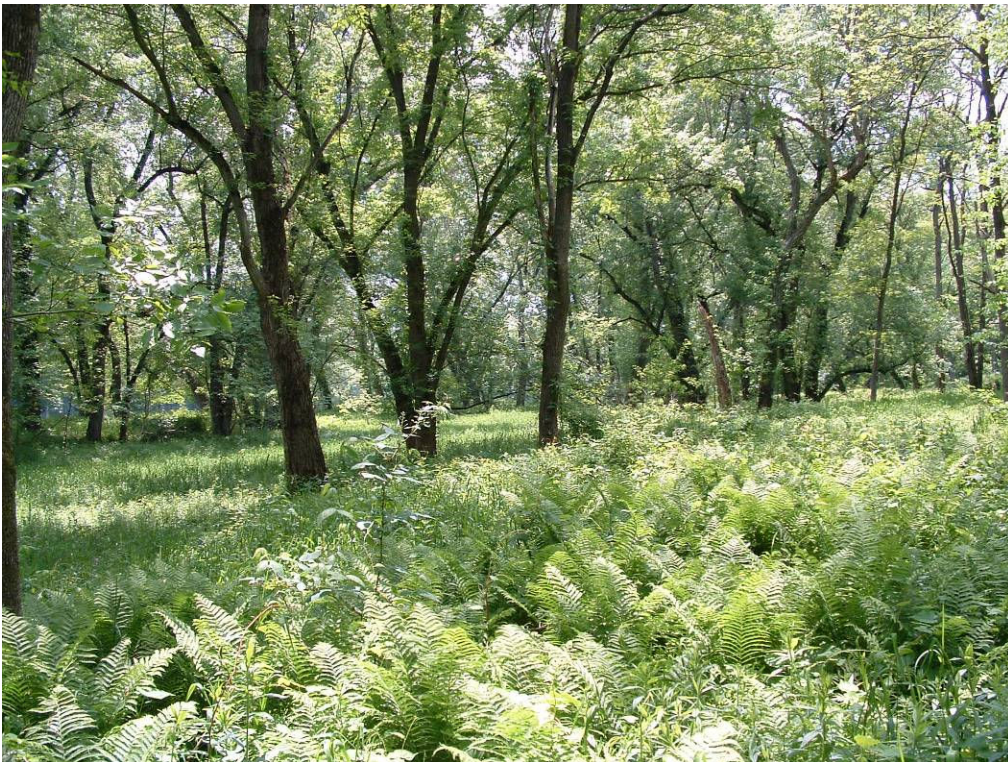


Figure 18b. Silver Maple Floodplain Forest in Delaware Water Gap National Recreation Area. Photograph by: Gregory Podniesinski, Pennsylvania Natural Heritage Program.

Sugar Maple Floodplain Forest

COMMON NAME: SUGAR MAPLE FLOODPLAIN FOREST

SYNONYMS

NVC English Name: *Sugar Maple - White Ash / American Hornbeam / Mayapple Forest*

NVC Scientific Name: *Acer saccharum - Fraxinus americana / Carpinus caroliniana / Podophyllum peltatum Forest*

NVC Identifier: *CEGL006459*

LOCAL INFORMATION

Environmental Description: This association occurs on low to mid terraces of the Delaware River and its tributaries. The soils appear to be alluvial in origin for the most part and include Barbour fine sandy loam, Galway loam, Pope silt loam and undifferentiated alluvium. These soils tend to be slightly acidic to alkaline. Stands on lower terraces may flood occasionally, but the period of inundation is short. The underlying bedrock is a variety of calcareous shale and siltstone, limestone and dolomite.

