

Use of Remote Sensing and GIS for Wetland, Riparian, and Watershed Assessment, Restoration, and Monitoring

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Advances in Technology

- Aerial imagery
 - Digital imagery for GIS applications
 - Online imagery (e.g., Google Earth)
- Digital geospatial data widely available
 - Wetlands
 - Streams
 - Soils
 - Land use/land cover
 - Elevation
- GIS Technology
 - Off-the-shelf
 - Desktop applications
 - Online mapping services (e.g., websoil survey)

Some Uses of Remote Sensing and GIS Technology

- Inventory of wetlands and waters
- Wetland functional assessment for large geographic areas
- Riparian habitat inventory
- Watershed health assessment

Inventory of Wetlands and Waters

- Digital Imagery
 - Onscreen interpretation
 - More accurate boundary delineation (geospatial) than done previously through cartography
- Other Digital Data
 - Aids to improving interpretation
 - Facilitates expanding classification

Expanded Wetland Classification

Existing Wetland Classification

- Characteristics Emphasized To Date (Cowardin et al. 1979)
 - Ecological System
 - Vegetation or Substrate
 - Water Regime
 - Water Chemistry
 - Human and Beaver Impacts

FWS Classification Shortcomings

- Shortcomings
 - No landscape position
 - No landform
 - No water flow direction
 - General pond classification
 - Features important for assessing many functions are lacking
- Most of these features can be interpreted from the maps

Some Questions

How many wetlands are there?

What is the size range of wetlands?

What is the average size of a given wetland type?

How many wetlands are in various size classes?

How much and how many

- occur along rivers? along streams?
in lake basins?
- **are isolated**? are sources of streams?
- have inflow but no outflow? **are connected to other wetlands or waters**?

What types of ponds are there and what is their extent?

By Enhancing the National Wetlands Inventory (NWI) Database, We Can:

- Better characterize wetlands for national wetland database
- Predict wetland functions
- Help assess significance of wetland losses and gains
- Predict functions expected from potential wetland restoration sites

Enhancing NWI

- Evolved for work on Massachusetts' Wetland Restoration Program
 - Watershed focus
 - Determine existing watershed capacity to perform a variety of wetland functions
 - Use NWI as basis, but needed to add other attributes to predict functions
 - Predict functions of existing wetlands plus functions of potential wetland restoration sites throughout the watershed

New Descriptors for the NWI Database

LLWW Descriptors

- Landscape Position - relationship between a wetland and an adjacent waterbody or not
- Landform - shape or physical form
- Water Flow Path - directional flow of water
- Waterbody Type – more specificity

Recognized as important features to consider adding to the national wetlands database by the Wetlands Subcommittee of the Federal Geographic Data Committee because it greatly increases the functionality of the database (more applications)

Landscape Position - Marine



Landscape Position - Estuarine



Landscape Position - Lentic



Landscape Position - Lotic



RIVER



STREAM

Landscape Position - Terrene



Landforms

- Slope
- Island
- Fringe
- Floodplain (basin, flat)
- Interfluve (basin, flat)
- Basin
- Flat

Water Flow Path

- Bidirectional Tidal
- Bidirectional Nontidal
- Throughflow (perennial, intermittent, entrenched, artificial)
- Outflow (perennial, intermittent, artificial)
- Inflow
- Isolated
- Paludified

Waterbody Types

- River and Stream Gradients (tidal, dammed, intermittent, high, middle, and low)
- Lakes (e.g., natural, dammed river valley-reservoir, other dammed, excavated)
- Ponds (e.g., natural, artificial, beaver, sinkhole, farm, golf, prairie pothole, vernal, Carolina bay, playa, stormwater treatment, sewage lagoon)
- Estuary (e.g., drowned river valley, bar-built)
- Ocean (e.g., open, reef-protected, atoll, fjord)

APPLICATIONS

- Better Wetland Characterizations for Study Areas
- Use for Predicting Wetland Functions for:
 - Watersheds or Larger Areas
 - Historic and Recent Wetland Losses and Gains
 - Potential Wetland Restoration Sites

Preliminary Functional Assessment

- 11 Possible Functions
 - Surface Water Detention
 - Streamflow Maintenance
 - Shoreline Stabilization
 - Nutrient Transformation
 - Carbon Sequestration
 - Coastal Storm Surge Detention
 - Sediment Retention
 - Fish and Shellfish Habitat
 - Waterfowl and Waterbird Habitat
 - Other Wildlife Habitat
 - Conservation of Biodiversity

Coordinated Effort To Develop Correlations

- Reviewed literature
- Worked with wetland specialists in the Northeast
 - Maine Wetland Advisory Group
 - NYCDEP
 - Nanticoke Wetlands Study Group
 - FWS biologists
 - Others



