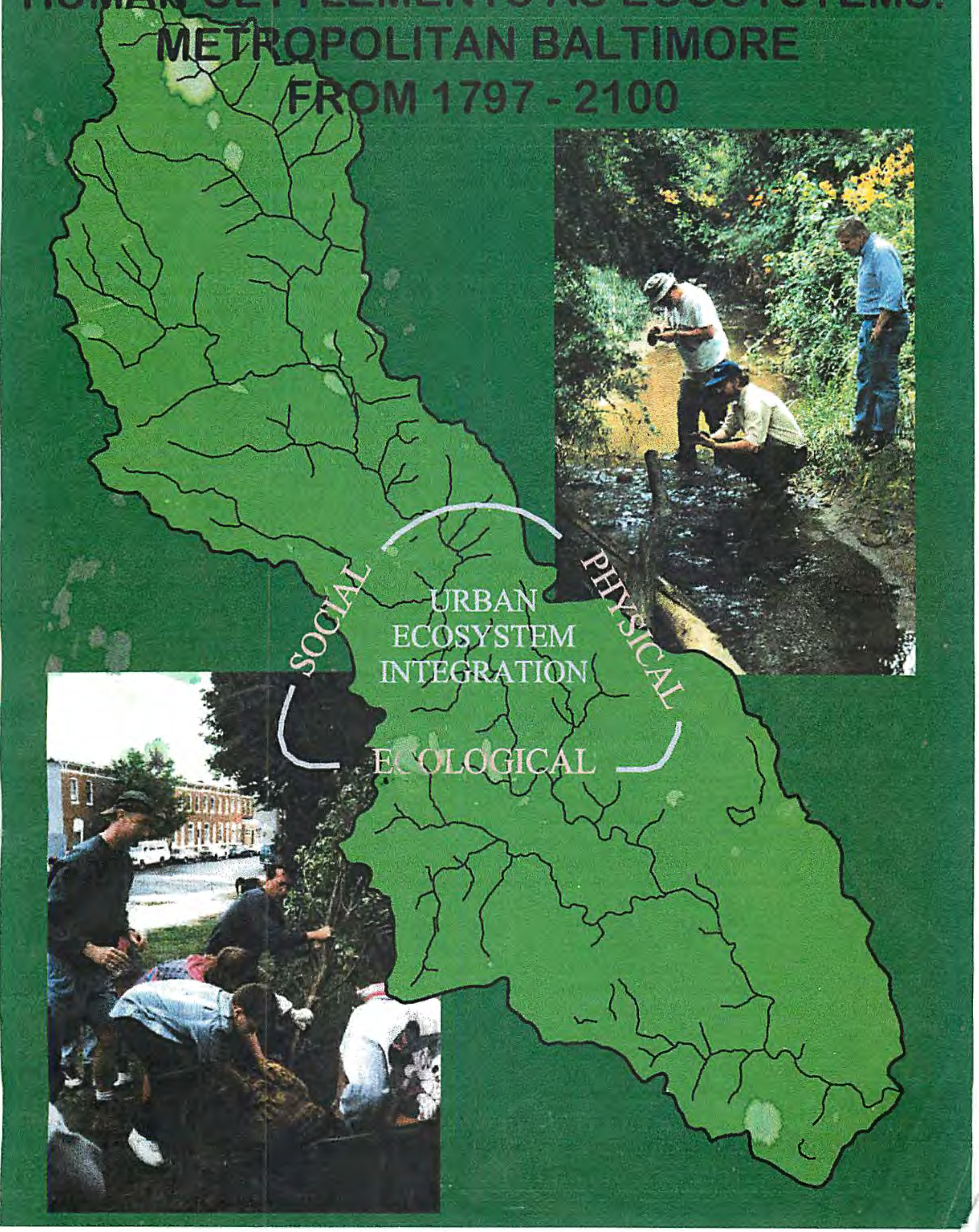
PICKETT

HUMAN SETTLEMENTS AS ECOSYSTEMS: METROPOLITAN BALTIMORE FROM 1797 - 2100



APPENDIX A

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e., program, division, etc.): LTER

☐ Topic A: Water and Watersheds ☐ Topic B: Technology for a Sustainable Environment ☐ Topic C: Decision Making and Valuation for Environmental Policy

FOR NSF USE ONLY — NSF PROPOSAL NUMBER: 9714835

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/If not in response to a program announcement/solicitation enter GPG, NSF 95-27
NSF/EPA Partnership for Environmental Research/NSF96-45 May 7, 1996

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	FILE LOCATION

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN): 22-3232968

SHOW PREVIOUS AWARD NO. IF THIS IS ☐ A RENEWAL OR ☐ AN ACCOMPLISHMENT-BASED RENEWAL

IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? YES ☐ NO ☒ IF YES, LIST ACRONYM(S)

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE: Institute of Ecosystem Studies

ADDRESS OF AWARDEE ORGANIZATION, INCLUDING ZIP CODE: Box AB, Millbrook, New York 12545-0129

AWARDEE ORGANIZATION CODE (IF KNOWN): 4001926

NAME OF PERFORMING ORGANIZATION, IF DIFFERENT FROM ABOVE:

ADDRESS OF PERFORMING ORGANIZATION, IF DIFFERENT, INCLUDING ZIP CODE:

PERFORMING ORGANIZATION CODE (IF KNOWN):

IS AWARDEE ORGANIZATION (Check All That Apply) (See GPG II.D.1 For Definitions) ☐ FOR-PROFIT ORGANIZATION ☐ SMALL BUSINESS ☐ MINORITY BUSINESS ☐ WOMAN-OWNED BUSINESS

TITLE OF PROPOSED PROJECT

HUMAN SETTLEMENTS AS ECOSYSTEMS: METROPOLITAN BALTIMORE FROM 1797 - 2100

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE
$ 4,200,000	72 months	January 1, 1998

CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

- ☐ BEGINNING INVESTIGATOR (GPG I.A.3)
- ☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.D.1)
- ☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG II.D.10)
- ☐ NATIONAL ENVIRONMENTAL POLICY ACT (GPG II.D.10)
- ☐ HISTORIC PLACES (GPG II.D.10)
- ☐ SMALL GRANT FOR EXPLOR. RESEARCH (SGER) (GPG II.D.12)
- ☐ GROUP PROPOSAL (GPG II.D.12)
- ☐ VERTEBRATE ANIMALS (GPG II.D.12) IACUC App. Date ______
- ☐ HUMAN SUBJECTS (GPG II.D.12) Exemption No.____or IRB App. Date ______
- ☐ INTERNATIONAL COOPERATIVE ACTIVITIES: COUNTRY/COUNTRIES ______
- ☐ FACILITATION FOR SCIENTISTS/ENGINEERS WITH DISABILITIES (GPG V.G.)
- ☐ RESEARCH OPPORTUNITY AWARD (GPG V.H)

PI/PD DEPARTMENT:

PI/PD POSTAL ADDRESS: Institute of Ecosystem Studies, Box AB, Millbrook, NY 12545

PI/PD FAX NUMBER: (914) 677-5976

NAMES (TYPED)	Social Security No.*	High Degree, Yr	Telephone Number	Electronic Mail Address
PI/PD NAME: Steward T.A. Pickett		Ph.D 1977		
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				

NOTE: THE FULLY SIGNED CERTIFICATION PAGE MUST BE SUBMITTED IMMEDIATELY FOLLOWING THIS COVER SHEET

*SUBMISSION OF SOCIAL SECURITY NUMBERS IS VOLUNTARY AND WILL NOT AFFECT THE ORGANIZATION'S ELIGIBILITY FOR AN AWARD. HOWEVER, THEY ARE AN INTEGRAL PART OF THE NSF INFORMATION SYSTEM AND ASSIST IN PROCESSING THE PROPOSAL. SSN SOLICITED UNDER NSF ACT OF 1950, AS AMENDED.

Human Settlements as Ecosystems:
Metropolitan Baltimore, Maryland, from 1797 to 2100

Principal Investigators

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PROJECT SUMMARY

We propose an Urban LTER for metropolitan Baltimore, Maryland, to address three questions: 1) How do the spatial structure of socio-economic, ecological, and physical factors in an urban area relate to one another, and how do they change through time? 2) What are the fluxes of energy, matter, capital, and population in urban systems, and how do they change over time? 3) How can people develop and use an understanding of the metropolis as an ecological system to improve the quality of their environment, and to reduce pollution loadings to downstream air and watersheds? We address these questions at a range of scales, from individual vegetation, socio-economic, or hydrological units, up to the entire Primary Statistical Metropolitan Area. In so doing, we will help resolve fundamental issues about the ecology and temporal dynamics of cities and suburbs - important environments that are increasingly common both nationally and globally - and quantify an end member ecosystem for comparison with less human-dominated ecosystems.

We have developed an integrated framework to study urban areas as ecological systems, which includes physical, ecological, and socio-economic components. We target processes that can control the function of urban areas as ecological systems, and their effects on other ecosystems. The framework can be tested by determining whether socio-economic, physical and ecological components of systems share common spatial structures, and whether each component responds to changes in the others in time or space.

Our "spatial" question (#1) will employ descriptive, historical and experimental analyses. We will characterize the dominant patch types in the Baltimore metropolitan area, using ecological, physical and socio-economic variables. By developing a better scheme for identifying patches than the current approach that emphasizes coarse land use categories, we will produce high resolution, whole-watershed and whole-city estimates of ecological and socio-economic fluxes (to address Question 2), as well as simulation models capable of depicting the interactive effects of land use, habitat and social change on ecological functions. Data from historical records and sediment pollen cores will allow us to test hypotheses about how social and ecological factors interact to affect how these functions have changed in the past and how they might change in the future. Two long-term experiments - an ecological manipulation of exotic plant species and an ecologically-based social initiative in neighborhood restoration - will test how human and ecological components of the system interact and change.

The research about system function (question 2) will address surface/atmosphere energy exchange, hydrologic and nutrient flux, atmospheric deposition, and the import/export of raw and processed materials and waste products, and of capital. It will be based on the mass balance concept widely applied in ecosystem ecology. Two scales will be considered - the whole-city scale and the small watershed scale - in part to foster comparison with other studies of natural and human-dominated ecosystems. For our urban ecosystem, the mass balance will include fluxes not normally found in ecosystem studies (e.g. inputs of imported food, sewage outputs, fluxes of commodities and money). Modeling (spatial and simulation) will play an important role in addressing both questions.

Our education objectives (question 3) will involve people in every aspect of the project, thereby providing useful ecological understandings and data, access to the research process, and direct support to students, teachers, managers and the general public. We will build close linkages with existing formal and nonformal education programs and institutions to build programs that improve the ecological literacy of students, citizens and decision makers.

TABLE OF CONTENTS

SECTION 1: RESULTS FROM PRIOR NSF SUPPORT

Results from Prior NSF Suppport - Steward T.A. Pickett

PIs: Steward T.A. Pickett, M.J. McDonnell, and Daniel Wartenberg
Award #: BSR 89-18551 (LTREB); Amount: $145,000; Duration: 2/1/93 - 12/31/95
Title: Patterns of community and population change in oldfields at the Hutcheson Memorial Forest

This project continued the successional study at the Hutcheson Memorial Forest Center. Begun in 1958, it is the longest yearly record of oldfield vegetation change in North America. We stabilized plot marking, assembled an digital data base of the 13,920 plot-years, and began spatial and temporal analyses. Initial condition has persistent effects through the first decade of succession, and novel patterns of spatial and temporal patchiness, based on life form and growth strategy determine community structure. Dr. Randall W. Myster, Mr. James W. Baxter, and Ms. M.L. Cadenasso have been trained in this research.

Twelve peer reviewed publications resulted from this award including these 5 examples:

Pickett, S.T.A. and M.J. McDonnell. 1989. Changing perspectives in community dynamics: A theory of successional forces. Trends Ecol. Evol. 4:241-245.

Pickett, S.T.A. 1989. Space-for-time substitution as an alternative to long-term studies. pp 110-135 In *Long-term Studies in Ecology: Approaches and Alternatives*

Armesto, J.J., S.T.A. Pickett, and M.J. McDonnell. 1991. The relationship of spatial heterogeneity to plant community organization and dynamics. pp 256-269 In, J. Kolasa and S.T.A. Pickett, eds. Ecological Heterogeneity. Springer-Verlag, New York

Myster, R.W. and S.T.A. Pickett. 1992. Association analysis and pathways of old field succession at the Hutcheson Memorial Forest Center. Jour. Ecol. 80:291-302.

Myster, R.W. and S.T.A. Pickett. 1994. A comparison of rate of succession over 18 yr in 10 contrasting old fields. Ecology 75:387-392.

PIs: Steward T.A. Pickett, M.J. McDonnell
Award #: DEB 9307252 Amount: $164,996; Duration: 1 July 1993 - 31 Dec 1996/
Title: Exogenous control of forest dynamics: experimental test of the role of edge.

We established a pioneering experiment of the function of forest edges, and have discovered that the abiotic gradients associated with the forest edge extend outward beyond the wall of vegetation at the edge, that seed rain, herbivore populations, seedling dynamics, and flux of throughfall are controlled by the structure of the forest edge. The results can help design restoration and management strategies for fragmented forests.

Publications:

Pickett, S. T. A., and M. L. Cadenasso. 1995. Landscape ecology: spatial heterogeneity in ecological systems. Science 269:331-334.

Cadenasso, M.L, M.M. Traynor, and S.T.A. Pickett. 1997. Functional location of forest edges: gradients of multiple physical factors. Canad. J. For. Res. *In press*

Cadenasso, M.L. and S.T.A. Pickett. Linking edge structure to edge function: mediation of herbivore damage. In preparation.

Results from Prior NSF Suppport - Peter M. Groffman

Pis: G.E. Likens, M.J. McDonnell, S.T.A. Pickett and P.M. Groffman
NSF Award: DEB-9216667, Amount: $90,000, Duration: 1/1/92 - 12/31/93
Title: "A Workshop on: Integrated Regional Models and Analysis of Human-Nature Interactions"

This workshop, which was held October 4-8, 1992, brought together 38 scientists from biological, physical and social sciences in roughly equal numbers to assess the role of integrated regional models (IRMs) for dealing with complex, environmental problems. Integrated regional models are conceptual and mathematically based models that include, within the structure of the model, mathematical descriptions of the physical environment, biological interactions and human decision-making and its consequences. This workshop resulted in a book (Groffman and Likens 1994), and contributed to the rapid development of the new field of "Integrated Assessment". The need for this type of integration is refelcted in the NSF Special Funding Opportunity on "Methods and Models for Integrated Assessment", the NSF/EPA Water and Watersheds program, which has a strong "integration" focus, and this special LTER competition.

Publications:

Groffman, P.M. and G.E. Likens, editors. 1994. Integrated Regional Models: Interactions Between Humans and Their Environment. Chapman and Hall, New York.

Pis: Peter M. Groffman, Charles Driscoll, Tim Fahey and Janet P. Hardy
NSF Award: DEB-9652678; Amount: $640,000, Duration 15 Sep 96 - 14 Sep 99.
Title: Snow depth, soil frost and nutrient loss in a north temperate forest

This grant funds a manipulation of snow depth and soil freezing at the Hubbard Brook Experimental Forest (an NSF LTER site). The effects of increases in the frequency and intensity of soil freezing on root, microbial and soil chemical processes is being evaluated in the context of climate change.

Pis: Charles Driscoll and Tim Fahey, principal investigators, Groffman is one of approximately 15 collaborators.
NSF Award: BSR92-11768; 1 Oct 92 - 30 Sept 98.
Title: Long-Term Ecological Research at the Hubbard Brook Experimental Forest

The overall goal of the LTER study at HBEF is to develop a better understanding of the responses of northern hardwood ecosystems to natural and anthropogenic disturbances. We are conducting research on sites within the HBEF with contrasting histories of disturbance, as well as continuing the collection and analysis of long-term data sets. Our strategy has been to build upon previous and ongoing work at the HBEF through the use of long-term records and manipulated watersheds. Thus, we have used LTER funds to help support monitoring activities, initiate process-level research projects, and improve data management to facilitate integration of past and current research at the HBEF. Groffman's portion of the Hubbard Brook LTER award has been used for studies of spatial and temporal variation in soil C and N pools and for detailed ^{15}N studies of the movement of N from plant litter to soil pools. Data are availabile at (http://www.yale.edu/edex/groffman.html).

Summary: The Eco-Inquiry curriculum we developed grew into a program for grades 5-8. It helps teachers transform their classrooms into centers of ecological research. Students learn about the flow of matter in ecosystems—a key concept in ecological literacy—as the practices of science are demystified and made engaging. The project was supported, in part, by grants from the National Science Foundation and the New York State Council on the Arts (NYSCA). Over 3,000 copies of the 400-page teacher's guide have been sold by its publisher, Kendall/Hunt Publishing Company. Eco-Inquiry is being disseminated through workshops around the country. Over 15 workshops involving more than 240 teachers and teacher-trainers already have been offered by Institute staff. Two additional Eco-Inquiry curriculum products are now available from Kendall/Hunt: *Rita* - a book for children, and *Promoting Student Thinking - A Teachers' Guide to Linking Science and Literature Through* Rita.

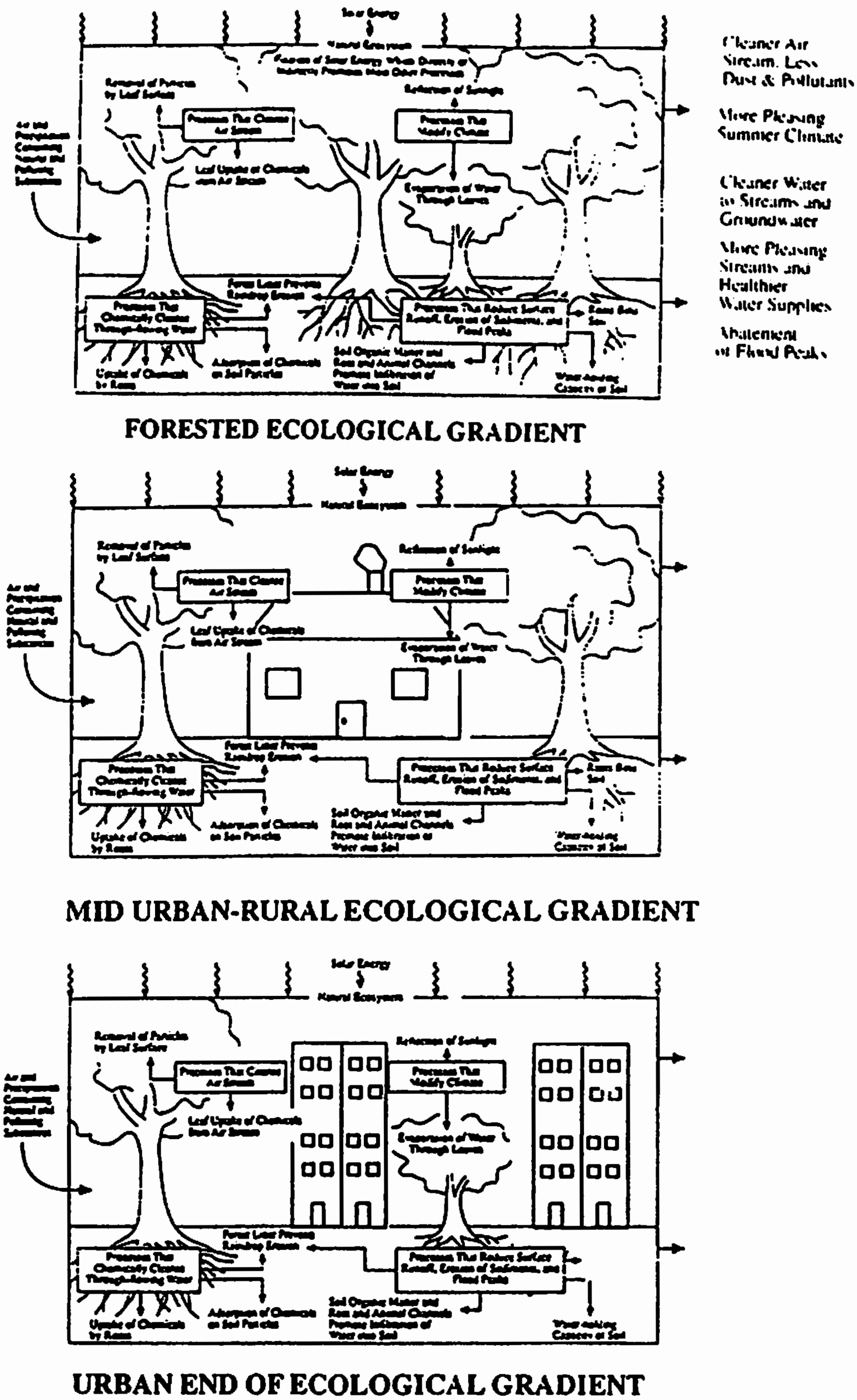


Figure 2.1. Conceptual addition of anthropogenic features to a standard ecosystem model. The base model is adapted from Bormann and Likens (1979). The addition of human structures shows that the basic processes remain the same, but the specific structures and sizes of the pathways likely changes with urbanization.

SECTION 2: RESEARCH FRAMEWORK AND ACTIVITIES.

I. INTRODUCTION: URBAN AREAS AS DYNAMIC ECOSYSTEMS

Cities and their surroundings are complex ecological systems that have hardly been examined from a rigorous ecological perspective (McDonnell and Pickett 1990, 1993). Clearly, urban areas are hot spots of ecological activity, concentrating and manipulating the fluxes of matter, energy, and organisms, and bringing about intense and widespread modification of the spatial structure of landscapes (Sukopp 1990, Nowak 1994). However, the quantitative magnitudes of these fluxes and modifications, and their ecological effects in and downstream from cities all remain virtually unknown (Costanza and Greer 1995). This gap in knowledge deprives basic ecology of the understanding of a widespread and extreme form of human intervention in the biosphere; it denies applied ecology the ability to assess management and restoration options in from the urban core to the suburban fringe; and it limits the capacity of decision makers and metropolitan residents to understand their environment, and to improve their quality of life. This lack of ecological knowledge is especially problematical because urbanization, including urban sprawl into suburban areas, is one of the major changes that people are causing on the global scale (Brown and Young 1990, Vitousek 1994).