Vegetation Description: The canopy height varies from 20 to 35 m with total cover 70 to 90%. The dominant canopy tree is sugar maple (*Acer saccharum*). White ash (*Fraxinus americana*) is a common associate and may be codominant in some stands. Other minor associate species include American beech (*Fagus grandifolia*), pignut hickory (*Carya glabra*), bitternut hickory (*Carya cordiformis*), shagbark hickory (*Carya ovata*), black cherry (*Prunus serotina*), black oak (*Quercus velutina*), American basswood (*Tilia americana*), Hackberry (*Celtis occidentalis*), black walnut (*Juglans nigra*) and American elm (*Ulmus americana*). The subcanopy can vary from 5 to 25 m in height with total cover ranging from sparse (5%) up to 30%. Sugar maple is often the only species in the subcanopy, or sometimes with American hornbeam (*Carpinus caroliniana*) and eastern hop-hornbeam (*Ostrya virginiana*) as minor associates. The tall-shrub layer is 2-5 m in height and is usually sparse (<10% cover) or absent. The most characteristic tall shrubs/saplings are northern spicebush (*Lindera benzoin*) and sugar maple, with black walnut (*Juglans nigra*) and American elm occasional. The short-shrub layer, less than 2 m in height, may also be sparse (under 5% total cover) or have up to 30% cover. Common short-shrub/sapling species include a few shrub/small tree species such as northern spicebush, American hornbeam, flowering dogwood, and the seedlings/saplings of canopy species, especially sugar maple. The herbaceous layer can be quite variable with respect to cover, ranging from as little as 20% to over 80%. The herb layer may be fairly diverse, and seasonally variable, with spring ephemerals giving way to taller ferns, graminoids and forbs. Bryoids are very minor. The herbaceous layer is usually less than 1 m in height. The herbaceous layer can be diverse, with characteristic species including jewelweed (*Impatiens capensis*), white wood aster (*Eurybia divaricata*), spring-beauty (*Claytonia virginiana*), Shawnee-salad (*Hydrophyllum virginianum*), skunk cabbage (*Symplocarpus foetidus*), yellow dog-violet (*Erythronium americanum*), wood nettle (*Laportes canadensis*), false stinging nettle (*Boehmeria cylindrica*), jumpseed

(*Polygonum virginianum*), white snakeroot (*Ageratina altissima*), dutchman's-breeches (*Dicentra cucullaria*), silver false spleenwort (*Deparia acrostichoides*), Christmas fern (*Polystichum acrostichoides*), cleavers (*Galium aparine*), sensitive fern (*Onoclea sensibilis*), whitegrass (*Leersia virginica*), and mayapple (*Podophyllum peltatum*). Other occasional herbs and grasses include enchanter's-nightshade (*Circaea lutetiana*), rough bedstraw (*Galium asprellum*), blue cohosh (*Caulophyllum thalictroides*), rough-leaved goldenrod (*Solidago rugosa*) and bottlebush-grass (*Elymus hystrix*).

Most Abundant Native Species:

<u>Stratum</u>	<u>Lifeform</u>	<u>Species</u>
Tree canopy	Broad-leaved deciduous tree	<i>Acer saccharum</i> , <i>Fraxinus americana</i>
Tree subcanopy	Broad-leaved deciduous tree	<i>Acer saccharum</i> , <i>Carpinus caroliniana</i> , <i>Ostrya virginiana</i>
Tall shrub/sapling	Broad-leaved deciduous shrub	<i>Acer saccharum</i> , <i>Lindera benzoin</i>
Short shrub/sapling	Broad-leaved deciduous shrub	<i>Lindera benzoin</i>
Herb (field)	Forb	<i>Galium aparine</i> , <i>Claytonia virginiana</i> , <i>Impatiens capensis</i> , <i>Erythronium americanum</i> , <i>Symplocarpus foetidus</i>
Herb (field)	Graminoid	<i>Leersia virginica</i> ,
Herb (field)	Fern or fern ally	<i>Deparia acrostichoides</i> , <i>Polystichum acrostichoides</i>

Characteristic Species: *Acer saccharum*, *Fraxinus americana*, *Lindera benzoin*, , *Deparia acrostichoides*, *Galium aparine*, *Onoclea sensibilis*, *Podophyllum peltatum*, *Polystichum acrostichoides*

Typical Invasive/non-native plant species:

Trees:

Shrubs: *Berberis thunbergii*, *Rosa multiflora*

Herbs: *Alliaria petiolata*
Glechoma hederacea
Microstegium viminium
Polygonum caespitosum
Allium vineale

Other Noteworthy Species: Information not available.

Subnational Distribution with Crosswalk data:

State	State Rank	Confidence	State Name	Reference
NJ	SNA	3	Rich Sugar Maple – Hardwood Floodplain Terrace Forest	Walz et al. 2006
NY	SNA	1	Floodplain forest	Edinger et al. 2002
PA	S4	1	no crosswalk	Fike 1999

Local Range: This association appears to be restricted primarily to floodplain terraces of the Delaware River and its tributaries, primarily below Matamoras, PA, and may also occur on low steps-in-slope over calcareous bedrock. Only one example was observed in the Upper Delaware above Matamoras, PA.

Classification Comments: This association is characterized by the dominance of *Acer saccharum* in nearly all strata. It differs from Sugar Maple - American Beech - Sweet Birch Forest in that the latter does not occur on floodplain terraces. It differs from Sugar Maple - American Basswood Forest in that *Tilia americana* is often absent and it rarely occurs on steep slopes. It differs from other floodplain forest communities in that *Platanus occidentalis*, *Betula nigra*, and *Acer saccharinum* are rare or absent.

