Abstract

Non-point source pollution is the primary water quality issue in the Musconetcong River and Pohatcong Creek watersheds in northwestern New Jersey. The purpose of this on-going project is to enhance and protect the Musconetcong and Pohatcong watershed riparian corridors. Using a geographic information systems (GIS) technology approach for riparian restoration site selection, the specific goals of the project are: 1) to identify and evaluate the health of riparian areas within the watersheds; 2) to build support for watershed protection through the installation of riparian forest buffers; and 3) to target educational programs for a variety of audiences including municipal officials, school children, watershed associations, environmental resource managers, and the general public. This project is a collaborative effort among the North Jersey Resource Conservation and Development Council, Rutgers University, New Jersey Department of Environmental Protection Upper Delaware Bureau, the Pohatcong Creek Watershed Association, the Musconetcong NPS Work Group, and the USDA Natural Resources Conservation Service. This paper describes the completion of the development of a GIS-based model to assess the health of riparian areas within the Musconetcong and the Pohatcong watersheds that will, in turn, be used to determine riparian areas in need of enhancement or restoration.

Introduction

Healthy streamside riparian areas are critical for maintaining the quality of water resources. These areas help remove non-point source pollutants, provide shade to aquatic environments, and improve the productivity of stream communities (New Jersey Water Supply Authority, 2000). Continuing increases in development and population within the Musconetcong River and the Pohatcong Creek watersheds place increasing pressure on the riparian areas in this region. The two watersheds, located in New Jersey Department of Environmental Protection (NJDEP) Watershed Management Area-1 (WMA-1), encompass approximately 136,000 acres (55,037 hectares), and extend 128 and 58 miles (206 and 93 km) respectively, through four northwestern New Jersey counties (Sussex, Warren, Morris and Hunterdon) and roughly three dozen municipalities (Figure 1). The predominant land covers within the watersheds are forest and agriculture (Table 1). There are approximately 322 miles (518 km) of rivers and streams, including the main stems of the Musconetcong River and the Pohatcong Creek (Figure 2).
Table 1. Land Use/Land Cover in the Musconetcong and the Pohatcong Watersheds

<table>
<thead>
<tr>
<th>Land use</th>
<th>Acres</th>
<th>(Hectares)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest</td>
<td>64,337</td>
<td>(26,036)</td>
</tr>
<tr>
<td>Agriculture</td>
<td>30,121</td>
<td>(12,190)</td>
</tr>
<tr>
<td>Urban</td>
<td>25,508</td>
<td>(10,323)</td>
</tr>
<tr>
<td>Wetlands</td>
<td>10,120</td>
<td>(4,095)</td>
</tr>
<tr>
<td>Water</td>
<td>5,478</td>
<td>(2,217)</td>
</tr>
</tbody>
</table>

Source: 1995/1997 NJDEP Landuse/LandcoverGIS coverage WMA-1

Both the Musconetcong River and Pohatcong Creek are on the NJDEP’s 303(d) list of impaired waters for phosphorus, temperature and fecal coliform. The main stem of the Musconetcong River is designated ‘trout maintenance’ and its tributaries are designated as ‘trout production’ according to the NJDEP Surface Water Quality classification. The Pohatcong Creek is designated as primarily ‘trout production’, with the exception of one tributary classified as ‘trout maintenance’. Trout productions waters are used for trout spawning and nursery purposes, and trout maintenance waters must support trout throughout the year. High water quality is necessary for this. These areas have few point-source initiated discharges. The majority of the 303(d)-listed water quality problems are therefore attributed to non-point source pollution.