The Urban LTER we propose for metropolitan Baltimore, Maryland, addresses three broad questions: 1) How do the spatial structure of socio-economic, ecological, and physical factors in an urban area relate to one another, and how do they change through time? 2) What are the fluxes of energy, matter, capital, and population in urban systems, and how do they change over the long term? 3) How can people develop and use an understanding of the metropolis as an ecological system to improve the quality of their environment, and to reduce pollution loadings to downstream air and watersheds? We address these questions at a range of scales, from individual elements of urban vegetation, households, or hydrological response units, up to the entire Primary Statistical Metropolitan Area. In so doing, we will help resolve fundamental issues about the ecology and temporal dynamics of cities and suburbs - important environments that are increasingly common on both national (Frey 1984, WRI 1996) and global scales (Vitousek 1994) - and describe an end member ecosystem for comparison with less human-dominated ecosystems.

We have developed an integrated framework to advance ecological knowledge of urban areas as ecological systems (Pickett et al. 1997, Grove and Burch 1997). The components include physical, ecological, and socio-economic components (Figure 2.1). The potential interactions between the components suggest the processes that can control the function of urban areas as ecological systems, and their effects on other ecosystems. The framework can be tested by determining whether socio-economic, physical and ecological components of systems share common spatial structures, and whether each component responds to changes in the other in time or space. In order to conduct such tests we rely on prior work by various members of our group.

Urban effects on ecosystems have been extensively examined in our work in two metropolitan areas - Baltimore and New York City. There are clear and significant differences between urban and rural areas in and near New York in soils, plant and animal species composition, nutrient deposition from the atmosphere and litter, nutrient processing, and community dynamics (Pouyat and McDonnell 1991, Pouyat et al. 1994, 1995, Goldman et al. 1995). Compensation of stress and disturbance effects by nutrient enrichment is a surprising result of these studies. In the Baltimore Metropolitan Area, we have demonstrated how key aspects of the socio-economic structure of neighborhoods affect local environmental factors that in turn affect quality of life (Burch and Grove 1993, 1996). The social science information has been used, in collaboration with city agencies, community groups, and the educational community, to improve ecological literacy and to add understanding of ecological processes to management and community restoration efforts (Grove et al. 1991, Dickey and Grove 1992). Application of this ecological information has contributed to the mitigation of water quality in the Chesapeake Bay (Grove et al. 1993, Costanza and Greer 1995). In order to synthesize and extend our empirical work, we are developing models focusing on fundamental hydrological processes (HSPF, Lumb et al. 1990, Neville 1996), distributed hydrological modeling that can account for the spatial complexity of vegetation and built surfaces in cities and suburbs (REHSSys, MacKay and Band 1994), and economic analyses of land use change in a large watershed with increasing suburbanization (PLM, Fitz et al. 1996). The HSPF and PLM activities have been carried out in rural and coarse scale venues in the Chesapeake Bay region near Baltimore, while work is underway to refine REHSSys to account for the unique spatial structure of cities (Creed et al. 1996). Our educational research and practice employs an inquiry-based approach (Berkowitz 1992, Hogan 1994). We have developed and disseminated curricula and teacher enhancement programs to support ecological study in city, suburban and rural schools through work in New York, Baltimore and nationwide.

Our proposed Baltimore Urban LTER will bring all these established efforts together to answer fundamental questions about urban areas as ecological systems and will address the goals set out in NSF's call for proposals (Table 2.1). An important benefit of conducting the project in Baltimore is that our prior social science and education activities there have built extensive community, governmental, and non-governmental links and collaborations. These will be crucial to the security and success of long term ecological research in the urban environment, and in assuring that education and outreach are a viable part of the program. Baltimore is well suited for the proposed research: ecologically it is diverse and located at a critical land/sea interface; physically it contains excellent small and medium-sized watersheds for study; and socially it provides a range of changing conditions and exceptional enthusiasm to experiment in neighborhood revitalization, community forestry and education.

II. UNIFYING CONCEPTUAL THEMES

A. Urban Areas are Ecological Systems

Considering cities as ecological systems challenges ecologists to apply the well established ecosystem approach to a new setting (Cronon 1991, Pickett and McDonnell 1993, Figure 2.1). The boundaries of urban areas go beyond the dense inner city residential and industrial areas, to include sparser city residential neighborhoods, suburban residential and commercial districts, and the rural hinterlands now coming under intense use and land transformation. The alterations of matter and energy flux in these areas are undoubtedly huge, yet, estimates of these fluxes are few (Nowak et al. *in press*). A firm mechanistic understanding of how ecological, physical, social, and economic factors combine to control the fluxes is lacking. The great heterogeneity of urban areas (Hamm 1982, Sukopp 1990) must be accounted for in understanding fluxes and other ecosystem processes. Geographic and land use-based perspectives on urban areas need to be given clearer, quantitative and mechanistic ecological interpretation (Wolman 1993) that lead to testable ecological hypotheses (Pickett 1993).

Ecological knowledge about metropolitan areas and their component patches is important for education, planning, management, and restoration. Educators with limited field trip and science equipment budgets or with limited ecological backgrounds require ways to present ecology in cities that motivate and build student interest in and understanding of their immediate environment. Planners need to know how ecological knowledge can inform the neighborhood-specific changes that are their stock in trade and to effectively achieve ecological benefits at regional scales (Flores et al. 1997).

B. Humans Should be Studied from Ecological and Spatial Perspectives

Just how to examine humans from an ecological perspective has been an issue in ecology since its beginning (Pickett and McDonnell 1993, S. Tjossem, pers com.). Often the approach has been simply to take humans as just another member of the biota, and to use variables such as population density and biological population structure to explain ecological variation. However, employing an ecological approach to humans means considering their species-specific features as well as their more general characteristics as a biological population. Hence, the rich social, cultural, institutional, and economic dimensions of human social ecology must be evaluated and used to understand the role of humans in ecosystems (Boyden 1993). The familiar ecosystem concept - which connects a biota with its physical environment through transformations of energy, matter, and information - can be used to integrate humans with their environment. Transformation of energy and use of resources in human-dominated systems depends on the social features of humans as well as the physical environment and the other biotic components of ecosystems (Burch and DeLuca 1984). A human ecosystem model must recognize the nature of the resources, the control over access to resources, the social organizations and their dynamics, the formal and

Table 2.1. NSF Objectives for an Urban LTER and how they will be actualized in the proposed Baltimore LTER project

NSF Goals	Baltimore LTER Proposed Approach
1. Integrate ecological, social, and economic factors.	1. Use the common spatial organization of social, economic, and ecological phenomena.
	2. Recognize rank hierarchies of socio-economic processes.
	3. Relate changes in land use, land cover, and watershed function over the long term to beedbacks between socio-economic and ecological processes.
2. Link and contribute to existing LTER efforts	1. Quantify the effects of a novel combination of ecological stresses and disturbances.
	2. Help the LTER network to recognize the role of humans as agents of ecological change.
	3. Provides a reference point for less obviously impacted and human-dominated systems.
3. Build on educational interactions at the K-12 level.	1. Involve students and teachers from inner city and suburban schools in inquiry based education and LTER research.
	2. Disseminate programs, procedures and insights via print, Internets and workshops. Career enhancement will be conducted through nonformal and school-based programs.
4. Develop an integrated conceptual framework	1. Build a novel framework on fundamental principles in ecology, hydrology, social science, and ecological economics.
	2. Evaluate and extend the model by the long-term research.
5. Address the five core areas that are a part of the LTER Network goals.	1. Research will include productivity, nutrient and water dynamics, population dynamics, soil and carbon dynamics, and natural and anthropogenic disturbance.
6. Assess the impact of changes in land use and land cover	1. Impacts will be assessed historically, remotely, and through contemporary process studies, to determine how land transformations affect the ecological processes embodied in the LTER core areas.
7. Manage the data for greatest availability and utility.	1. Data will be well documented and thoroughly available to metropolitan educators and decision makers, and to scientists in the larger ecological community.
	2. We will employ watershed based models to drive integration at fine and medium scales, and economic-landscape modeling at the regional scales, and seek cross scale linkages between the two approaches.

informal control of behavior of individuals and groups at different scales (Machlis et al. 1997, Grove and Burch 1997).

The basic role of resources in human ecological systems requires that ecological economics be integrated into the framework (Costanza 1989). The cross-disciplinary field of ecological economics takes as its core problem the sustainability of interactions between economic and ecological systems. Sustainability in that context requires an appropriate temporal and spatial scale, fair distribution of resources, and efficient resource allocation (Costanza et al. 1992). Such sustainability is founded on biophysical processes and the dynamics of ecological systems. Because such functions are often beyond the scope or awareness of traditional modes of valuation based on "willingness to pay", understanding and promoting knowledge about ecosystem function is a goal of ecological economics (Costanza et al. 1992). These pursuits require information on the relevant scales, hierarchical structure, and integration of socio-economic and ecological systems.

A comprehensive framework suggests potential mechanisms of interaction of socio-economic and ecological processes (Vayda 1983) through social hierarchies (Logan and Molotch 1987), allocation mechanisms (Hall 1993), social dynamics (Padoch 1993), and social organization at different scales (from individuals to nations). Social hierarchies can be described in terms of status, power, access to wealth and knowledge, and control of territory (Burch and DeLuca 1984). Individuals, groups, and organizations have distinct social roles and responsibilities, and have different positions in social hierarchies. Further, social and spatial positions change over time, and are controlled by sets of formal and informal social norms and institutions. This array of states and interactions suggests a complex human ecological system (Figure 2.2). Resources for such a system ultimately rest on ecological structures and processes, but also include socio-economic and cultural components. Therefore, the systems approach, which is so familiar in studying feedbacks and interactions in ecology (Pacala 1993), can serve as a common integrating tool with social dimensions. Both socio-economic and ecological factors can be studied in terms of patterns and processes, and flows of critical resources (Shachak and Pickett 1997, Grove and Burch 1997). Thus, the human ecological systems framework (Figure 2.2) is an expression of ecological systems thinking, and shows how human socio-economic hierarchies and other processes can be integrated with familiar ecological processes (Pickett et al. 1997; Figure 2.3).

Socio-economic and ecological factors can be integrated because they share a common spatial setting. Indeed, the ecological, socio-economic, and cultural resources upon which the human ecological system depends, all have a spatial arrangement (Shevky and Bell 1955, Hamm 1982, Frisbie and Kasarda 1988). Use of resources clearly takes place in space and leaves a spatial footprint (Costanza et al. 1993, Wackernagle and Rees 1996). Similarly, the social control of territory is explicitly a spatial phenomenon. However, groups and individuals representing different levels in the remainder of the social hierarchies – wealth, power, status, and knowledge – can also be arranged differentially in space, and profoundly influence the spatial distribution of people, and the sources, sinks, and fluxes of critical resources in a human ecological system (Murdie 1976, Burch 1976, Logan and Molotch 1987, Grove 1996).

C. Human Ecological Systems Must be Studied in the Long Term

The necessity of long-term studies in natural ecological systems is by now well known (Likens 1989, Risser 1991). Episodic events, community and ecosystem succession, climate change, natural disturbance, wide population variation, and many more gradual, stepped, or pulsed ecological processes generate long-term change in ecological systems (Pickett et al 1997). Human dominated systems are equally, if not more, susceptible to long-term changes (Vayda 1993, Padoch 1993). Indeed, because humans can learn and communicate rapidly, and their institutions can purposefully adjust to changing conditions, ecological systems of which humans are a part are especially prone to change over a variety of temporal scales. Cities are extremely mutable types of social organizations (Yaro and Hiss 1996, Rybczynski 1995). They spread through space, and their density and infrastructure change as fashion, human demography, level of economic investment, production, aesthetics, and other socio-economic factors at both fine and coarse scales (Batty 1995). Some changes may be cyclic, as for example, when neighborhoods change as a result of the decline of an elderly population and rejuvenation by the immigration of younger residents and families with young children into the community. Other changes may essentially be irreversible, as when a residential avenue is converted to large scale commercial development. The two sorts of trend may have

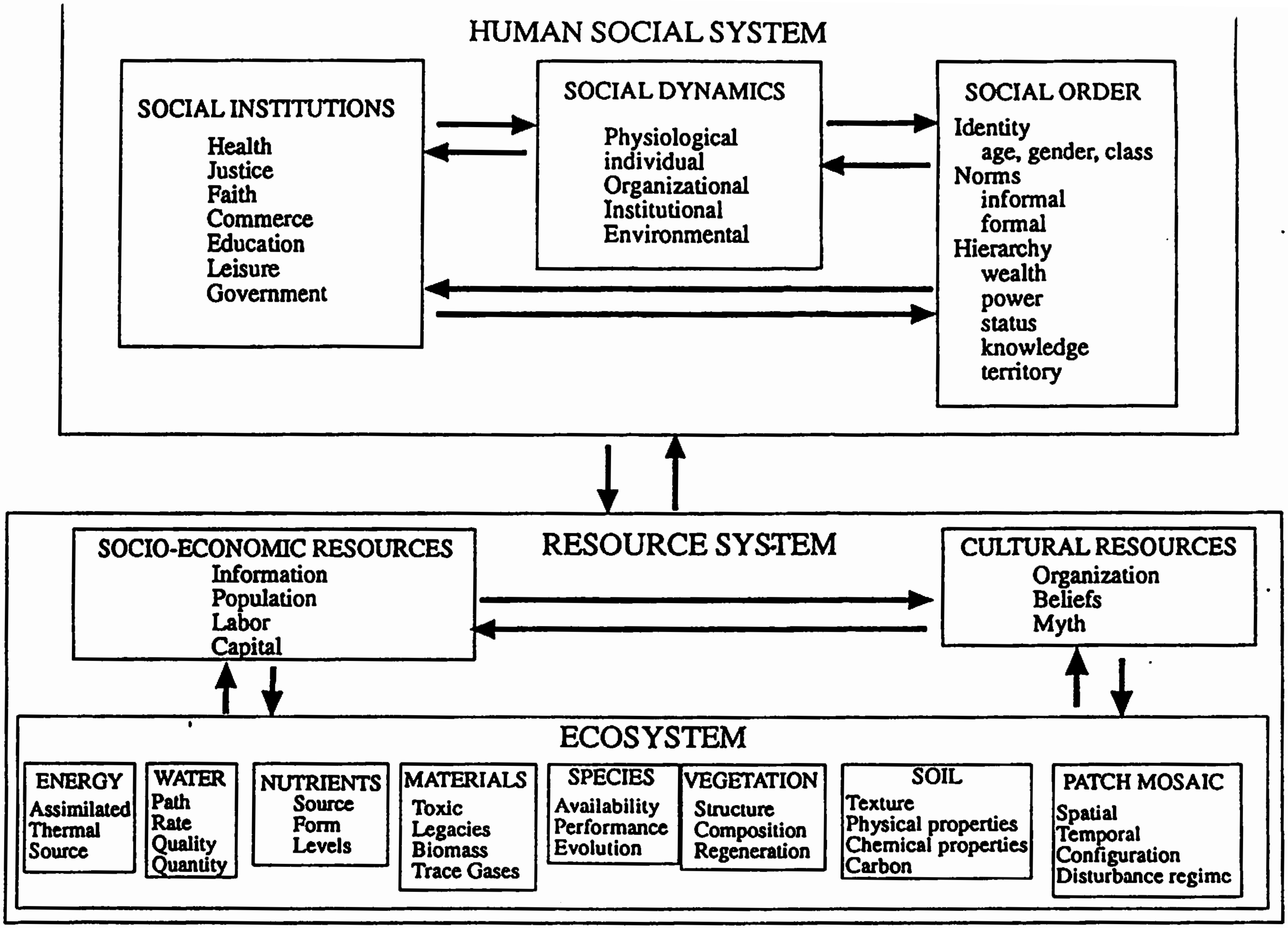


Figure 2.2. An array of states and interactions for a human ecological system. Ecosystems influence human social systems through natural resources. These resources yield not only socio-economic benefits but also cultural benefits.

different ecological implications locally and downstream.

Two zones stand out in urban areas as especially prone to long term and significant change. Most familiar to ecologists and conservationists is the rapid development on the urban fringe (Makse et al. 1995). Suburban and exurban settlements abutting wild lands are common in many areas of the United States, and most of the urban growth in North America is projected to be in suburban areas (UN Population Division 1995). The alterations accompanying suburban spread clearly alter many ecological structures and processes, although there is a need to quantify those impacts (Medley et al. 1995). At the opposite extreme of urban density are changes in the urban core. Abandonment of aging industrial infrastructure and housing stock, with the related reduction in retail services occupancy in many neighborhoods, is profoundly altering the cover and use of the urban core (Berry 1990). The increasing pressure on the suburban fringe complements the thinning of the city.

The presence of such rapidly changing areas within the metropolis provides great potential to capture both strong/direct and subtle/indirect ecological effects with careful long-term monitoring (Machlis and Wright 1984). Experiments can test hypothesized mechanisms of the linkage between social and ecological processes (McDonnell and Pickett 1990, Sukopp and Werner 1982). These experimental and comparative approaches, along with modeling based on temporal and spatial patterns, can accomplish the integration required to fully understand urban areas as ecological systems (Groffman and Likens 1994).

III. QUESTIONS, HYPOTHESES AND APPROACHES

A. Three overarching questions

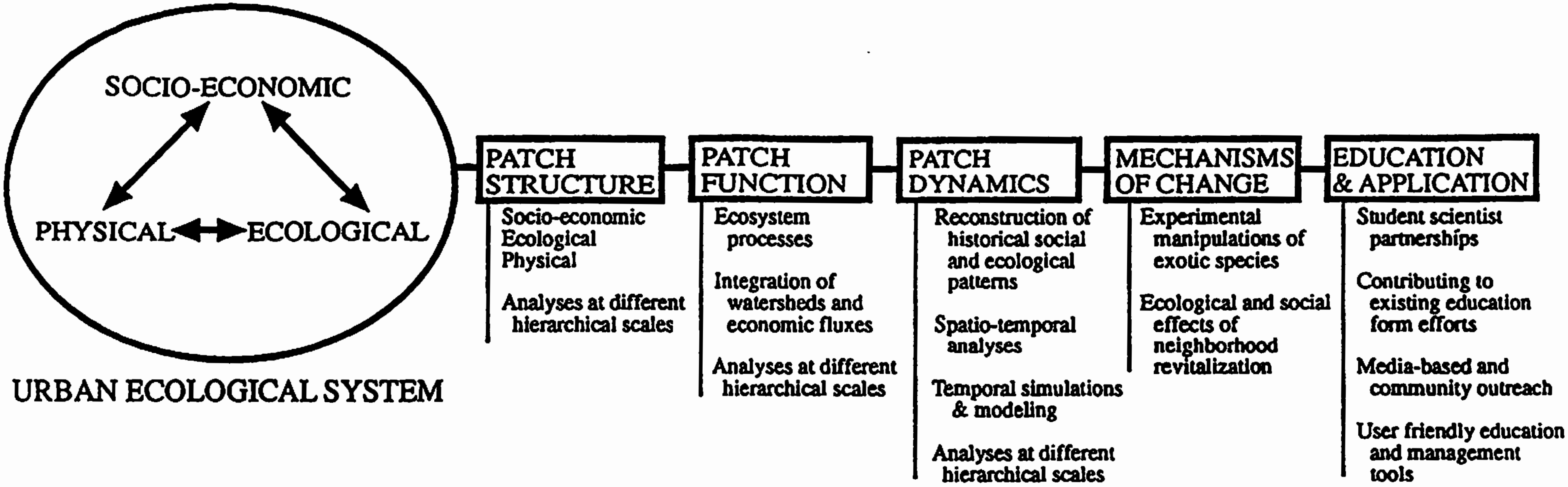
The conceptual themes outlined above all emphasize that it is essential to focus on both the structure and function of urban areas, using conceptual and quantitative models of integrated systems containing both natural and human components.

Question 1. How do the spatial structure of socio-economic, ecological, and physical factors in an urban area relate to one another, and how do they change through time?

This question will be addressed with a mixture of descriptive, historical and experimental analyses. We will define, locate and characterize each of the dominant and important patch types within the Baltimore metropolitan area, using ecological, physical and socio-economic variables. By developing a better scheme of identifying and describing patches than the currently used one that emphasizes only coarse land use categories (Wolman 1993), this work will allow us to produce high resolution, whole-watershed and whole-city estimates of ecological and socio-economic fluxes (to address Question #2), as well as simulation models capable of depicting the interactive effects of land use, habitat and social change on ecological functions. Adding data from historical records and sediment pollen cores will allow us to test hypotheses about how social and ecological factors interact to affect how these functions have changed in the past and how they might change in the future. Two long-term manipulation experiments - an ecological manipulation of exotic plant species and an ecologically-based social change initiative/experiment in neighborhood restoration - will test how human and ecological components of the system interact and change.

Question 2. What are the fluxes of energy, matter, capital, and population in urban systems, and how do they change over the long term?

The research about system function will address surface/atmosphere energy exchange, hydrologic and nutrient flux, atmospheric deposition and the import/export of raw and processed materials and waste products, and of capital. It will be based on the input-output mass balance concept that has been widely applied in ecosystem ecology. Two scales will be considered - the whole-city scale (sub-regional), and the small watershed scale - in part to foster comparison with past, present and future studies of natural and human-dominated ecosystems. For our urban ecosystem, the mass balance equation will include many fluxes not normally found in ecosystem studies (e.g. inputs of imported food, sewage outputs, fluxes of commodities and money). Modeling (spatial and simulation) will play an important role in addressing both



A. GENERAL QUESTIONS
1. What is an urban area from an ecological perspective?
2. How does it function ecologically?
3. How do socio-economic and ecological patterns and processes change over time?

B. APPROACH
1. Define and integrate ecological, physical, and socio-economic patterns to characterize heterogeneity within an urban landscape.
2. Define watershed and economic fluxes at different hierarchical scales.