Correlation Report

- **CORRELATING ENHANCED NATIONAL WETLANDS INVENTORY DATA WITH WETLAND FUNCTIONS FOR WATERSHED ASSESSMENTS: A RATIONALE FOR NORTHEASTERN U.S. WETLANDS (October 2003)**

Study Areas

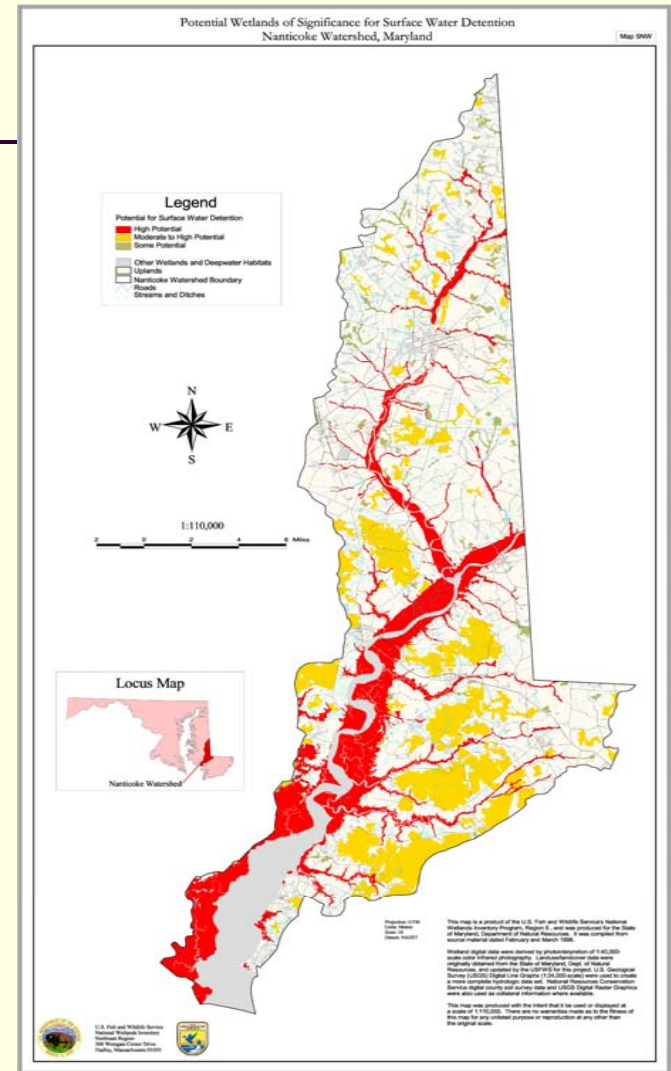
- Completed:
 - Casco Bay Watershed (ME)
 - 3 New York City Water Supply Watersheds
 - 11 Small watersheds (NY)
 - Coastal Bays Watershed (MD)
 - Nanticoke River Watershed (MD/DE)
 - 1998 and Pre-settlement analyses
 - Pennsylvania Coastal Zone
- In Progress:
 - Cape Cod and the Islands (MA) – draft report
 - New Jersey (entire state) – QC/data analysis
 - Rhode Island (entire state) – QC/data analysis
- Others Applying Techniques:
 - Northeast - Delaware
 - Midwest – Michigan, Minnesota (planned)
 - West - Montana

Web-based Watershed Reports

- CD Version and Online reports (View on Internet at: library.fws.gov/ and some at wetlands.fws.gov)
 - Text
 - Statistics
 - Maps

