TS-PIC-89301
June 1989

LANDSCAPE CHARACTERIZATION FOR ECOLOGICAL MONITORING

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Contract No. 68-03-3532

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Warrenton, Virginia 22186, FTS 557-3110

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LAS VEGAS, NEVADA 89114

NOTICE

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ABSTRACT

The U. S. Environmental Protection Agency (EPA) is initiating an Environmental Monitoring and Assessment Program (EMAP) to monitor the status and trends of the nation's near coastal waters, forests, freshwater wetlands, surface waters and agroecosystems. This program is also intended to evaluate the effectiveness of Agency policies at protecting ecological resources occurring in these systems. Monitoring data collected for all ecosystems will be integrated for national status and trends evaluations.

EMAP's component ecosystems share a common need for up-to-date, baseline information on landscape spatial characteristics, particularly within the geographic areas that will represent EMAP sample cells in a nationwide monitoring network. In the following report, a methodology for landscape characterization is demonstrated on a prototype EMAP sample cell of 40 square kilometers, located near Broad Brook, Connecticut. The characterization methods employ remote sensing technology to compile vegetational, hydrologic, anthropogenic and physiographic baseline data in Geographic Information System (GIS) format. According to the requestors' specifications, the characterization methodology used aerial photography as its primary data source, in order to demonstrate the identification, delineation and detailed classification of ecological features through use of a very high resolution (1-2 meters ground-resolved distance) sensor. Though the demonstration of satellite technology and other potential characterization sources was beyond the scope of this assignment, a brief discussion of these additional options has been included in this report.

The concepts initially put forth in this study, as a prototype design, have not been peer-reviewed or finalized. This characterization methodology is expected to undergo review by the EMAP project team. The GIS data base design elements and standards essential to a fully operational characterization data base were not developed within the scope of this study.

The U. S. EPA's Environmental Photographic Interpretation Center in Warrenton, Virginia, a Branch of the Advanced Monitoring Systems Division, Environmental Monitoring Systems Laboratory in Las Vegas, Nevada, performed this study at the request of the Office of Modeling, Monitoring Systems and Quality Assurance and the EMAP program manager. Work was completed in June 1989.

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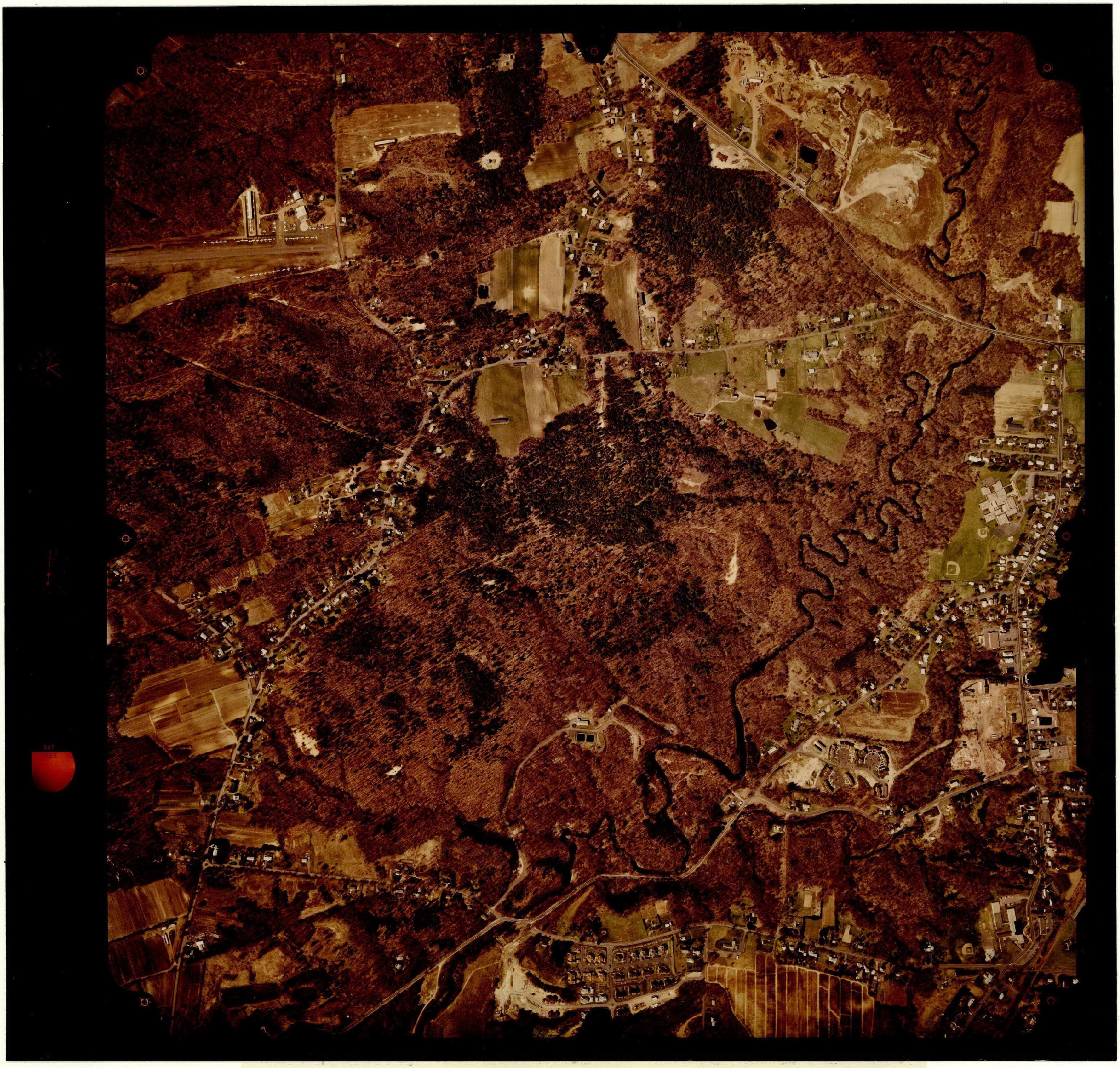

Figure 1: Broad Brook, CT Area, April 25, 1989

INTRODUCTION

The U. S. Environmental Protection Agency (EPA) is initiating an Environmental Monitoring and Assessment Program (EMAP) to monitor the status and trends of the nation's near coastal waters, forests, freshwater wetlands, surface waters and agroecosystems. This program is also intended to evaluate the effectiveness of Agency policies at protecting ecological resources occurring in these systems. Monitoring data collected for all ecosystems will be integrated for national status and trends evaluations.

EMAP's component ecosystems share a common need for up-to-date, baseline information on landscape spatial characteristics, particularly within the geographic areas that will represent EMAP sample cells in a nationwide monitoring network. In the following report, a methodology for landscape characterization is demonstrated on a prototype EMAP sample cell of 40 square kilometers, located near Broad Brook, Connecticut. The characterization methods employ remote sensing technology to compile vegetational, hydrologic, anthropogenic and physiographic baseline data in Geographic Information System (GIS) format. According to the requestors' specifications, the characterization methodology used aerial photography (see Figure 1) as its primary data source, in order to demonstrate the identification, delineation and detailed classification of ecological features through use of a very high resolution (1-2 meters ground-resolved distance) sensor. Though the demonstration of satellite technology and other potential characterization sources was beyond the scope of this assignment, a brief discussion of these additional options has been included in this report.

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The Purposes for Characterization

Several primary and ancillary purposes for landscape characterization have been identified during EMAP planning and design. These purposes are related to the basic ecological monitoring process itself, and to future contributions of characterization toward modeling and diagnosis of correlations between stressors and ecosystems.

The characterization process is the primary source of baseline status -- in particular the extent, distribution and classification -- of EMAP's target ecosystems. As such, characterization data can fulfill a major, nationwide informational need for each ecosystem monitoring team. From a statistical perspective, characterization provides a quantitative description of each ecosystem target population and potential subpopulations (at regional and national scales), consequently also identifying ecosystem units for sampling at each sample cell of the EMAP network (at local scales). In addition, as a current benchmark of ecosystem extent and distribution, a characterization data base provides the initial measurements for future monitoring of ecosystems' spatial and structural changes. For ecosystems such as wetlands that are known to have serious habitat loss and fragmentation problems, it is particularly important to have the capability to monitor these spatial changes because they may be of equal or greater concern than trends in condition or health. Characterization, therefore, is also a source for monitoring trends as well as status.

Other purposes for characterization center on the advantages of developing an integrated landscape characterization data base around a sampling network common to all ecosystems, as compared to separate characterization projects for each major ecosystem. In addition to the integrated approach's evident benefits of cost-sharing, data-sharing, common format, and consistency, the landscape characterization data comprise a "lowest common denominator" of landscape attributes that are linked to each ecosystem's condition. These attributes are broadly defined as the physiography, vegetation, hydrology, land use and other human-induced modifications of any area under study. These fundamentals of landscape analysis are the basic building blocks for a wide array of potential diagnostic approaches to analyzing EMAP monitoring data, ranging from cumulative impact assessment methodologies to predictive models.

In summary, the characterization process supplies the initial foundation for EMAP by describing the nature of ecosystem target populations, identifying units for sampling, and documenting current baseline status for the major ecosystem types and their immediate surroundings. Over time, characterization is a source for measuring trends and changes in ecosystem distribution, extent and structure, as well as a source of raw data for GIS-based modeling, correlation of stressors with impacts, and investigation of cause-effect relationships, all of which are the logical sequels to the discovery of environmental problems through monitoring.

Objectives of This Study

This study was undertaken to design and demonstrate the central component of the characterization process, which is the acquisition, interpretation, and archiving of landscape data. In contrast, this study was not intended to review, identify or evaluate all potential characterization methodologies or issues, nor does the characterization prototype sample cell in this study represent the GIS data base design that will be developed for characterization information.

Specific objectives of this study include the following:

* Develop a conceptual design for characterization that a) consolidates standard, operational land classification methods and concepts useful to all EMAP components; and b) can be applied in a cost-effective and nationally consistent manner;

* Demonstrate the interpretation of aerial photographs as a methodology for applying the characterization design at high levels of classification detail and spatial resolution; and

* Compile photointerpreted characterization data in digital (GIS) format.

Design Considerations

The requirements for a characterization design are numerous. The overriding consideration for monitoring is date, as the baseline characterization data must be representative of the temporal period during which the monitoring program will begin. Also of primary importance is the provision of spatial data (extent, distribution and structure), amounting to "taking stock" of the resource as the monitoring program begins. Classification of subpopulations of each ecosystem is also very important, though secondary to establishing ecosystems' spatial extent for the baseline temporal period. In addition, the methodology and tools of characterization need to be capable of detection and measurement of potentially subtle spatial or structural changes in these subpopulations.

