

3.0 FOUNDATION PROGRAMS FOR THE DELAWARE CEMRI FRAMEWORK

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A complete review of all the national monitoring programs that could possibly contribute to the Delaware River Basin (DRB) CEMRI Framework is beyond the scope of this report. The U.S. Environmental Protection Agency (EPA) Mid-Atlantic Integrated Assessment developed a Web-based annotated inventory of such monitoring programs for the mid-Atlantic region. Olsen et al. (1999) also provide a detailed assessment of the major national environmental surveys and how they might be integrated. Presented below is a brief description of the major monitoring programs that were used to initiate the Delaware CEMRI and that served as foundation programs for the core of the framework in the DRB.

3.1 Tier 1: Intensive Monitoring and Research Areas (IMRAs)

Areas of intensive multidisciplinary research were limited within the DRB before the CEMRI, but were sufficient to serve as a base program for three IMRAs in forested landscapes (Fig. 3.1). Participating agencies agreed to conduct collaborative monitoring and research at temporal and spatial scales sufficient to assess the processes and controlling factors relevant for one or more of the environmental issues selected for analysis. A brief description of the existing infrastructure on which the IMRAs were established is presented here.

3.1.1 USGS Neversink Research Watershed, New York

The USGS maintains several field offices throughout the U.S. where watershed research and basic monitoring of surface and ground waters are conducted. The program in the DRB provides not only several long- and short-term research projects that contributed data or infrastructure to the CEMRI pilot, but also a network of stream discharge and water quality stations that generate long-term data for tracking trends. The USGS New York District research program has been conducting studies on streams draining forested watersheds in the Neversink River Basin since 1982 and has established a set of 12 nested discharge and water quality monitoring stations on watersheds ranging from 130 to 1 km² in area. Past projects in the Neversink Basin established detailed monitoring programs for forest condition, soil condition (chemistry, pedology, and temperature), soil water quality, stream volume and quality, deposition volume and quality, and climate variables. Deposition, ground water, soil water, and snowmelt monitoring equipment are also operating in the Neversink IMRA as part of various research projects. A research laboratory for processing low-ionic strength water samples is located in the New York District office in Troy, New York. For this region the longest records of discharge and water quality, including total organic carbon (TOC), dissolved organic carbon (DOC) concentrations, base cations, and acid anions are on the main stem Neversink River above the Neversink Reservoir (50 years of record); two headwater stations have 20 years of water quality and discharge data and several other sites have up to 12 years of records.

The Neversink watershed also serves as an analog for other northeastern forests experiencing disturbances such as acidification, soil calcium (Ca) depletion, and forest pest infestation. These issues were among those chosen for testing the collaborative strategy in the DRB.

The Catskill Mountains receive the highest rates of acidic deposition in the Northeast US. (Murdoch et al. 2000), and soil base cation concentrations are among the lowest reported