C. RESEARCH QUESTIONS:
1. How do the spatially structured socio-economic, physical and ecological conditions and processes in the metropolis affect each other through time?
2. What are the fluxes of energy and matter by natural and human dominated processes in urban ecosystems and how do they change over time?
3. How can urban residents develop and use an understanding of the metropolis as an ecological system to improve the quality of their environment, and their daily lives?

Figure 2.3. Diagram of the integration of physical, ecological and socio-economic factors into an urban ecological system and the methods to be employed in analyzing its structure and function. The methods are designed to test whether patch structure, function, and dynamics of socio-economic, physical, and ecological factors share the same scales and are functionally linked. Functional links are explored in experiments on mechanisms of patch change and in a synthetic model. Education and applications are important components to integrate research finding into the public sector. We indicate the A) the general questions, B) key research approaches, and C) the main research

questions.

Question 3. How can people develop and use an understanding of the metropolis as an ecological system to improve the quality of their environment, and to reduce pollution loadings to downstream air and watersheds?

This questions will be addressed by involving people in every aspect of the project, thereby providing useful ecological understandings and data, access to the research process, and direct support to students, teachers, managers and the general public. We will build close linkages with existing formal and nonformal education programs and institutions to build programs that improve the ecological literacy of students, citizens and decision makers.

B. Hypotheses and Literature Review

Hypothesis 1. There are coherent relationships between ecological, socio-political and physical patch structures within an urban ecosystem that control ecological functions related to the fluxes of water, nutrients and carbon, and to biodiversity.

This is the central hypothesis of the Baltimore Urban LTER. It expresses the idea that the function of urban ecosystems depends on heterogeneity of three controlling domains - physical, ecological and social. We argue that understanding and managing the function of urban ecosystems requires linking these domains and that patch theory can provide guidelines for linkage and integration. Ecosystem function depends on heterogeneity of the three domains at different scales. Therefore, the first step in linking physical, ecological, and social-economic phenomena on an urban landscape is to discover comparable patterns and processes within the three realms (e.g., McDonnell and Pickett 1993). Ecological and social scientists have independently developed systems for identifying and mapping recognizable units in their disciplines (Zonneveld 1989; Kuchler and Zonneveld 1988; Bailey 1983; Bailey 1985; Rowntree 1981). Such systems can be used to measure heterogeneity and to link comparable social and ecological units (Grove 1997; Bailey and Mulcahy 1972); scales (Johnson 1993; Burch and Grove 1993; Daniel et al. 1993; Thompson and Warburton 1985b; Allen et al. 1984); and classification systems (Zonneveld 1989, Grove 1996).

In the urban LTER we will initially focus on hydrologic processes and utilize the watershed approach. We, therefore, follow with a discussion of hydrological, ecological, and socio-economic heterogeneity. Other processes will be investigated in the near future, such as atmospheric transport of acidic compounds, which can be approached in a similar fashion.

Hydrological heterogeneity. The hydrologic patterns of watersheds are spatially heterogeneous. Different areas, or patches, within a watershed contribute variable amounts of water and nutrients to stream flow, depending upon their landscape position in the watershed and the physical attributes of the soil. This is a Variable Source Area (VSA) concept (Hewlett and Nutter 1969, Dunne and Leopold 1978, Black 1991) which is in essence a dynamic model that reflects the abiotic attributes of the watershed, such as seasonal fluctuations in precipitation and temperature, and physical characteristics including topography, soil properties, water table elevation and antecedent soil moisture (Dunne and Leopold 1978).

Urban areas are a mosaic of patches and scales, and therefore present a particular challenge to the integrating hydrology with ecological and social regulators. Land use can be considered a larger scale patchwork, while actual land cover is a smaller scale patchwork. Land cover, if classified to represent the actual surface features, is more relevant to urban hydrology than land use (Neville 1996). In contrast, land use may be used to infer statistical distinctions in the land cover distributions. We can view land covers as existing along a gradient of hydrologic pathways - impermeable cover predominantly produces quickflow, surface runoff, while forested sites have predominantly slowflow, groundwater pathways (Figure 2.4). Fields, lawns, and other disturbed sites are intermediate. Hydrological length scales can range from a kilometer (forest and agricultural tracts) to meters (streets, lawns, houses). Larger areas are necessarily mixtures of these covers - suburban land use of varying density having perhaps the greatest mix, and dense urban, agricultural and forested patches having the most homogeneous land covers. Therefore, we require a nested sampling design to scale measurements to the plot through subcatchment

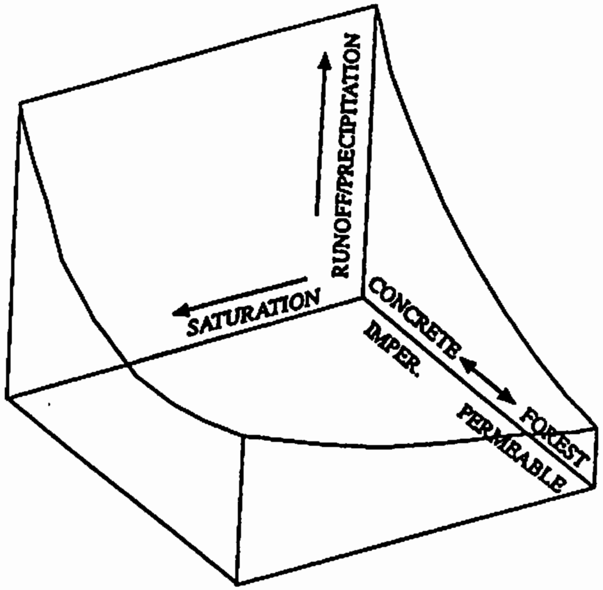


Figure 2.4. Prediction of runoff/precipitation ratio as a function of the permeability or flow rate and path, and saturation of substrate.

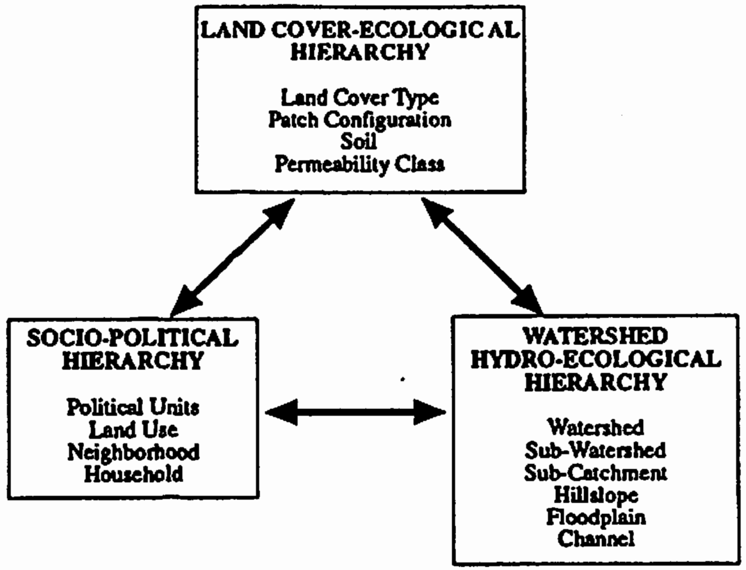


Figure 2.5. The three hierarchies of patch or land units to be integrated in the proposed research. Socio-political units are those defined by political or administrative entities. Watershed hydro-ecological units are those delimited by decomposing large watersheds into smaller units that contribute runoff. The land cover-ecological hierarchy describes the specific surface features that govern the flow rate and pathway of runoff, and the degree

up to full watershed level, with analogous sociocultural units ranging from household through political units (Figure 2.5).

Ecological heterogeneity. The second component of this approach is based upon the relationship between the extent, distribution, structure and species composition of vegetation, and the spatial heterogeneity of the resultant bioregulation of hydrologic processes in the watershed. Although the watershed approach has traditionally dealt with watersheds as relatively homogeneous units, this approach can be enhanced by considering spatial heterogeneity (Malanson 1993), which is virtually universal (Forman and Godron 1986, Turner 1989, Wiens 1995). Heterogeneity and patchiness are related to extinction and recolonization (Hanski 1994), the flow of limiting resources, such as water (Shachak and Brand 1991) and nutrients (Peterjohn and Corell 1984, Groffman et al. 1993), and successional dynamics of communities (Pickett and White 1985). Patchiness is an important regulator of biodiversity (Huston 1994, Pickett et al. 1997), and is a major organizing principle in ecology (Turner 1989, Kolasa and Pickett 1991, Hansson et al. 1995). Relating spatial patchiness of ecosystems to social variables and hydrology in a variety of watersheds tests generalizations about the role of ecological patchiness in a new research arena. Both empirical research and modeling are required for spatial patchiness to be of greater utility in ecology (Murcia 1995, Pickett and Cadenasso 1995).

Socio-economic heterogeneity. Social differentiation has been a central focus in the social sciences (Schnore 1958, Grusky 1994). Social scientists have used concepts of social identity (age, gender, class, caste, and clan) and social hierarchies (wealth, power, status, knowledge, and territory) to study how and why human societies become differentiated (Garfinkel 1981, Burch and DeLuca 1984, Machlis et al. 1995, Figure 2.1). Social differentiation is an important concept for the study of human ecological systems because it affects the allocation or distribution of critical resources (natural, socioeconomic, and cultural) within a human ecological system (e.g., Lenski 1966, Burch and DeLuca 1984, Parker and Burch 1992, Machlis et al. 1995). This distribution of critical resources is rarely equitable. Processes of social differentiation of human ecological systems also have a spatial dimension that is characterized by patterns of territoriality and spatial heterogeneity (Morrill 1974, van den Berghe 1975, Agnew 1987, Burch 1988, Agnew and Duncan 1989). Further, various processes of social differentiation occur at different hierarchical scales and have corresponding spatial patterns (Grove and Hohmann 1992). Some examples of these patterns and processes include urban-rural hierarchies (Morrill 1974, Cronon 1991, Rusk 1993), the distribution of land uses within urban areas (Burgess 1925, Hoyt 1939, Harris and Ullman 1945, Guest 1977, Clarke et al. 1996), social stratification within residential areas (Shevky and Bell 1955, Johnston 1976, Agnew 1987, Logan and Molotch 1987, Harvey 1989, Grove 1996), and social differentiation within individual neighborhoods (Fox 1992, Grove and Hohmann 1992, Burch and Grove 1993, Grove et al. 1995).

Integrating hydrological, ecological and sociocultural processes. To understand the hydrological, ecological, and sociocultural controls of water quantity and quality in an urban-rural watershed, the processes of these three domains need to be linked. In human-dominated ecosystems, social attributes measured with a revised social area analysis approach (Shevky and Bell 1955, Johnson 1976, Hamm 1982, Frisbie and Kasarda 1988, Grove 1996) can be used to extend an abiotic/biotic Variable Source Area (VSA) approach in order to measure the impact of social heterogeneity on ecological patterns and processes at different hierarchical levels. In essence, this represents a social-ecological VSA approach that integrates physical, biotic, and social attributes at comparable levels of analysis and provides the basis for a dynamic model to study hydrologic processes using a human ecosystem and landscape approach. Such integration is a pressing need (Groffman and Likens 1994).

Hypothesis 2a. Human impact (per capita) on energy, water and nutrient fluxes declines with increases in density and increases with socio-economic status.

In densely populated areas, there are increases in the efficiency of energy, water and material usage such that human impact (per capita) on environmental fluxes is greatly reduced. As density decreases, people drive more, have bigger living spaces, influence surrounding semi-natural ecosystems more (e.g. fertilize lawns). These density changes are somewhat independent of socio-economic status but there is high covariance between density and socio-economic status (i.e. rich people live in low-density suburbs). Moreover, wealthy people will have a bigger environmental influence than poor people at all density levels through differences in consumption patterns.

Hypothesis 2b. Nutrient (N,P,K,Ca,Mg) input-output budgets will show net retention, as natural ecosystems usually do, but the input and output fluxes will be much larger, and the level of retention will be much less (e.g. 20% instead of 90% for N).

A variety of factors including high inputs of labile nutrients and extensive hydrologic alteration contribute to the nature and extent of nutrient retention in urban ecosystems. This retention is important to the quality of drainage and receiving water bodies. Nutrient budgets in urban ecosystems require fuller accounting of organic material and nutrient flows including imports of food, fertilizer, and manufactured products than budgets for less human-dominated ecosystems. We will develop nutrient budgets for the entire Baltimore metropolitan area as well as for a series of small watersheds within this area.

Data on forests within the New York City metropolitan area show how nutrient cycling and retention can be altered by urban environments. Unmanaged oak stands had higher concentrations of heavy metals and salts (Pouyat and McDonnell, 1991, Pouyat et al., 1995), larger recalcitrant C pools (Groffman et al., 1995), lower abundances of litter fungi and soil microinvertebrates (Pouyat et al., 1994), and higher net nitrification rates (McDonnell et al., 1997) than more rural oak stands 100 km away. These urban effects on C and N dynamics are driven by enhanced N deposition (G. Lovett et al., unpublished data) that can increase soil N availability and thus nitrification (Aber et al., 1989); increased exposure to pollution, especially ozone, which can decrease litter quality inhibiting decomposition and N mineralization (Findlay and Jones, 1990, Findlay et al., 1996); and the introduction of non-native tree species, many of which possess different life histories and quality of litter.

Hypothesis 3a. Social patch change and ecological patch change are related, and have strong effects on adjacent and downstream ecosystems.

Local changes in ecological conditions, e.g., invasion of exotic insect, mammal or plant, or of social conditions, e.g., investment or knowledge base, will lead to complex changes in congruent and adjacent patches. At a larger temporal and spatial scale, major changes such as shifts in land transformation should correspond to changes in stream water quality, sediment deposition, etc. in the Chesapeake Bay (Burch 1994).

Hypothesis 4a. Ecosystems dominated by exotic species will have higher productivity, "tighter" nutrient cycles, more soil carbon and higher human value than those dominated by native species. Ecosystems dominated by exotic species will have altered patterns of biodiversity and soil-atmosphere trace gas fluxes.

Our hypothesis is based on the idea that exotic species outcompete native species by more efficient use of water, light and nutrients, leading to increased productivity and more competition for nutrients leading to lower loss, i.e. "tighter nutrient cycles". Increased productivity will result in higher levels of soil carbon storage. A tenable alternative hypothesis, that exotics create "windows for ecosystem leaks" is based on the idea that exotics are often early successional, or disturbance-adapted species (Kowarik 1990, Sukopp 1990).

The effect of exotic species is a central question in ecology (Vitousek 1994). Urban areas, important centers for the introduction of exotic species (Bagnall 1979, Hobbs 1988, Rudnicky and McDonnell 1989, McDonnell and Pickett 1990, Sukopp 1990, Rapoport 1993), represent an ideal venue for testing ideas about the importance of these species to alter food web structure and ecosystem function (Vitousek 1989). Exotic species can be key regulators of biodiversity (e.g. birds, small mammals) and soil-atmosphere trace gas fluxes (e.g. CH_4, N_2O, CO_2). Exotic species are often seen to inhibit the regeneration or lead to the extirpation of native species of plants or birds (Drayton and Primack 1996), changing the dynamics of communities (Guilden et al. 1991), and presumably ecosystems through time. Food webs may also be altered, through changes in such plant-based features as herbivore feeding cues or digestibility or toxicity (Schierenbeck et al. 1994), or alterations of predator populations. One of the most crucial features of communities and ecosystems to be affected by exotic plant species is likely to be community regeneration.

The persistence of closed canopy forests in urban woodlands, riparian zones, and parks, may depend on the impact of exotic vines or trees (Rudnicky and McDonnell 1989, Guilden et al. 1990).

Just how exotic species may affect ecosystem function is less clear. The longer growing season of exotic trees increase ecosystem productivity, and hence carbon storage, and may reduce the role of previously important vernal species in nutrient retention (cf. Marks and Bormann 1972). If exotics fail to resorb nutrients from leaves, the nutrient retention in the altered litter may be compromised and soil-based fluxes of gases (CO_2, N_2O, CH_4) changed (Pastor et al. 1984, Coleman et al. 1992, Jones et al. 1994, Goldman et al. 1995). Many exotic plants are fast growing pioneer species, suggesting that they may be more susceptible to windthrow or snow and ice loading than native species. The rates of succession on abandoned lots and restored areas may also be affected by the dominance of exotic species. These are open questions in need of empirical analysis spanning the range of urban patch types including street trees, tree patches, herbaceous communities, riparian zones, and yards. The aggregated effect on the urban area as a whole, and the implications for hydrological and nutrient retention, and atmospheric exchanges may be profound.

We will test the hypothesis by establishing a series of long-term ecosystem succession experiments where the establishment of exotic species is controlled. We will follow succession in "old fields" in urban core and suburban fringe settings and in forest gaps in residential areas where exotics are either eliminated as they develop or are allowed to grow. Ecological response variables will include net primary productivity, nitrogen and carbon cycling, trace gas fluxes, and components of biodiversity (e.g. birds and small mammals). Human values/concerns about exotics will be assessed before and after initiation of the manipulations and an associated educational effort.

Hypothesis 4b. Ecological restoration can function as a catalyst for the social revitalization of under served communities within an urban ecosystem.

Our research applies the human ecosystem framework outlined by Pickett et al.(1997) and tests whether critical resources of the human ecosystem - access to capital and information - are limiting factors of social and ecological processes. In the case of inner-city neighborhoods in Baltimore, previous research indicates that 1) there is an abundance of land and labor, but a shortage of capital and information and 2) an absence of allocation mechanisms that a) provide access to capital and information, or b) retain these resources once they are introduced into the neighborhood) (Grove 1996, Cuadrado and McManus 1996).

While there has been an overall recognition of the need to link ideas of critical resources and allocation mechanisms in the natural resource / community development literature (see for example Cernea, 1991, Gilmour and Fisher 1991, Parker 1994, Parker and Burch, 1992, Rambo and Sajise 1984, particularly of note is the Grameen Bank or micro-lending / micro-enterprise approach), these efforts have not been placed explicitly in the context of a human ecosystem framework, studied over the long-term, nor applied to the environmental restoration of urban areas.

To address this question using a human ecosystem framework, we will build upon previous community forestry / gardening initiatives and partnerships (e.g. The Urban Resources Initiative (Burch & Grove, 1993, Burch et al. 1997, Grove 1995, Grove et al. 1994) and The Revitalizing Baltimore Program (Loomis, Grove & Neville, 1995) as well as new financing partnerships (see letters of support from Hollis, and Dupont) to institute micro-lending / micro enterprises as a means to link neighborhood revitalization and environmental restoration. We will compare pilot initiatives in three neighborhoods with a) three similar "comparison" neighborhoods and b) other community forestry and/or neighborhood revitalization efforts in the City of Baltimore.

Hypothesis 5a. The study of the city as an ecological system is an engaging and motivating vehicle for building scientific, civics and environmental literacy, contributing to locally and nationally identified goals for education reform.

National and state curriculum and teaching standards - in science, math, geography, and earth sciences - all call for student-centered inquiry, and for teachers and schools to provide a rich range of opportunities for students to engage in genuine investigations of the real world around them (NCTM 1989, AAAS 1989, 1993, AGI 1991, Geographic Education Standards Project, 1994, NRC 1996a). Much to the satisfaction

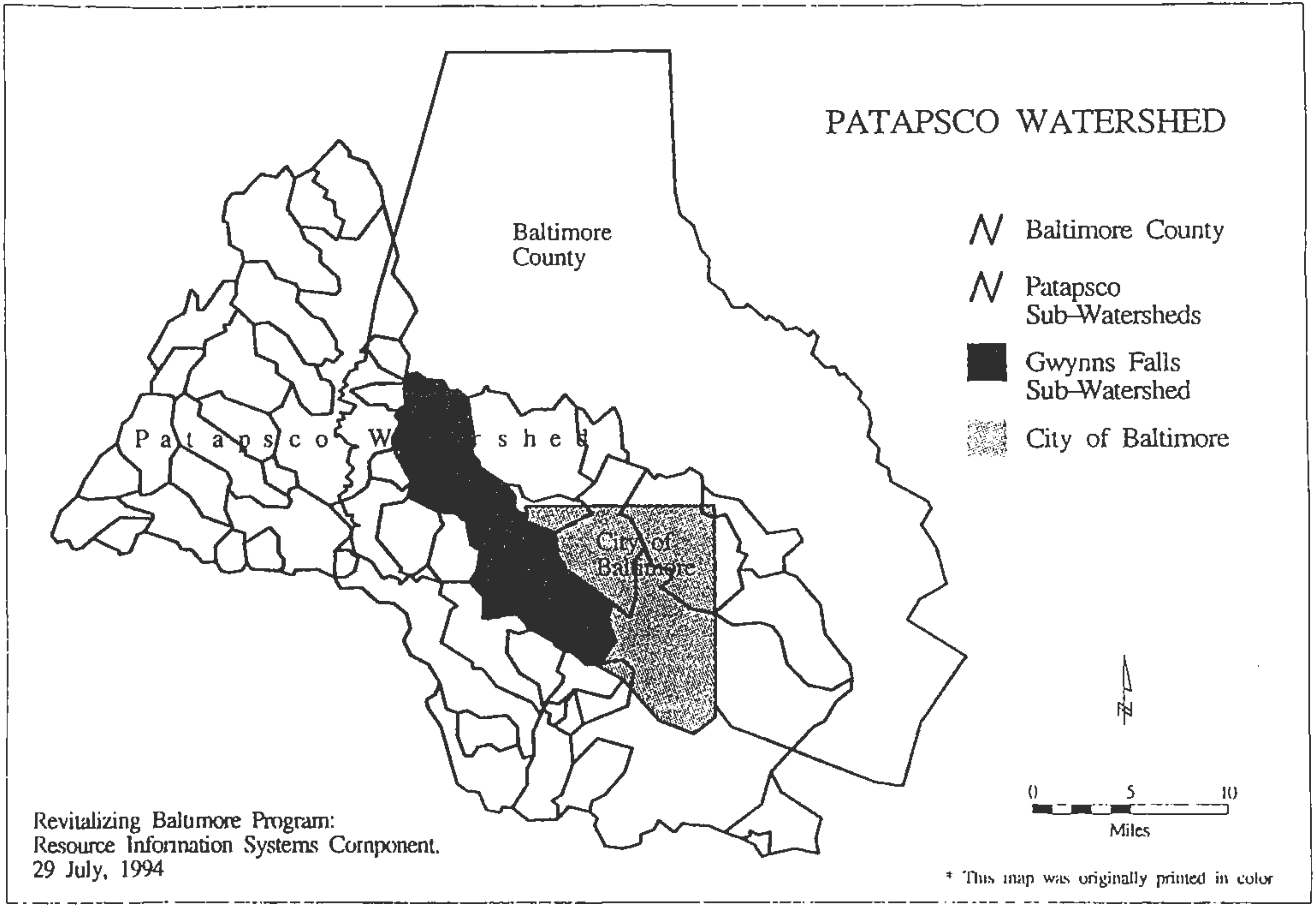


Figure 2.6. Location of the Gwynns Fall watershed with respect to the City of Baltimore, Baltimore County, and Patapsco Watershed, Maryland.

of professional ecologists, ecology has a very strong place in virtually all of the required curricula. Ecological literacy is viewed as an essential and highly motivating field for engaging student interest, requiring that they study their immediate environment (Risser 1986, Berkowitz et al. 1991a, Carter 1991, Feinsinger et al. 1997a), and build an understanding of the ecology of human existence (Wackernagle and Rees 1996, Berkowitz et al. 1997). Thus, in the metropolis we must teach the ecology of human settlements - the focus of this LTER proposal - building on effective urban environmental education programs (e.g., Hogan 1994, Hollweg 1997) and well established approaches for exploring schoolyard ecology (e.g., Dissinger 1984, Feinsinger et al. 1997a and 1997b).