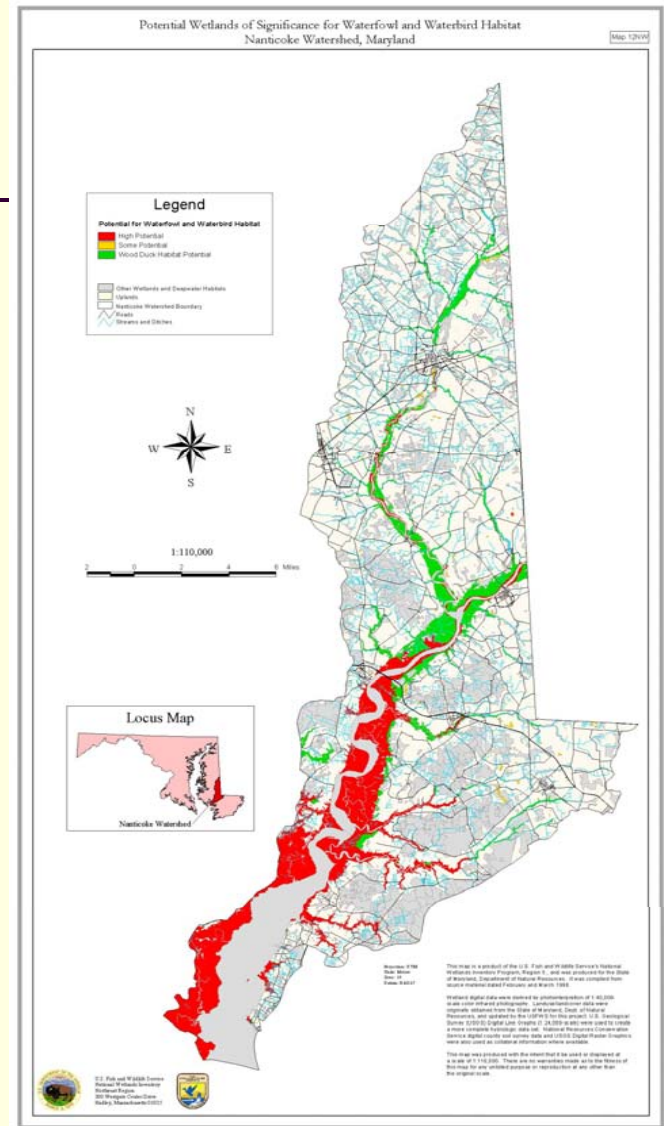
Nanticoke Watershed Surface Water

28% High
69% Moderate
(97% of all wetlands)



Nanticoke Watershed Waterfowl & Waterbird Habitat

13% High
7% Moderate
(20% of all wetlands)



Limitations of Landscape-level Assessment

- First approximation - PRELIMINARY
- Source data limitations
 - All wetlands not shown
 - Possible upland inclusions
 - All streams not shown
 - Age of data
- LLWW wetland classifications based largely on map or image interpretation (field review variable)
- Correlations between functions and characteristics = work in progress (report available for Northeast US; most applicable nationwide, need some modification for habitat functions)

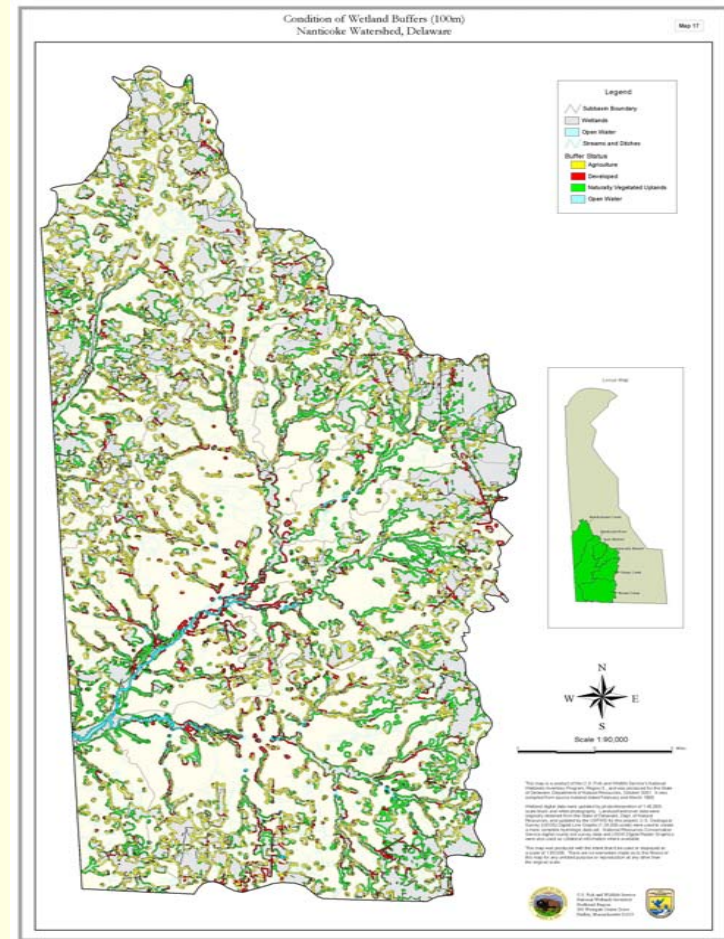
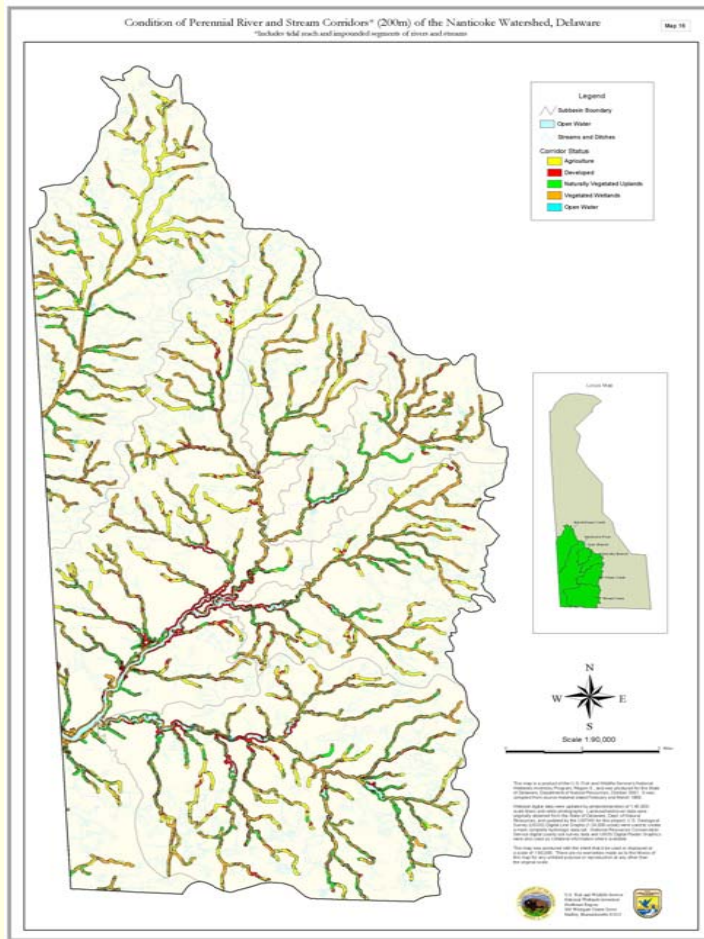
Bottomline