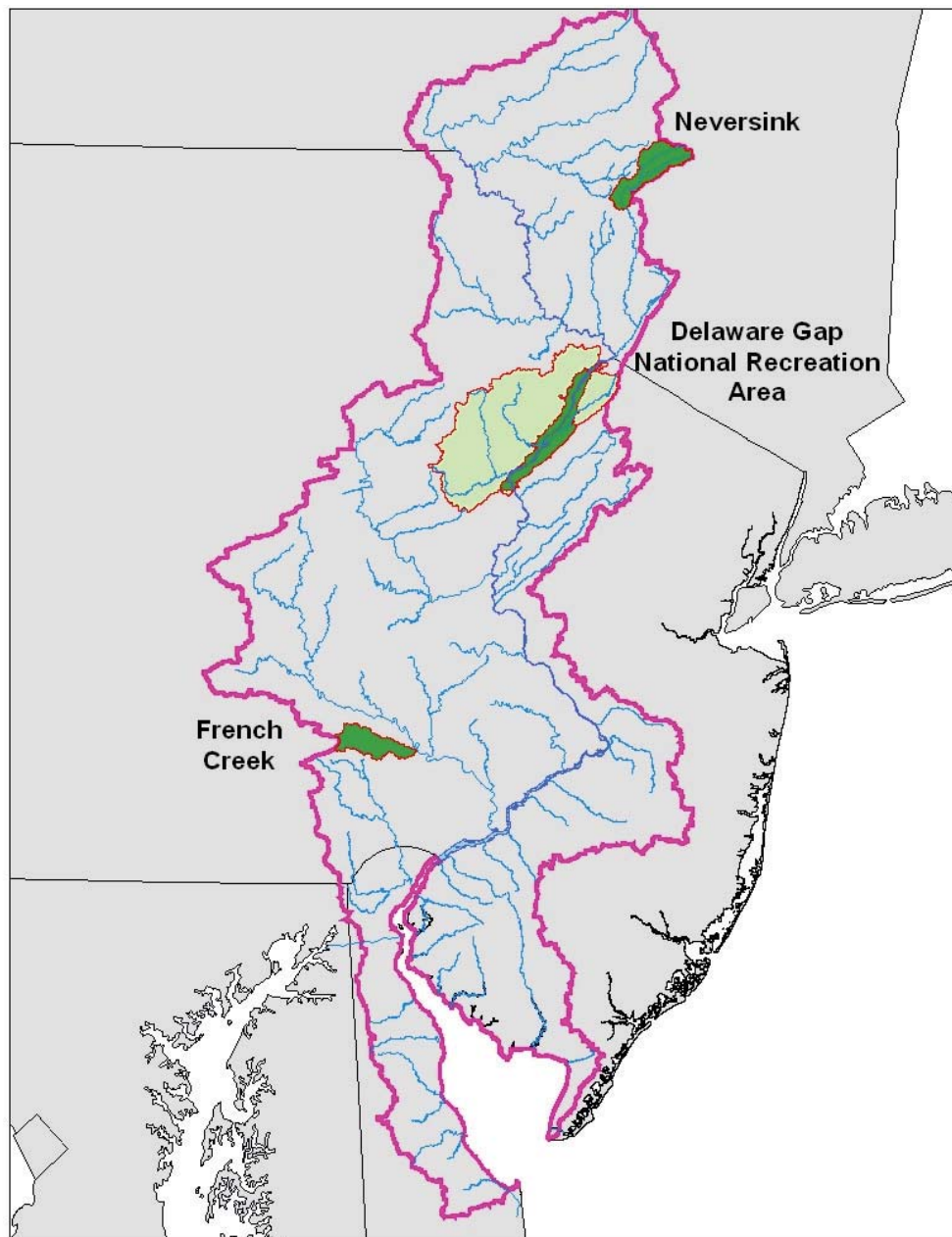


Figure 3.1.—Locations of intensive monitoring and research areas (IMRAs) within the Delaware River Basin.

for the region (Lawrence et al. 1994). Data on episodic changes in stream chemistry have been collected since the mid-1980s. The hemlock woolly adelgid was first observed in the watershed in 2003, allowing researchers to assess both pre- and early-infestation hemlock condition, and girdling experiments within the watershed have simulated the effects of hemlock death on soil chemistry and runoff (Yorks 2001). Logging studies in small sub-catchments of the Neversink Watershed were underway before the CEMRI to determine the threshold percentage of basal area removal above which large amounts of nitrogen (N) are released to surface waters from the logged area. This combination of historical record, monitoring infrastructure, and the availability of landscapes affected by the issues being addressed was the basis for selecting the Neversink River Basin as an IMRA.

3.1.2 Delaware Gap National Recreation Area (DEWA)

Before the CEMRI, the National Park Service (NPS) had established special forest plots at the DEWA for studying the effects of the hemlock woolly adelgid. Fourteen pairs of hemlock and hardwood stands (28 stands total) within DEWA had been selected based on a detailed landscape analysis to maximize similarities of landscape setting between the pairs. Soil and surface water chemistry, forest condition, and invasive species have been documented, and ongoing research and monitoring at the plots was funded through the first 2 years of the CEMRI timeframe. The CEMRI used this paired plot network to establish the DEWA IMRA for forest carbon (C) and invasive pest research. The NPS also has a legal mandate to monitor water quality in streams draining through the DEWA and to take actions to ensure no net degradation of water quality. The park established “boundary control points,” where tributaries to the Delaware River cross the boundary between the DEWA and the private headwaters, as the monitoring points for this mandate. A program of periodic stream discharge and water quality measurement was established through joint USGS-NPS funding during the CEMRI. This program was enhanced by the CEMRI to provide process-level data for the forest fragmentation issue.