Hypothesis 5b. Students and scientists can derive mutual benefit from collaboration on the LTER research. Students 1) learn about the environment (physical, biological, sociological) from their own investigations, 2) gain practical skills, 3) have positive role models and work experiences, and 4) are encouraged to pursue academic study and careers. Scientists 1) get useful data, 2) are helped in implementing their studies, 3) foster public understanding of and support for their work.

There is much agreement that professional scientists have essential roles to play in 1) fostering ecological literacy, 2) providing people with the tools and information they need to make sound environmental decisions, and 3) giving youngsters skills and motivation to pursue meaningful careers (Feinsinger 1987, Alberts 1991, Berkowitz et al. 1991b, Berkowitz 1992, NRC 1996b). We propose to involve students, teachers, decision makers and the general public in each facet of the LTER research, emphasizing the development of science process and inquiry skills (Mechling and Oliver 1983, Pearsall 1992, Hogan 1994, NRC 1996a). In this way, people will be better able to think for themselves about the metropolis as an ecological system, and use the perspectives, tools and ongoing collaborative support we provide to develop and apply new understandings in their daily lives.

Partnerships involving students, teachers, community organizations and scientists can be very effective at fostering inquiry-based teaching and learning (Condon 1991, Berkowitz 1992, 1997, Sussman 1993, NRC 1996b). Programs such as GLOBE (Global Learning and Observations to Benefit the Environment), the University of New Hampshire's Forest Watch, Feeder Watch and GREEN (Global Rivers Environmental Education Network, Barstow et al. 1997) build on this synergy and will be used as models and as sources of methods and/or dissemination for our project. Both the direct involvement in meaningful work - research, near-peer teaching, neighborhood restoration and applying ecological knowledge - and the contact students will have with diverse role models will go a long way to attracting and sustaining interest in academic and ecological careers among urban residents (Beane 1988, Bentley et al. 1993, Walker 1990, ECO 1992, Hill et al. 1990).

Hypothesis 5c. Genuine involvement of the public - students, families, citizen groups - in ecological research through the LTER project (data collection, experimentation, synthesis, application) can have a positive effect on the local and adjacent environments.

Two avenues, both very much long-term propositions, should lead to positive impacts of increased ecological understanding on the environment. The first avenue involves the direct provision of information and skills to people in the neighborhoods we'll be working in, engaging them in key decisions and in implementing changes that are part of the long-term project. The integrative approach to cities being taken in the LTER research - combining ecological, physical and social processes, and addressing several spatial and temporal scales - represents untrodden ground as far as curricula or user-friendly tools are concerned. Thus, together with the people of Baltimore, the scientists and educators of the LTER will build a usable and practical framework.

Second, we hope to build a local pool of talent and professional achievement in the environmental field. Minority and disadvantaged urban residents are under-represented in science in general and in ecology in particular (Rendon and Nora 1987/8, Holland et al. 1992, Blockstein 1990, NSF 1990, Walker 1990, Blockstein et al. 1992, ECO 1992, Hill et al. 1990). If we succeed in involving city folk in studying and managing their environment from an ecological perspective, and in creating rewarding and respected pathways for work in the area, then the diversity of the local environmental workforce should increase over

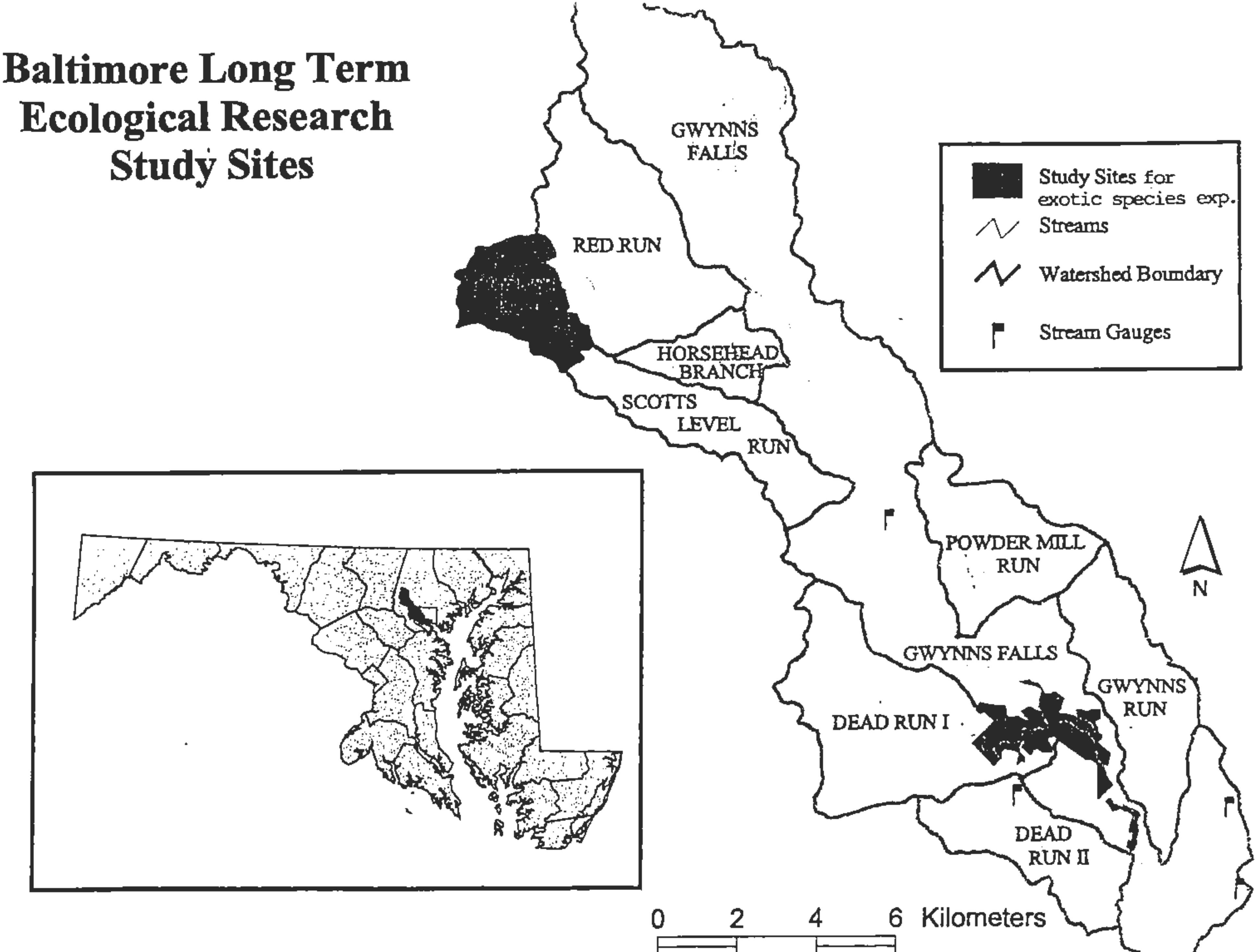


Figure 2.7. Watershed boundaries of catchments and study site locations for exotic species experiment.

time. This, in turn, should result in increased environmental awareness from within the communities involved.

IV. EXPERIMENTAL METHODS

In this section we first describe the research sites that will be heart of the LTER (sec. A). We then present methods for characterizing patch structure, including vegetation and human-built structure (sec. B). This is followed by methods for measurement of patch function (sec. C), changes through time (sec. D), mechanism of change, i.e. manipulation studies (sec. E), and education (sec. F).

A. Research sites

The research proposed for the Baltimore LTER has a hierarchical structure in order to test the proposition that heterogeneity at certain scales exists in socio-economic and ecological structure, and that affects ecological function of the urban system. While our ultimate objective is to characterize structure and function for the entire metropolitan area, our research approach will be to use a series of small watersheds to represent the range of conditions within this area (urban core, residential, suburban fringe) and to use plot, or patch, studies to characterize the range of conditions within the small watersheds. Below we describe the boundary for the metropolitan area, the small watersheds that we have identified for long-term study, and our approach to defining, locating and characterizing plot, or patch, sites for intensive measurements.

1. Boundary of the LTER study

The boundary for the Baltimore LTER site will be the Baltimore Primary Metropolitan Statistical Area (PMSA), which is within the Washington-Baltimore Consolidated Metropolitan Statistical Area. The PMSA is defined by the U.S. Office of Management and Budget and comprises Anne Arundel, Baltimore, Carroll, Harford, Howard and Queen Anne's Counties and Baltimore City. Its extent is based on "commuting ties" (M. Ratcliffe, Geography Division, U.S. Census Bureau, personal communication).

The PMSA is a logical boundary for our urban LTER ecosystem for several reasons. It has ecological relevance because it contains distinct "urban core", "residential" and "suburban fringe" elements. We feel that these elements are the fundamental components of urban ecosystems (Figure 2.1). The PMSA also has strong socio-political relevance. Analysis of the PMSA requires quantification of the substantial amount of transport and flux of material, energy and capital assets across and within its boundaries. In this regard the PMSA is a useful base area for socioeconomic and land use information as it is a primary socio-economic reporting unit with a hierarchy of smaller areas (county/city, census tracts and block units) embedded within it. Information available from the federal census as well as state, county and city agencies provides an empirical base to test for a hierarchical socioeconomic patch structure within the PMSA (and surrounding regions for local boundary conditions) and interpatch interaction, described below. A convenience of using the PMSA as the primary large scale system boundary is the ability to compare socioeconomic and, if available, ecosystem variables with other PMSA in the U.S. and abroad (WRI 1996).

2. Small watersheds

Small watersheds have been widely used as experimental units in ecosystem ecology and are central to several of the existing LTER studies (Bormann and Likens 1979, Hornbeck and Swank 1992). We have located four small watersheds within the Baltimore metropolitan area, distributed among the its urban core, residential, and suburban fringe elements of the city (Figures 2.6, 2.7, Table 2.2). These watersheds will allow us to conduct more detailed input-output mass balance analyses than the whole city (sub-regional analyses), and they will provide a basis for comparing our results to results from other LTER sites. Variation in density and socio-economic factors among the watersheds will allow for rigorous testing of the hypotheses described above.

Three of the four small watersheds are located within the Gwynns Falls catchment area while the fourth

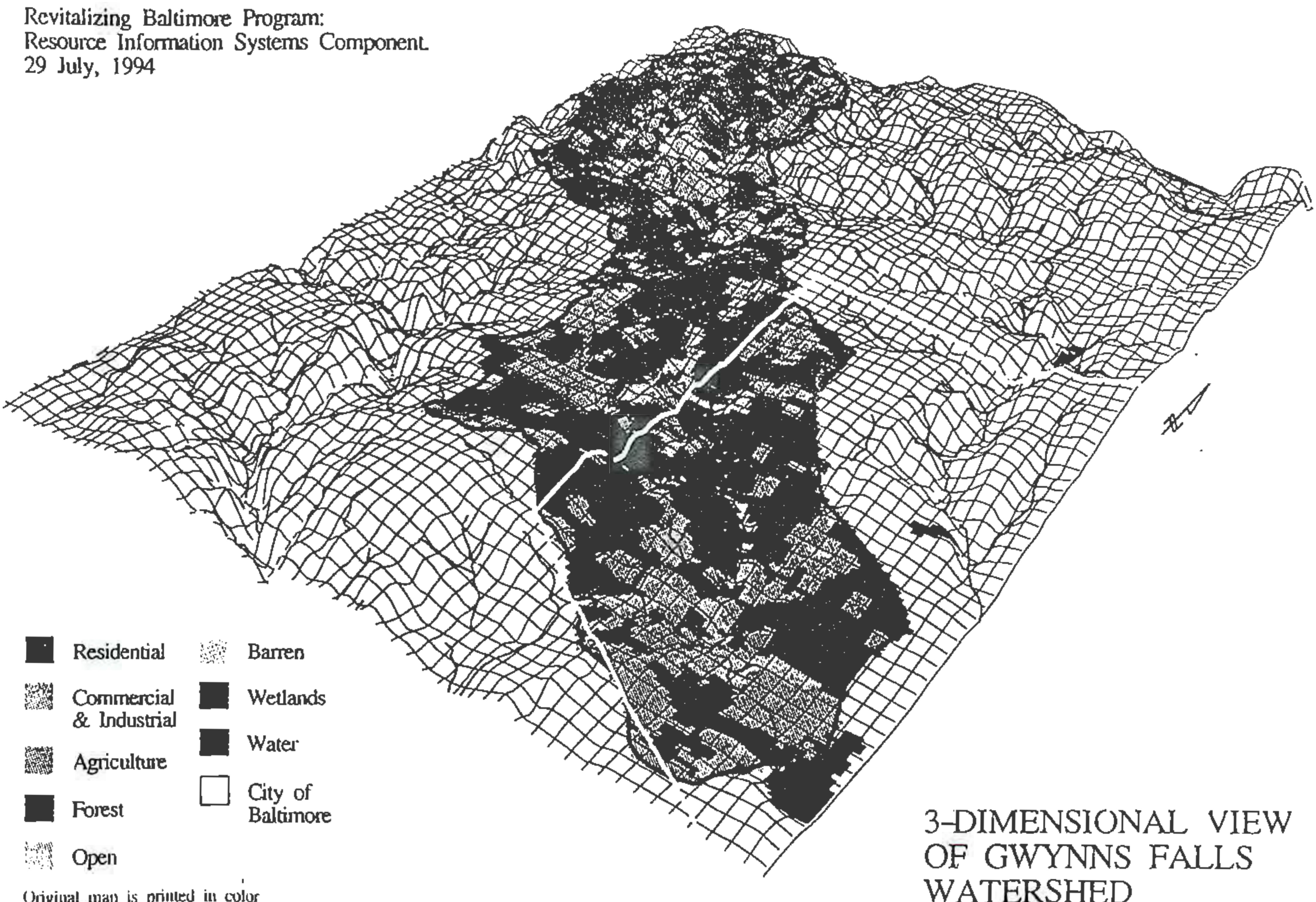


Figure 2.8. Anderson Level 1 classification of the Gwynns Falls watershed Baltimore, Maryland.

is in the adjacent drainage of the North Branch Patapsco River. This fourth catchment was chosen to satisfy the need for a currently undeveloped drainage. The three small watersheds nested within the Gwynns Falls watershed will allow their water, sediment and chemical discharge can be scaled to that of the full drainage basin.

In addition to these four small watersheds, the Gwynns Falls will be divided into two reaches for monitoring. These will integration inputs above two "boundary conditions." The upper reach bounds the residential and suburban portion of Gwynns Falls, while the lower reach bounds urban conditions.

3. Patch (plot) studies

The patch studies will characterize structure and function of the small watersheds and the entire PMSA. We will have enough patches to represent the range of physical, socio-economic and ecological conditions within the small watersheds and the PMSA. We will use GIS and simulation models to scale from the patch studies to the small watershed and PMSA scales. Data from patch studies provides input for the models (Sec. E).

These studies will 1) define and 2) quantify the extent of the key patch types within the PMSA, 3) locate specific examples of the different patch types for sampling and 4) characterize structure and function within these examples. Definition, quantification and location of the patch types will be done using existing geographic information system (GIS) databases and models (Sec. E). Final selection of permanent plots will use both the GIS databases and field surveys. We will have two groups of patch sites. We will locate a large group (100 sites) of sites for "extensive" characterization and a smaller group (20 sites) of secure sites for "intensive" study. Based on our existing knowledge of patch structure in the Baltimore area, and the need to represent core urban, residential, and suburban fringe areas, we have already located many of the "intensive" sites. A major criterion was to identify secure locations where we can leave equipment and have guaranteed access. These secure locations include private property where we have agreements with owners, and isolated, restricted city and county properties. Ten of these sites are located within the small watersheds described above.

B. Characterization of patch structure

1. Patch definition

At the PMSA scale, patch definition begins with the coarse Anderson Level II land use classification system (Anderson et al. 1976, Lillesand and Kiefer 1987, Figure 2.8). This classification, which is available for the Baltimore PMSA for 1973, 1981 and 1990 includes agricultural, barren, commercial/industrial, forest, open land, residential, water and wetlands. We will develop models of patch structure that combine socio-economic, physical (primarily hydrologic) and ecologic information with the land use data to produce a more ecologically functional characterization of patch structure within the PMSA. We will develop these methods in our small watersheds and use the results of these analyses to fill out our matrix of "extensive" and "intensive" monitoring sites within our small watersheds and the PMSA.

Delineation of hydrologic patches (hydrologic response units). Our measures of physical-ecological-socioeconomic of patch structure will be compatible with existing hydrological models (Sec. E) that can be combined with socio-economic and ecological data to produce the integrated patch definition model. The new model will be incorporate modules (from HSPF [Lumb et al. 1990] and RHESSys [Band et al. 1991]) that incorporate vegetation canopy information derived from 30 m resolution thematic mapper data, and soil data acquired from soil surveys at a scale of 1:15,840. The patch delineation will support a catenary or patch based model in which internal variance of subcatchments is represented as a drainage sequence associating soil, vegetation and topographic variables. The sequences are combined from overlay of remotely sensed canopy variables, DEM derived terrain variables, and local soil measurements or maps. We expect that the spatial heterogeneity of vegetation and soils within urban landscapes will be greater than in rural areas, which will necessitate acquiring data at higher resolutions. Moreover, within urban landscapes, rather than associating vegetation and other land cover variables at the level of land use categories, we will sample the variance and covariance of required terrain and land cover variables at high

Table 2.2. Location and description of small watersheds to be used for Baltimore LTER project

Boundary Condition Watersheds

1 Boundary Station 1. Gwynns Falls at Villa Nova. This is an existing USGS stream-gaging station that drains an area that represents the boundary condition for the suburban portion of Gwynns Falls watershed. The site is secure, as attested to by the 40 year USGS data record for this site.

2 Boundary Station 2. Gwynns Falls at Route 1. This became a USGS water-quality monitoring site in 1994 and drains an area that represents the boundary condition for entire Gwynns Falls above head of tidal influence. This station will allow for evaluation of the urban portion of the Gwynns Falls watershed by comparison with the Gwynns Falls at Villa Nova station (station #1 above). The site has standard USGS security measures which have proven adequate over the past three years. Monthly water quality sampling has been conducted at this site since 1994.

Small Watersheds

Vegetation for all the small watersheds throughout the Baltimore metropolitan area is the same regional type. In the uplands includes tulip poplar as the dominant canopy species with various species of oak and hickory. Sub-canopy species include ironwood and dogwood, with a shrub layer of mainly mountain laurel on north facing slopes and mixed blueberry and viburnums on south facing slopes. Vegetation in the lowlands includes sycamore-box elder-green ash-silver maple as dominant canopy species with some cottonwood stands, red maple and white pine (escaped from plantings), and a shrub layer with spicebush and a number of vines including poison ivy, honeysuckle and greenbrier (Brush 1980). Herbaceous, managed, and ruderal vegetation will be described as part of the proposed research, but should be typical of Mid-Atlantic oldfields, cultivated and successional lands (e.g. Bard 1952, Pickett 1982).

1. Small Watershed 1. Locust Run at Holbrook. This is a new site that we will establish with a standard USGS gauging station to represent a baseline, stable rural condition. The station will sample a perennial east-west stream draining greater than 300 ha of stable rural land. Land use is predominantly forested with limited agriculture and rural residential along roads that trace parts of the southern and eastern watershed divide. The area has a moderately affluent socioeconomic status. Security should be easy to establish using standard USGS techniques.

2 Small Watershed 2. Horsehead Branch near McDonogh School. This is a new site that we will establish with a standard USGS gauging station to represent transitional, suburban residential land use. The station will sample a perennial west-east stream draining approximately 300 ha of new (5 - 20 year old) suburban residential land use. The land use consists of single-family homes (low-medium density), townhomes, lawns and forest (with similar composition as described for small watershed #1 above). The area has a moderately affluent socioeconomic status. Security should be easy to establish using standard USGS measures.

3. Small Watershed 3. Unnamed tributary to Gwynns Falls at Howard Park at Baltimore. This is a new site that we will establish with a standard USGS gauging station to represent a stable, suburban/urban residential (neighborhood). The station will sample an intermittent north-south stream draining greater than 300 ha of an established medium density suburban residential neighborhood. Most of drainage is sewered with an outfall to the Gwynns Falls near Forest Park Avenue. The land use consists of single-family houses (medium density), lawns, strip commercial developments, a public park and a golf course. Vegetation is dominated by the upland association described for site #1 above but with more dominance by oak and less by tulip poplar. The area has a middle class socioeconomic status. Security should be moderately easy to establish using standard USGS measures - secure equipment enclosures will be required.