Other Comments: The correct crosswalk to the NVCS and the New Jersey state classification for this association is questionable. This association is also similar to NVCS CEG006114 [*Acer saccharum* - *Fraxinus* spp. - *Tilia americana* / *Matteuccia struthiopteris* - *Ageratina altissima* Forest] and to CEG006914 [*Acer saccharinum* - (*Acer saccharum*, *Juglans cinerea*, *Juglans nigra*, *Ulmus rubra*, *Ulmus americana*, *Prunus serotina*, *Celtis occidentalis*) Forest].

USFWS Wetland System: Palustrine

Local Description Authors: G.S. Podniesinski (PNHP)

Plots and Data Sources: Podniesinski et al.2007, Perles et al. 2007.

References: Cowardin et al. 1979, Eastern Ecology Working Group n.d., Eyre 1980, Harrison 2004, Harrison and Stango 2003, Lea 2000, Thomson et al. 1999.



Figure 19b. Sugar Maple Floodplain Forest in Delaware Water Gap National Recreation Area. Photograph by: Gregory Podniesinski, Pennsylvania Natural Heritage Program.



Figure 20b. Sugar Maple Floodplain Forest in Delaware Water Gap National Recreation Area. Photograph by: Gregory Podniesinski, Pennsylvania Natural Heritage Program.

Sycamore-Mixed Hardwood Floodplain Forest

**COMMON NAME: SYCAMORE–MIXED HARDWOOD
FLOODPLAIN FOREST**

SYNONYMS

NVC English Name: ***Sycamore - Green Ash Forest***

NVC Scientific Name: ***Platanus occidentalis - Fraxinus pennsylvanica
Forest***

NVC Identifier: ***CEGL006036***

LOCAL INFORMATION

Environmental Description: This association typically occurs on floodplain low to mid terraces of major tributaries to the Delaware River, such as Bushkill Creek and Flat Brook. It also occurs on islands, bars, and mid terrace shorelines of the Delaware River. These mid terraces are often slightly elevated above the water's channel and consequently flood less frequently than Sycamore Floodplain Forest. The substrate is typically moderately well-drained sandy loam or moderately well-drained very stony, recent Alluvium consisting of sand, silt and/or gravel.

Vegetation Description: The canopy of this floodplain forest contains a mixture of species, including sycamore (*Platanus occidentalis*), red maple (*Acer rubrum*), silver maple (*Acer saccharinum*), white ash (*Fraxinus americana*), and birches (*Betula lenta*, *Betula allegheniensis* and *Betula nigra*), black willow (*Salix nigra*), northern red oak (*Quercus rubra*), and green ash (*Fraxinus pennsylvanica*) can be associates while sugar maple (*Acer saccharum*) and American basswood (*Tilia americana*) are found on richer sites. Sycamore covers only 25-50% of the canopy and shares dominance with the other species. Tuliptree (*Liriodendron tulipifera*) may also be scattered in the canopy. At some sites, white pine (*Pinus strobus*) can be common in the canopy. The canopy trees typically extend 20-25 m in height, while subcanopy trees range in height from 6-15 m. The subcanopy can be sparse to moderately dense and contains American hornbeam (*Carpinus caroliniana*), sugar maple, bitternut hickory (*Carya cordiformis*), red maple, American elm (*Ulmus americana*), slippery elm (*Ulmus rubra*) and silver maple. The sparse tall- and short-shrub layers can include species from the canopy and subcanopy, as well as silky dogwood (*Cornus amomum*), northern spicebush (*Lindera benzoin*), common winterberry (*Ilex verticillata*), common ninebark (*Physocarpus opulifolius*), American witchhazel (*Hamamelis virginiana*) and smooth alder (*Alnus serrulata*). The herbaceous layer is typically moderately dense to dense; common species include ostrich fern (*Matteuccia struthiopteris*), mayapple (*Podophyllum peltatum*), cleavers (*Galium aparine*), white snakeroot (*Ageratina altissima* var. *altissima*), skunk-cabbage (*Symplocarpus foetidus*), king of the meadow (*Thalictrum pubescens*), broadleaf enchanter's nightshade (*Circaea lutetiana* ssp. *canadensis*), water knotweed (*Polygonum amphibium*), Canada goldenrod (*Solidago canadensis*), common ladyfern (*Athyrium filix-femina*), Shawnee salad (*Hydrophyllum virginianum*), sensitive fern (*Onoclea sensibilis*),

rough avens (*Geum canadense*) and touch-me-nots (*Impatiens* spp.). Virginia creeper (*Parthenocissus quinquefolia*), eastern poison ivy (*Toxicodendron radicans*) and grapes (*Vitis* spp.) are also common. Typical woodland or floodplain herbs may occur also, such as: fringed loosestrife (*Lysimachia ciliata*); Indianhemp (*Apocynum cannabinum*); deertongue (*Dichanthelium clandestinum*), feathery false lily of the valley (*Maianthemum racemosum*), upright sedge (*Carex stricta*) common ladyfern (*Athyrium filix-femina*) smallspike false nettle (*Boehmeria cylindrical*), stinging nettle (*Urtica dioica*), wrinkleleaf goldenrod (*Solidago rugosa*), spotted ladysthumb (*Polygonum persicaria*) swamp smartweed (*Polygonum hydropiperoides*) big bluestem (*Andropogon gerardi*).