- By adding **LLWW descriptors** to wetland data the functionality of the NWI database is greatly expanded
- It becomes a powerful tool to begin reporting status and trends of wetland functions for large geographic areas

Other Possibilities for Inventory and Assessment

- Wetland and waterbody buffers
- Potential wetland/riparian restoration sites
- Wetland condition (health) based on remotely sensed data plus available geospatial data
- Overall condition of watershed in terms of amount of “natural habitat” remaining

Buffers along Rivers, Streams, Wetlands, Lakes, and Ponds (includes Riparian Habitat)

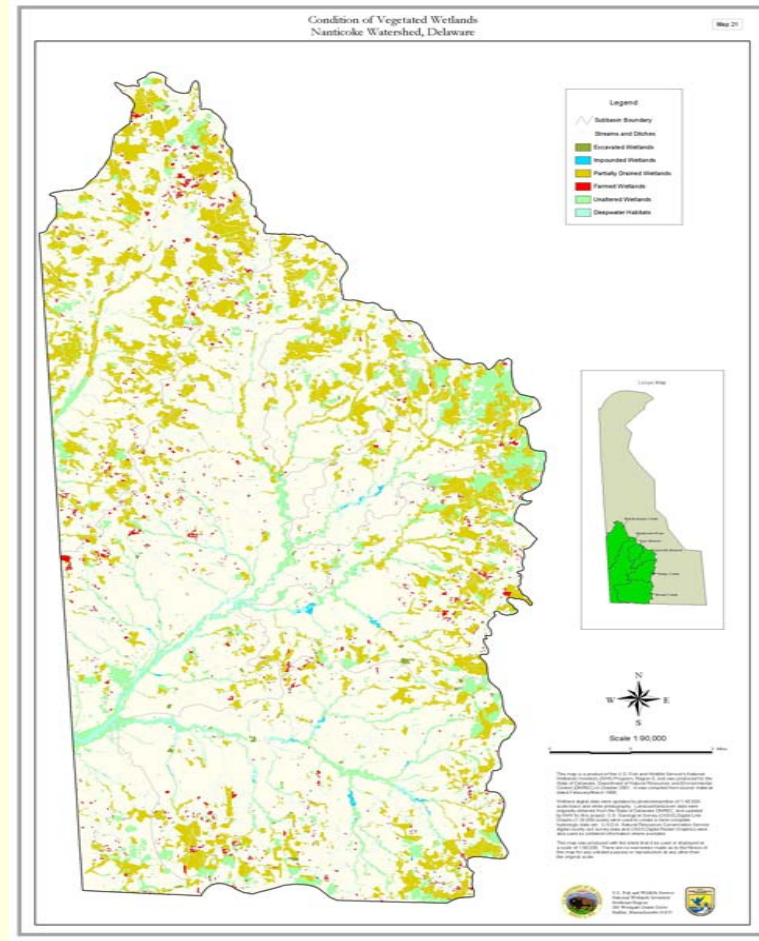


Potential Restoration Sites

- Lost wetlands in restorable condition based on current land use (e.g., hydric soil areas in agricultural use) = Type 1 Wetland Restoration Sites
- Altered wetlands (e.g., PFO1Ad, Pf) = Type 2 Restoration Sites
- Nonvegetated riparian corridors (e.g., cropland, pasture, clearing)
- Nonvegetated wetland buffers

Modified Wetlands = Potential Restoration Sites (Type 2 Restoration)

- Farmed
- Excavated
- Impounded
- Partly Drained
- **ADD** Former Wetlands with restoration potential (Type 1 Restoration)