4. Small Watershed 4. Union Square Storm Sewer at Baltimore. This will be a new site to sample a storm sewer draining high-density urban residential land use. The site will be designed to sample > 300 ha of high density urban residential land use with vacant lots and a park and will be located in a "manhole" to be identified with City assistance. Vegetation in the park will be similar that described for small Watershed #1. Socioeconomic status will range from middle class through poverty level. Security will not be a problem because there will not likely be any permanent equipment installations, or they will be isolated from public contact (such as in manholes).

resolution. Because soil variables cannot be continuously imaged as can land cover, we will use a network of field plots to characterize soil/vegetation conditions and runoff processes.

Therefore, within our four small watersheds, we will delimit vegetation patches using high resolution data in combination with digital terrain data, soil map units and land use categories, and develop functional hydrologic patches, to serve as hydrologic response units (HRU's). We will sample land surface conditions at two levels - the first to delimit HRU's, and the second to determine internal, or subgrid, variability within the HRU's. Within each gauged small watershed, land use, as determined by Anderson Level-3 (Anderson et al. 1976) maps, soil map units (Baltimore County soil survey maps), topography (DEM), and vegetation cover will be overlaid using GIS to determine hydrologic units with a minimum size of 10 ha. Neville (1996) found 30 categories based on soil permeability, land use, and canopy cover to adequately describe samples of the Gwynns Falls watershed. Within the four small watersheds, higher resolution data will be collected to delimit patch configuration to a minimum of 0.01 ha. This higher resolution sampling will provide internal HRU variance and covariance of critical terrain and land cover variables for simulation modeling (Sec. E).

Delineation of socio-economic patches. To determine sociocultural patterns and relate them to the hydrologic, HRU-based measurements, we will determine how these patterns and processes are related to the heterogeneous distribution of physical and biological attributes of the watershed at comparable levels of analysis. The following methods for a social area analysis (Hamm 1982) address two levels of analysis designed to match our delineation of HRUs: social stratification within landuses and social differentiation within communities.

1) Social stratification within land uses. This level of analysis determines the differences between communities within each land use type. Comparisons between communities are based upon Logan and Molotch's (1987) political economy theory of place. An ecosystem and landscape approach in human ecology begins with the delineation and classification of homogeneous social areas. U.S. census block groups can be used for this research because a) census block groups correspond to the types of neighborhoods or communities that Logan and Molotch (1987) describe; b) block groups are small and can be treated as relatively homogeneous (Langbein and Lichtman 1978, Rives and Serow 1984, Weiss 1988, Garson and Biggs 1992), containing on average 400 housing units; c) block groups match both an ecosystem approach and Logan and Molotch's (1987) social stratification theory since they focused on the distribution of and comparisons between social areas and ignored variation within each social area (Shevky and Bell 1955); d) block groups as a unit of analysis work well with social area analysis techniques (Hamm 1982); and e) block groups boundaries are relatively consistent over time (Garson and Biggs 1992) and are designated for all metropolitan areas following Census Bureau guidelines.

This level of analysis corresponds approximately to the delineation of HRU's described above, and focuses on the relationship between indicators of social stratification and measures of the extent, distribution and structure of the vegetation for different HRU's. In addition, this analysis makes division into finer resolutions possible.

To classify block groups, we use the theoretical parameters identified by Logan and Molotch (1987), Choldin (1984) and Bullard (1990) with the adjustments recommended by Johnston (1976), Murdie (1976) and Hamm (1982). In addition, this approach has been successfully tested in a number of cities in the US (Bogue and Bogue 1976, Johnston 1976, Murdie 1976, Bogue 1984a, Bogue 1984b, Frisbie and Kasarda 1988). The four indices of patterns and processes of residential social stratification include: 1.) Socio-economic index; 2.) Household index; 3.) Ethnicity or community empowerment index; and 4.) Population density. Data for block group boundaries and socio-economic and household data were obtained from the 1970, 1980 and 1990 census. In 1990, there were approximately 895 block groups in the Gwynns Falls (mean size = 9.23 ha). Time series data (1970, 1980 and 1990) are used to measure any response lag between indicators of social stratification and vegetation.

2) Social differentiation within communities. This level of analysis differentiates households within communities. Data at the household level are collected by field surveys and focus group and informant interviews which will be digitally mapped as property regimes, normative behavior, and cultural practices (Community Profiling Committee/UDP 1991, Bruce 1989, RRA 1987). This information is registered with government records containing street address information which can be "address-matched" to a GIS street coverage of the watershed (Grove 1996, ARC-INFO 1995, Dalton 1994, Grove and Hohmann 1992).

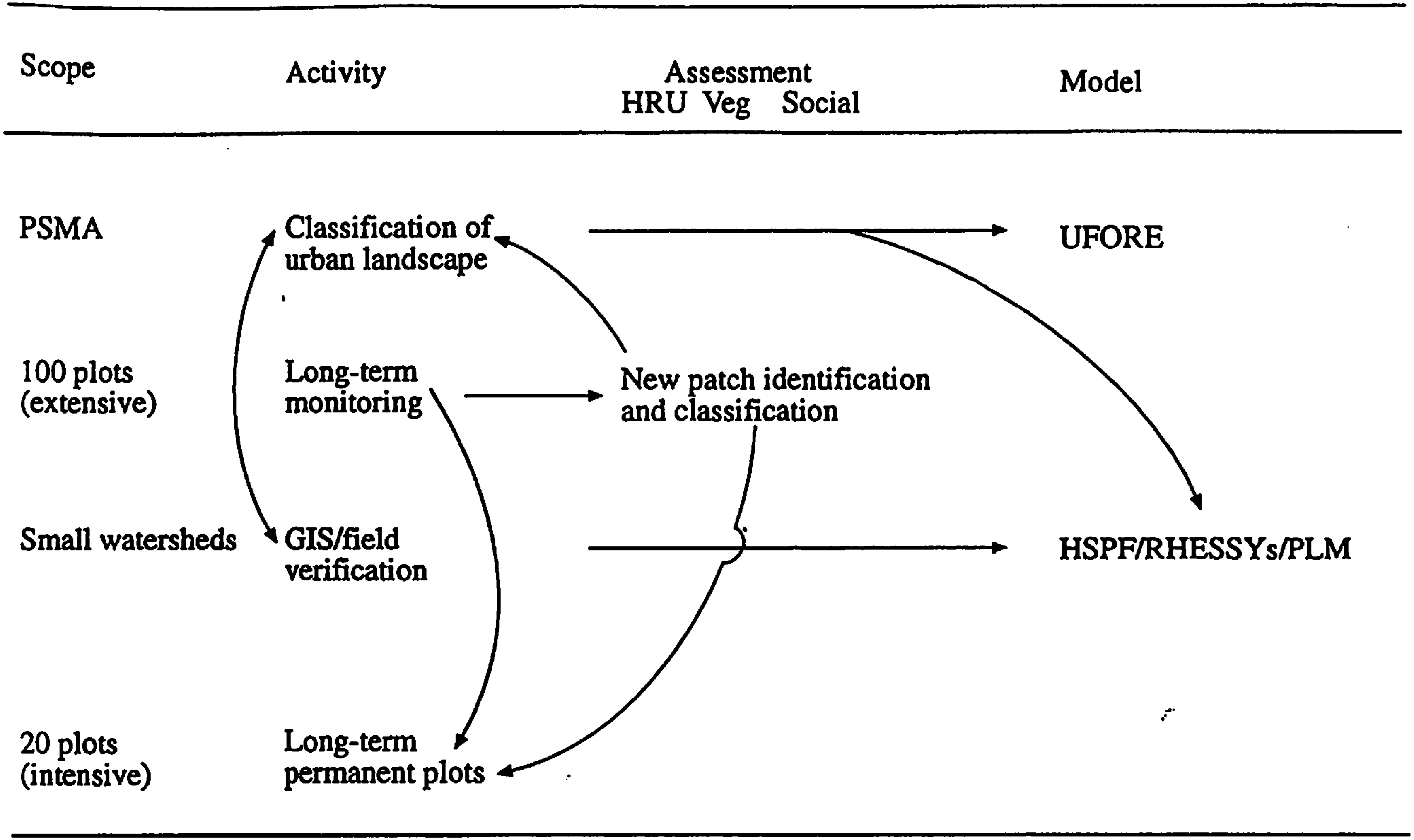


Figure 2.9. Diagram of the relationships between sampled plots, spatial analyses, integration of physical, socio-economic and ecological processes. Initial efforts at integration use the extensive sampled plots. The socio-economic, physical, and ecological patch classification is statistically related to the broader PSMA and is verified by applications to the small watersheds. Permanent-long term sample plots are selected from this array. The model of atmospheric fluxes (UFORE) is based on the PSMA classification, with validation in other research projects. The new synthetic model integrates socio-economic, ecological, and hydrological processes and operates at both the coarse scale of the PSMA and the fine scale of the small watersheds to test the influence of different scales of heterogeneity on human ecological systems.

This level of analysis corresponds to the fine scale resolution and subsampling of HRU's described above. Analysis at this scale relates measures of property regimes (Bromley 1991, Bruce 1989) with social order and normative behavior (, Machlis et al. 1995, Community Profiling Committee/UDP 1991), access to information and cultural practices (Bormann et al. 1995, RRA 1987), and biophysical indicators.

The variables for mapping property regimes, normative behavior and cultural practices and allocation mechanisms (exchange, authority, tradition and information) emerge from the theory identified by Burch and Deluca (1984), Bromley (1991), Parker and Burch (1992), Wrong (1994), Machlis et al. (1994) and Grove and Burch (1997). The digital mapping of property regimes, normative behavior, and cultural practices through field surveys and focus group and informant interviews uses community forestry techniques (Community Profiling Committee/UDP 1991, Bruce 1989, RRA1987) that have been adapted and applied to the Gwynns Falls watershed (Dalton 1994). This information is registered with census income and education data at the block level (Langbein and Lichtman 1978, Rives and Serow 1984, Garson and Biggs 1992) and address-based state and city/county government records of: 1) environmental violations / citations, and 2) property and violent crimes (Dalton 1994, Grove 1992).

Delineation of ecological patches. For each small watershed, we will conduct a complete vegetation assessment, defining patch type, configuration, composition, and spatial location. The ecological delineation will be combined with the physical-hydrologic and socio-economic delineations described above to complete our multi-disciplinary, integrated characterization of patch structure.

Patches will be delineated through photointerpreting 1991 ortho-digital aerial photographs at a scale 1:12000 following procedures outlined by Naveh and Lieberman (1984). For an urban landscape, the background matrix is the urban morphology and the vegetation defines the patches and corridors. Patches will be divided into three categories: herbaceous, shrub, and tree. A herbaceous patch is dominated by plants between 4 and 50 cm in height, a shrub patch is dominated by vegetation >50 cm in height but <2.5 cm dbh; and a tree patch is dominated by trees > 2.5 cm dbh. Minimal patch size will be 1/4 ha. Photoanalysis will be field verified.

Patches will be digitized using a vector based GIS, ARC/INFO. The digitized patches will be rectified to a 1:24000 USGS topographic base map and Universal Transverse Mercator coordinates to define patch location. The GIS also will be used to overlay a road map (TIGER file from the Census Bureau) to find patches for field reconnaissance.

In addition to location, each delineated patch will be characterized by its vertical structure, historic origin, size, and shape. Vertical structure will be assessed using both aerial photointerpretation and site verification. Historic information will be determined through site visits, interviewing adjacent landowners, and using historic aerial photographs to conduct a spatio-temporal analysis of the patches. Shape will be defined by the Patton's diversity index.

Grass and shrub patch types will be measured using a line intercept method (McDonnell et al. 1990; Hemond et al. 1983). Tree patches with understory will be divided into three strata: canopy, shrub, and seedling/herbaceous (McDonnell et al. 1990). To inventory the grass and shrub strata, the same methods will be used as in grass and shrub patch types. Tree patches <0.5 ha in size will be fully tallied for species and dbh. For tree patches >0.5 ha, ten percent of the area will be tallied using 200 m^2 circular plots.

Integration of physical-hydrologic, socio-economic and ecological patch delineations. We will use multivariate analysis to combine the hydrological, ecological, and socio-economic features of sample points to determine whether identifiable spatial patches effectively combine these three components at specific spatial scales (Figure 2.9). The suite of 100 extensive plots will yield the broad statistical assessment, which will be applied via GIS to combine estimate physical, ecological, and socio-economic heterogeneity over the entire PSMA. The GIS model of patch types appropriate to the entire PSMA will be tested by detailed application with ground truth to the four small watersheds associated with Gwynns Falls. An atmospheric flux model (UFORE) appropriate to the entire PSMA (Nowak 1993, McPherson et al. 1997), and our combined ecological-hydrological-socio-economic model will also synthesize the patch studies. The synthesis will test whether the results of the combined hydro-ecological-socio-economic model (Sec. E) are congruent at the metropolitan and the small watershed scales. Incongruence of the outputs would indicate an important role for spatial heterogeneity and processes specific to one or the other scale. In addition, the plot studies will be integrated through the determination of ecosystem processes and ecosystem status in the extensive and intensive plots. A temporal dimension will also synthesize plot results (Sec. D). The integrated description of patch types based on physical (hydrological), socio-

Table 23. Ecological and physical data collected on the extensive plots. These data will be used identify and classify patchetypes based on socio-economic, ecological, and physical attributes. In addition, these data are used for the UFORE model and will be used for mass balance analyses.

Data code	Description
LANDUSE	designated landuse
FD_PLOT	plot number
FD_LDUSE	land use designation for the plot
BLDGCOV	percent of the plot cover in building cover
DOM_BLDG	material of the dominant building: B-brick, W-wood, A-aluminum, S-steel, C-cement
BLDG_HT	height of the dominant building
P_CEMENT	percent of the plot cover in cement
P_TAR	percent of the plot cover in tarred surfaces
P_OTHER	percent of the plot cover in other materials
P_SOIL	percent of the plot cover in soil
P_DUFMUL	percent of the plot cover in duff/mulch
P_ROCK	percent of the plot cover in rock
P_HERB	percent of plot cover in herbaceous plants
P_GRASS	percent of the plot cover in maintained grass
P_WILGR	percent of the plot cover in unmaintained grass
P_WATER	percent of the plot cover in water
P_SHRUB	percent of the plot cover in shrub
P_TREE	percent of the plot cover in trees when driplines are projected to the ground
BLOCK_NO	the block number
TREE_CODE	tree species code
DBH	diameter at breast height
STEMS	number of stems for mulistemmed trees
HEIGHT	height of the tree
BOLE_HT	ground level to lower branches
CRNWIDTH	crown width
CR_SHAPE	crown shape
NO_C_SHP	percent of crown shape occupied by the tree crown
PER_VOID	percent of the crown without leaves
TREE_HIST	tree origin, P-planted, E-emergent, R-remnant
CND	condition of the crown E-excellent, less than 1% dieback G-good, 1 to 10% dieback F-fair, 11 to 25% dieback P-poor, 26 to 50% dieback C-critical, 51 to 75% dieback D-dying, 76 to 99% dieback K-dead, 100% dieback

economic, and ecological parameters will permit us to finalize the selection of the permanent study plots described below. Most of these 20 plots will be located within the four small watersheds.

2. Characterization of permenant patch study sites

Extensive (100) plots. In order to extend ecological and physical measurements beyond the small watersheds, and to validate the coarse scale classification of the patch types of all metropolitan Baltimore watersheds, we will use an array of 100 extensively located, rapid assessment plots. These plots will be periodically revisited to permit long-term monitoring of the ecological status of the metropolitan matrix. Standardized methods of extensive assessment of urban vegetation and anthropogenic structure have been developed and implemented in Baltimore, Boston, New York, and Philadelphia as part of a current research project (Luley et al., 1995, Nowak et al., in press). Although some measures of urban tree mortality have been made (Nowak et al., 1990), long-term continual measurement of urban area-wide vegetation structure are non-existent, but are essential to understanding changes, particularly regeneration, growth, disturbance, and mortality rates of urban vegetation. Long-term, ecosystem wide measurements will allow for assessments of how and why vegetation functions and structure differ across the urban landscape (e.g., Nowak and McBride, 1991 and 1992). These data will be input to the Urban Forest Effects (UFORE) model (Nowak et al., in press; Sec. E., Table 2.3).

Two hundred and fifteen 0.04 ha plots were measured within the City of Baltimore in 1995 to assess vegetation and artificial surface structure as part of an existing research project (Luley et al., 1995; Nowak et al., in press). For each plot, data were collected on land use, ground cover types (e.g., building, tar, grass), building characteristics and materials, and shrub and tree species, dimensions, and condition. From these measures, leaf surface area, leaf and tree biomass, and artificial surface areas are calculated using the UFORE model (e.g., Nowak, 1994, 1996).

For the LTER, we will locate 100, 0.04 ha plots that we will visit every three years. The location of these permanent plots will be recorded by GPS, but will be concealed to avoid unwanted and deliberate outside manipulation. For all plots detailed information on vegetation and artificial surface characteristics (e.g., dbh, tree height, crown width, condition) and location will be recorded on data sheets and data loggers. Repeated sampling of the permanent plots will be used to determine changes in structure, particularly vegetation growth, regeneration and mortality by patch type. These data will provide the base structural data for assessing various urban vegetation functions and urban change in the future. Data will be input into the UFORE model for calculation of vegetation and artificial surface structural characteristics (Nowak et al., in press).

To the variables used in UFORE, we will add ecosystem variables appropriate to the LTER Network goals. At all sites (100) soils will be sampled and analyzed for total carbon and nitrogen, depth to C horizon and bulk density. Total carbon and nitrogen will be quantified with a Carlo-Erba NA 1500 CNS analyzer available in the IES analytical laboratory. These analyses, coupled with estimates of impervious surface will allow for calculation of soil carbon storage in the different patch types. Concentrations of heavy metals (DTPA extractable Cu, Pb, Cr, Cd, and Zn) will be quantified using a Perkin-Elmer 6000 inductively coupled plasma emission spectrophotometer with graphite furnace, autosampler and a model 7500 data station available in the IES analytical laboratory. These soil analyses will be done every three years to detect long-term ecosystem changes over an extensive array of sites in the urban area.

Intensive (20) plots. The intensive plots will be located in or adjacent to the LTER small watersheds so that they are associated with the physical measurements taken there. Vegetation characterization for the intensive plots will be as described in the section on "delineation of ecological patches" above. In addition to the soil variables listed above (total C and N, heavy metals, depth, bulk density), a series of soil functional variables (N mineralization, trace gas fluxes) will be quantified using methods detailed in the "patch function" section below.

At five of the intensive sites we will continuously monitor soil temperature and moisture using thermistors and time domain reflectometry. Three small, waterproof, thermistors (accurate to +/- 0.1°C) will be installed in the soil at 0.1 m. Three Campbell Scientific CS 510 TDR probes (with individual printed circuit boards that eliminate the need for a cable tester) will estimate soil moisture. Campbell Scientific CR10x dataloggers with storage modules will acquire, process, and store all data. Dataloggers and battery will be housed in an insulated enclosure to minimize temperature extremes on the reference

Table 2.4. National Weather Service Climatological Stations in the Baltimore Metropolitan Area

Name	Period	County
BWI Airport	1950-Present	Anne Arundel
Baltimore	1948-Present	Baltimore City
Cylburn	1964-Present	Baltimore City
Millers 4 NE	1987-Present	Carroll County
Parkton	1953-1987	Baltimore
Phoenix	1994-Present	Baltimore
Pikesville	1948-Present	Baltimore
Towson	1948-Present	Baltimore
Westminster 2 SSE	1948-1979	Carroll
Westminster	1961-Present	Carroll
Woodstock	1948-Present	Baltimore

Notes:

1. Several stations have records prior to 1948. For example, records have been collected for over 100 years at Baltimore and Woodstock.

2. Data include daily precipitation, daily minimum and maximum temperatures, and temperature at time of observation.

3. Hourly precipitation and temperature data are available at Baltimore and BWI airport.

4. The Baltimore, Cylburn, Pikesville, and Woodstock stations are located near the watershed boundaries and effectively bracket the climatological conditions for the watershed. They will be supplemented by localized data collection for the proposed study.

thermistor. Soil temperatures will be scanned every minute with hourly average values stored, soil moisture will be scanned every hour, with daily average values stored.

At five of the intensive sites, a sampling plan will be instituted to measure atmospheric conditions over the range of conditions in the urban mosaic. A standard sensor package will be deployed at standard screen height for synoptic air temperature and humidity measurements, and include continuous measurement of air temperature, humidity, wide speed and direction, and net radiation. Loggers will sample at 5-second intervals and average over each hour to coincide with observations at first order weather stations. Standard deviation of wind direction will measure turbulence intensity. These measurements will be made during all seasons.

Standard height measurements will be started in the first year with five sensor systems. One of these will be used to sample a forested condition that is as close as possible to being undisturbed by urban influences. Another will be located in a large open area with as uniform a fetch in all directions as possible. These two systems will provide reference conditions upon which to compare wind speed, air temperature, and humidity measurements in a range of urban-disturbed conditions. The reference stations will located in two of the small watersheds along with a tipping bucket rain gauge, with the expectation that they can be used indefinitely into the future and that they will remain relatively unmodified. Each of the remaining three small watersheds will have tipping bucket gauges located in secure areas in order to quantify local precipitation (described below). A larger network of manually read rain gauges will be deployed to quantify spatial variability of precipitation.

For sampling surface meteorology over the full range of urban patch conditions, a pattern of ca. 40 sample points will be selected to include a range of vegetation and built-structure conditions within several kilometers of the reference sites. These points will include disturbed sites, and will be sampled by the remaining full sensor packages which will be rotated among the sample points for periods sufficiently long to represent all seasons at each point. A sensor system operating for 4 to 6 months out of a total year at each point will reasonably well categorize the point. Ultimately, the data will be used to model the below-canopy microclimate under as wide a range of synoptic weather regimes as possible. The resulting model will provide a means of extrapolating results throughout the LTER site. Because the sensor packages are highly portable, they can be moved in a systematic fashion to eventually make measurements at each of the sample points. Additional packages of sensors will be added in following years. Experience of our group in other urban areas has produced successful methods to secure the stations (Nowak 1994).