Other considerations are logistical; the characterization process, as a foundation for most subsequent EMAP activities, requires operational rather than research-mode, incompletely tested techniques. These methods would need to be immediately available for implementation of the process, in order to support the start of field monitoring activities dependent on a characterization data base. Because EMAP is national in scope, the characterization approach would also need to be consistently applicable and accurate from region to region.

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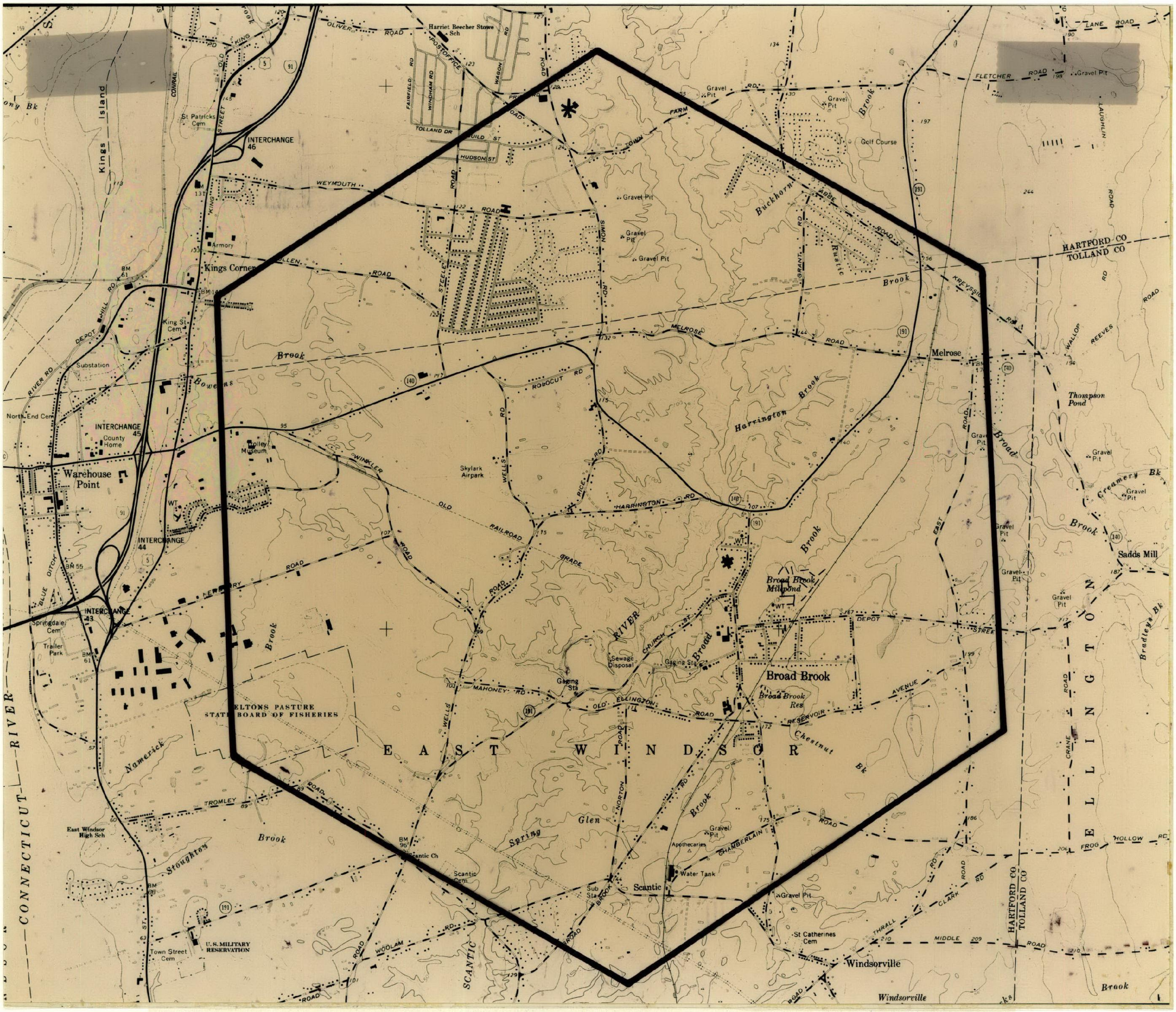


Figure 2 : Location Map, Broad Brook, CT Quadrangle

METHODOLOGY

Interpretation

The study site (Figure 2) was flown on April 25, 1989 to acquire current, normal-color aerial photographs of the study area at a scale of 1:24,000. The 40-square kilometer, hexagonal plot location was deliberately selected to cover a wide variety of terrain characteristics, and is not an actual EMAP sample cell. The analysis was performed by viewing backlit transparencies through stereoscopes. Stereoscopic viewing creates a perceived three-dimensional effect which, when combined with viewing at high magnification, enables the analyst to identify different landscape attributes or conditions.

Interpretation was performed in two phases. In the analysis of site physiography, the landforms and surficial geologic characteristics were classified and delineated. In analyzing the landscape ecology of the site, multiple aspects of the vegetation, hydrology, land use, and anthropogenic modifications of the site were classified and delineated, without field verification. The ecological components (particularly wetlands) and the landform interpretations were performed by specialists in ecological remote sensing and photogeology, respectively. Photo interpretations were archived in a GIS to enable storage and retrieval of data sets and subsets.

Classification

The characterization process is similar, but not identical to, land classification. In characterization, the landscape in the study area is classified in several different ways using standard classifications and routine photo interpretation techniques. Through streamlining the process, three iterations of photo interpretation yielded eleven classification functions. These are reproduced in full in Appendix 1. Through GIS technology, multiple land classification systems can be composited in a complex but functional data base.

The basic land-use attributes were characterized according to the national standard, USGS Professional Paper 964 Land Use Classification (Anderson et al., 1976). Wetlands and deepwater habitats were categorized according to the national standard classification system employed by the U.S. Fish and Wildlife Service National Wetlands Inventory (Cowardin et al., 1979). Vegetational parameters, though not restricted to a single classification system, were developed to ensure compatibility with the Cowardin system's vegetation growth form, height and cover concepts. Physiographic landforms were classified according to a hybrid of two international landform classification schemes, both designed for use with aerial photography (Way, 1973; Liang, 1951). Other characterization attributes not already included in any of the above classification schemes were derived from routine photo interpretation conventions of terrain analysis.

RESULTS

Ecological Characterization Data Set

The contents of this data set are vegetational, hydrologic and anthropogenic features of the study area. A total of ten characterization attributes were incorporated into this part of the characterization design. Five of these are ecological and five are land use-related, as listed in Tables 1 and 2. All ten of these attributes share the common property of being subject to change in spatial extent or physical structure over a moderately short time period, such as a five- or ten-year monitoring cycle. These attributes and their spatial changes, then, can theoretically be the subject of a first-level monitoring effort.

Any specific point within the study area, through this characterization method, is classified according to the ten different listed attributes. The analysis is nonetheless not complex and can be accomplished through a two-step photo interpretation process (land use phase, ecological phase); less complex terrain may be interpretable for all ten attributes in a single step.

The storage, retrieval and manipulation of these several landscape attributes is simplified by GIS technology; manually it would be impossible to portray such an array of landscape characteristics legibly on a single map. In the following several pages, this characterization data set is broken out into its main components for illustration and further discussion.

Table 1: Ecological Characterization Attributes
(see Appendices 1 and 2 for complete listing)

VEGETATION GROWTH FORM
VEGETATION HEIGHT CLASS
PERCENT AREAL COVER OF VEGETATION
HYDROLOGY (WETLANDS AND DEEPWATER HABITATS)
SUBSTRATE

Table 2: Land Use Characterization Attributes
(see Appendix 1 for complete listing)

LAND USE TYPE
USE INTENSITY FACTOR
MAN-MADE SUBSTRATE MODIFICATION
MAN-MADE VEGETATION MODIFICATION
MAN-MADE HYDROLOGIC MODIFICATION

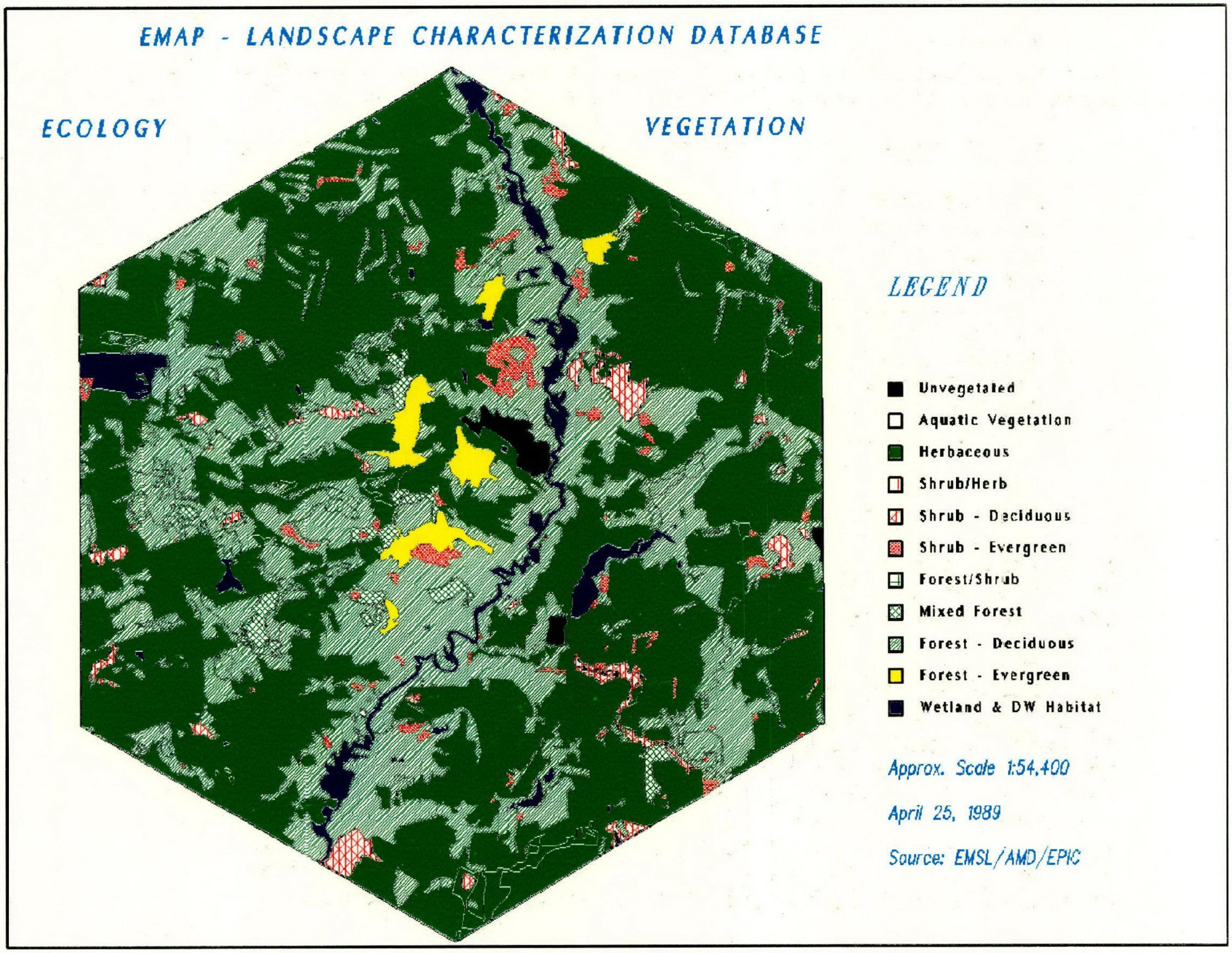
Vegetation Cover

Vegetation is characterized in three ways: vegetative growth form or physiognomy, percent areal cover, and height class. The following categories of each of these attributes are used:

Growth Form	Percent Areal Cover	Height Class
Unvegetated	0 - 10 %	< 6 ft.
Aquatic Vegetation	10 - 30 %	6 - 20 ft.
Herbaceous	30 - 50 %	20 - 60 ft.
Herb/Shrub	50 - 70 %	> 60 ft.
Shrub, Deciduous	70 - 90 %	
Shrub, Evergreen	90 - 100%	
Shrub/Forest		
Mixed Forest		
Forest, Deciduous		
Forest, Evergreen		

The classification of vegetated wetlands, discussed separately in this text, is consistent with the vegetative classification parameters listed above. Both approaches use a 30% areal cover threshold for assigning dominance of a vegetative class and also use similar categories of growth form and height.

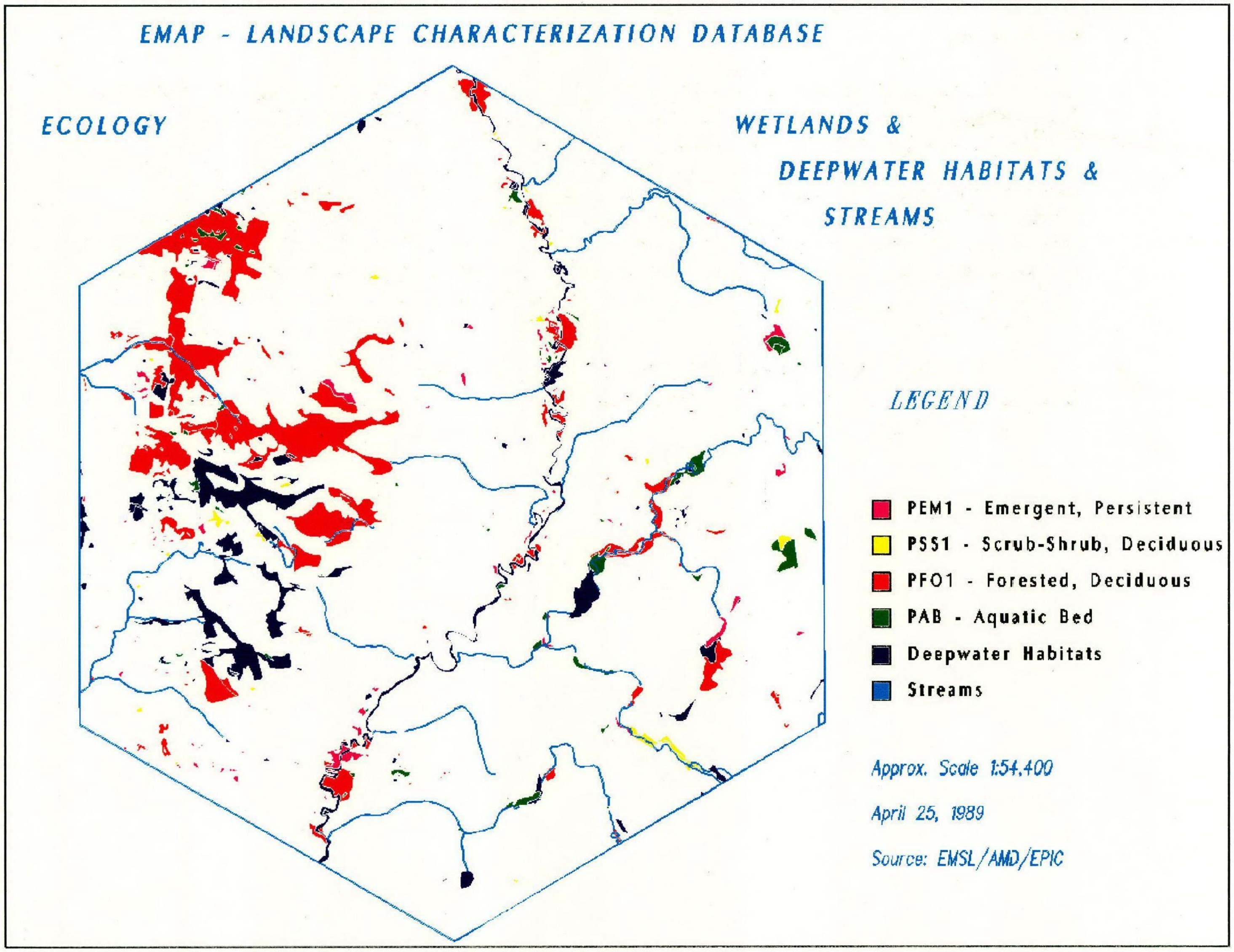
The vegetation characterization method presented here is not equivalent to the "cover" component of land use/cover classification. Characterizing vegetation includes assigning the parameters above to land use areas as well as natural terrain; the dominant vegetational characteristics of areas such as cropland and residential areas are classified in addition to the predominant land use category. Land use-dominated terrain can vary considerably as to ecological characteristics within a single land use classification category, hence the need to characterize the landscape from a number of perspectives.


EMAP - LANDSCAPE CHARACTERIZATION DATABASE
ECOLOGY
VEGETATION
LEGEND
Unvegetated
Aquatic Vegetation
Herbaceous
Shrub/Herb
Shrub - Deciduous
Shrub - Evergreen
Forest/Shrub
Mixed Forest
Forest - Deciduous
Forest - Evergreen
Wetland & DW Habitat
Approx. Scale 1:54,400
April 25, 1989
Source: EMSL/AMD/EPIC

Hydrology

Characterization of hydrology is particularly significant to the Inland Wetlands, Surface Waters, and Near Coastal ecosystem monitoring programs of EMAP. The flexible, hierarchical classification scheme of Cowardin, as is or with is capable of accomodating most if not all the classification categories of interest to these three programs. This system can be modified within its own stated protocol as well, enabling customized data of optimal value to EMAP. Both linear (stream reaches) and areal (rivers, lakes and wetlands) patches of these ecosystems are classifiable.

The Cowardin classification system's categories and hierarchical levels, too numerous to list here in full, are listed in Appendix 2.


EMAP - LANDSCAPE CHARACTERIZATION DATABASE
ECOLOGY
WETLANDS &
DEEPWATER HABITATS &
STREAMS
LEGEND
PEM1 - Emergent, Persistent
PSS1 - Scrub-Shrub, Deciduous
PFO1 - Forested, Deciduous
PAB - Aquatic Bed
Deepwater Habitats
Streams
Approx. Scale 1:54,400
April 25, 1989
Source: EMSL/AMD/EPIC

Land Use

Identification of land use patterns is the most familiar and well-established element of the characterization process. The USGS Professional Paper 964 system (Anderson et al., 1976) was used for this step; land use intensity categories were also adapted from this source. The following categories are standard to the level II classification process:

1 Urban:
- 11 Residential
- 12 Commercial
- 13 Industrial
- 14 Transportation
- 15 Indust/Comm Complexes
- 16 Mixed Urban
- 17 Other Urban

2 Agricultural:
- 21 Cropland and Pasture
- 22 Orchards, Vineyards, Nurseries
- 23 Confined Feeding Operations
- 24 Other Agricultural Land

3 Rangeland:
- 31 Herbaceous Rangeland
- 32 Shrub/Brush Rangeland
- 33 Mixed Rangeland

4 Forest Land:
- 41 Deciduous
- 42 Evergreen
- 43 Mixed

5 Water:
- 51 Streams
- 52 Lakes
- 53 Reservoirs
- 54 Estuaries

6 Wetlands:
- 61 Forested
- 62 Nonforested

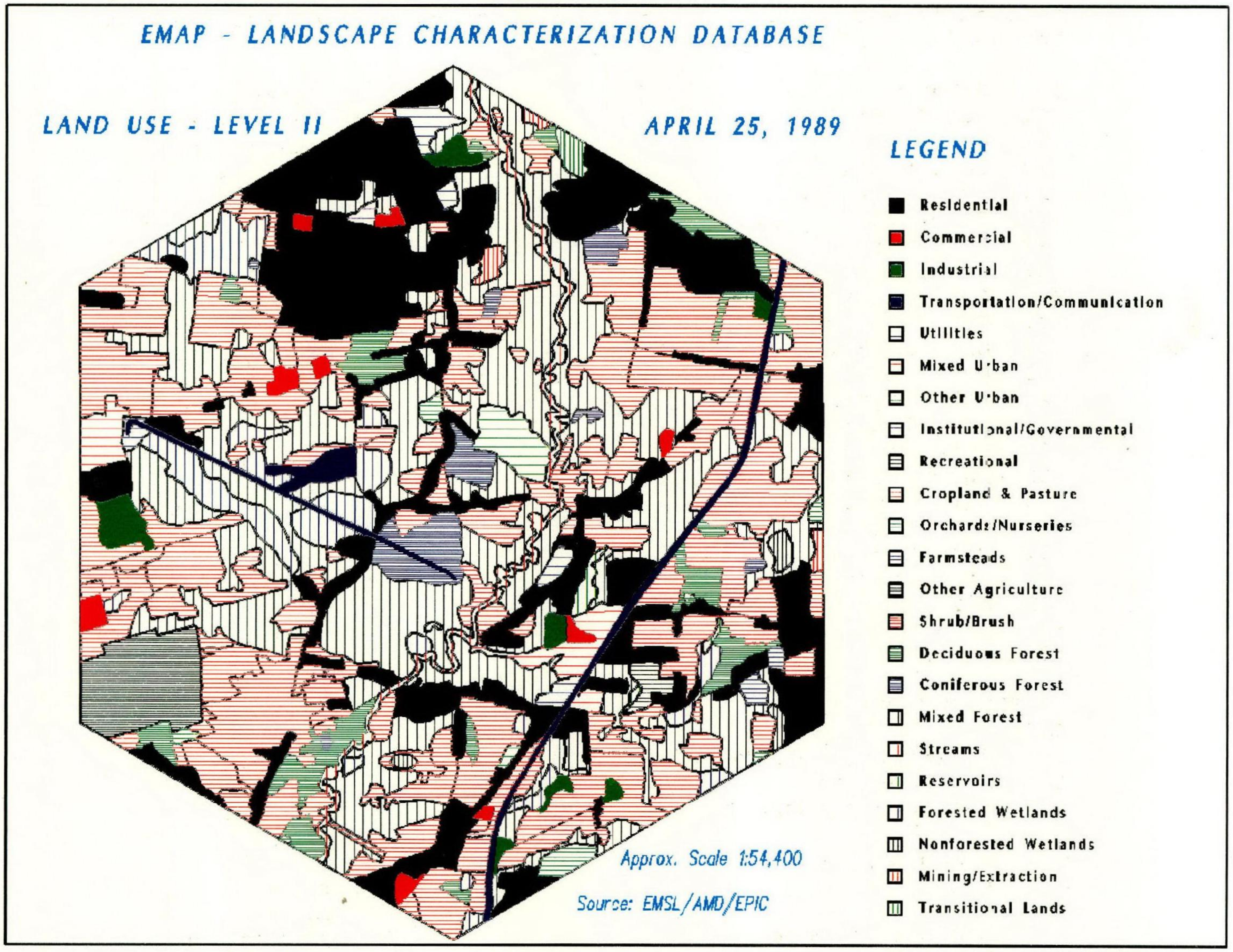
7 Barren Land:
- 71 Dry Salt Flats
- 72 Beaches
- 73 Sandy Non-Beach
- 74 Bare Rock
- 75 Extraction
- 76 Transitional
- 77 Mixed Barren