On disturbed sites, black locust (*Robinia pseudoacacia*), black cherry (*Prunus serotina*) and black walnut (*Juglans nigra*) can be common in the canopy or subcanopy, and species such as white ash, American hornbeam, and elm may be more abundant than in higher quality intact stands.

Most Abundant Native Species:

<u>Stratum</u>	<u>Lifeform</u>	<u>Species</u>
Tree canopy	Broad-leaved deciduous tree	<i>Platanus occidentalis</i> , <i>Acer saccharum</i> , <i>Acer rubrum</i> , <i>Acer saccharinum</i> , <i>Betula nigra</i> , <i>Fraxinus americana</i>
Tree subcanopy	Broad-leaved deciduous tree	<i>Carpinus caroliniana</i> , <i>Platanus occidentalis</i>
Tall shrub/sapling	Broad-leaved deciduous shrub	<i>Cornus amomum</i>
Short shrub/sapling	Broad-leaved deciduous shrub	<i>Lindera benzoin</i> , <i>Physocarpus opulifolius</i>
Herb (field)	Vine/Liana	<i>Parthenocissus quinquefolia</i> , <i>Toxicodendron radicans</i>
Herb (field)	Forb	<i>Ageratina altissima</i> var. <i>altissima</i> , <i>Galium aparine</i> , <i>Podophyllum peltatum</i> , <i>Lysimachia ciliata</i> , <i>Apocynum cannabinum</i>
Herb (field)	Fern or fern ally	<i>Matteuccia struthiopteris</i>

Characteristic Species: *Platanus occidentalis*, *Acer rubrum*, *Acer saccharinum*, *Acer saccharum*, *Betula nigra*, *Carpinus caroliniana*, *Fraxinus americana*, *Physocarpus opulifolius*, *Parthenocissus quinquefolia*, *Toxicodendron radicans*, *Matteuccia struthiopteris*, *Polygonum amphibium*, *Symplocarpus foetidus*

Invasive/non-native plant species:

Trees:

Robinia pseudoacacia

Shrubs:

Berberis thunbergii

Euonymus alata

Lonicera morrowii
Rosa multiflora
 Vines:
Celastrus orbiculatus
 Herbs
Alliaria petiolata
Microstegium viminium
Polygonum cuspidatum

Polygonum persicaria

Invasive shrubs may be prominent in the tall- and short-shrub layers, including multiflora rose (*Rosa multiflora*), Morrow's honeysuckle (*Lonicera morrowii*), Japanese barberry (*Berberis thunbergii*), and winged burning bush (*Euonymus alata*). The herbaceous layer can be dominated by the invasive species garlic mustard (*Alliaria petiolata*), and Japanese stiltgrass (*Microstegium vimineum*). The oriental bittersweet (*Celastrus orbiculatus*) can be a common vine

Other Noteworthy Species: Information not available.

Subnational Distribution with Crosswalk data:

State	State Rank	Confidence	State Name	Reference
NJ	SNR	2	Mixed Hardwood Floodplain Terrace Forest	Walz et al. 2006
PA	S4	1	Sycamore – (river birch) – box-elder floodplain forest	Fike 1999

Local Range: This forest type is found in the floodplain of Bushkill Creek, Flat Brook, other major tributaries, and the Delaware River.

Classification Comments: Sycamore - Mixed Hardwood Floodplain Forest is distinguished from Sycamore Floodplain Forest by the codominance of *Platanus occidentalis* (25-50% cover) with *Acer saccharum*, *Acer rubrum*, *Acer saccharinum*, *Fraxinus americana*, and/or *Betula nigra*. In Sycamore Floodplain Forest, *Platanus occidentalis* is clearly dominant, covering 50-90% of the canopy. Also, Sycamore Floodplain Forest occurs on lower elevation terraces, typically immediately adjacent to the water's channel, with somewhat poorly drained finer textured substrate and a higher flood frequency. Sycamore - Mixed Hardwood Floodplain Forest occurs on slightly higher elevation mid terraces, with moderately well-drained coarser substrates and less frequent flood events.