C. Patch Function

1. Hydrologic budgets for small watersheds.

Estimation of hydrologic budgets for the catchments described above requires measurement of precipitation inputs, stream outflow, an estimate of net groundwater flow or an assessment of its significance, and estimation of watershed evapotranspiration. Small watershed station #4 will be located in a storm sewer and will require approaches to flow measurement and water-quality sampling different from, but comparable with, those at other locations.

Precipitation input: There are currently nine National Weather Service meteorological stations operating in the Baltimore area (Table 2.4). These provide daily precipitation and air temperatures, and two of the stations provide hourly precipitation data. Within the Gwynns Falls watershed these will be augmented with a combination of tipping bucket (automated recording) and a larger number of event precipitation gauges (manually read) to capture spatial variability of precipitation. Tipping bucket gauges will be located in or near each of the small watersheds at schools or other institutions and will contribute to educational activities. Depending on local security and physical conditions, gauges will be located on rooftops or other secure areas. A larger number of manually read event precipitation gauges are required to capture localized convectional events that are typically dominant in summer and will be located as required around the PMSA. We plan to incorporate future NEXRAD precipitation products to characterize the regional precipitation input patterns as part of an augmented submission, but it is not envisioned to be part of this proposal.

Water imports: A large amount of the water input to these watersheds may be derived from domestic water supply originating outside the area. As part of the project we will need to quantify how much of the water supply is locally supplied (well water) and how much is imported. Domestic, commercial and industrial water use will be estimated using information from the city and county, along with local survey. The proportion of water consumption that is drained into the watershed system (e.g. irrigation, lawn watering, leakage) will be estimated in each of the catchments.

Watershed runoff: Each catchment will be gauged for continuous sampling of outflow. All gauges will be established and maintained by subcontract to the USGS. Gary Fisher, USGS Hydrologist will be liaison to this project. Standard USGS operations produce a digital data base of stage (depth) and discharge (volume per time) with a 15-minute time step. The time step may be reduced to 5 minutes at some sites; an approach used in previous urban work in Baltimore on small, highly impervious watersheds. A relationship is established between stage and discharge at each station, and regular field work is done to develop this relationship and to continuously assess its validity. Data are recorded using an autonomous electronic data logger. Typical USGS stations are visited every 6 weeks, but our stations will be visited more frequently especially during the development of the initial stage-discharge relationship. In addition urban sites require a little extra attention. Data are processed and analyzed promptly and entered into USGS data bases. These data will be available to LTER immediately and will be put into compatible formats for other data management systems. Although USGS publications are done on an annual basis and include a daily-mean discharge only, all data will be maintained and available in the data base. Quality assurance and quality control will be done not only to evaluate each individual record for errors due to site conditions, equipment problems, and weather impacts (such as freezing) but on all collected field data. Our storm sewer site will be a special case that will likely require a unique approach. This site will not likely have continuous flow, may not have a suitable surface site to house equipment and may require specialized equipment (e.g. a flume within the sewer).

Evapotranspiration: Although evapotranspiration will be computed on annual time steps as the residual of inputs-outputs, it will be estimated with pan evaporation and various estimation and modeling approaches on shorter (daily) time steps. The independent estimation of evapotranspiration is required as a check on how well we modeled a hydrologic budget given potential groundwater loss or storm and sanitary sewer leakage.

Plot measurements: Several manually read gauges will be located under canopies in several of the intensive patch characterization plots (described in the "patch analysis" section below) to quantify interception loss. Stemflow collars will be installed on 3-5 trees in each plot to characterize the quantity and quality of total storm stemflow. Other urban interception loss such as rooftop ponding will have to be evaluated within the project. Plot measurements will be linked with educational activities.

Information collected in the four small and two boundary condition main-stem watersheds will be used to calibrate and test models of differing degrees of complexity for runoff production and water quality for various socio-economic configurations. These model include HSPF which has been previously calibrated and operated for the Gwynns Falls watershed (Neville 1996), RHESSys (Band et al 1993, 1996, Creed et al 1996) which is being modified to incorporate urban land cover, and the Patuxent Landscape Model (Costanza et al. 1993) which has been calibrated and operated in the nearby Patuxent watershed. Each of these models contains certain advantages compared to the others in dealing with ecosystem processes, the range of water quality processes covered, and interaction with land use dynamics. Modeling activities are described in more detail in sec. D.2 below (Analysis, modeling and hypothesis testing).

2. Small watershed nutrient input and output budgets.

Runoff and precipitation will be sampled for water quality parameters weekly through the year and more frequently in the spring. Given proximity and easy access to sampling sites, more intensive sampling of water quality parameters will be selectively carried out to characterize within storm dynamics at several times of the year. Water quality samples will be analyzed for NO_3^-, NH_4^+, dissolved organic C and N, total suspended solids, PO_4^-, total P, base cations, Cl^- and SO_4^{2-} in the analytical laboratories at IES. Data will be compared with the two existing USGS water quality sampling stations in the Baltimore area (Table 2.5).

Table 2.5. Exsiting U.S. Geological Survey Hydrological Stations in the Baltimore Metropolitan Area

Name	Period	Drainage (km^2)
Gwynns Falls near Owings Mills	1958-1975	12.7
Scotts Level Br.	1994-1995*	N.D.
Gwynns Falls at Villa Nova	1957-1988 1994-1995* 1997-Present	84.2
Dead Run at Franklintown	1960-1987 1994-1995*	14.3
Gwynns Falls at Rt.	1994-1995*	N.D.

* Station operated for monthly water-quality sampling only.

N.D. = Not Determined

Dry deposition. N deposition monitoring in Maryland consists of two NADP/NTN sites and one CASTNet dry deposition site (Lynch et. al., 1995). Supplemental measurements of N deposition will occur at each site by analyzing bulk precipitation, throughfall, and stemflow. Dry deposition will be measured using triple filter packs (Johnson and Lindberg, 1992) at one site near the urban center and at one of the rural sites. These measurements will be supervised by Jon Hom (USFS).

Leaching losses will be quantified using zero-tension lysimeters, similar to the design of Driscoll et al. (1988). Lysimeters will be installed in triplicate at 30 cm depth in each of our 20 intensive "patch analysis" (described above) plots by excavating a pit and installing lysimeters beneath undisturbed soil profiles. Many of these plots will be located within the small watersheds. There will be sufficient plots in each patch type to allow us extrapolate leaching loss data from plots to compute small watershed budgets. Sampling at a single depth will quantify nutrient loss below the majority of the root zone in all of the different vegetation types in the urban ecosystem. This protocol follows procedures established at the LTER Soil Methods Standardization workshop held in March 1996 (Groffman attended this workshop). Pits will be backfilled after installation to allow for soil water collections during the winter months. Soil solutions will be monitored at monthly intervals throughout the year, with collections weekly during spring (March-April). Solutions will be analyzed as described above for runoff and precipitation samples.

Manufactured goods. Our goal in this proposal is to obtain measurements that are comparable with other small watershed based LTER sites (Hubbard Brook, Coweeta, Andrews, Konza) to address the question of how nutrient flux in urban ecosystems is different from other more natural areas. It is difficult to predict how detailed our analysis of the human-dominated fluxes will be. Quantifying input-output of manufactured goods and wastes will require data from census long form, survey and retail databases keyed to postal codes. City and county authorities can provide information on the "waste stream", e.g. how much is picked up by city/county sanitation, how much is recycled, composted, where is it landfilled.

3. Soil nutrient cycling processes

***In situ* net N mineralization and nitrification** will be measured at each of the intensive sites four times per year (January, April, July, October) using a "closed core" procedure (Raison et al. 1987). At each sample date, five intact soil cores (O, A and B horizons to 30 cm) will be taken in the field. The ends of one of the cores will be covered with a polyethylene bag and returned to the soil while the other will be transported to the laboratory at IES for extraction (2N KCl) followed by colorimetric analysis of NH_4^+ and NO_3^-. The field-placed cores will be left in place for one month and will then be extracted and analyzed. Five replicate cores will be incubated in each plot. Net mineralization will be quantified as the accumulation of NH_4^+ plus NO_3^- in the field-placed cores minus the levels of NH_4^+ and NO_3^- in the initial cores. Net nitrification will be quantified as the accumulation of NO_3^- alone.

Trace gas fluxes will be measured at least-six times per year at each site, including overwinter. Three chamber bases will be permanently installed 4 cm into the soil at each site. The chambers will be constructed from 16.5 cm wide by 20 cm long pieces of PVC pipe fitted with a septum as described by Holland et al (in press). An air-tight well cap will be placed on the chambers to initiate flux measurements. Samples will be taken with an air-tight syringe every 10 min for 0.5 h and added to evacuated vials. The vials will be returned to the laboratory at IES and analyzed for CH_4 by flame ionization GC for CO_2 by thermal conductivity GC and N_2O by electron capture GC available. Standards, spikes and field blanks will be prepared along with chamber samples.

4. Plant physiological responses to multiple stress

The Baltimore - Washington corridor experiences some of the most severe ozone episodes in the northeastern U.S. The ozone monitoring network (AIRS) in the region is extensive, showing wind direction (from SW), and highest ozone concentrations, along the corridor. A preliminary analysis of ozone monitoring sites shows an ozone gradient exists. Lower ozone levels occur to the west and south and higher levels to the north and east (Figure 2.10). In addition, Dr. Nowak will provide ozone, CO_2, dry deposition and NOx monitoring at the flux tower site.

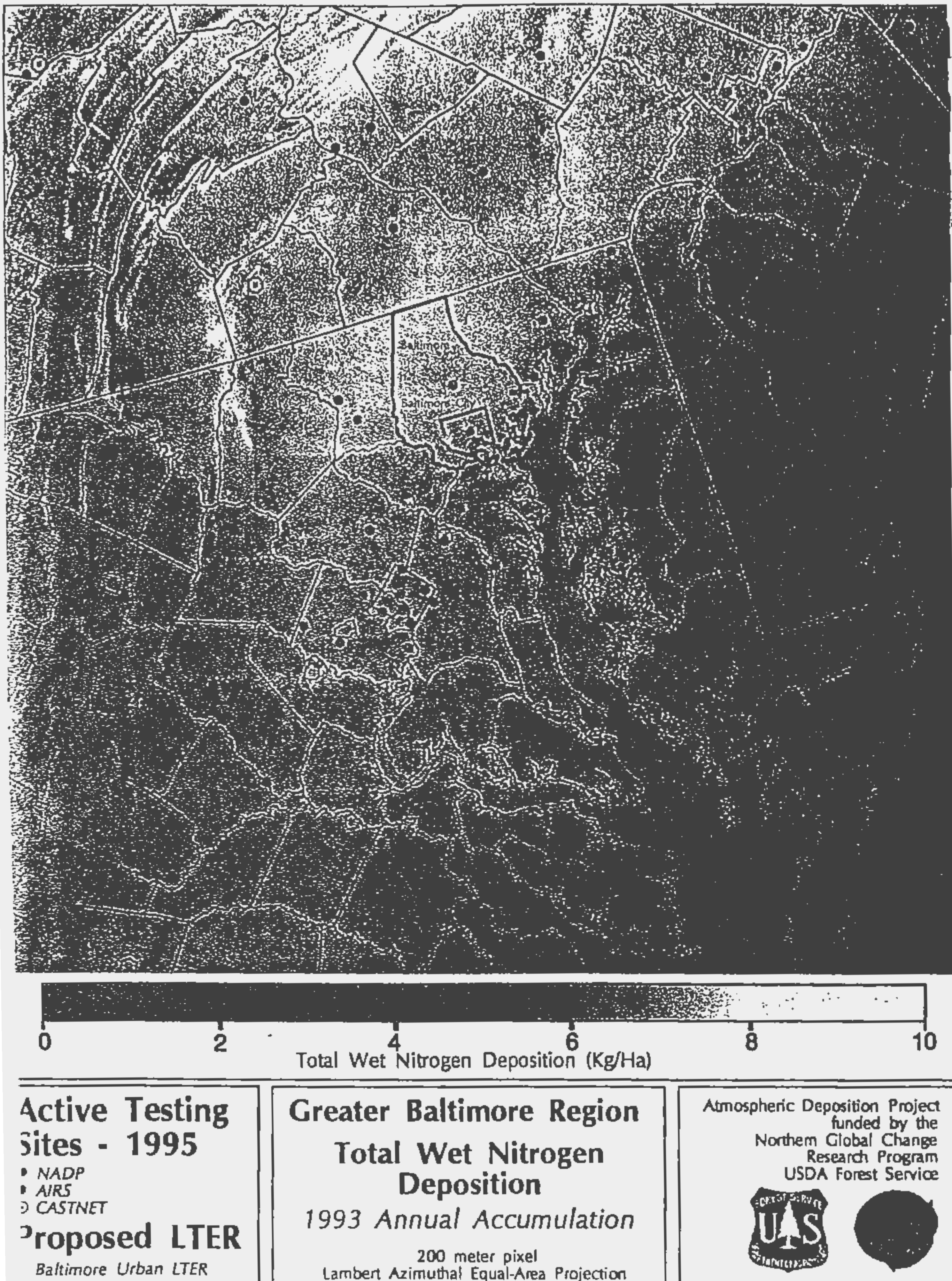


Figure 2.10. Illustration of a nitrogen gradient across the proposed study site.

We predict three effects from elevated levels of O_3, CO_2 and nitrogen deposition. 1) Elevated levels of O_3, CO_2, and nitrogen deposition will differentially affect oak spp. and yellow poplar efficiency of acquiring, utilizing, and retaining carbon and nitrogen along an urban air pollution gradient. 2) The faster growing, yellow poplar (indeterminate leaf growth form) will be more photosynthetically responsive to elevated ozone, CO_2, and nitrogen deposition along the urban air pollution gradient than the slower growing, determinate growth oak spp. 3) The fast growing, indeterminate leaf growth form of yellow poplar will show greater leaf senescence, compensatory allocation to new leaves, and larger changes in tissue C:N ratios and decomposition rates than the slower growing oak spp. along the urban air pollution gradient.

Yellow poplar (*Liriodendron tulipifera*), northern red oak (*Quercus rubra* L.), and white oak (*Quercus alba* L.) have previously been studied in air pollution and elevated CO_2 research, providing valuable physiological response data (Norby et al. 1986, Foster et al., 1990, Wullschleger et al. 1996, Samuelson and Kelley 1996). Yellow poplar is one of the few tree species studied under long term exposure to ozone and elevated carbon dioxide, showing compensatory growth when exposed to two times ambient levels of O_3 and CO_2 (Rebbeck 1995).

Three study sites will be selected to represent the range of urbanization. All sites will have similar aged mixed oak spp./hickory/yellow poplar forest stands and relatively undisturbed forest floor, and have road access for a bucket truck to access the forest canopy. Sites will be monitored with active and passive ozone monitors to characterize each sites (Grosjean 1995). Inexpensive passive monitors (Eco Badge, Vistanomics, Inc., Glendale, CA.) utilize an ozone sensitive filter paper which can be part of the educational effort to increase awareness of air pollution effects through this LTER project. N deposition monitoring activities are described above. Since diurnal patterns of CO_2 are expected to be higher in urban areas, with distinct pulses during the morning and evening rush hours a Li-Cor 6262 CO_2 analyzer will be used to monitor diurnal carbon dioxide concentrations periodically.

Leaves are major receptors of air pollution stress. Photosynthetic response to light, stomatal conductance, and CO2 response curves are good predictors of relative sensitivities of species to air pollutant stress. Photosynthetic measures of carbon assimilation and photosynthetic efficiency will be obtained with a Li-Cor 6400 portable photosynthetic system. Maximum photosynthesis, dark respiration, light curves, temperature curves will be measured using a light and temperature controlled cuvette on fully expanded leaves through the middle and latter growing season. Biochemical efficiency of the photosystem will be analyzed from A/Ci curves. Water use efficiency and nitrogen use efficiency will be calculated from the gas exchange measurements and nutrient analysis. Isotopic analysis on the variation of carbon in leaves will be used as an integrated, long term measurement of water use efficiency (Farquhar and Richards, 1984).

A Minolta SPAD 502 chlorophyll meter will be used to survey leaf chlorophyll content, and as an indicator of leaf nitrogen. It will be calibrated to detect changes in chlorophyll content, such as photosystem integrity with the onset of leaf senescence. Leaf material will be analyzed for carbon and nutrient content. Litter will be collected for chemical analysis and decomposition studies. Nitrogen isotope variation in tree rings will provide insights into historic information on atmospheric nitrogen deposition to the forest ecosystem while isotopically d15N in the foliage will be used to indicate increased canopy loading and uptake (Poulson et al. 1995).

Scaling from leaf to canopy gas exchange can be estimated by using the stem heat balance method (Dynamax) to establish relationships between water use, leaf gas exchange and the microenvironment. This method allows us to know the time period and rate of water use, which allows for estimates of canopy gas exchange as well as plant ozone uptake.

Results from this research also will be used to paramaterize ecosystem process, and deposition models. The use of passive ozone monitors and bioindicator plant species can be used to enhance educational awareness of air pollution effects. Collaboration with the large scale clearing experiments to add an indicator species from the air pollution gradient would result in more controlled, comparative studies to mature forest canopy studies. Future projects may include air pollution exclusion experiments (i.e. charcoal filtering) to study the effects of pollutants on species diversity in understory and successional species. Results from this and future research will link directly to the Chesapeake Bay Program which estimates nitrogen retention in forested watersheds and to the FACTS II open fumigation system in Rhinelander, WI using CO2 X O3 treatments in ecosystem level studies.

Table 2.6. Historical and paleoecological data sources.

Historical data will include:	The paleoecological data will consist of organisms and materials preserved in sediment that can be used as indicators:
a) For species composition of the vegetation: witness tree records, aerial photographs, published studies of the vegetation at specific times in the past (e.g. Shreve's studies in the late 1800s), Forest Inventory data, as well as floristic and ecological Master's and doctoral dissertations at colleges and universities throughout the state (Shreve et al. 1910, Semmes 1929, Stetson 1956, Brush 1982, Brush et al. 1980)	a) No comparable paleoecological sources
b) Size and distributions of human populations from historical journals and census data (Brush 1997)	b) Species composition of the vegetation from pollen and seeds of plants (Brush and Hilgartner IN PRESS)
c) Land cover and land use (forests to concrete) from agricultural census data and records of road building, housing developments road and railroad construction, etc. (Khan and Brush 1994)	c) Land cover and land use from pollen and seeds of plants and the proportion of arboreal to non arboreal to ragweed pollen (Brush and Brush 1994)
d) Precipitation and river/stream discharge from the National Climate Data Center and the U.S. Geological Survey	d) Precipitation and river discharge from sedimentation rates (Hinnov and Brush 1997)
e) Distribution of animal populations--from the Maryland Department of Natural Resources, the Patuxent Migratory Bird Habitat Research Lab, Smithsonia Institution and wildlife journals	e) Distributions of animal populations from aquatic invertebrates such as cladocera and copepods and aquatic insects (e.g. Fritz et al. 1987)
f) Fertilizer usage from farm records and agricultural extension service records	f) Fertilizer usage--carbon, nitrogen and phosphorous; diatom species; plant pigments (Cooper and Brush 1991, Laevitt et al. 1989)
g) Inputs and outputs of sewage from sewage treatment plant effluent records	g) Sewage outputs--nitrogen and phosphorus; diatom species; plant pigments (Brush 1984)
h) Movement of eroded soil through the system historical records of filling up of streams and tributaries with sediment (Gottschalk 1945).	h) Movement of eroded soil through the system--sedimentation rates (Brush 1984, 1989).

5. Biodiversity

The plant diversity will be defined using data collected as described above. Preliminary analysis of small mammal populations in New York City natural areas reveals a significant effect on seed availability and forest regeneration. With the characterization of different vegetation patches and patch types, fauna will be surveyed through appropriate trapping regimes to permit mark-recapture analysis of such species as footed mouse, eastern cottontail, meadow vole, gray squirrel and appropriate survey techniques for species such as white tailed deer. Breeding bird censuses will be conducted in cooperation with local bird clubs and the Patuxent Migratory Bird Habitat Research Laboratory.

In addition, soil macroinvertebrates will be inventoried on the 20 intensive permanent plots. This work builds on previous work identifying the importance of earthworm effects on nutrient and carbon dynamics in urban ecosystems (Pouyat et al. 1995, Steinberg et al. 1997). Further earthworm analyses may be tied to the manipulation studies described in sec. E.

6. Energy fluxes

Energy fluxes in the urban landscape include not only tropic levels but also energy consumption by humans. Funding will be sought for the construction and operation of towers from other sources for energy flux analyses. The LTER base funding will support the site selection for tower placement, and measurement of the surrounding landscape features. Input and partitioning of energy and matter in the study site will be quantified using UFORE and urban energy balance models (described in sec. D.2). In conjunction with EPA emissions data and collected field data, the model will ascertain flux magnitudes and how the components of the flux are partitioned and linked within and among different patch types. Model flux estimates will be validated against eddy-flux tower measurements (if outside grant money is obtained). Input of solar radiation will be measured using pyranometers mounted on local meteorology stations. Partitioning of net all-wave radiation into various components (e.g., sensible and latent heat) will be measured at an eddy-flux tower site (if outside grant money is obtained, see below). Modeling of urban energy flux will be done using an urban energy/water balance model (Grimmond et al., 1986; Grimmond and Oke, 1991; Grimmond, 1992).