3.1.3 The French Creek Watershed, Pennsylvania

French Creek is a tributary of the Delaware River that drains a rapidly suburbanizing watershed west of Philadelphia. Although intensive site research on the effects of forest fragmentation on ecosystem health was not well established within the Delaware Basin before the CEMRI, surface water quality monitoring in rivers such as French Creek, draining landscapes representing a range of disturbances, had been established in several locations by the USGS National Water Quality Assessment (NAWQA) program and other long-term monitoring programs (see Tier 2 foundation programs). The pre-development landscape of French Creek was approximately 40 percent agricultural and 60 percent forest, and the rapid suburbanization made it an excellent field laboratory for assessing the effects of forest fragmentation on river water quality. A USGS stream gauging station on French Creek near its junction with the Schuylkill River in Phoenixville, Pennsylvania, has been monitored for discharge and water quality since 1996 as part of the NAWQA program. Changes in land use since the 1940s were documented by a separate USGS project before and during the CEMRI for the French Creek Watershed (http://mcmcweb.er.usgs.gov/de_river_basin). The Hopewell Furnace National Historic Site, owned by the NPS, is also located within the French Creek IMRA, ensuring that some protected long-term forest research plots would be available in the French Creek Watershed for the CEMRI network.

3.1.4 The USGS National Water Quality Assessment Program (NAWQA)

The NAWQA program was designed to assess the status and trends in the Nation’s ground water and surface water quality and to determine the human-induced causes of water quality degradation (Gilliom et al. 1995). The basic NAWQA monitoring program included a network of deterministically selected integrator stations on large rivers with multiuse watersheds, indicator stations on medium-scale rivers with watersheds dominated by a single use, and multiple survey-sampling sites that represent a gradient of exposure to a specific land use (Fig. 3.2). The NAWQA monitoring program includes several water quality parameters, including major ions, nutrients, pesticides, and metals; ecological parameters including fish, invertebrate, and algae; and habitat condition. The type of measurements made varies depending on the site type, but the NAWQA program provides an overall baseline dataset for tracking biological and biogeochemical indicators in aquatic environments of the DRB.