GOING FURTHER

■ WATERSHED ASSESSMENT

- Use of Remotely-sensed Data and Existing Digital Geospatial Data
 - Large geographic areas
 - Broad overview
 - Focus on Variables detectable via remote sensing
 - Option – include field-derived data

“Natural Habitat” Defined

- Land with “natural cover” – wetlands, forests, prairies, dunes, old fields, and thickets (plus commercial forest lands in successional stages) = wildlife habitats
- It is not developed lands:
 - Agricultural land (cropland, grazed pastures, orchards, vineyards)
 - Turf (lawns, golf courses, turf farms)
 - Impervious surfaces

“Natural Habitat Integrity Indices”

Habitat Extent

- Natural Cover
- Stream Corridors
- Wetland Buffers
- Pond Buffers
- Lake Buffers
- Wetland Extent
- Standing Waterbody Extent

Disturbances

- Damming of Streams
- Channelization
- Wetland Alteration
 - Farmed
 - Excavated
 - Impounded
 - Partly Drained
- Fragmentation by Roads
- Others?

“Natural Habitat Integrity” Defined

- “the state or condition of unbroken natural habitat”
- Focus on “natural” ecosystems not on highly managed, altered ecosystems

Assessment Products – Report and Geospatial Database

■ Statistics

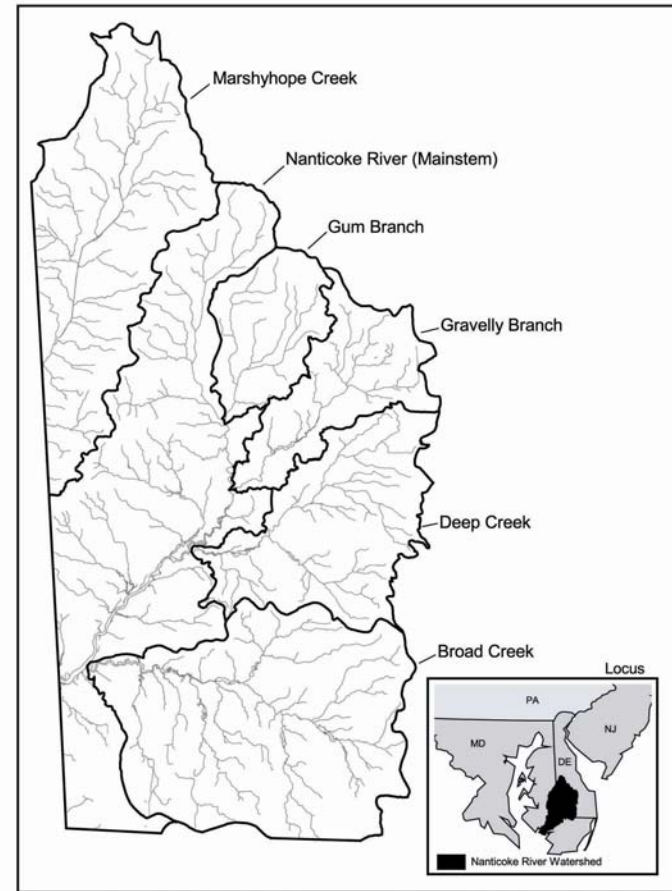
- Index Values between 1.0 and 0.0 (=%)
 - Area A/Total A; Miles of A/Total Miles
- Habitat Extent Index Example: Natural Cover Index
 - Area in Natural Cover/Land Area
 - 1.0 = undeveloped watershed (100% integrity)
 - ~ 0.0 = a major city
- Habitat Disturbance Index Example: Channelized Stream Length
 - **Miles of Channelized Streams/Miles of Streams**
 - 1.0 = all streams channelized
 - 0.0 = all streams not channelized (100% integrity)

■ Maps

■ Database (for additional analyses)

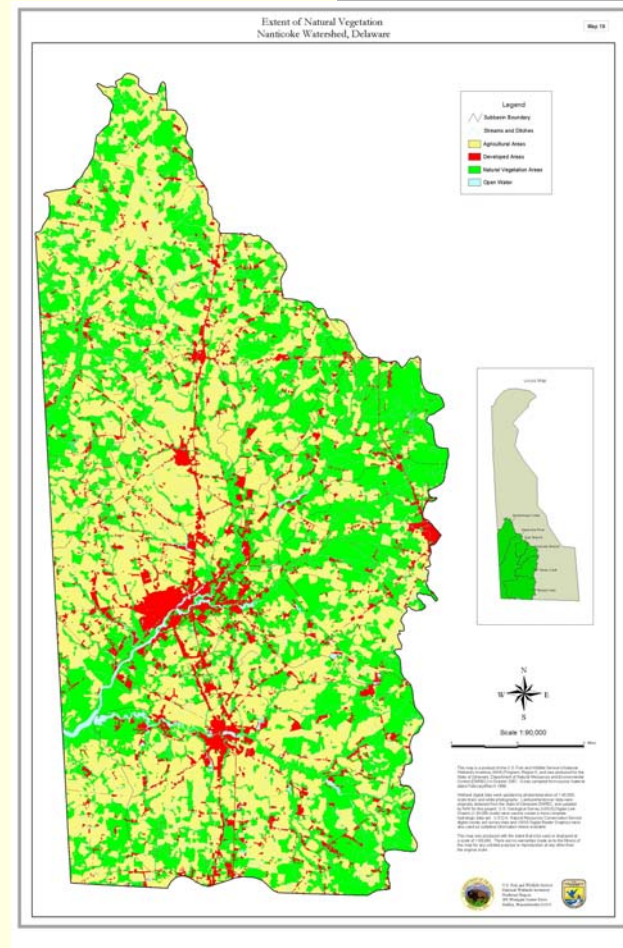
Examples from Natural Habitat Integrity Assessment