In recent years, extensive research by the USDA Forest Service (Welsch, 1991) and others (Lowrance, et. al, 1985; Lowrance, et. al, 1995; Schultz, et al, 1995; Correll, 1996) show that riparian forest buffers are an effective best management practice for reducing non-point source pollutant loading in rivers and streams. In an effort to promote the value and function of healthy riparian areas to the communities within the watersheds, a coalition was formed composed of the North Jersey Resource Conservation and Development Council (RC&D), Rutgers Cooperative Extension (RCE), New Jersey Department of Environmental Protection (NJDEP) Upper Delaware Bureau, the Pohatcong Creek Watershed Association, the Musconetcong NPS Work Group, and the USDA Natural Resources Conservation Service (NRCS). This project was subsequently proposed and funded through a Section 319 “Non-point Source Pollution Control and Management Implementation Grant”, administered by the NJDEP. The five-year project began in October 2000.

In 1998, the North Jersey RC&D found that a large portion of the main stem of the Musconetcong River south of Hackettstown, NJ was in need of riparian restoration (North Jersey RC&D, 1998). Similarly, in 1999, using aerial photography of the Pohatcong Creek, the North Jersey RC&D determined that the riparian corridor there was inadequate to sufficiently buffer the stream from agricultural operations and other development along its banks (North Jersey RC&D, 1999). Prior to the development of this model, a series of meetings was held with stakeholders to determine areas within the two watersheds for restoration. Site selection was made based on traditional paper maps, and a series of field visits. This process was time consuming and subjective. To automate the procedure to identify and assign priorities to riparian areas within these watersheds in need of restoration, a simple, low-cost GIS model was developed. The two sites selected for restoration prior to model development compared favorably to the model output. Therefore, the GIS model will
now be used to select two additional riparian areas within the watersheds for restoration.

Educational materials and programming will be developed and targeted for municipal officials, school children, watershed associations, environmental resource management professionals and the general public. Two communities in the project area will be selected as models to receive financial and planning assistance. Assistance will include: assessing the communities’ land development regulations; determining political barriers for protecting riparian lands; evaluating and/or developing protection ordinances; and marketing riparian protection strategies within their respective communities. This paper describes the development and implementation of the GIS model for delineating and assessing the health of the riparian areas within the watersheds. The discussion section describes how this model will be used in the future to make resource management decisions within the watersheds.

Software and Data

The GIS model is developed using ArcView 3.2 and Spatial Analyst 2.0 (ESRI, Redlands, CA). The GIS data coverages are obtained from the NJDEP, the USGS, and the NRCS. All data are public domain and most coverages can be downloaded from the internet. A detailed description of the data coverages is given in Appendix A.

Model Overview

The GIS model developed in this study represents an accurate, yet relatively simple methodology for defining and characterizing the health of streamside riparian areas within the Musconetcong and the Pohatcong watersheds in northwestern New Jersey. The model contains two parts, the first defining riparian areas based solely on hydrology, the second, ranking those areas based on land use/land cover and biology. A detailed description of the model is available in the CRSSA Technical Report 0101 (Hughes et al., 2001)

Methodology

Part I of this model defines the riparian areas within the watershed based solely on hydrology. GIS coverages used (Appendix A) are wetlands (NJDEP), soils (NRCS), and flood prone areas (U.S. Geological Survey (USGS)). An area is delineated as riparian if any one of the following conditions is met: an area is a wetland, an area is prone to flooding, or an area contains hydric soils. Areas that are defined as riparian by the above definition, but are not associated with water bodies are eliminated from the final model output. An intermediate data coverage representing ranked surface water quality (as applied to this watershed) is created using the riparian areas delineated in part I, and the statewide Surface Water Quality data coverage (NJDEP).
Part II of the model ranks the riparian areas from 1 (lowest health) to 5 (highest health) based on 1995/1997 updated land use/land cover (NJDEP), ranked surface water quality, and the presence of threatened and endangered species (NJDEP) (Appendix A). The assumptions made for this model are that all of these factors contribute equally to the health of the area. To apply this model to other areas it is possible to weight the relative significance of any of the inputs to this model. A detailed flowchart of this model is shown in Figures 3 and 4. Verification and guidance for determining the relative rankings for surface waters, land use and land cover, and soil classifications within these watersheds were obtained from biologists and soil specialists within NJDEP and NRCS.