8 Tundra:
- 81 Shrub/Brush
- 82 Herbaceous
- 83 Bare
- 84 Wet Tundra
- 85 Mixed

9 Snow and Ice:
- 91 Perennial snow
- 92 Glaciers

INTENSITY FACTOR (LAND USE-SPECIFIC CATEGORIES AS DESCRIBED):

Code		for use with:
0	No Intensity Factor	any land use
1	Low Density	Residential
2	Medium-High Density	Residential
3	Suburban	Commercial
4	Urban Central Business	Commercial
5	Light	Industry
6	Heavy	Industry
7	Light Duty Road	Transportation
8	Highway	Transportation
9	Parking Lot	Transportation
10	Row Crop	Agriculture
11	Field Crop	Agriculture
12	Pasture	Agriculture
13	Idle	Agriculture
14	Managed - plantation	Forestry
15	Managed - logging	Forestry
16	Created	Water, Wetland
17	Other (special data entry)	any land use


EMAP - LANDSCAPE CHARACTERIZATION DATABASE
LAND USE - LEVEL II
APRIL 25, 1989
LEGEND
Residential
Commercial
Industrial
Transportation/Communication
Utilities
Mixed Urban
Other Urban
Institutional/Governmental
Recreational
Cropland & Pasture
Orchards/Nurseries
Farmsteads
Other Agriculture
Shrub/Brush
Deciduous Forest
Coniferous Forest
Mixed Forest
Streams
Reservoirs
Forested Wetlands
Nonforested Wetlands
Mining/Extraction
Transitional Lands
Approx. Scale 1:54,400
Source: EMSL/AMD/EPIC

Land Use - Modifications of Substrate, Vegetation and Hydrology

Conventional land use/cover classification and mapping does not consistently classify human-induced alterations of the physical and biological environment, though many modifications are detectable from conventional remote sensing sources. An effort was made to develop a system to identify and classify a number of detectable categories of terrain modification. The following categories were developed:

SUBSTRATE MODIFICATION:

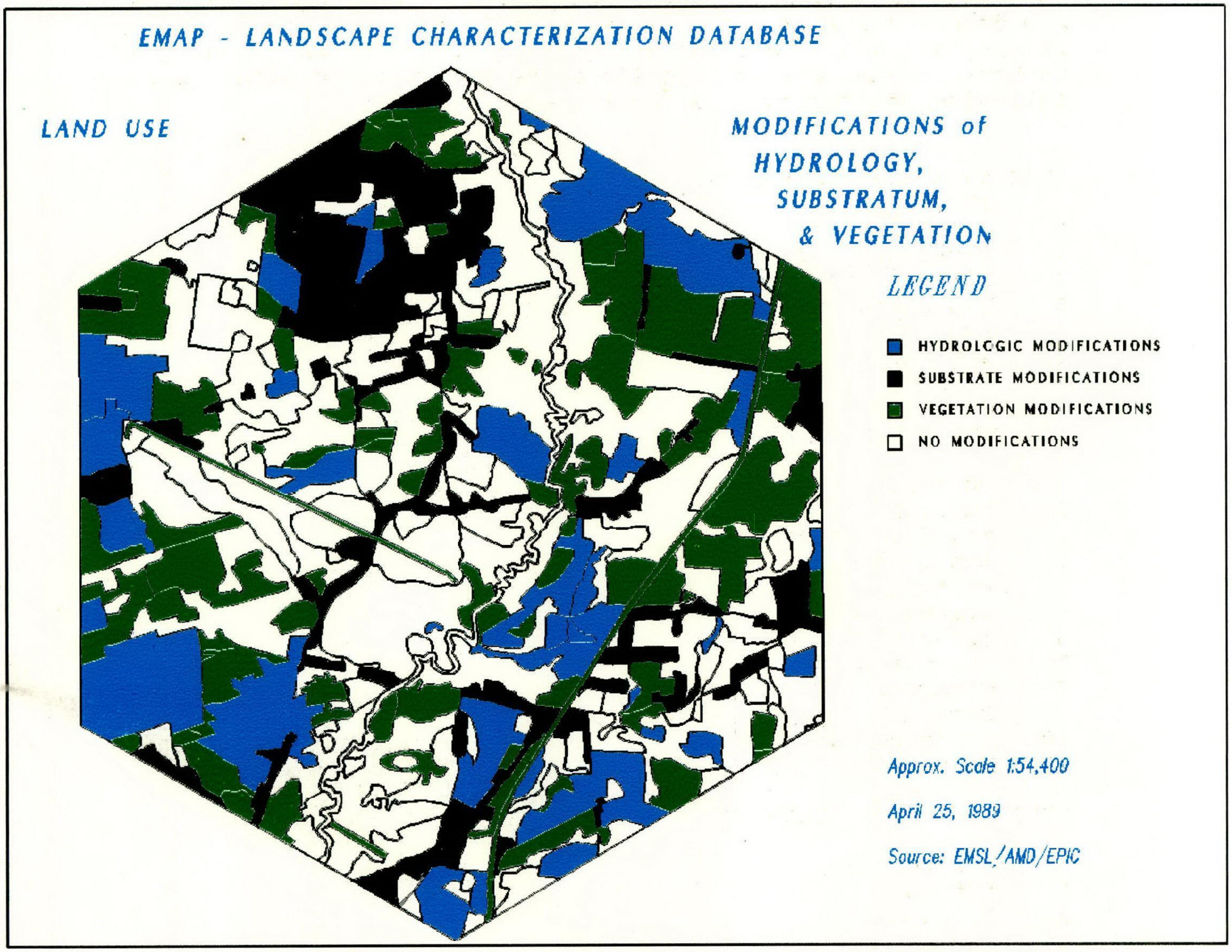
0 Unaltered
1 Paved or Surfaced
2 Fill or Spoil Deposition
3 Waste Deposition (Landfill or Dump)
4 Excavation or Extraction
5 Grading
6 Tilling

VEGETATION MODIFICATION:

0 Unaltered
1 Removal
2 Mowed or Hayed
3 Landscaped
4 Farmed
5 Grazed
6 Plantation
7 Selective Cutting
8 Clear Cut
9 Burned
10 Stressed/Damaged
11 Conversion

HYDROLOGIC MODIFICATION:

0 Unaltered
1 Ditched
2 Irrigated
3 Excavated
4 Impounded, Diked or Dammed


EMAP - LANDSCAPE CHARACTERIZATION DATABASE
LAND USE
MODIFICATIONS of HYDROLOGY, SUBSTRATUM, & VEGETATION
LEGEND
HYDROLOGIC MODIFICATIONS
SUBSTRATE MODIFICATIONS
VEGETATION MODIFICATIONS
NO MODIFICATIONS
Approx. Scale 1:54,400
April 25, 1989
Source: EMSL/AMD/EPIC

EMAP Ecosystem Data Subsets

In the following pages, data subsets representing four of the five EMAP target ecosystems in the study area are portrayed and briefly discussed; because of the study site's inland setting, a near coastal data subset was not produced.

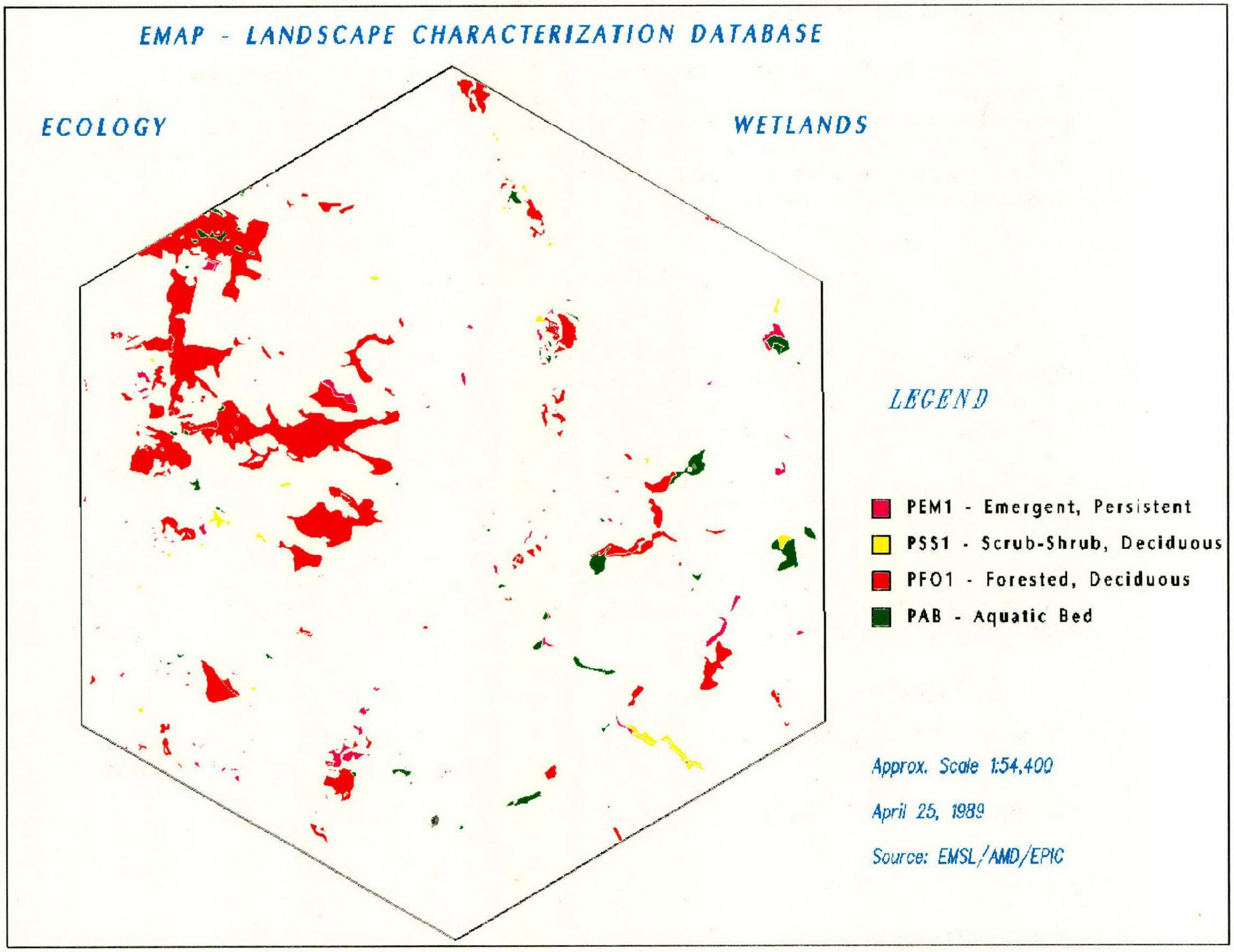
The portrayal of data subsets is one of the most simple functions of a GIS that contains landscape data. Compositing of multiple data layers and subsequent environmental analysis through GIS are potentially large areas of data base design and data management, beyond the scope of this initial characterization study.