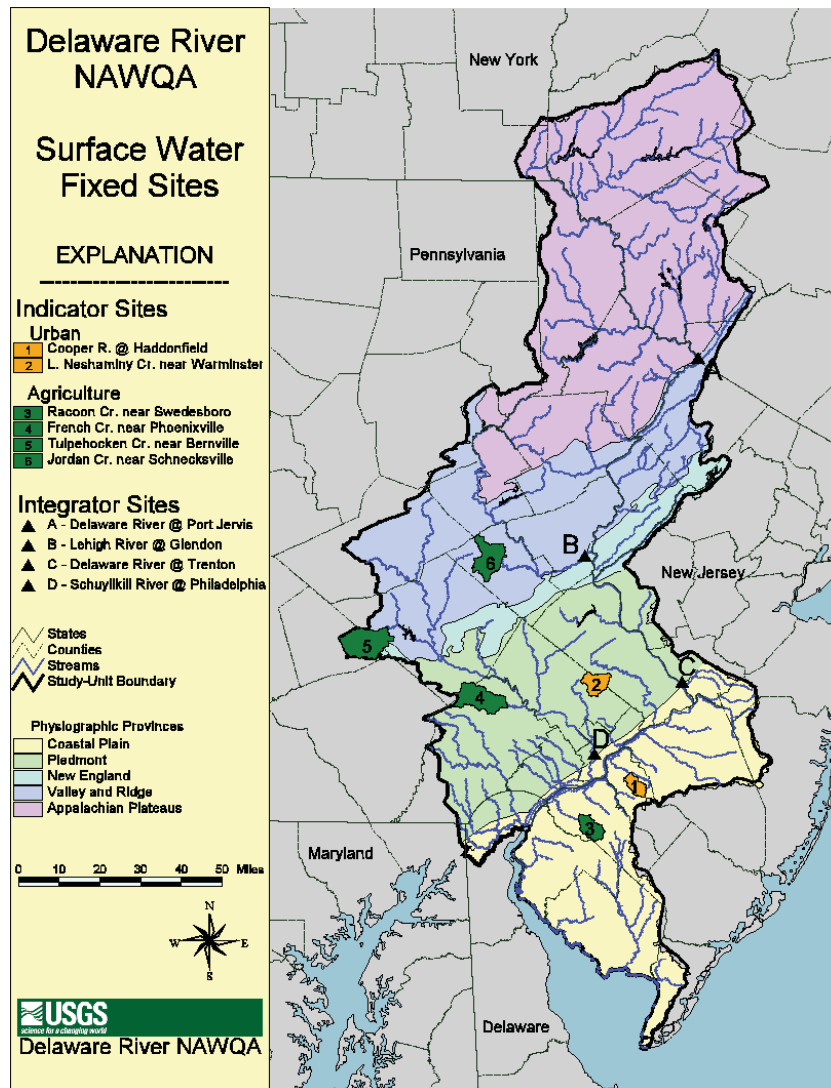


Figure 3.2.—National Water Quality Assessment program stations in the Delaware River Basin. (From Fischer et al. 2004)

Originally 60 mesoscale rivers were selected as the integrating unit for the program, and a 7-year rotational cycle was used to assess 20 of those rivers at a time (Gilliom et al. 1995). Discharge and water quality monitoring stations have been operated since 1996 or longer in support of NAWQA on the main-stem Delaware River at Trenton, New Jersey, and on several tributary rivers draining watersheds representing a range of agricultural and suburban landscapes. The USGS has been tracking discharge since 1912 and water quality since the mid-1960s at the Trenton station (Fischer et al. 2004). Detailed measurement of chemical and sediment exports at the Trenton gauge allows the estimation of chemical exports in surface water for most of the DRB, and thus creates a frame of reference for balancing estimates of C and N flux from the watershed. The Delaware River at Trenton was therefore selected as the largest integrating unit for determining the CEMRI regional C budget.

3.1.5 The National Park Service Vital Signs Monitoring Program

At the time of the CEMRI, the NPS Vital Signs program was being designed to track sentinel species and environmental parameters for early detection of environmental degradation. Monitoring sites for this program included park lands in two of the three

IMRAs selected for intensive study (Hopewell Furnace in the French Creek headwaters and DEWA) in the CEMRI assessment. The CEMRI was therefore designed with the needs of this foundation program in mind. Vital Signs monitoring will focus on biological indicators, including herbaceous vegetation and fauna sensitive to environmental change (Marshall and Piekielek 2007).

3.2 Tier 2: Gradient Study Sites

Gradient study sites are points of data collection representing a range of conditions for a specific issue. The intensity and ecological comprehensiveness of the sampling protocol depend upon the issue being addressed and the temporal variability of the parameters being measured. Foundation programs were sought for the Delaware CEMRI that either provided regional gradient datasets from previous studies that could be used to support the CEMRI assessments, or that established networks of sites within the DRB that CEMRI investigators could visit, thus avoiding site installation costs and capturing ancillary data useful to the investigations. These programs are described briefly below.

3.2.1 USGS NAWQA Program Synoptic Stations

As part of the Delaware NAWQA program, the USGS established fixed-site data collection stations on 43 streams representing a range of development in the surrounding watersheds. Water quality and channel condition data were collected at these “synoptic” stations both before and during the CEMRI through NAWQA funding and thus provided a cost-effective base for developing landscape disturbance data that could be correlated with the available river disturbance data from the NAWQA program. The cyclic nature of the NAWQA program also made it likely that these sites would be measured periodically (Fischer et al. 2004).