Results

Model results for the Musconetcong and the Pohatcong watersheds are shown in Figures 5-7. Output (data and maps) are presented based on the natural HUC-11 boundaries for the two watersheds (NJDEP), i.e. the Pohatcong Creek and the Musconetcong River north of Trout Brook, and the Musconetcong including and south of Trout Brook. Acreage of ranked riparian areas (not including natural and artificial lakes) is shown below in Table 2. There are no areas in either of these watersheds ranked as low as 1 (worst health), and few areas in the Musconetcong are ranked as high as 5 (best health). In the Pohatcong, over 340 acres (138 hectares) are ranked 5. In general, the highest ranks (best health) appear to be found in the headwaters of the watersheds.

Table 2. Model output of ranked riparian health by acreage (hectares) determined from the GIS Model. (These values exclude areas that fall within natural and artificial lakes.)

<table>
<thead>
<tr>
<th></th>
<th>Rank 1</th>
<th>Rank 2</th>
<th>Rank 3</th>
<th>Rank 4</th>
<th>Rank 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pohatcong</td>
<td>0</td>
<td>801.6 (324)</td>
<td>1642.9 (665)</td>
<td>1107.7 (448)</td>
<td>341.4 (138)</td>
</tr>
<tr>
<td>Musconetcong North</td>
<td>0</td>
<td>1742.8 (705)</td>
<td>3857.2 (1,561)</td>
<td>2816.8 (1,140)</td>
<td>54.0 (22)</td>
</tr>
<tr>
<td>Musconetcong South</td>
<td>0</td>
<td>849.2 (344)</td>
<td>1835.3 (743)</td>
<td>1080.9 (437)</td>
<td>3.1 (1.3)</td>
</tr>
</tbody>
</table>

Discussion

Riparian areas provide an important buffering system for protecting the quality of water in lakes and streams. As population and development pressures continue to increase in New Jersey as well as in other regions, accurately defining and characterizing these riparian areas is increasingly important. The ability to target riparian areas for restoration is made easier through the use of GIS technology. GIS models help to answer a variety of questions relating to ecology and land use such as: Which riparian areas are in need of restoration? How much of the defined riparian area is forested? How much contiguous land exists within the riparian area? What areas should be considered for preservation and conservation purposes and do these areas add to existing riparian areas?

One of the main objectives for this project is to use the output from the GIS model to select areas within the watersheds to restore riparian forest buffers. Prior to
the development of the GIS model, one site within each of the two watersheds was selected based on stakeholder input and numerous field visits. This selection process included one formal evening meeting, numerous telephone conversations and ‘one-on-one’ on-site meetings with stakeholders, and four or five days actively locating, evaluating, and selecting sites. The pre-selected site on the Pohatcong Creek is located in Alpha Boro, in the southern part of Warren County, NJ and the pre-selected site in the Musconetcong is located on the grounds of the M & M Mars Company in Hackettstown Township, Warren County, NJ. Planting design for these sites are based on the U.S. Forest Service’s three-zone riparian forest buffer system (Welsch, 1991) and uses native species. Volunteers provide labor for installation and maintenance.

Prior to restoration of the north bank of the Pohatcong Creek in the spring of 2001, the vegetation of that site consisted primarily of lawn grasses with a few herbaceous and woody species present. The southern bank of the creek at that location consists of early successional forest, with a mixture of long grasses and red cedar. The GIS model ranked the health of the riparian area at the restored site as a ‘2’, with the southern bank (early successional forest) given a rank of ‘3’. The pre-selected site on the Musconetcong (to be planted in fall 2001) also received a rank of ‘2’ with some areas ranked ‘3’ from the model output. This suggests that the GIS based model is successful at targeting degraded riparian areas for site restoration. Currently, using this model, we are identifying riparian areas within the watersheds that are ranked ‘2’, bordering on areas ranked ‘3’ and ‘4’ as a basis for choosing the remaining two restoration sites. In this way, we will be able to bring better information to stakeholders early on and decrease the amount of time and money needed to select appropriate sites for planting. A sampling of field areas with all rankings (2-5) are also being evaluated and field checked for accuracy.