INLAND WETLANDS

The figure on the opposite page represents the extent and distribution of inland wetlands within the study area. This local population of wetlands has been classified in one of many potential classification approaches; optimal classification of each ecosystem during characterization will be determined through combined evaluation of EMAP needs and the capabilities of the characterization data source or sensor.

In addition to classification, which can potentially include the full detail of the Cowardin classification system, the following data relevant to wetlands are present in the characterization data base:

Attribute	Category
Substrate Modification	Fill or Spoil Deposition Excavation or Extraction
Vegetation Modification	Removal Mowed or Hayed Farmed Burned
Hydrologic Modification	Ditched Impounded, Diked or Dammed
Physiography - Landforms	Underlying Landform Characteristics
Physiography - Soils	Hydric Soils, Other Soil Characteristics


EMAP - LANDSCAPE CHARACTERIZATION DATABASE
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April 25, 1989
Source: EMSL/AMD/EPIC

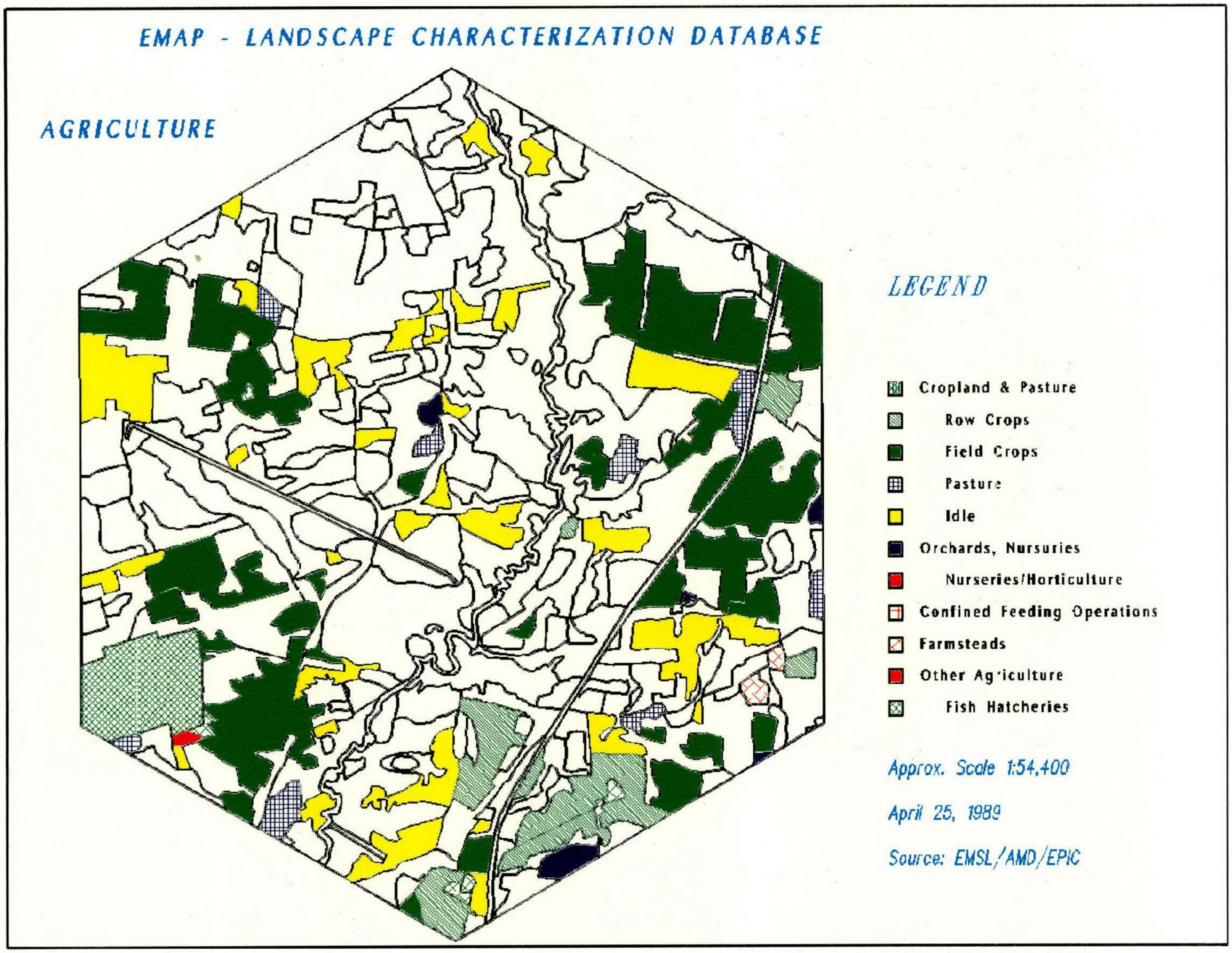
EMAP Ecosystem Data Subsets:

AGROECOSYSTEMS

The figure on the opposite page represents the extent and distribution of agroecosystems within the study area. This local population of agroecosystems has been classified in one of many potential classification approaches; optimal classification of each ecosystem during characterization will be determined through combined evaluation of EMAP needs and the capabilities of the characterization data source or sensor.

In addition to classification, the following data relevant to agroecosystems are present in the characterization data base:

Attribute	Category
Land Use Intensity Factor	Row Crop Field Crop Pasture Idle
Substrate Modification	Excavation Grading Tilling
Vegetation Modification	Removal Mowed or Hayed Farmed Grazed Conversion
Hydrologic Modification	Ditched Irrigated Impounded, Diked or Dammed
Physiography - Landforms	Relevant Landform Characteristics
Physiography - Soils	Standard Soil Survey Information


EMAP - LANDSCAPE CHARACTERIZATION DATABASE
AGRICULTURE
LEGEND
Cropland & Pasture
Row Crops
Field Crops
Pasture
Idle
Orchards, Nursuries
Nurseries/Horticulture
Confined Feeding Operations
Farmsteads
Other Ag'iculture
Fish Hatcheries
Approx. Scale 1:54,400
April 25, 1989
Source: EMSL/AMD/EPIC

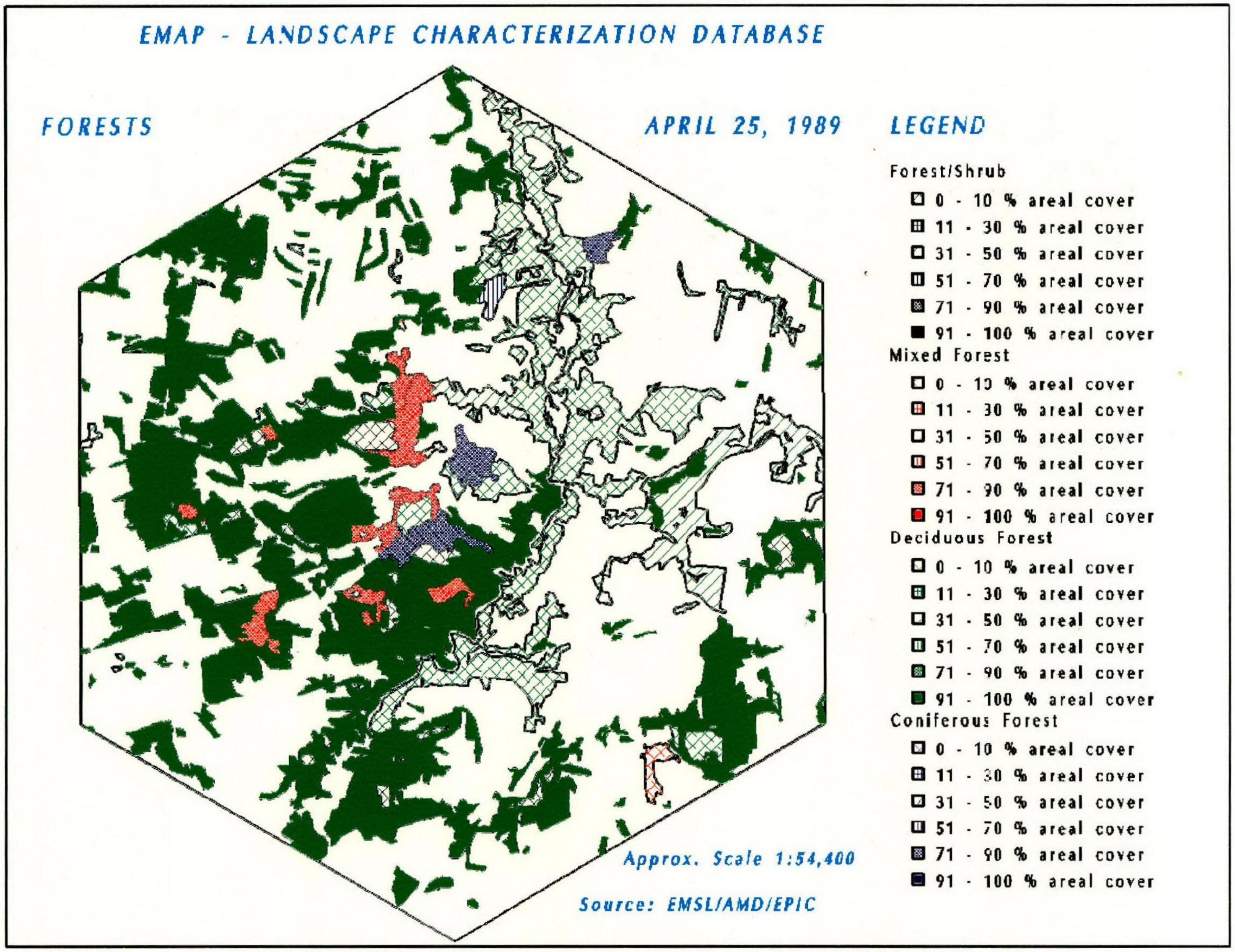
EMAP Ecosystem Data Subsets:

FORESTS

The figure on the opposite page represents the extent and distribution of forests within the study area. This local population of forests has been classified in one of many potential classification approaches; optimal classification of each ecosystem during characterization will be determined through combined evaluation of EMAP needs and the capabilities of the characterization data source or sensor.