Nanticoke Watershed (Delaware)



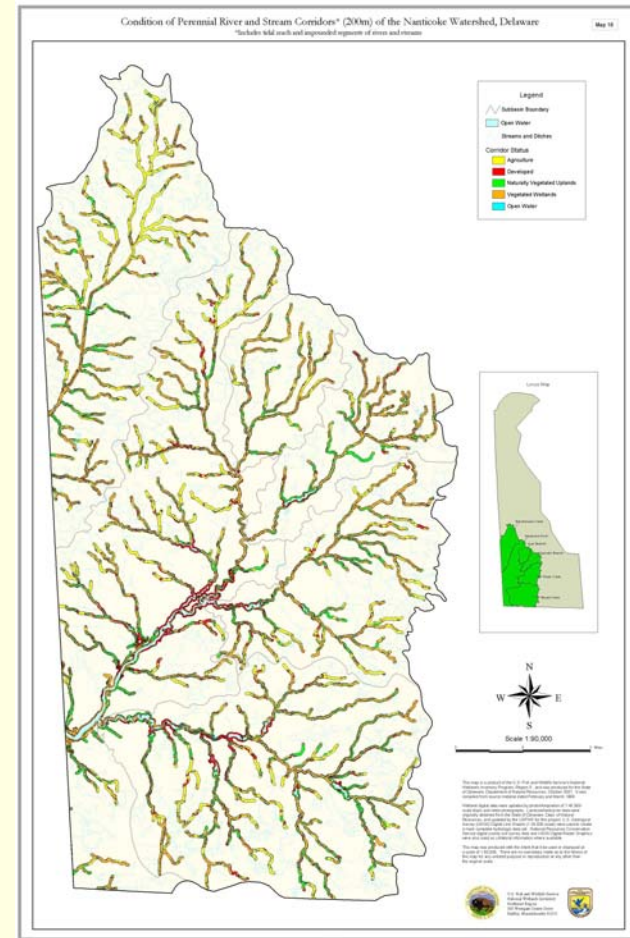
Habitat Extent Index: Natural Cover Index

- Area of Natural Cover in Watershed/Total Land Area
- 51,813/126,582
- = 0.41



River-Stream Corridor Integrity

- Area of River-Stream Corridor in Natural Vegetation/Area of the Corridor
- 11,369/19,143
- = 0.59



Disturbance Index: Channelized Stream Length Index

- Length of Channelized Streams/Total Length of Streams
- 700.5km/890.7km
- = 0.79