3.2.2 US Forest Service Hyperspectral Methods Development Project

The USFS Research Laboratory in Durham, New Hampshire, has been studying the use of hyperspectral imagery for determining forest condition and foliar chemistry in the White Mountains of New Hampshire and the northern DRB in New York. As part of that study, samples were collected from soil and foliage at plots representing a range of soil nutrient status. These data, collected before the CEMRI, were used to assess the relationship between foliar Ca and available soil Ca without the expense of a gradient-based sampling program (R. Hallet, U.S. Forest Service, oral communication, 2002).

3.2.3 DEWA Hemlock Decline Plots

The forest research plots established by the NPS at DEWA also represented a gradient of infestation and dieback from hemlock woolly adelgid. These plots were used by CEMRI investigators to correlate soil and runoff chemistry to hemlock decline and assess the potential environmental parameters that either encourage or slow adelgid infestation (R. Evans, National Park Service, oral communication, 1999).

3.2.4 Forest Fragmentation and Suburban Development Study

Rapid suburbanization just outside the borders of the DEWA is a concern to NPS managers because of the potential effects of suburban development on the water entering and exiting the park. To quantify the relationships between forest fragmentation and water quality, three watersheds representing a gradient of residential development were established for study (see chapter on forest fragmentation).

3.3 Tier 3: Regional Surveys

Several established regional survey programs were available in the Delaware Basin as foundation programs for Tier 3 monitoring in forested landscapes. Each survey network is briefly described here.