D. Patch change

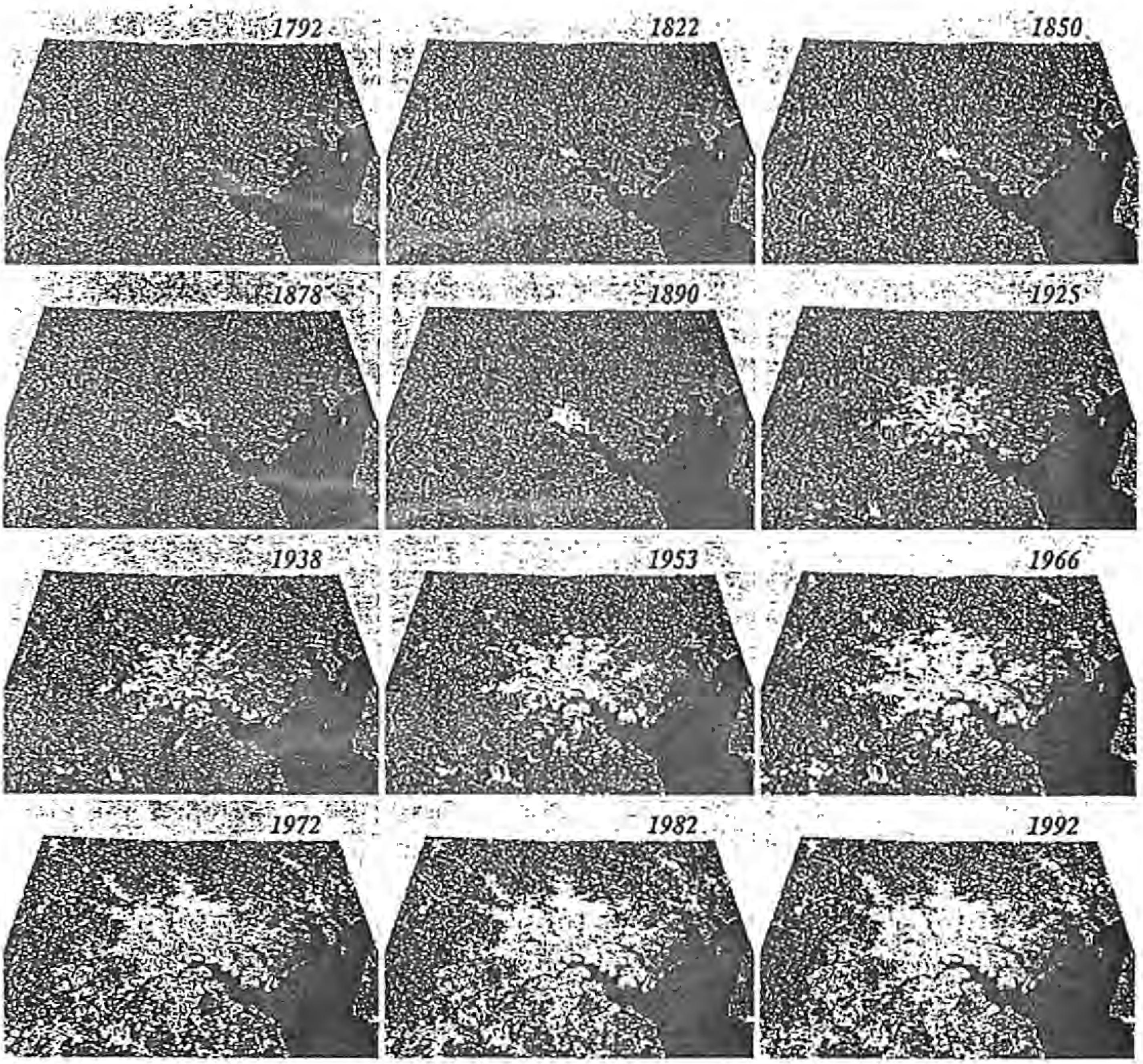
In this section we describe activities to test the temporal component of our central LTER question, i.e. how do the spatially structured socio-economic, physical and ecological conditions and processes in the metropolis affect each other through time? This will be done by a combination of historical analysis (literature and archive searches, sediment coring), a spatio-temporal analysis of patches within each small watershed, and simulation modeling.

1. Historical and Paleoecological Studies

Reconstructing the spatial structure of ecological, physical, and socio-economic factors over time will be accomplished through historical and paleoecological studies (Table 2.6). The historical and paleoecological data will consist of measurements or indicators of fluxes of materials that have flowed in and out of the parts of the ecosystem, as it has evolved over the past 200 years from a forested to an agricultural to an urban and suburban ecosystem (Figure 2.11). Measurements and indicators of processes and rates of processes that affect the flows will also be made to the degree that it is possible. Spatio-temporal analysis of patches within each small watershed will be conducted with historic aerial photographs dating to 1938.

Paleoecological data has already collected from over 200 cores throughout the Chesapeake Bay and tributaries and will be compiled to provide a regional history of environmental conditions over the past 2000 years, with particular emphasis on a comparison of the Medieval Warm Period of 1000 years ago and the period since European settlement. This paleoecological data will be supplemented by obtain sediment cores within the selected watersheds and at heads of streams Potential paleoecological sites have been identified at some of the sites such as a pond at site 1, and wetlands at other sites. In

Perspective View of 200 Years of Urban Growth in Baltimore



Visualization by Penny Masuoka, UMBC, NASA Goddard Space Flight Center and William Acevedo, USGS, NASA Ames Research Center

Figure 2.11. Urban growth in Baltimore, MD from 1792 to 1992.

addition, cores will also be collected at several locations downstream from where the Gwynns Falls enters the Patapsco River.

2. Modeling activities

Our conceptual model of the urban landscape fuses the approaches of a watershed based input-output scheme with that of a patch dynamics system. This is done by viewing any watershed as a hydrologically connected set of patches with temporally and spatially variable attributes. The set of patches may be destroyed and reformed by disturbance processes, and the state of any patch is at least partially dependent on surrounding and distant patches as influenced by drainage and advection/diffusion processes. A significant attribute of urban landscapes is that disturbance in the form of development and redevelopment can alter not only the patterns and characteristics of patches, but also the topography and drainage sequence to the extent that the horizontal redistribution of water and nutrients can locally be redefined. This degree of topographic and drainage change typically does not occur in other landscapes on the same time scales. Distinct assemblages of vegetation, urban form and socioeconomic characteristics may form an urban catena in which surface patterns may be described at scales ranging from upland to bottomland sequences along a single hillslope, or through the full watershed structure.

The Gwynns Falls watershed follows a pattern common in many older US cities in which a dense urban region with a central commercial area around the river mouth or waterfront is surrounded by poorer residential and commercial areas, which in turn are surrounded by more affluent and less dense suburbs. The distribution and heterogeneity of patch types within each zone must be considered in terms of the different typical soils, vegetation structure and other land cover, and the drainage sequence to understand and compute the flux of carbon, water and nutrients across the landscape and between land surface and atmosphere.

With the simulation models we seek to parameterize and operate over this scale range are fully consistent with our conceptual view of the landscape, described above. The set of model approaches we will use are designed to incorporate different levels of surface heterogeneity into the patch structure, and will provide both a conceptual approach and a framework to collect, organize and analyze information sampled across the urban landscape. RHESSYS (Band et al 1993, 1996) operates at the hillslope level and explicitly incorporates variation in patch structure and function down a drainage sequence from hillslope crest to the riparian zone. Mackay and Band (in press) and Creed et al (1996) have shown that this structure is critical to the flux of water and nutrients from catchments, as well as long term ecological-hydrological interactions. RHESSys can be scaled to larger watersheds by progressively aggregating the landscape into larger, more complex "hillslopes" and transferring spatially explicit patch heterogeneity between hillslopes into within hillslope distribution functions. HSPF and the Patuxent Landscape Model (PLM, http://kabir.umd.edu/PLM/PLM_proj.html) (Costanza et al 1993) operate at more spatially lumped levels, although PLM is also designed as a grid-based distributed model with the ability to operate a high resolution commensurate with the operation of RHESSys. HSPF is designed to compute a wider range of constituent transport (e.g. sediment, contaminants) and operates at the subcatchment level. It has already been parameterized and applied to the Gwynns Falls watershed, but requires the more explicit treatment of vegetation flux processes and dynamics that RHESSys and PLM can provide.

We plan to measure and simulate runoff production and nutrient dynamics in small subcatchments and investigate scaling behavior to the larger watersheds using a combination of the approaches. Data collect for analyzing patch structure and function (secs. B and C) used to parameterize RHESSys, HSPF and PLM and will be combined from remotely sensed canopy variables and DEM derived terrain variables. We expect that the spatial heterogeneity of vegetation and soils within urban landscapes will be greater than in rural areas, thus requiring the high resolution of data on patches. Moreover, within urban landscapes, rather than associating vegetation and other land cover variables at the level of land use categories, we will sample the variance and covariance of required terrain and land cover variables at high resolution. In addition HRUs, stream physical and ecological characteristics will be measured to relate spatial patterns of human activity, the physical structure and dynamics of stream networks, and the spatial structure and functioning of lotic and riparian ecosystems. The hydrological and ecological sampling described below will be hierarchical, allowing aggregation to discover the scales at which patterns and interactions occur. Specific scales of interest will be at the "neighborhood" level where extremely high resolution data (e.g. 5m cells) will be collected for selected areas within the test catchments. The level of the test catchments (a few hundred hectares, mapped at the 30m grid of standard DEM and TM data) and the full Gwynns Falls to the Baltimore PMSA at 30m to 1km grid resolution will be part of the Incorporation of Socioeconomic Feedback within The Patuxent Model.

The scaling exercise discussed above will be useful to calibrate the biophysical processes that may need to be described at much higher levels of aggregation (e.g. 100m-1km grids) for PLM at the full watershed scale. Compared to RHESSys and HSPF, PLM will add the important dimension of explicit interaction with the socioeconomic processes involved in land use change. Using a mass balance approach to incorporate process-based data at a reasonably high resolution within the entire watershed, changing spatial patterns and processes can be analyzed within the context of altered management strategies such as the use of best management practices. By incorporating spatial articulation of patches in an ecological model we can realistically address large scale management issues within the heterogeneous system of the larger watersheds and metropolitan region.

For the spatially explicit PLM, the modeled landscape is partitioned into a spatial grid of square unit cells (Costanza et al. 1993). The model is hierarchical in structure, incorporating an ecosystem-level "unit" model that is replicated in each of the unit cells representing the landscape. The unit model (Fitz et al. 1996) itself is divided into a set of model sectors that simulate the important ecological dynamics at a daily time step. While the unit model simulates ecological processes within a unit cell, horizontal fluxes across the landscape occur within the domain of the broader spatial implementation of the unit model to form the PLM. Such fluxes are driven by cell-cell head differences of surface water and of ground water in saturated storage. Within this spatial context, the water fluxes between cells carry dissolved and suspended materials, determining water quality in the landscape.

Because the same generic unit model structure will be run in each cell, there is a database of parameters that serves as input to the model to accommodate the different patch types within an urban landscape. A set of values of initial conditions, rate parameters, stoichiometric ratios, etc. that are specific to the cell's patch type, are input to the unit model for each unit cell. The vegetation communities in the cells respond to changing hydrologic and nutrient regimes via successional switching algorithms which are defined by current ecological knowledge. Thus, when run within the spatial framework of the overall PLM, the landscape response to hydrology and water quality is effectively simulated as material flows between adjacent cells.

The ecological model is linked to an economic model which predicts the probability of land use change within the area. The economic model allows human decisions to be modeled as a function of both economic and ecological spatial variables. Probabilities of land conversion are calculated from costs of conversion and predicted land value in residential land use. Land value predictions are modeled as a function of local and regional characteristics such as distance to employment centers, percent open space in the neighborhood and various other spatially-explicit variables. The empirical model generates the relative likelihood of conversion of cells. Information about growth pressures allows final estimates of new residential development to be made. The linked model allows the effects of both direct land use change through human actions and indirect effects through ecological change to be evaluated.

Combining the two modeling approaches -- the fine scale, spatially explicit combination of HSPF and RHESSys, which incorporate ecological and physical processes, with the coarser scale Patuxent Landscape Model, which incorporates ecosystem processes at the 0.4 km^2 scale and combines ecological and hydrological processes with economic processes, will allow a new level of understanding the functioning of urban watersheds. The PLM has been previously applied in a rural and suburbanizing landscape matrix. Thus all the modeling approaches need to be refined to match the scale and complexity of spatial heterogeneity, as well as the novel combinations of ecological and infrastructural patch types. Applying these modeling approaches together with an empirical assessment of the spatial heterogeneity of social, ecological, and physical processes in an urban region will determine whether the heterogeneity at fine scales acts as mechanisms for the fluxes at the coarser scales. Evaluating the entire metropolitan area, and subsets represented by watersheds contrasting in land cover, management, and socio-economic processes will add substantially to the ability to understand long-term dynamics of urban ecosystems and the downstream environments they affect.

The UFORE model is designed to quantify urban vegetation structure, biogenic volatile organic compound emissions, vegetation carbon storage and sequestration, dry deposition to vegetation and other urban surfaces of gaseous and particulate pollutants, and the effects of vegetation of local building energy and use, and consequent power plant emissions. This model has been calibrated for Baltimore, Boston, New York, Philadelphia and Atlanta, allowing for comparison of results from this study with other cities. Data from the 200 intensive plots will be used for this model.

E. Mechanisms of patch change

In this section we describe two long-term manipulation experiments that will form the core experimental component of the LTER. The experiments vary ecological and socio-economic factors in a controlled way to increase our mechanistic understanding of the way that physical, socio-economic and ecological factors interact in time and space. Manipulation experiments

1. Manipulation of Exotic Vegetation.

We propose to establish a series of long-term experiments to evaluate the effect of exotic tree and shrub species on ecosystem function and to foster understanding of the human values associated with native and exotic vegetation. The experiments will focus on the development of vegetation during secondary succession in "old fields" and in forest gaps.

We will establish four experimental areas for this work; 1) a field in a large park in the urban core that has been mowed for many years, 2) a field on the rural fringe that has either been mowed or plowed for many years, 3) a series of forest gaps in a large park in the urban-residential area of the city and 4) a series of forest gaps in a large park or reservoir watershed in on the rural fringe of the city. Candidate sites for these areas have been located and tentative permission for use of the sites has been granted. The old field experiment sites will consist of six large (1 ha) plots with two treatments. The forest gap experiment sites will consist of six gaps (from 0.3 to 0.6 ha in size) located within a large tract of forest.

In the control treatment, vegetation will develop with no intervention. In the "removal" treatment, exotic (species not native to the area) tree and shrub species will be removed as soon as they develop to a stage where they can be identified. Plots will be instrumented with soil temperature and moisture and meteorological monitoring equipment as described above.

Ecological response variables to be measured (using methods described earlier in this proposal) include:

- plant species composition
- plant biomass
- net primary production
- total soil carbon
- potential net nitrogen mineralization and nitrification
- trace gas fluxes
- biodiversity

In addition to evaluating the effects of exotic species on ecological functions, we will explore the possibility of assessing human values associated with native and exotic vegetation before and after initiation of our experiments and an associated education/outreach program. Design of this work will require the identification and funding of an individual with expertise in assessment of "human response to nature." Execution of the work would be done by student interns as part of the Educational Activities described below.

The first step of the assessment of human response to exotic species will be to survey attitudes about native and exotic vegetation before our study begins. We would need to develop information about opinions of and knowledge about the effects of exotics on ecosystem functions, the aesthetic

Table 2.7. Baltimore Urban LTER Project - Education amd Outreach Activities

Key Goal	Program Area	Year 1998	1999	2000	2001	2002	2003	Long Term Goals & Products
Foster interest and achievement in environ-mental careers via student/ scientist partnerships.	middle school student programs	• build on Kids Grow, RAISE and other programs		• develop after school, week-end and summer programs combining recreation, vocational exposure and ecological research for middle school children				• exposure to ecology careers and thinking • lasting collaborations
	high school / young scholars / mentorship programs	• build on Tree Troops, SoS and RAISE programs • initiate a high school mentorship program		• continue and expand the student/science partnership and college student mentorship portions of the program • expand to more schools within and beyond the Gwynns Falls watershed				• building interest of diverse students in ecology careers • empowerment through action
	college student internship programs	• provide mentors for Tree Troops, etc. • start a small REU program		• link w/ other programs working with college students (e.g., teacher preparation project) • expand near-peer mentoring program and consider adding opportunities for pre-service teachers				• quality training of diverse college students for ecology careers • serve students from other LTER's & cities
Contribute to and collaborate with existing education reform efforts.	school-based student research programs	• begin with 2-3 HS, 2-3 Jr. HS & Com. Colleges in Gwynns Falls Watershed • plan with schools, Steering Committee		• develop infrastructure of sites and technolgoy to support a network of school-based research projects		• extend the network to include other cities		• Project produces a model for multi-site research ideas and data exchange. • Project coordinates multi-city research and data exchange.
	curriculum development	• plan with schools, Steering Committee	• develop module(s) for use in city and county schools • continue planning and coordination with schools • write proposals		• pilot test and refine module(s) • craft new modules	• complete development, refinement and evaluation of curriculum modules • disseminate curriculum to other cities		• Project produces a curriculum of "City as Ecosystem", integrating ecology and social sciences, etc., available on the Internet and in print.
	teacher development & support	• plan with schools, Steering Committee • offer workshops • provide resources • write proposals		• develop teacher training and support mechanisms to sustain school-based research programs • engage teachers in curriculum development, testing and evaluation • teachers take the lead in disseminating the model developed in Baltimore				• Baltimore becomes a site for teacher development programs for a national audience of urban educators, building on curriculum and programmatic elements of this and related projects.
Increase awareness of "city as ecosystem" in the general public.	Media-based and community outreach	• build interest • build on watershed & trails programs	• start broadcasting student / researcher data about Baltimore's environment • work with and expand community-based programs • hold first annual event		• link to data collection efforts in other cities to provide comparisons, etc. • continue 1-2 annual events • help coordinate regional environmental justice, environmental quality and ecological restoration oriented projects			• routine reporting of environmental success stories in the media w/ data from public, students, teachers and researchers • increased public awareness
	Develop and make available user friendly tools and information	• plan workshops • coordinate with LTER research work • begin developing user-friendly models		• offer workshops to managers, citizens, etc. • develop print and/or on-line resources • continue and expand involvement of public in research and management				• citizens and decision makers benefit from and contribute to LTER research

values that people place on "pretty" exotic species and their willingness to pay for extirpation of exotic species to preserve ecosystem functions. We then need to determine if science and/or education can influence human attitudes and values. This effort would be closely tied to the field manipulation experiment via educational displays and other outreach activities. We would then go back and survey some years later and ask the same questions, noting if the respondents are aware of the experiments.

2. The effect of neighborhood revitalization on ecological processes.

Community forestry / gardening programs will be initiated in three communities through partnerships with the USDA Forest Service Revitalizing Baltimore Program (RB) and the Parks & People/ Department of Recreation & Parks Urban Resources Initiatives (URI) (see for example, Burch and Grove 1993, Burch et al. 1997, Grove 1995, Grove et al. 1994, Loomis et al. 1995). A new approach to these initiatives will be to institute micro-lending / micro enterprises and training programs as a means to fully test our hypotheses (see letters of support from Hollis and Dupont).

We will compare the three pilot initiatives with a) three similar "comparison" neighborhoods and b) other community forestry and/or neighborhood revitalization efforts in the City of Baltimore. The methods described earlier for measuring differences between communities and within communities will be used to measure physical, ecological and social changes in these neighborhoods as well.

F. Educational activities

Programmatic efforts will include: 1) student / scientist partnerships, 2) work with teachers, school groups and curriculum, 3) general public outreach, and 4) developing and making available user friendly tools and information (Table 2.7).

1. Student / Scientist Partnership Program

We propose to work with Baltimore City and County middle and high schools, community centers, and local community and four year colleges who already have during- and after-school, and summer programs in environmental science. The idea is to create an integrated, multi-year track of opportunities for students to work in partnership with scientists, with activities paralleling (for the younger students) or integral to (for the older students) the LTER field work (Table 2.8). The scientist partners will be LTER researchers and near-peer participants from the higher levels of the program (e.g., high school students for the middle school kids, college students for the high school kids). We will start in Years 1-3 with a small number of schools and community centers within the core area of the LTER research - the Gwynns Falls Watershed - to develop and test the model. Then, in Years 4-6 we will expand to more locations, both within the Gwynns Falls and elsewhere. The schools from Baltimore City are part of the Baltimore Urban Systemic Initiative, and we will work closely with their staff to combine our efforts.

Goals for student participants are to: 1) learn about the environment (physical, biological, sociological) from their own investigations, 2) gain practical skills, 3) build and sustain interest in the environment, 4) consider and be empowered to pursue careers and/or higher education in an environmental field, and 5) make concrete contributions to environmental understanding and environmental quality in their community. These goals are consistent with those of the Baltimore Urban Systemic Initiative (BUSI), and both the Project Director (Dr. Jonathan Wilson, Morgan State University) and one of the key BUSI collaborators from the city schools (Ms. Ruth Andrione) are enthusiastic collaborators on the Baltimore Urban LTER project. For the scientists, this effort will contribute 1) useful data collection (Table 2.8) a firm connection between the research and the local community, and 3) assistance in implementing and managing experimental manipulations (Berkowitz 1997).

Starting in Year 1, we will work with these programs: KidsGrow (middle school), Tree Troops (high school), Project RAISE (middle and high school), Save our Streams (all grades) and college internship programs coordinated through the Shriver Center which draws from 12 local institutions including Catonsville Community College, Towson State University, Morgan State University, and the

Table 2.8. Possible research topics and data collection for students and teachers. * Indicates topics which may be made available as modules with modest supplies to teachers as part of the LTER's education and data collection efforts.

Urban, suburban, and rural forestry
- stand delineation
- street tree inventory
- the use of Global Positioning Systems
- geographic information systems applications (ArcView 3.0, CITYgreen)

Studies of ecological fluxes
- decomposition
- litter fall
- nutrient leakage
- *human resource use surveys
- *stream sampling
- *nutrient deposition onto buildings
- schoolyard nutrient budgets
- ecological "footprints" of schools or neighborhoods

Studies of biodiversity
- *small mammal sampling
- *bird counts
- *worm sampling
- surveys of exotic plants and animals
- experimental removal of exotic plants

Air quality
- *ozone sensitive pea plant phytometers
- *lichen and leaf yeast bio-indicators
- *dust sampling
- *meteorological sampling
- odor sampling

Socioeconomic studies
- attitudes towards the environment
- perceptions of environmental quality
- behavioral surveys
- assessment of policy and management implications of the research
- attitudes towards exotic species
- involvement in neighborhood restoration - planning, implementation and documentation

Ecological restoration studies
- community forestry
- community gardens
- schoolyard restoration
- street tree planting and maintenance
- stream corridor restoration

University of Maryland - Baltimore County. The LTER Education Coordinator will join forces with coordinators of these programs, and with school teachers, to develop urban ecosystem-based modules, and also to help integrate these modules into existing instructional programs (see sec. 2 below).