Other Comments: The crosswalks to the NVCS and the New Jersey state classification system are uncertain. Other possible crosswalks may include NVCS CEG006914 [*Acer saccharinum* - (*Acer saccharum*, *Juglans cinerea*, *Juglans nigra*, *Ulmus rubra*, *Ulmus americana*, *Prunus serotina*, *Celtis occidentalis*) Forest], CEG006917 [*Acer rubrum* - *Platanus occidentalis* - *Ulmus americana* / *Lindera benzoin* Forest] or CEG006944 [*Acer saccharinum* - *Liriodendron tulipifera* - *Platanus occidentalis* / *Lindera benzoin* - *Acer negundo* Forest].

USFWS Wetland System: Palustrine

Local Description Authors: S.J. Perles (PNHP), Feldmann, A.L. (NYNHP)

Plots and Data Sources: DEWA.54, DEWA.241, DEWA.251, UPDE.134, UPDE.140; Fike 1999, Podniesinski and Wagner 2002.

References: Clancy 1996, Eastern Ecology Working Group n.d., Edinger et al. 2002, Enser 1999, Fike 1999, Frye and Quinn 1979, Kearsley1999b, Metzler and Barrett 2001, Newbold 1994, Newbold et al. 1988, Nichols et al. 2001, Overlease 1978, Overlease 1987, Russell and Schuyler 1988, Sperduto 2000a, Sperduto 2000b, Swain and Kearsley 2000, Thompson and Sorenson 2000, WPC and TNC2002, Wistendahl 1958 NatureServe n.d., Podniesinski and Wagner 2002

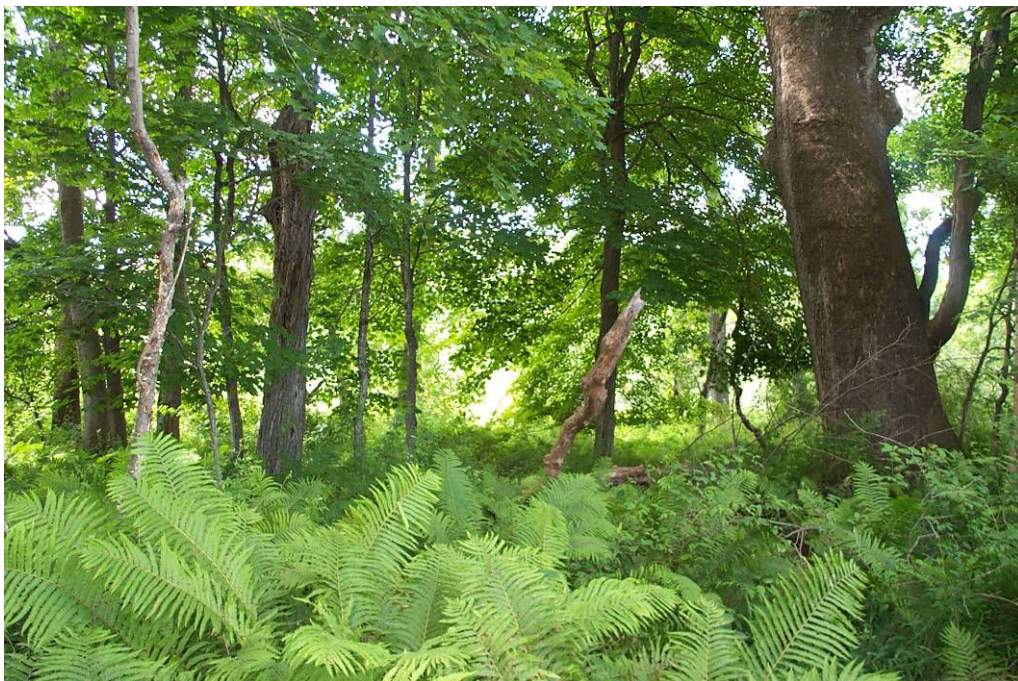


Figure21b. Sycamore – Mixed Hardwood Floodplain Forest in Delaware Water Gap National Recreation Area. Photograph by: Stephanie Perles, Pennsylvania Natural Heritage Program.



Figure 22b. Sycamore – Mixed Hardwood Floodplain Forest in Delaware Water Gap National Recreation Area. Photograph by: Stephanie Perles, Pennsylvania Natural Heritage Program.

Sycamore-Mixed Hardwood Riverine Shrubland

COMMON NAME: SYCAMORE-MIXED HARDWOOD RIVERINE SHRUBLAND

SYNONYMS

NVC English Name: *River Birch - Sycamore - (Sandbar Willow, Carolina Willow) Shrubland*

NVC Scientific Name: *Betula nigra - Platanus occidentalis - Salix (interior, caroliniana) Shrubland*

NVC Identifier: *CEGL003896*

LOCAL INFORMATION

Environmental Description: This sycamore-dominated riverine shrubland typically occurs on cobble bars and sand/gravel bars that are adjacent to or contiguous with the shoreline of the Delaware River. This type can also occur on the upstream ends of islands. They are subject to frequent floods, high stream velocity and ice-scour, though these disturbances are often less intense than those experienced by Sycamore - (Willow) - Mixed Hardwood Riverine Dwarf-shrubland.