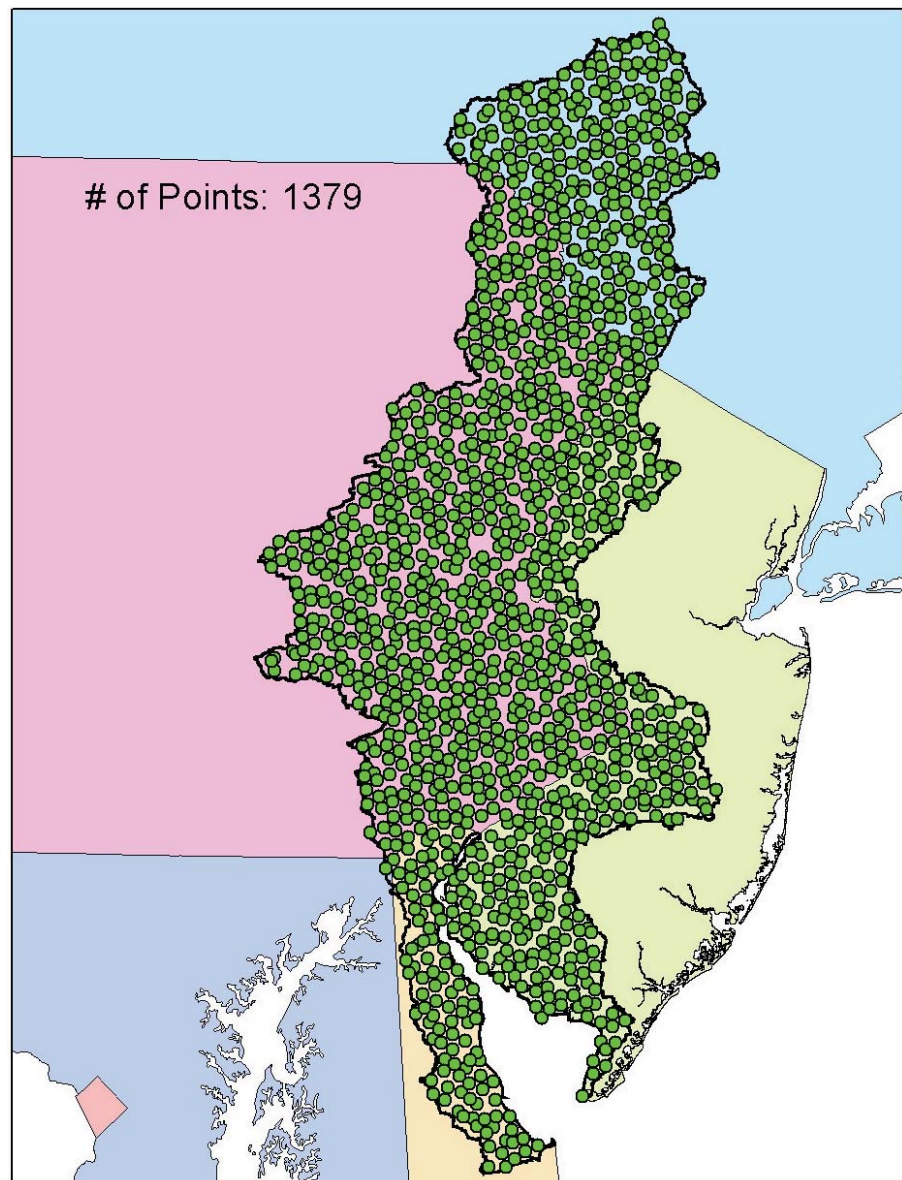


Figure 3.3.—Forest Inventory and Analysis plots in the Delaware River Basin drainage area, as of 2001.

3.3.1 Forest Inventory and Analysis (FIA)

FIA provides periodic assessments of the amount, status, and character of the forest resources of the Nation. Since World War II, U.S. forest inventories have used multiphase sampling designs involving remote sensing and ground measurements (Birdsey and Schreuder 1992, Schreuder et al. 1995). Historically, the phase 1 sample consisted of interpretation of high-altitude color infrared photography or other aerial photography, widely available and highly accurate for estimating changes in forest area and locating field sample plots. In recent years the phase 1 area estimate has been made from satellite imagery, typically the Landsat Thematic Mapper. The phase 2 sample consists of more than 150,000 permanent field sample locations that are remeasured periodically (typically once every 5 to 7 years) to provide statistics on disturbance (e.g., harvest, mortality), growth, species composition change, and a host of observed and calculated site descriptors such as ownership and forest type. These measurements are then expanded to the population level using the statistics from the phase 1 sample. Currently there are 1,379 phase 2 sample plots in the DRB (Fig. 3.3).

A third sample phase (formerly known as Forest Health Monitoring) is the basis for more intensive ecosystem measurements. Data on soils, coarse woody debris, understory vegetation, and other ecological variables are collected on these plots, which are linked statistically to the phase 1 and 2 samples. Phase 3 consists of approximately 5,000 sample plots nationally and about 50 sample plots in the DRB. At the intensive research sites in the DRB, and at selected locations in the Allegheny Plateau, about 50 supplemental phase 3 plots were established to increase the sample size. Additional measurements were taken at these plots to provide more complete ecosystem productivity and carbon estimates (described in a later chapter).

3.3.2 Forest Health Protection (FHP)

Disturbance from pests and disease is tracked on a network of State-monitored plots to provide data on the regional extent of pest infestation. Site selection for this network is based on presence/absence of pests. Measurements include pest presence/absence, infestation, and forest condition. (www.fs.fed.us/foresthealth)

3.3.3 USFS Northern Global Change Research Program (NGCP)

The NGCP is a USFS research program dedicated to understanding, predicting, and mitigating the effects of air pollution and climate change on northern forest ecosystems. This program has national responsibility for estimating how much carbon dioxide (CO₂) is taken up and released by U.S. forests, evaluating how this uptake may change in the future as a consequence of forest management and natural disturbances, and evaluating policy options for increasing the role of forests as C sinks (R. Birdsey, U.S. Forest Service, oral communication, 2004).

3.3.4 Environmental Monitoring and Assessment Program

The U.S. Environmental Protection Agency (EPA) Environmental Monitoring and Assessment Program (EMAP) established a network of survey sites in the DRB during the early 1990s where aquatic ecology, stream geomorphology, and water quality were measured. The sites were probabilistically selected but too few in number to provide reliable statistics on stream condition in the DRB. The EMAP survey design team gave the CEMRI a probability-based survey design that provided statistics on aquatic resource conditions in three subregions of the upper DRB, as well as a separate survey for the whole river basin. A probability-based survey of first-order streams was also designed for correlation on a sub-regional scale with data collected on forest condition at the FIA forest plots. The EMAP-style probability-based survey served as a foundation water quality monitoring program for CEMRI (Olsen et al. 1999).