As the model’s output is verified, and the riparian forest buffer sites are restored, the project is positioned to attain its overall goal of promoting the importance of watersheds and riparian corridors to the communities within the two watersheds. Various educational and demonstrational programs will be completed over the remaining three years of the project for specific target audiences. Resource management agencies, municipalities and watershed associations will continue using the model’s output to further restore and enhance riparian buffers in the watersheds. Finally, the NJDEP has shown interest in adapting and using the model for evaluating riparian corridors in other watersheds within New Jersey.

Conclusions

This paper describes a geographic information systems (GIS) based methodology for defining and assessing the health of riparian areas within the Musconetcong River and the Pohatcong Creek watersheds in northwestern New Jersey. Model output has been verified against two pre-selected restoration sites, one in each watershed. The GIS modeled output will now be used to identify additional riparian areas in need of enhancement or restoration. Modeled and mapped output will augment the ability to build support for watershed protection throughout the communities living in these watersheds.
Figure 1. The New Jersey DEP Watershed Management Area 1, and the location of the Pohatcong and the Musconetcong watersheds shown by land cover.
Figure 2. Rivers and streams within the Pohatcong and the Musconetcong watersheds.
Part I. Delineating riparian areas

Figure 3. Flowchart for delineating riparian areas in the Pohatcong and the Musconetcong watersheds based on hydrology.

Part II: Assessing the health of riparian areas.

Figure 4a-b. Flowchart for (a) creating a riparian area coverage based on surface water quality and (b) ranking the health of riparian areas within the watersheds.
Figure 5. Riparian areas ranked and mapped by health in the Musconetcong North watershed. Ranking is scaled from 1 (worst) to 5 (best). There is no riparian area with rank = 1.
Figure 6. Riparian areas ranked and mapped by health in the Musconetcong South watershed. Ranking is scaled from 1 (worst) to 5 (best). There is no riparian area with rank = 1.
Figure 7. Riparian areas ranked and mapped by health in the Pohatcong watershed. Ranking is scaled from 1 (worst) to 5 (best). There is no riparian area with rank = 1.
References


Appendix A

Data and Coverages

Data Overview

The model data come primarily from the NJDEP, and may be downloaded from their web page (http://www.state.nj.us/dep/gis/) in ArcView shapefile format (New Jersey State Plane, NAD83 projection). The NJDEP surface water quality data coverage for WMA-1 was supplied by S. McGinnis, North Jersey RC & D, and the threatened and endangered species grid was supplied by M. Dey, Division of Fish and Wildlife, NJDEP. Because the NRCS has not yet completed updated soil coverages for Sussex and Warren Counties, the soil data coverage is a combination of the NJDEP 1986 soil delineation coverage, and updated NRCS hydric soil data supplied by C. Smith, NRCS. (see http://www.nj.nrcs.usda.gov/soils/digitalsurvey.html for updated information). The NJDEP will eventually make NRCS soils data available on its web page for download in ArcView format. The data used are all public domain. All data files are in vector format, except for the threatened and endangered species data, which is in grid format. A detailed description of the model is presented in CRSSA Technical Report 0101 (Hughes et al., 2001). (Disclaimer - All maps produced for this paper using the NJDEP coverages are secondary products and have not been verified by NJDEP and is not state-authorized).