In addition to classification, the following data relevant to forests are present in the characterization data base:

Attribute	Category
Vegetation Modification	Removal Plantation Selective Cutting Clear Cut Burned Stressed/Damaged
Physiography - Soils	Standard Soil Survey Information


EMAP - LANDSCAPE CHARACTERIZATION DATABASE
FORESTS
APRIL 25, 1989
LEGEND
Forest/Shrub
0 - 10 % areal cover
11 - 30 % areal cover
31 - 50 % areal cover
51 - 70 % areal cover
71 - 90 % areal cover
91 - 100 % areal cover
Mixed Forest
0 - 10 % areal cover
11 - 30 % areal cover
31 - 50 % areal cover
51 - 70 % areal cover
71 - 90 % areal cover
91 - 100 % areal cover
Deciduous Forest
0 - 10 % areal cover
11 - 30 % areal cover
31 - 50 % areal cover
51 - 70 % areal cover
71 - 90 % areal cover
91 - 100 % areal cover
Coniferous Forest
0 - 10 % areal cover
11 - 30 % areal cover
31 - 50 % areal cover
51 - 70 % areal cover
71 - 90 % areal cover
91 - 100 % areal cover
Approx. Scale 1:54,400
Source: EMSL/AMD/EPIC

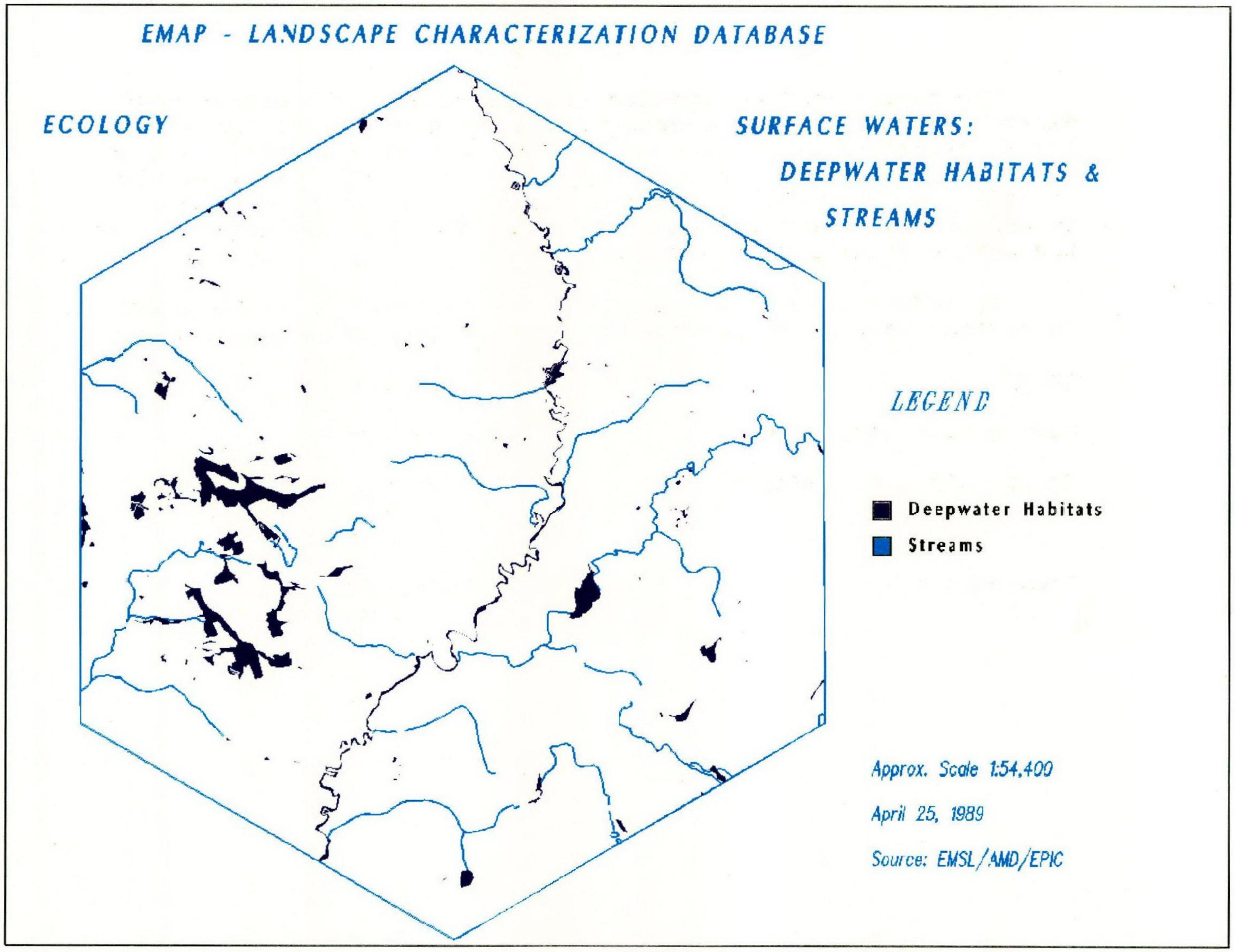
EMAP Ecosystem Data Subsets:

SURFACE WATERS

The figure on the opposite page represents the extent and distribution of surface waters within the study area. This local population of surface waters has been classified in one of many potential classification approaches; optimal classification of each ecosystem during characterization will be determined through combined evaluation of EMAP needs and the capabilities of the characterization data source or sensor.

In addition to classification, the following data relevant to surface waters are present in the characterization data base:

Attribute	Category
Substrate Modification	Excavation
Hydrologic Modification	Ditched Impounded, Diked or Dammed
Physiography	Underlying Landform, Watershed Soils



EMAP - LANDSCAPE CHARACTERIZATION DATABASE
ECOLOGY
SURFACE WATERS:
DEEPWATER HABITATS &
STREAMS
LEGEND
Deepwater Habitats
Streams
Approx. Scale 1:54,400
April 25, 1989
Source: EMSL/AMD/EPIC

Physiographic Characterization Data Set

The physiographic elements of the landscape were derived from two sources: aerial photography and soil surveys. Unlike the land use and ecological attributes previously discussed, physiography in most cases does not change within the temporal span implicit in the EMAP monitoring plan, and therefore is produced one time without requiring periodic update in most regions.

Landforms are interpretable from aerial photography (Liang, 1951; Way, 1973) and provide a general portrayal of surficial geologic and morphological conditions. Soils, especially where a completed soil survey is available, are useful ancillary data for all ecosystem investigations. The following pages illustrate these components of the physiographic characterization process.

Table 3: Physiographic Characterization Attributes
(see Appendix 1 for complete listing)

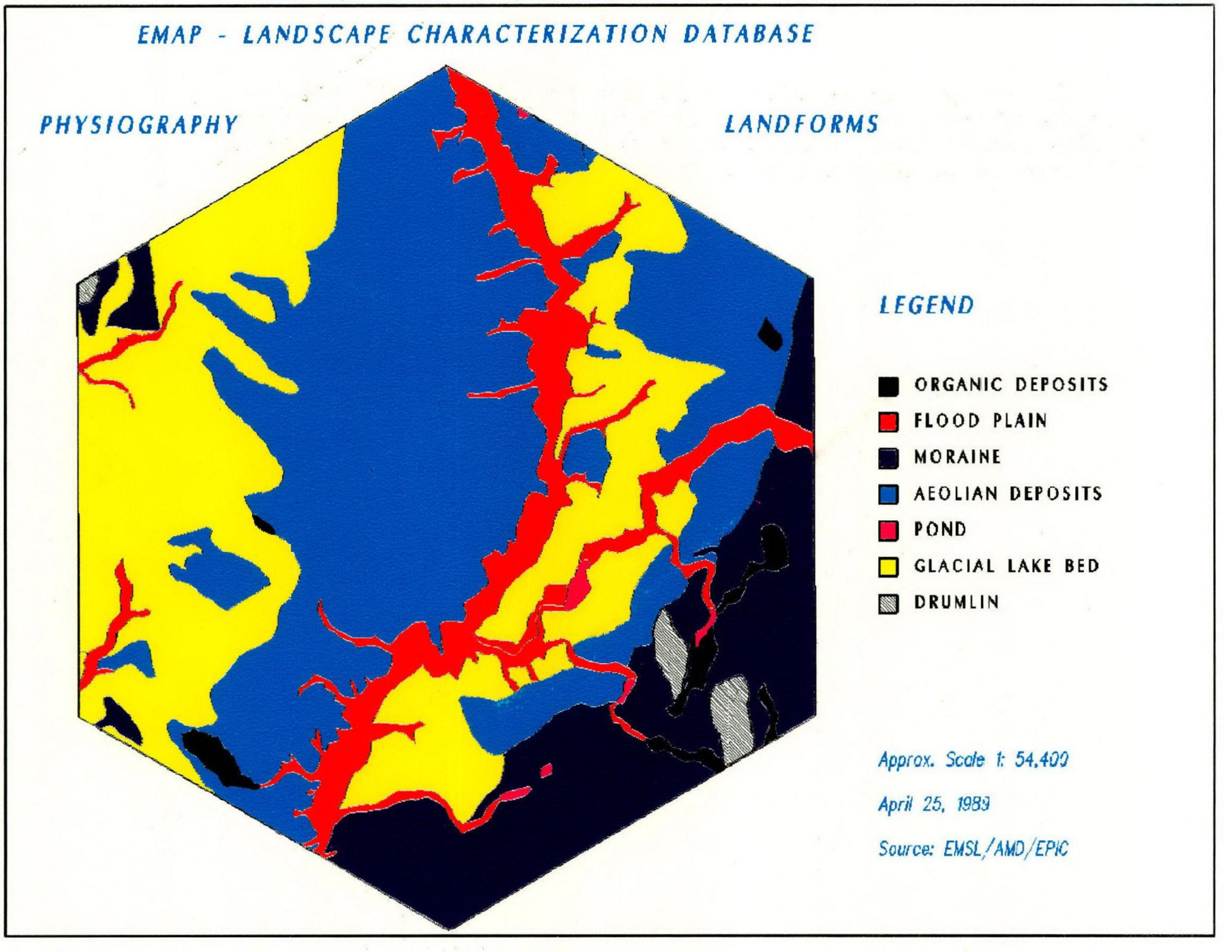
LANDFORM

Sedimentary
Igneous
Metamorphic
Fluvial
Glacial
Aeolian
Other

SOIL TYPE
(after Soil Taxonomy)

LANDFORMS

The study area is located in the glaciated Northeast, accounting for fairly complex terrain dominated by glacial and fluvial landforms. Aeolian deposits, in this location, are the windblown sands of a former glacial lake.