3.4 Tier 4: Remote Sensing and Mapping

Programs for collecting remote sensing and mappable fixed-site monitoring data are generally tracking environmental conditions at a scale that is broader than, but inclusive of, the DRB. The resulting coverages are therefore useful as foundation datasets for the CEMRI investigators. The programs used in the CEMRI are briefly described here.

3.4.1 The National Atmospheric Deposition Program/ National Trends Network (NADP/NTN)

The NADP network of deposition monitoring stations provides data on weekly precipitation volume and chemistry at 150 stations throughout the U.S. Several stations within and immediately outside of the DRB make up a baseline monitoring network for deposition, and the nature of deposition chemistry allows data from these sites to be modeled for mapping regional deposition patterns. No additional deposition collection stations were established by the CEMRI. (<http://nadp.sws.uiuc.edu>)

3.4.2 USGS Urban Dynamics Program

The study of current and historical land use change in the greater Philadelphia region conducted by the USGS Urban Dynamics program is being used to create regional maps of land use change through correlation with Landsat imagery. In the CEMRI, these scientists

developed spatially explicit maps of land use history to provide information for the modeling, forest fragmentation, and C cycling estimation efforts. (<http://landcover.usgs.gov/urban/intro.php>)

3.4.3 National Aeronautics and Space Administration (NASA)

NASA provided funding for the DRB CEMRI through a competitive grant entitled “Large-scale validation of carbon stock and flux estimates from remote sensing.” This grant facilitated the regional interpretation of Landsat Thematic Mapper imagery for estimating forest area and, when imagery representing different periods of time is analyzed, for detecting forest change. MODIS imagery was also interpreted through this grant for estimating annual forest productivity.

3.4.4 USFS Special Monitoring Studies

The USFS sponsors aerial photo flights and interpretation at locations of interest throughout the United States. Aerial photos of the DRB acquired in 2000 were used by the CEMRI to assess recent changes in forest fragmentation in the watersheds of French Creek, the Delaware Water Gap tributary watersheds, and the NAWQA synoptic watersheds. This aerial photography interpretation capability is a foundation for national collaborative monitoring strategies.

3.4.5 Hyperspectral Imagery

Interpretation of hyperspectral imagery by the USFS research program and associated contract laboratories represents a new and growing foundation capability that was available to the CEMRI in the DRB. Correlations between forest soil, foliar Ca, and the spectra of forest imagery enabled researchers to develop methods for mapping forest health in broad regions through remote technology. These capabilities were applied in the Neversink Tier 1 site within the DRB during the CEMRI. (R. Hallett, U.S. Forest Service, oral communication, 2002).

3.5 Enhancement of the Foundation Programs

These foundation programs were improved to fill gaps in existing survey data collection capability relative to the assessment issues selected for the CEMRI. Each of the CEMRI IMRAs was selected for intensive study because it contained not only existing monitoring infrastructure or programs, but also features that allowed the partners to address the selected assessment questions. Two of the IMRAs selected for the pilot project—the Neversink River Basin and the DEWA—lie within the Appalachian Plateau Province. The third IMRA—the French Creek Watershed—is located in the mid-basin Piedmont Province. The Neversink Basin is 95 percent forested, with little development pressure, but soils and surface waters have been acidified and depleted of Ca by acid rain. The DEWA and French Creek watersheds are mostly forested but are under intense pressure from summer home development and suburban sprawl, respectively. The three IMRAs span the range of climatic conditions in the Delaware Basin, and forest types in the three areas range from northern hardwoods and spruce-fir in the northern Neversink Watershed to tulip poplar and oak-hickory in the French Creek Watershed. Collaborative research and monitoring for CEMRI began in the Neversink and DEWA IMRAs during the summer of 2000 and in the French Creek Watershed in the summer of 2002.

The foundation gradient- and probability-based surveys were supplemented by the CEMRI to address regional soil and surface water C stocks and fluxes, and supplemental aerial photointerpretation was added to the Tier 4 foundation programs to enable the assessment of forest fragmentation effects, and enhance the land cover data available for comparison to aquatic data provided by the NAWQA program. The integration of these new and foundation data collection activities is described in this report for each issue of the Delaware CEMRI.