Coverages

1995/1997 Land Use/Land Cover Data:

Originator: NJ Department of Environmental Protection (NJDEP), Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA)
Publication Date: 20001201
Title: 1995/97 Land use/Land cover Update, Upper Delaware Watershed Management Area WMA-1
Edition: 1.3; (FINAL)
Geospatial Data Presentation Form: vector digital data
Publication Place: Trenton, NJ
Publisher: NJDEP
Online Linkage: http://www.state.nj.us/dep/gis/digidownload/zips/lulc95/w01lu95.zip
NJDEP Watershed Management Areas
Originator: Department of Environmental Protection (NJDEP), New Jersey Geological Survey (NJGS), Gregory C. Herman (ed.), Jeff Hoffman, Tom Cosmas, Tom McKee
Publication Date: 20000405
Title: NJDEP Watershed Management Areas
Edition: final
Geospatial Data Presentation Form: vector digital data
Publication Place: Trenton, NJ 08625
Publisher: New Jersey Department of Environmental Protection (NJDEP), Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA)
Online Linkage: http://www.state.nj.us/dep/gis/digidownload/zips/statewide/depwmas.zip

14 digit Hydrologic Unit Code delineations
Originator: New Jersey Geologic Survey, Department of Environmental Protection
Publication Date: 20000405
Title: 14 digit Hydrologic Unit Code delineations
Edition: 1
Geospatial Data Presentation Form: map
Publication Place: Trenton, NJ 08628
Publisher: NJDEP

11 digit Hydrologic Unit Code delineations created from dephuc14
Environmental Remediation, Division of Water Quality, Point-source Pollution, Region 1
Publication Date: 20000405
Title: 11 digit Hydrologic Unit Code delineations created from dephuc14
Edition: 1
Geospatial Data Presentation Form: map
Publication Place: Trenton, NJ 08628
Publisher: NJDEP
New Jersey Streams
Originator: BGIA, OIRM, NJDEP
Publication Date: 19981101
Title: New Jersey streams
Edition: 1.0
Geospatial Data Presentation Form: none
Publication Information:
Publication Place: NJDEP, Trenton NJ
Publisher: BGIA, OIRM, NJDEP

Surface Water Quality Designations for Watershed
Originator: NJ Department of Environmental Protection (NJDEP), Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA) and the Division of Watershed Management
Publication Date: 20000901
Title: Surface Water Quality Designations for Watershed Management Area 1, Upper Delaware
Edition: 1
Geospatial Data Presentation Form: vector digital data
Series Name: Surface Water Quality Designations
Issue Identification: WMA2000
Publication Place: Trenton, NJ
Publisher: New Jersey Department of Environmental Protection
Online Linkage: http://www.state.nj.us/dep/gis/digidownload/zips/swqs/swqs01.zip

Floodprone Areas
Taken Directly from USGS Flood-prone Maps on the 4-volume CD-ROM set GIS Resource Data
New Jersey Department of Environmental Protection Geographic Information System
Mapping the Present to Protect New Jersey's Future
Mapping and Digital Data Standards
prepared by:
New Jersey Department of Environmental Protection
Office of Information Resources Management
Bureau of Geographic Information Analysis
CN 428
Trenton, NJ 08625
August 1995
Soils Boundaries
Data Soils - by county - 24k soils coverages are derived from NJDEP 1986 ITUM (lulc,geol,soil) vector data and are not official USDA NRCS SSURGO 4-volume CD-ROM set GIS Resource
New Jersey Department of Environmental Protection Geographic Information System Mapping the Present to Protect New Jersey's Future Mapping and Digital Data Standards prepared by:
New Jersey Department of Environmental Protection Office of Information Resources Management Bureau of Geographic Information Analysis
CN 428 Trenton, NJ 08625 August 1995

Hydric Data supplemented by NRCS
Originator: U.S. Department of Agriculture, Natural Resources Conservation Service Title: Soil Survey Geographic (SSURGO) database Publication Place: Fort Worth, Texas Publisher: U.S. Department of Agriculture, Natural Resources Conservation Service Personal Communication: Chris Smith, NRCS

Threatened and Endangered Species:
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