EMAP - LANDSCAPE CHARACTERIZATION DATABASE
PHYSIOGRAPHY
LANDFORMS
LEGEND
ORGANIC DEPOSITS
FLOOD PLAIN
MORAINE
AEOLIAN DEPOSITS
POND
GLACIAL LAKE BED
DRUMLIN
Approx. Scale 1: 54,400
April 25, 1989
Source: EMSL/AMD/EPIC

SOILS

Soil survey maps where available are a primary information source for most natural resources inventory and monitoring activities. The figure shown opposite this page depicts general soil associations only; most modern soil surveys provide soil series, and subcategorize these into types classified on the basis of internal properties and external factors such as slope.

A primary feature of the soils characterization data is the multiple interpretations of soil characteristics, capabilities and use constraints, generally included in county soil surveys. If the soils data layer is present in a GIS, virtually all such interpretations are accessible individually or in combination with ecosystem or other attributes; these interpretations of raw soils data significantly increase the cost-effectiveness of entering these data in a characterization data base. County soil surveys are available for most of the conterminous U.S., and some are already digitized into GIS format.

Some common interpretations of soil type are as follows:

erosion potential
percolation rate
prime cropland
slope
depth to water table
depth to bedrock
agricultural capability unit
seasonal high water table
forest capability unit
drainage class
sand and gravel resources

EMAP - LANDSCAPE CHARACTERIZATION DATABASE

Soil Associations

DISCUSSION

In this study, methods for EMAP characterization were designed and initially tested. Insofar as a trial application of these concepts and methods can indicate, a feasible design option for landscape characterization has been developed and this study's objectives were met. The feasibility of this methodology is supported also by the track record of its component classifications and routine photo interpretation methods. Advantages, disadvantages, and issues that came to light during this project are discussed below.

The advantages of this characterization approach appear to be numerous. If applied regionally or nationally, it is capable of fulfilling the primary EMAP requirement of describing the target ecosystems' population structure and regional nature in an up-to-date manner. It generates units for sampling and baseline measurements of ecological structure that can be repeated to monitor change. The approach is GIS-based and compatible with multiple levels of field and collateral data.

Remote sensing in general offers considerable cost savings over field measurement of spatial characteristics, especially when large amounts of acreage are involved. As the highest resolution remote sensing option, aerial photography potentially can meet or come close to the ecological classification specifications for many of EMAP's program elements. The characterization design is compatible with aggregation or disaggregation of data in a hierarchical manner, and can easily incorporate greater classification detail from field activities. Under average conditions, an aerial approach also enables detection and analysis of two significant types of ecological structure not yet consistently accessible from other remote technology or maps -- vertical structure such as vegetation height, and fine linear features such as stream reaches. Beyond what has been interpreted, the photography will remain a valued source, its uses ranging from reanalysis for a specialized data need to simply carrying aerial photographs in the field.

The photo interpretation process used in this study generates multiple data layers with each phase of analysis; three interpretations create eleven data layers. Digitizing the soil survey is another cost-effective step that adds several more data layers to the characterization data base. Areas for improvement in the interpretation process mainly consist of removing redundancies between the land use/cover phase and the ecological phase, to eliminate possibly contradictory interpretations and streamline production. Though this study's results are in GIS format, the EMAP GIS data base design is not complete and also deserves further development of its potential for optimal data storage, access and analysis.

The variability in some parts of EMAP's target ecosystems will present a challenge to characterization. One aerial photograph's date may capture some landscape data well and miss other attributes that appear in a different season. For example, early spring photography may be optimal for delineating deciduous forested wetlands, but aquatic beds would be better detected in late summer. No one season is optimal, though the majority of characterization attributes can be interpreted in either the spring or summer seasons. A related concern is the high temporal and spatial within-system variability of some ecosystems in some locales; as a snapshot in time, the remote sensing approach sometimes would require significant variation to be addressed. Multitemporal remote data and other sources can contribute to addressing both these concerns.

Because it is sample-based, the approach demonstrated in this study can yield high detail on sample sites without the burden of providing 100%, nationwide coverage. The nationwide approach to characterization would imply significant reduction in classification detail and spatial resolution. Alone this is not a favorable option. Nonetheless, there are benefits for having nationwide, lower resolution satellite background data to accompany and complement the sample site-specific, highly detailed photographic characterization. Larger ecosystems (such as major wetlands or lakes) could be more completely described, and the basic characteristics of greater watersheds and airsheds could be more accessible. Yet the photo-based characterization will still provide the necessary detail at the sample cells, where the greatest level of activity will occur. If different seasons are represented by the different levels of sensor, such as early spring aerial photography paired with summer satellite coverage, seasonal information availability and variation might be of less concern. However, by itself a less detailed and lower resolution approach to characterizing the sample cells would fall far short of the level of ecological detail required by the EMAP ecosystem monitoring teams.

In summary, the approach designed in this study is potentially operational and would benefit from pilot testing and evaluation. Because of this methodology's adherence to fully operational data sources and analysis methods and its use of standard classification systems, many potential obstacles to implementation are not present. This characterization option needs review, refinement and streamlining, but it is not an experimental approach in need of a significant research and development investment before implementation. The issues noted above should be explored and evaluated, with the intent to implement a sound characterization design and process. The final approach will benefit from looking beyond the immediate needs for baseline characterization toward optimizing the data base's near- and long-term potential for other uses, in order to maximize the return on EMAP's characterization effort.

REFERENCES

Aerial Photographs:

DATE	AGENCY	MISSION CODE	AGENCY FRAME #	ORIG. SCALE	EPIC FRAME #
April 25, 1989	EPA[1]	89/024	001-052	1:24,000	89/024: 001-052

Literature:

Anderson, J.R., E.E. Hardy, J.S. Roach and R.D. Witmer. 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data; U. S. Department of Interior, Geological Survey Professional Paper 964. 28 pp.

Cowardin, L.M., V. Carter, F.C. Golet and E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States; U. S. Fish and Wildlife Service, Office of Biological Services, Washington, DC. FWS/OBS-79/31. 130 pp.

Liang, T. 1951. Landform Reports: A Photo-Analysis Key for the Determination of Ground Conditions; Cornell University, Ithaca, NY. Vol. 1 - 6.

Way, D.S. 1973. Terrain Analysis; McGraw-Hill, NY. 438 pp.

Maps:

SOURCE	NAME	SCALE	DATE
USGS[2]	Broad Brook, CT	1:24,000	1964, photorev. 1984

[1] United States Environmental Protection Agency

[2] U. S. Geological Survey, U. S. Department of Interior

APPENDICES

APPENDIX 1: CHARACTERIZATION CATEGORIES LIST

****
LAND USE ATTRIBUTES
****

LAND USE TYPE:
(TWO-DIGIT CODES ADAPTED FROM USGS PAPER 964 LAND USE CLASSIFICATION)

1	Urban	11	Residential
		12	Commercial
		13	Industrial
		14	Transportation
		15	Indust/Comm Complexes
		16	Mixed Urban
		17	Other Urban
2	Agricultural	21	Cropland and Pasture
		22	Orchards, Vineyards, Nurseries
		23	Confined Feeding Operations
		24	Other Agricultural Land
3	Rangeland	31	Herbaceous Rangeland
		32	Shrub/Brush Rangeland
		33	Mixed Rangeland
4	Forest Land	41	Deciduous
		42	Evergreen
		43	Mixed
5	Water	51	Streams
		52	Lakes
		53	Reservoirs
		54	Bays and Estuaries
6	Wetlands	61	Forested
		62	Nonforested
7	Barren Land	71	Dry Salt Flats
		72	Beaches
		73	Sandy Non-beach Areas
		74	Bare Exposed Rock
		75	Mining/Extraction
		76	Transitional Lands
		77	Mixed Barren Land
8	Tundra	81	Shrub and Brush Tundra
		82	Herbaceous Tundra

		83	Bare Ground Tundra
		84	Wet Tundra
		85	Mixed Tundra
9	Perennial Snow and Ice	91	Perennial Snowfields
		92	Glaciers

INTENSITY FACTOR (LAND USE-SPECIFIC CATEGORIES AS DESCRIBED):

Code		for use with:
0	No Intensity Factor	any land use
1	Low Density	Residential
2	Medium-High Density	Residential
3	Suburban	Commercial
4	Urban Central Business	Commercial
5	Light	Industry
6	Heavy	Industry
7	Light Duty Road	Transportation
8	Highway	Transportation
9	Parking Lot	Transportation
10	Row Crop	Agriculture
11	Field Crop	Agriculture
12	Pasture	Agriculture
13	Idle	Agriculture
14	Managed - plantation	Forestry
15	Managed - logging	Forestry
16	Created	Water, Wetland
17	Other (special data entry)	any land use

SUBSTRATE MODIFICATION:

0	Unaltered
1	Paved or Surfaced
2	Fill or Spoil Deposition
3	Waste Deposition (Landfill or Dump)
4	Excavation or Extraction
5	Grading
6	Tilling

VEGETATION MODIFICATION:

0	Unaltered
1	Removal
2	Mowed or Hayed
3	Landscaped
4	Farmed
5	Grazed
6	Plantation
7	Selective Cutting
8	Clear Cut

9 Burned
10 Stressed/Damaged
11 Conversion

HYDROLOGIC MODIFICATION:

0 Unaltered
1 Ditched
2 Irrigated
3 Excavated
4 Impounded, Diked or Dammed

****
ECOLOGICAL ATTRIBUTES
****
VEGETATION TYPE:

0 Unvegetated
1 Aquatic Vegetation
2 Herbaceous
3 Shrub/Herb
4 Shrub, Deciduous
5 Shrub, Evergreen
6 Forest/Shrub
7 Mixed Forest
8 Forest, Deciduous
9 Forest, Evergreen

SUBSTRATE:

0 Artificial Surface
1 Soil or Sand
2 Gravel/Cobble
3 Rock

HYDROLOGY: (Adapted from Cowardin et al., 1979; for detail beyond system level shown here, see Appendix 2)