Composite Index for Watershed

- Weighted Habitat Extent Indices – Weighted Habitat Disturbance Indices

$$0.5 \text{ NC} + 0.125 \text{ RSC} + 0.125 \text{ WB} +$$

$$0.05 \text{ PLB} + 0.1 \text{ WE} + 0.1 \text{ SWE} = 0.485$$

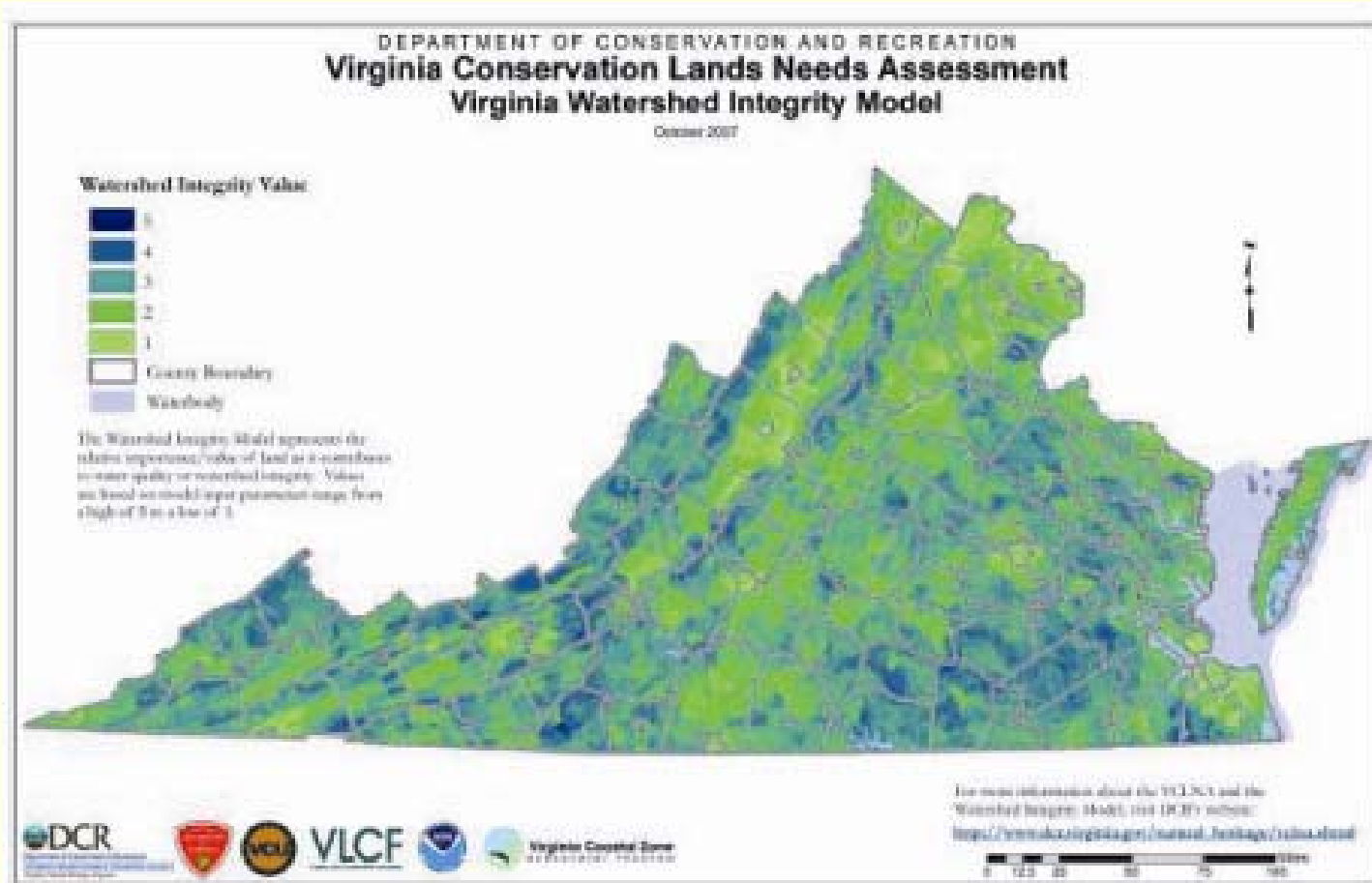
$$0.1 \text{ DSF} + 0.1 \text{ CSL} + 0.1 \text{ WD} + 0.2 \text{ HF} = 0.191$$

$$0.485 - 0.191 = \mathbf{0.294} \text{ (severely degraded watershed)}$$

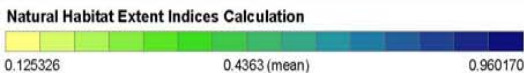
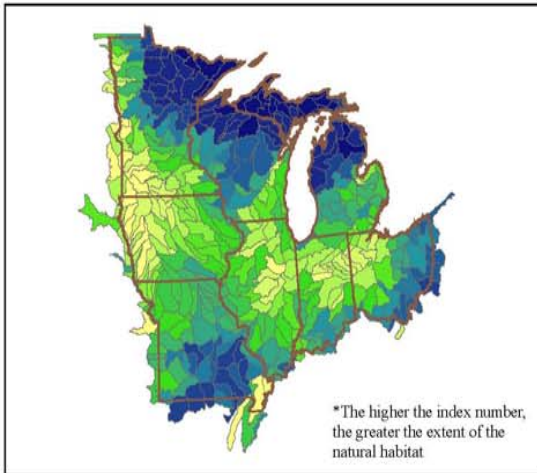
Watershed Health

- Use indices to generate maps and reports for large geographic areas
 - Watersheds
 - Counties
 - States
 - Regions