Vegetation Description: This community is characterized by a substantial layer of tall shrubs (2-5 m in height) usually dominated by sycamore (*Platanus occidentalis*) that covers at least 25% of the area and is sometimes a monoculture. River birch (*Betula nigra*) or silver maple (*Acer saccharinum*) can also be codominant in the tall-shrub layer. Individual sycamores may also be scattered in a sparse tree canopy that is 5-10 m in height. Black willow (*Salix nigra*), sycamore and river birch are dominant in the sparse short-shrub layer, with silver maple and black ash (*Fraxinus nigra*). The herbaceous layer ranges from sparse to moderately dense and can contain a wide variety of typical wetland and prairie species. Common species include marshpepper knotweed (*Polygonum hydropiper*), reed canarygrass (*Phalaris arundinacea*), Big bluestem (*Andropogon gerardi*), switchgrass (*Panicum virgatum*), whitegrass (*Leersia virginica*), Pennsylvania smartweed (*Polygonum pensylvanicum*), deertongue (*Dichanthelium clandestinum*), upland bentgrass (*Agrostis perennans*), calico aster (*Symphotrichum lateriflorum*), swamp milkweed (*Asclepias incarnata*), smallspike false nettle (*Boehmeria cylindrica*), sensitive fern (*Onoclea sensibilis*), Canadian clearweed (*Pilea pumila*), water willow (*Justicia americana*) and swamp smartweed (*Polygonum hydropiperoides*). Vines such as riverbank grape (*Vitis riparia*) and eastern poison ivy (*Toxicodendron radicans*) are often found throughout this tall sycamore-dominated shrubland.

Most Abundant Native Species:

<u>Stratum</u>	<u>Lifeform</u>	<u>Species</u>
Tall shrub/sapling	Broad-leaved deciduous shrub	<i>Platanus occidentalis</i> , <i>Betula nigra</i>

Short shrub/sapling	Broad-leaved deciduous shrub	<i>Salix nigra</i> , <i>Platanus occidentalis</i> , <i>Betula nigra</i>
Herb (field)	Vine/Liana	<i>Vitis riparia</i>
Herb (field)	Forb	<i>Lythrum salicaria</i> , <i>Polygonum hydropiper</i> , <i>Polygonum pensylvanicum</i>
Herb (field)	Graminoid	<i>Leersia virginica</i> , <i>Panicum virgatum</i> ,

Characteristic Species: *Platanus occidentalis*, *Betula nigra*, *Salix nigra*, *Leersia virginica*, *Panicum virgatum*, *Polygonum hydropiper*

Invasive/non-native plant species:

Trees:

Shrubs:

Rosa multiflora

Herbs:

Coronilla varia

Lythrum salicaria

Polygonum cuspidatum

Phalaris arundinacea

This association is highly susceptible to colonization by purple loosestrife (*Lythrum salicaria*), Japanese knotweed (*Polygonum cuspidatum*), multiflora rose (*Rosa multiflora*), purple crownvetch (*Coronilla varia*), reed canary-grass (*Phalaris arundinacea*) and other invasive plants.

Other Noteworthy Species: Information not available.

Subnational Distribution with Crosswalk data:

State	State Rank	Confidence	State Name	Reference
NJ	SNR	1	Birch - Willow Riverbank Shrubland	Walz et al. 2006
PA	S4	1	River birch - sycamore floodplain scrub	Fike 1999
NY	SNA	1	Floodplain forest	Edinger et al. 2002

Local Range: This vegetation type is common Delaware River.

Classification Comments: This association is distinguished from other riparian types by the substantial tall-shrub layer of *Platanus occidentalis*, often with *Betula nigra*. The height of the shrubs (2-5 m) differentiates this type from Sycamore - (Willow) - Mixed Hardwood Riverine Dwarf-shrubland in which shrubs are less than 2 m in height. Also, the shrubs in Sycamore - (Willow) - Mixed Hardwood Riverine Dwarf-shrubland remain

stunted because they typically receive more frequent or more intense scour than Sycamore - Mixed Hardwood Riverine Shrubland.

Other Comments: None.

USFWS Wetland System: Palustrine

Local Description Authors: S.J. Perles and G.S. Podniesinski (PNHP), Feldmann, A.L. (NYNHP)

Plots and Data Sources: DEWA.103, DEWA.106, DEWA.110, UPDE.158; Fike 1999, Perles et al. 2004.