0 Upland
1 Wetland, Palustrine
2 Wetland, Lacustrine
3 Wetland, Riverine
4 Wetland, Estuarine
5 Wetland, Marine
6 Deepwater Habitat, Riverine
7 Deepwater Habitat, Lacustrine
8 Deepwater Habitat, Estuarine
9 Deepwater Habitat, Marine
10 Deepwater Habitat, Palustrine

VEGETATION DENSITY:

0 0 - 10% Areal Cover

1 10 - 30% Areal Cover
2 30 - 50% Areal Cover
3 50 - 70% Areal Cover
4 70 - 90% Areal Cover
5 90 - 100% Areal Cover

VEGETATION HEIGHT:

0 Less Than 6 Feet
1 6 - 20 Feet
2 20 - 60 Feet
3 > 60 Feet

****
Physiography
****

LANDFORMS AND PHYSIOGRAPHIC FEATURES

I. Sedimentary Rock Landforms
- Flat-lying Sedimentary Rock Landforms
  - Sandstone Plain
  - Sandstone Plateau
  - Shale Plain
  - Shale Plateau
  - Limestone Plain
  - Limestone Plateau
- Tilted Sedimentary Rock Landforms
  - Anticlinal Ridge
  - Anticlinal Valley
  - Synclinac Ridge
  - Synclinac Valley
  - Homoclinac Ridge
  - Homoclinac Valley

II. Igneous Rock Landforms
- Intrusive Igneous Rock Landforms
  - Batholith
  - Sills and Dikes
- Extrusive Igneous Rock Landforms
  - Lava Flows
  - Fragmental Rock Deposits
  - Volcanic Mountains

III. Metamorphic Rock Landform

IV. Fluvial Landforms
- Alluvial Fan
- Filled Valley
- Flood Plain
- Lacustrine Plain
- Playa Plain
- Coastal Plain

Terrace
Beach
Beach Ridge
Tidal Flat
Delta
Organic Deposits

V. Glacial Landforms
- Till Landforms
  - Moraine
  - Drumlin
  - Till Plain
- Ice-contact Stratified Drift Landforms
  - Esker
  - Kame
- Outwash Landforms
  - Outwash Plain
  - Valley Train
  - Outwash Terrace
  - Kettle
- Glacio-lacustrine Landform
- Glacial Lake Bed
- Glacial Beach Ridge
- Glacial Delta

VI. Aeolian Landforms
- Sand Dune
- Loess Plain
- Aeolian Deposits

VII. Water Bodies
- River
- Pond
- Lake
- Ocean

VIII. Miscellaneous Landforms
- Periglacial Structures
- Mass Wasting

APPENDIX 2: WETLANDS AND DEEPWATER HABITATS CLASSIFICATION (after Cowardin et al., 1979)

Introduction

The Classification of Wetlands and Deepwater Habitats (Cowardin et al., 1979) is a hierarchical, ecologically based classification system. The complete system is too complex to diagram on a single page. For summary purposes, the system is broken into three parts represented in the following pages. The first part is a tree diagram, reproduced from the Cowardin publication, that details the classification process through the more general levels of system, subsystem, and class. The second part, also reproduced from Cowardin, is a list of subclasses found in association with each class. The third part is a list of modifiers, which are used in the most detailed application of the system to add ancillary data about each wetland.

As a hierarchical system, the Cowardin scheme is adaptable for use on any of its hierarchical levels, and amenable to further refinement efforts by its users.

SYSTEMS, SUBSYSTEMS AND CLASSES
(reproduced from Cowardin et al., 1979, p. 5)

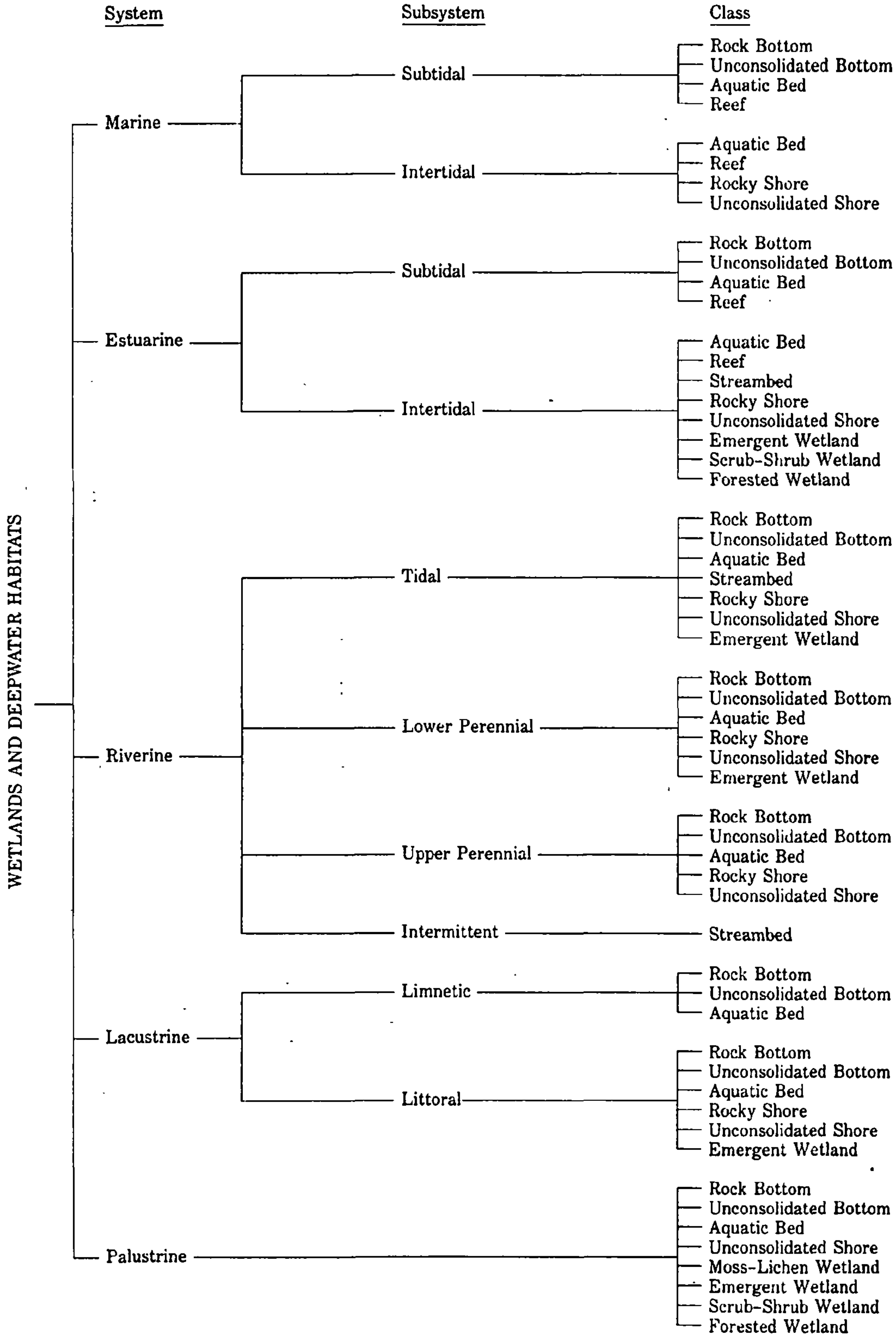


Fig. 1. Classification hierarchy of wetlands and deepwater habitats, showing Systems, Subsystems, and Classes. The Palustrine System does not include deepwater habitats.

SUBCLASSES
(reproduced from Cowardin et al., 1979, p. 6-7)

Table 1. *Distribution of Subclasses within the classification hierarchy.*

	System and Subsystem[a]										
	Marine		Estuarine		Riverine				Lacustrine		Palustrine
Class/Subclass	ST	IT	ST	IT	TI	LP	UP	IN	LM	LT	–
Rock Bottom											
Bedrock	X		X		X		X		X	X	X
Rubble	X		X		X		X		X	X	X
Unconsolidated Bottom											
Cobble-Gravel	X		X		X	X	X		X	X	X
Sand	X		X		X	X	X		X	X	X
Mud	X		X		X	X	X		X	X	X
Organic			X		X	X			X	X	X
Aquatic Bed											
Algal	X	X	X	X	X	X	X		X	X	X
Aquatic Moss					X	X	X		X	X	X
Rooted Vascular	X	X	X	X	X	X	X		X	X	X
Floating Vascular			X	X	X	X	X		X	X	X
Reef											
Coral	X	X									
Mollusk			X	X							
Worm	X	X	X	X							
Streambed											
Bedrock				X	X			X			
Rubble				X	X			X			
Cobble-Gravel				X	X			X			
Sand				X	X			X			
Mud				X	X			X			
Organic				X	X			X			
Vegetated								X			
Rocky Shore											
Bedrock		X		X	X	X	X			X	
Rubble		X		X	X	X	X			X	
Unconsolidated Shore											
Cobble-Gravel		X		X	X	X	X			X	X
Sand		X		X	X	X	X			X	X
Mud		X		X	X	X	X			X	X
Organic		X		X	X	X	X			X	X
Vegetated					X	X	X			X	X
Moss-Lichen Wetland											
Moss											X
Lichen											X
Emergent Wetland											
Persistent				X							X
Nonpersistent				X	X	X	X			X	X
Scrub-Shrub Wetland											
Broad-leaved Deciduous				X							X
Needle-leaved Deciduous				X							X
Broad-leaved Evergreen				X							X
Needle-leaved Evergreen				X							X
Dead				X							X
Forested Wetland											
Broad-leaved Deciduous				X							X
Needle-leaved Deciduous				X							X
Broad-leaved Evergreen				X							X
Needle-leaved Evergreen				X							X
Dead				X							X

[a] ST = Subtidal, IT = Intertidal, TI = Tidal, LP = Lower Perennial, UP = Upper Perennial, IN = Intermittent, LM = Limnetic, LT = Littoral.

Wetlands and Deepwater Habitats
MODIFIERS
(from Cowardin et al., 1979)

Water Regime Modifiers

Tidal:
- Subtidal
- Irregularly Exposed
- Regularly Flooded
- Irregularly Flooded

Nontidal:
- Permanently Flooded
- Intermittently Exposed
- Semipermanently Flooded
- Seasonally Flooded
- Saturated
- Temporarily Flooded
- Intermittently Flooded
- Artificially Flooded

Water Chemistry Modifiers

Inland:
- Hypersaline
- Eusaline
- Mixosaline
  - Polysaline
  - Mesosaline
  - Oligosaline
- Fresh

Coastal:
- Hyperhaline
- Euhaline
- Mixohaline
  - Polyhaline
  - Mesohaline
  - Oligohaline
- Fresh

Soil Chemistry Modifiers

pH:
- Acid
- Circumneutral
- Alkaline

Special Modifiers

- Excavated
- Impounded
- Diked
- Partly Drained
- Farmed
- Artificial