State Applications – VA and MT

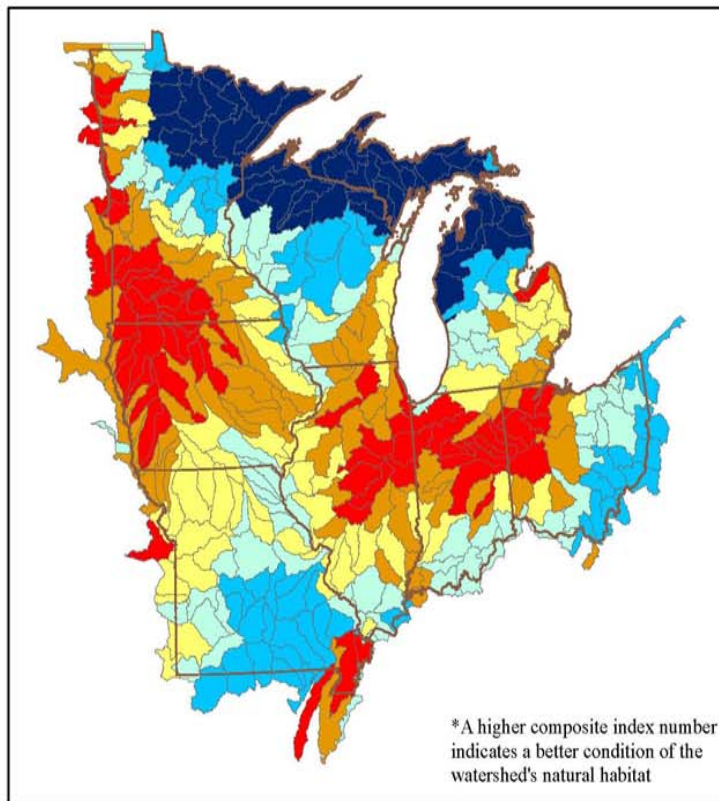


An Evaluation of Watershed Health in Region 3

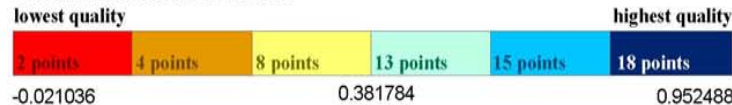


Natural Habitat Extent

- Index 1 Proportion of watershed represented by natural vegetation
- Index 2 Area of river-stream corridor buffer (100 meter on each side) in natural vegetation
- Index 3 Area of wetland buffer (100 meter) in natural vegetation
- Index 4 Area of pond/lake buffer (100 meter) in natural vegetation
- Index 5 Proportion of historic wetland extent currently existing
- Index 6 Standing waterbody extent (demonstrated gain in region, Therefore, index set to 1.0)



Overall Watershed Index



Composite Natural Habitat Integrity Index Formula

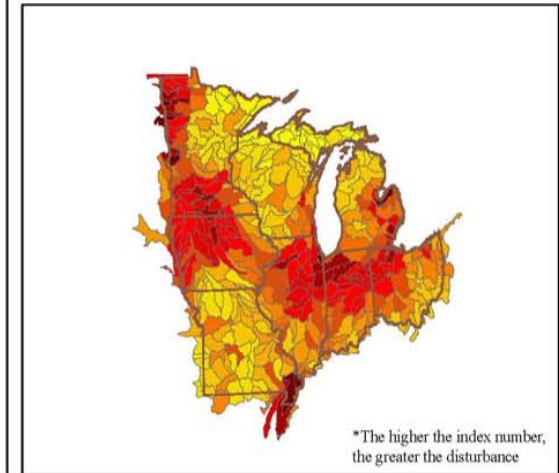
Positive Indices $((\text{Index01} * 0.5) + (\text{Index02} * 0.125) + (\text{Index03} * 0.125) + (\text{Index04} * 0.05) + (\text{Index05} * 0.1) + (\text{Index06: } 1.0 * 0.1))$

-Negative Indices $((\text{Index07} * 0.1) + (\text{Index08} * 0.1) + (\text{Index09} * 0.1) + (\text{Index10} * 0.1))$

Human-caused Disturbance

- Index 7 Length of perennial streams & rivers impounded by dams
- Index 8 Length of perennial streams & rivers that are channelized
- Index 9 Proportion of watershed that is intensely farmed or urbanized (G.T. 75% of landbase within 1 sq. mi. area is developed or farmed)
- Index 10 Proportion of watershed area covered by roads

Human-caused Disturbance Indices Calculation



Model design based on:

Tiner, Ralph W., 2004. Remotely-sensed indicators for monitoring the general condition of "natural habitat" in watersheds: an application for Delaware's Nanticoke River watershed. Ecological Indicators 4 (2004), 227-243.



U.S. Fish and Wildlife Service
Region 3 National Wildlife Refuge System
Division of Conservation Planning
Twin Cities, Minnesota 55111

With Today's Remote Sensing and GIS Technology

- We can:
 - Produce better wetland and riparian habitat data
 - Use these data to predict wetland functions at the landscape level
 - Identify potential restoration sites for:
 - Wetlands, Wetland Buffers, and Riparian Habitats
 - Perform landscape-level assessments of watershed condition/health

This information can be used to:

- Improve natural resource conservation and management
- Improve restoration efforts by presenting a holistic view of opportunities
- Monitor changes in condition of wetlands, riparian habitats, and watersheds when conducted at periodic intervals – “a natural resource report card”

Questions?

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