References: CAP pers. comm. 1998, Eastern Ecology Working Group n.d., Edinger et al. 2002, Fike 1999, Harrison 2004, Kartesz 1999, Perles et al. 2004, TNC and WPC 2004



Figure 23b. Sycamore – Mixed Hardwood Riverine Shrubland in Delaware Water Gap National Recreation Area. Photograph by: Stephanie Perles, Pennsylvania Natural Heritage Program.



Figure 24b. Sycamore – Mixed Hardwood Riverine Shrubland in Delaware Water Gap National Recreation Area. Photograph by: Stephanie Perles, Pennsylvania Natural Heritage Program.

Sycamore-(Willow)-Mixed Hardwood Rivering Dwarf Shrubland

COMMON NAME: SYCAMORE-(WILLOW)-MIXED HARDWOOD RIVERINE DWARF SHRUBLAND

SYNONYMS

NVC English Name: ***Black Willow / Reed Canarygrass - Indian-hemp Temporarily Flooded Shrubland***

NVC Scientific Name: ***Salix nigra / Phalaris arundinacea - Apocynum cannabinum Temporarily Flooded Shrubland***

NVC Identifier: ***CEGL006065***

LOCAL INFORMATION

Environmental Description: Most occurrences of this association are located on low terraces and bars attached to riverbanks of the Delaware River; however, the type can occur on islands as well. The substrate is predominantly cobbles along with sand and gravel. Due to flooding, high stream velocity and ice-scour to which these areas are frequently exposed, the majority of the shrubs remain short-statured (<2 m in height). This community occurs between Riverine Scour Vegetation and the tall shrubland or the floodplain forest along low terraces and toward island heads.

Vegetation Description: This association is characterized by a moderately dense to dense short-shrub layer less than 2 m in height. The species composition of the short-shrub layer is mixed and varied, with no one species consistently dominating. Stunted individuals of black willow (*Salix nigra*) may be codominant, along with one or more other species of willow (*Salix eriocephala*, *Salix sericea*) or sycamore (*Platanus occidentalis*). Other typical woody species are silver maple (*Acer saccharinum*), eastern cottonwood (*Populus deltoides*), river birch (*Betula nigra*), and red maple (*Acer rubrum*). Individual tall shrubs (2-5 m in height) of the same species may be scattered throughout the shrubland. The herbaceous layer can be sparse to dense and contains a wide diversity of herbaceous and graminoid species. Some common species are reed canarygrass (*Phalaris arundinacea*), Indian-hemp (*Apocynum cannabinum*), American water-willow (*Justicia americana*), deertongue (*Dichanthelium clandestinum*), marshpepper knotweed (*Polygonum hydropiper*), big bluestem (*Andropogon gerardi*), switchgrass (*Panicum virgatum*), wingstem (*Verbesina alternifolia*), upland bentgrass (*Agrostis perennans*), and Virginia wildrye (*Elymus virginicus*).

Most Abundant Native Species:

<u>Stratum</u>	<u>Lifeform</u>	<u>Species</u>
Short shrub/sapling	Broad-leaved deciduous shrub	<i>Salix</i> spp., <i>Platanus occidentalis</i>
Herb (field)	Forb	<i>Apocynum cannabinum</i> , <i>Polygonum hydropiper</i>

Herb (field)

Graminoid

Dichanthelium clandestinum
Andropogon gerardi
Panicum virgatum

Characteristic Species: *Salix* spp., *Platanus occidentalis*, *Apocynum cannabinum*,
Polygonum hydropiper

Invasive/non-native plant species:

Trees:

Shrubs:

Herbs:

Lythrum salicaria
Phalaris arundinacea

Other Noteworthy Species: Information not available.

Subnational Distribution with Crosswalk data:

State	State Rank	Confidence	State Name	Reference
NJ	SNR	2	Willow River-Bar Shrubland	Walz et al. 2006
PA	S4	1	Black willow shrub/scrub wetland	Fike 1999
NY	S2S3	1	Floodplain forest	Edinger et al. 2002

Local Range: This vegetation type occurs throughout the Delaware River.

Classification Comments: This association is identified by the presence of a substantial short-shrub layer of *Salix* spp. and/or *Platanus occidentalis*. The height of the shrubs (<2 m in height) differentiates this type from Sycamore - Mixed Hardwood Riverine Shrubland in which shrubs are 2-5 m in height. Also, the shrubs in Sycamore - (Willow) - Mixed Hardwood Riverine Dwarf-shrubland remain stunted because they typically receive more frequent or more intense scour than the tall-shrub community.

Other Comments: None.

USFWS Wetland System: Palustrine

Local Description Authors: S.J. Perles (PNHP)

Plots and Data Sources: DEWA.105, UPDE.AA.464; Fike 1999, Perles et al. 2004.

References: Eastern Ecology Working Group n.d., Fike 1999, Gawler 2002, Metzler and Barrett 2001, Nichols et al. 2001, Perles et al. 2004



Figure 25b. Sycamore (Willow) – Mixed Hardwood Riverine Dwarf Shrubland in Delaware Water Gap National Recreation Area. Photograph by: Stephanie Perles, Pennsylvania Natural Heritage Program.



Figure 26b. Sycamore (Willow) – Mixed Hardwood Riverine Dwarf Shrubland in Upper Delaware Scenic and Recreational River. Photograph by: Gregory Podniesinski, Pennsylvania Natural Heritage Program.

Water Willow Emergent Bed

COMMON NAME: WATER WILLOW EMERGENT BED

SYNONYMS

NVC English Name: *American Water-willow Herbaceous Vegetation*

NVC Scientific Name: *Justicia americana Herbaceous Vegetation*

NVC Identifier: *CEGL004286*

LOCAL INFORMATION

Environmental Description: This association is found at the heads of islands, along the edges of bars, banks, terraces, and spits, and in shallow sections of the river channel in the Delaware River. The lower portions of the plants' stems are under water for most of the year, with the tops of the plants emerging above the flowing water. These beds are entirely submerged by most flood events. During extreme low water periods, the soil below the beds can be exposed, showing a varied mixture of sand, gravel, and cobbles, often with deposits of silt and muck.

Vegetation Description: American water-willow (*Justicia americana*) is the dominant species in this association and is often the only species present in a colonial bed. Since American water-willow spreads by rhizomes, the species can form extensive monocultural colonies. Many other herbaceous species may be associates, including rice cutgrass (*Leersia oryzoides*), water knotweed (*Polygonum amphibium*), spikerushes (*Eleocharis* spp.), waterweed (*Elodea* sp.), softstem bulrush (*Schoenoplectus tabernaemontani*), common threesquare (*S. pungens*), spikerushes (*Eleocharis* spp.) and field horsetail (*Equisetum arvense*). Scaldweed (*Cuscuta gronovii*) is an infrequently associated herbaceous vine. Scattered shrub seedlings of black willow (*Salix nigra*), river birch (*Betula nigra*), silver maple (*Acer saccharinum*), or sycamore (*Platanus occidentalis*) may also be present.

Most Abundant Native Species:

Stratum

Herb (field)

Herb (field)

Lifeform

Forb

Graminoid

Species

Justicia americana

*Schoenoplectus
tabernaemontani*

Characteristic Species: *Justicia americana*, *Leersia oryzoides*, *Polygonum amphibium*

Invasive/non-native plant species:

Trees:

Shrubs:

Herbs:

Lythrum salicaria

The invasive exotic purple loosestrife (*Lythrum salicaria*) may be common in this vegetation type.

Other Noteworthy Species: *Schoenoplectus tabernaemontani*

Subnational Distribution with Crosswalk data:

State	State Rank	Confidence	State Name	Reference
NJ	SNR	1	Water-willow Rocky Bar and Shore	Walz et al. 2006
PA	S5	1	Water-willow (<i>Justicia americana</i>) - smartweed riverbed	Fike 1999
NY	SNA	1	Cobble shore wet meadow	Edinger et al. 2002

Local Range: This vegetation type is common throughout the Delaware River.

Classification Comments: This type is distinguished by the clear dominance of *Justicia americana* which is partially submerged for most of the year.

Other Comments: None.

USFWS Wetland System: Palustrine, Riverine?

Local Description Authors: S.J. Perles (PNHP), Feldmann, A.L. (NYNHP)

Plots and Data Sources: DEWA.101, DEWA.104, UPDE.148; Fike 1999, Perles et al. 2004.

References: Allard 1990, Anderson 1982, Anderson 1996, Fike 1999, Fleming et al. 2001, Harrison 2004, Hoagland 1997, Hoagland 2000, Major et al. 1999, McCoy 1958, Nelson 1986, OHNHD unpubl. data, Palmer-Ball et al. 1988, Peet et al. unpubl. data 2002, Penfound 1953, Perles et al. 2004, Schafale 1998b, Schafale 2002, Schafale and Weakley 1990, Schmalzer and DeSelm 1982, Schotz pers. comm., Southeastern Ecology Working Group n.d., TDNH unpubl. data, TNC and WPC 2004



Figure 27b. Water-willow Emergent Bed in Delaware Water Gap National Recreation Area. Photograph by: Stephanie Perles, Pennsylvania Natural Heritage Program.



Figure 28b. Water-willow Emergent Bed in Delaware Water Gap National Recreation Area. Photograph by: Stephanie Perles, Pennsylvania Natural Heritage Program.