KidsGrow is currently a six-week summer and after- school environmental education program for middle school students, operating out of several of Baltimore's 58 recreation centers including 3 in the Gwynns Falls watershed. During the past three years, KidsGrow has provided environmental education and action programs for over 200 children in some of Baltimore's most dramatically underserved communities. We will work with the KidsGrow staff to expand its curriculum, creating a three-year track - Beginning, Intermediate, and Advanced KidsGrow - drawing activities from the LTER effort (Table 2.8). By creating a three-year KidsGrow track, middle school students will have summer programming opportunities that will allow them to build on the previous summers' and school years' programs, with some serving as near-peer mentors for younger students in the program.

Tree Troops is a new program of the Parks & People Foundation and the University of Maryland - Baltimore County. High school students conduct field data inventories of the urban forest and then develop neighborhood planting atlases with planting targets that can be implemented through the Parks & People Foundation's Community Forestry Program, taking advantage of Maryland's unique requirement for 75 hours of community service for all high school graduates. College interns will receive academic or community service credit as they lead teams of 6-10 high school students on-site and community residents will participate in data collection of their local parks, street trees, and vacant lots, and will use data to develop, in conjunction with community foresters and students, neighborhood planting atlases. Work will begin at four schools in 1998 - Western and Edmondson High Schools (City), McDonough and Park Schools (County) - and expand to more schools in 2001. We have established relationships with each of these schools, and teachers in each are excited about the opportunity to integrate data that students collect themselves in the field into their regular Math and Science curricula. To provide changes challenges for students who remain in the program from year to year, Tree Troops will be expanded to include modules on soils, hydrology, biodiversity, habitat assessments, social area assessments, and other data collection regimes as needed by LTER scientists (Table 2.8), the students themselves, and/or community residents.

Project RAISE (Raising Ambitions to Increase Self-Esteem) is a mentoring program of the Baltimore City Schools for middle and high school students, aimed at helping city kids stay in school until graduation and exposing them to career and higher educational opportunities. The LTER Education Coordinator will work with two groups of RAISE students in Baltimore City, one in Lemmuel Middle School (6-8th graders), and one in Edmondson High School (9-12th graders), in a summer job program funded predominantly through Maryland's Commonwealth program (i.e., we will not have to pay for students' work time, but must provide meaningful employment experiences for them). From these pools, groups of students will be recruited to participate in the other summer and after school programs as they are expanded during the course of the LTER project.

Save our Streams is a project that involves students and community groups in monitoring stream water quality in a number of watersheds throughout the Baltimore metropolitan area. Their Impact Monitoring Program includes 17 sites in the Gwynns Falls Watershed and includes macro-invertebrate sampling, pebble counts, analysis of chemical constituents and determining stream cross sections. We will work with the SoS staff to integrate these activities into the middle and high school components of the project (see Table 2.8).

College student internships are integral to the Tree Troops program. A number of local institutions already have expressed interest in providing interns for the program. In addition to these student/mentoring position, we will build on our 10 years of experience running a highly successful REU program here at IES (Berkowitz et al. 1995) to build a similar program of research internships in Baltimore, where students would work directly with LTER scientists on projects of their own design. Both internship programs, and the commitment of the LTER research leaders to hire local talent whenever possible for technical positions, will provide capstone employment experiences for some of the students coming through the multi-year program.

Table 29. Local Education Steering Committee Members.

Ms. Ruth Andrione, Coordinator, Math and Science Education, Baltimore City Department of Schools

Dr. Sari Bennet, Director, Maryland Geographic Alliance, Department of Geography, University of Maryland - Baltimore County

Ms. Valerie Brennan, High School Science Teacher, Western High School of Technology and Environmental Science

Dr. Gary Heath, Coordinator, Math, Science and Environmental Education, Maryland State Department of Education

Mr. Michael Johnson, Director, Educational Opportunity Program, RAISE, Inc.

Dr. Loretta Molitor, Director, Center for Mathematics and Sciences Education, Towson State University

Dr. Chris Fox, Coordinator, Environmental Project, Catonsville Community College

Mr. Joe Harbor, Project Director, Natural Connections, Irvine Natural Science Center

Ms. Kim Lane, Deputy Director, Maryland Save Our Streams

Ms. Sally Loomis, Director of Program Development, Parks and People Foundation

Ms. Corinne Parks, Director, Carrie Murray Environmental Education Center, Baltimore City Recreation and Parks

Mr. Chris Ryer, Director, Baltimore Program, Trust for Public Lands

Ms. Anita Stockton, Coordinator, Math and Science Education, Baltimore County Department of Education

Dr. Jonathan E. H. Wilson, Baltimore Urban Systemic Initiative, Morgan State University

2. Work with teachers, school groups and curriculum.

As we begin to involve students from middle and high schools in the Gwynns Falls Watershed in the student/scientist partnership programs described above, we also will start working with teachers from these same schools. The ultimate goal is to infuse the study and understanding of the city as an ecosystem into the formal curriculum (using the broadest definition of ecosystem to include ecological, physical and socio- economics, etc.), so that more than just the few students participating directly in the intensive partnership programs still can benefit from the LTER. We will work very closely with an Education Steering Committee (Table 2.9) to find ways that the LTER can contribute to the achievement of local and nationally recognized goals for education reform. The more immediate goals are to 1) build clear connections between what the students are doing and their formal curriculum, 2) identify the needs and opportunities for curriculum development and/or faculty development in these and other local schools, 3) explore concrete ways of involving more students and teachers in the field-based research activities, and 4) devise an action plan for years 3-6. This plan might include a system of teacher and curriculum development and support, a network for exchanging student-centered investigations, a teacher / scientist partnership program, etc. Grants to support these initiatives will be sought as the needs and ideas are identified.

As part of this effort, we will provide resources (simple modules including background information, protocols, and modest supplies) to teachers and schools that express an interest so that they can collect data as part of the LTER project (see possible topics in Table 2.8). Participating teachers and schools will contribute their findings to a common database, and will receive periodic summaries from the entire metropolitan area. In the long run, we hope that the project might disseminate both its model of teacher-based student research in urban ecology and its curriculum modules to a national audience of teachers and educators. However, this will not be possible without leveraging of additional funds for program development, evaluation and documentation.

3. General public outreach

The media can play a dynamic role in bringing the results of the project into the public's eye. From routine reporting of some of the monitoring and research results (e.g., water and air quality, biological indicators, etc.) to periodic features about the scientists, managers, educators and teachers involved, the project can become the focal point of a concerted urban ecology information campaign. The emphasis should be on POSITIVE things people can do to make a difference, not environmental gloom and doom. One or two high profile public events (e.g., associated with African American Earth Day) will be developed as well.

4. Developing and making available user-friendly tools and information.

Decision makers and managers will be involved, directly, in developing a set of "models" of the metropolis that are useful for them in their work. Easy-to-use interfaces will be constructed based on that interaction so that decision makers in government and non-governmental organizations, as well as community groups can explore the ecological implications of changes in the environments of concern to them. Effective links with communities and decision makers are key to legitimizing and sustaining scientific research in an urban setting.

SECTION 3: LITERATURE CITED

AAAS (American Association for the Advancement of Science). 1989. Science for All Americans. Oxford University Press. New York, NY.

AAAS (American Association for the Advancement of Science). 1993. Project 2061. Benchmarks for science literacy. American Association for the Advancement of Science, Washington, D.C., USA.

Aber, J. D. 1978. A method for estimating foliage-height profiles in broad-leaved forests. Journal of Ecology 67:35-40.

AGI (American Geological Institute). 1991. Earth science content guidelines grades k-12. American Geological Institute, Alexandria, VA, USA.

Agnew, J. A. 1987. The geographical mediation of state and society. Allen and Unwin, Boston.

Agnew, J. A., and J. S. Duncan, editors. 1989. The power of place: bringing together geographical imaginations. Allen and Unwin, Boston.

Alberts, B.M. 1991. Elementary science education in the United States: how scientists can help. Current Biology. 1:339-341.

Allen, T. F. H., R. V. O'Neill, and T. W. Hoekstra. 1984. Interlevel relations in ecological research and management: some working principles from hierarchy theory. USDA Forest Service General Technical Report RM-110:1-11.

Anderson, J. R., E. E. Hardy, J. T. Roach, and R. E. Witmer. 1976. Land use and land cover classification systems for use with remote sensor data. US Geological Survey, USGS Professional Paper 964.

ARC-INFO. 1995. ARC-INFO user's manuals. Volume 7.03 Workstation. Environmental Systems Research Institute, Inc, Redlands.

Bagnall, R. G. 1979. A study of human impact on an urban forest remnant: Redwood Bush, Tawa, near Wellington, New Zealand. New Zealand Journal of Botany 17:117-126.

Bailey, K. D., and P. Mulcahy. 1972. Sociocultural versus neoclassical ecology: a contribution to the problem of scope in sociology. Sociological Quarterly 13:37-48.

Bailey, R. G. 1983. Delineation of ecosystem regions. Environmental Management 7:365-373.

Bailey, R. G. 1985. The factor of scale in ecosystem mapping. Environmental Management 9:271-276.

Band, L. E., D. Peterson, S. W. Running, J. C. Coughlan, R. B. Lammers, J. Dugan, and R. Nemani. 1991. Ecosystem processes at the watershed scale: basis for distributed simulation. Ecological Modelling 56:151-176.

Band, L. E., D. S. Mackay, I. F. Creed, R. Semkin, and D. Jeffries. 1996. Ecosystem processes at the watershed scale: Sensitivity to potential climate change. Limnol. Oceanogr. 4(15):928-938.

Band, L. E., P. Patterson, R. Nemani, and S. W. Running. 1993. Forest ecosystem processes at the watershed scale: incorporating hillslope hydrology. Forest Meterology 63:93-126.

Barstow, D., R.E. Tinker, and S.J. Doubler, editors. 1997. National Conference on STudent & Scientist Partnerships. Conference Report. TERC, Cabmridge, MA, USA.

Batty, M. 1995. New ways of looking at cities. Nature 377:574.

Beane, D.B. 1988. Mathematics and science: Critical filters for the future of minority students. The Mid-Atlantic Center for Race Equity, American University, Washington, D.C., USA.

Bentley, B., A. Berkowitz, C. Cid, D. Freckman, L. Graumlich, M. Holland, K. Hollweg, C. Hunsaker, J. Lanza, L. Metzgar, T. Muir, E. Niebla, S. Ortega, M. Ruggiero and J. Weis. 1993. Mechanisms to Increase Recruitment and Retention of Women and Other Under-represented Groups in Ecology. Report from the Strategic Planning Workshop, Ecological Society of America, Washington, D.C. USA.

Berkowitz, A.R. 1992. The role of professional biologists in pre-college ecology education. Association of Southeastern Biologists Bulletin 39:170-173.

Berkowitz, A.R. 1997. A simple framework for considering the benefits of student scientist partnerships. Pages 38-41 *in* D. Barstow, R.E. Tinker, and S.J. Doubler, editors.National conference on student & scientist partnerships. Conference report. TERC and the Concord Consortium, Cambridge, MA, USA.

Berkowitz, A.R., M. Archie and D. Simmons. 1997. Defining environmental literacy: a call for action. Bulletin of the Ecological Society of America. 78:170-172.

Berkowitz, A.R., P. Feinsinger, K.S. Hollweg, K. Strickler, M.E. Krasny, V.C. Chase, and W.H. Martin. 1991. Ecology education for children: A handbook for ecologists. Ecological Society of America, Tempe, AZ.

Berkowitz, A.R., P. Feinsinger, K.S. Hollweg, K. Strickler, M.E. Krasny, V.C. Chase, and W.H. Martin. 1991. Ecology education for children: A framework for excellence. Ecological Society of America, Tempe, AZ.

Berkowitz, A.R., S.T.A. Pickett and S.E.G. Findlay, editors. 1992. Undergraduate Research Reports -- 1989 and 1990. Occasional Publication of the Institute of Ecosystem Studies, Number 6. Millbrook, New York USA.

Berkowitz, A.R.,.S.T.A. Pickett and S.E.G. Findlay, editors. 1995. Undergraduate Research Reports -- 1991, 1992 and 1993. Occasional Publication of the Institute of Ecosystem Studies, Number 10. Millbrook, New York USA.

Berry, B. J. L. 1990. Urbanization. Pages 103-120 *in* B. L. Turner II, W. C. Clark, R. W. Kates, J. F. Richards, J. T. Matthews and W. B. Meyer, editors. The Earth as transformed by human action: global and regional changes in the biosphere over the past 300 years. Cambridge University Press, New York.

Black, P. E. 1991. Watershed hydrology. Pentice Hall, Englewood Cliffs.

Blockstein, D.E. 1990. Women and minorities -- how are the AIBS societies doing? BioScience 40(8): 607-609.

Bogue, D. J. 1984a. Ecological community areas. Pages 1-25 *in* D. J. Bogue and M. J. White, editors. Essays in human ecology, 2nd Edition. Volume 2. The Community and Family Study Center, University of Chicago, Chicago.

Bogue, D. J. 1984b. Procedure for delimiting ecological community areas. Pages 27-36 *in* D. J. Bogue and M. J. White, editors. Essays in human ecology, 2nd Edition. Volume 2. The Community and Family Study Center, University of Chicago, Chicago.

Bogue, D. J., and E. J. Bogue. 1976. Micro-demography and research on the ecology of the urban community. Pages 85-138 *in* D. J. Bogue and E. J. Bogue, editors. Essays in human ecology, 1st Edition. Volume 1. The Community and Family Study Center, University of Chicago, Chicago.

Bormann, F. H., and G. E. Likens. 1979. Pattern and process in a forested ecosystem. Springer-Verlag, New York.

Boyden, S. 1993. The human component of ecosystems. Pages 72-77 *in* M. J. McDonnell and S. T. A. Pickett, editors. Humans as components of ecosystems: the ecology of subtle human effects and populated areas. Springer-Verlag, New York.

Bromley, D. W. 1991. Environment and economy: property rights and public policy. TJ Press, Cornwall.

Brown, L. R., and J. E. Young. 1990. Feeding the world in the nineties. Pages 59-78 *in* L. R. Brown, editor. State of the world: 1990. W. W. Norton, New York.

Bruce, J. W. 1989. Community forestry: rapid appraisal of tree and land tenure. Food and Agriculture Organization, Rome.

Bullard, R. D. 1990. Dumping in Dixie: race, class and environmental quality. Westview Press, Boulder.

Burch, W. R. 1988. Human ecology and environmental management. Pages 145-159 *in* J. K. Agee and J. Darryll, editors. Ecosystem management for parks and wilderness. University of Washington Press, Seattle.

Burch, W. R., Jr. 1976. The prergrine falcon and the urban poor: some sociological interrelations. Pages 308-316 *in* P. J. Richerson and J. McEvoy III, editors. Human ecology: an environmental approach. Duxbury Press, North Scituate.

Burch, W. R., Jr., and D. DeLuca. 1984. Measuring the social impact of natural resource policies. University of New Mexico Press, Albuquerque.

Burch, W. R., Jr., and J. M. Grove. 1993. People, trees, and participation on the urban frontier. Unasylva 44:19-27.

Burch, W. R., Jr., and J. M. Grove. 1993. People, trees, and participation on the urban frontier. Unasylva 44:19-27.

Burch, W. R., Jr., and J. M. Grove. 1996. Life on the city streets: some lessons from Baltimore for reaching out to grow trees, kids, and communities. Journal of Public Service and Outreach 1.

Burch, W. R., Jr., J. Aley, B. Conover, and D. Field. 1997. Adaptive strategies for natural resource organizations in the twenty-first century. Taylor Francis, Washington,DC.

Burgess, E. W. 1925. The growth of the city: an introduction to a research project. Pages 47-62 *in* R. E. Park, E. W. Burgess and R. D. McKenzie, editors. The city. University of Chicago Press, Chicago.

Carter, J.L. 1991. A new national priority: Providing quality field experiences for all students. Bulletin of the Ecological Society of America Supplement 71(2).

Cernea, M. M., editor. 1991. Putting people first: sociological variables in rural development. Oxford University Press, Oxford.

Choldin, H. M. 1984. Subcommunities: neighborhoods and suburbs in ecological perspective. Pages 237-276 *in* M. Micklin and H. M. Choldin, editors. Sociological human ecology: contemporary issues and applications. Westview Press, Boulder.

Clarke, K., S. Hoopen, and L. Gaydos. 1996. Methods and techniques for rigorous calibration of a cellular automaton model of urban growth. Third international

conference/workshop on integrating GIS and envrionmental modeling, Santa Fe, New Mexico.
Coleman, D.C., E.P. Odum, and D.A. Crossley, Jr. 1992. Soil biology, soil ecology, and global change. Biology and Fertility of Soils 14:104-111.
Community Profiling Committee, U. D. P. U. D. W. G. 1991. Handbook on community profiling for people-oriented forestry. (Mala: Department of Environment and Natural Resources).
Condon, M. 1991. Mutualistic interactions between scientists and children. BioScience 41:163-165.
Costanza, R., and J. Greer. 1995. The Chesapeake Bay and its watershed: a model for sustainable ecosystem management? Pages 169-213 *in* L. H. Gunderson, C. S. Holling and S. S. Light, editors. Barriers and bridges to the renewal of ecosystems and institutions. Columbia Universtiy Press, New York.
Costanza, R., B. G. Norton, and B. D. Haskell, editors. 1992. Ecosystem health: new goals for environmental management. Island Press, Washington, DC.
Costanza, R., L. Wainger, C. Folke, and K.-G. Mäler. 1993. Modeling complex economic systems: toward an evolutionary, dynamic understanding of people and nature. BioScience 43:545-555.
Creed, I. C., L. E. Band, N. W. Foster, I. K. Morrison, J. A. Nicholson, R. S. Semkin, and D. S. Jeffries. 1996. Regulation of nitrate-N release from temperate forests: a test of the N flushing hypothesis. .
Cronon, W. 1991. Nature's metropolis: Chicago and the great west. Norton, New York.
Daniel, C., J. M. Grove, and M. Hohmann. 1993. A Methodology to assess and inventory urban forests in the United States. URI Working Paper No 12, The Urban Resources Inititative, Yale School of Forestry and Environmental Studies, New Haven.
Dicker, J., and J. M. Grove. 1992. Community Forestry and Stewardship Handbook. Department of Recreation and Parks. Baltimore. 30 pp.
Dissinger, J.F. 1984. Field instruction in school settings. ERIC/SMEAC Environmental Education Digest 1:2-4.
Drayton, B., and R. B. Primack. 1996. Plant species lost in an isolated conservation area in metropolitan Boston from 1894 to 1993. Conservation Biology 10:30-39.
Dunne, T., and L. B. Leopold. 1978. Water in environmental planning. W.H. Freeman, New York.
ECO (Environmental Careers Organization). 1992. Beyond the green - redefining and diversifying the environmental movement. The Environmental Careers Organization, Boston.
Farquhar, GD and RA Richards. 1984. Isotopic composition of plant carbon correlates with water-use efficiency of wheat genotypes. Austr. J. Plant. Physiol. V11: 539-52.
Feinsinger, P. 1987. Professional ecologists and the education of small children. Bulletin of the Ecological Society of America. 68:13-15.
Feinsinger, P., A. Grajal and A.R. Berkowitz. 1997a. Some themes appropriate for schoolyard ecology and other hands-on ecology education. Bulletin of the Ecological Society of America. 78:144-146.
Feinsinger, P., L. Margutti and R.D. Oviedo. 1997b. School yards and nature trails: ecology

education outside the university. Trends in Ecology and Evolution. 12:115-120.

Findlay, S., and C. G. Jones. 1990. Exposure of cottonwood plants to ozone alters subsequent leaf decomposition. Oecologia 82:248-250.

Findlay, S., M. Carreiro, V. Krischik, and C. G. Jones. 1996. Effects of damage to living plants on leaf litter quality. Ecological Applications 6:269-275.

Fitz, H., E. B. DeBellevue, R. Costanza, R. Boumans, T. Maxwell, L. Wianger, and F. H. Sklar. 1996. Development of a general ecosystem model (GEM) for a range of scales and ecosystems. Ecological Modeling 88:263-297.

Flores, A., S. T. A. Pickett, W. C. Zipperer, R. V. Pouyat, and R. Pirani. 1997. Adopting a modern ecological view of the metropolitan landscape: the case of a greenspace for the New York City region. Landscape and Urban Planning.

Forman, R. T. T., and M. Godron. 1986. Landscape Ecology. John Wiley and Sons, New York.

Foster, JR, KV Loats, KF Jensen. 1990. Influence of 2 growing seasons of experimental ozone fumigation on photosynthetic characteristics of white oak seedlings. Environ. Pollution. V65:371-380.

Fox, J. 1992. The problem of scale in community resource management. Environmental Management 16:289-297.

Frey, H. T. 1984. Expansion of urban areas in the United States: 1960-1980. United States Department of Agriculture Economic Research Service Staff Report Number AGES83615.

Frisbie, W. P., and J. D. Kasarda. 1988. Spatial processes. Pages 629-667 *in* N. J. Smelser, editor. Handbook of sociology. Sage Publications, Newbury Park, CA.

Frisbie, W. P., and J. D. Kasarda. 1988. Spatial processes. Pages 629-667 *in* N. J. Smelser, editor. Handbook of sociology. Sage Publications, Newbury Park, CA.

Garfinkle, A. 1981. Forms of explanation: rethinking the questions in social theory. Yale University Press, New Haven.

Garson, G. D., and R. S. Biggs. 1992. Analytic mapping and geographic databases. Sage University Press, Newbury Park, CA.

Geography Education Standards Project. 1994. Geography for life. National Geographic Research and Exploration, Washington, DC, USA.

Glimour, D. A., and R. J. Fisher. 1991. Villagers, forests and foresters: the philosohpy, process and practice of community foresty in Nepal. Sahayogi Press, Katmandu.

Goldman, M.B., P.M. Groffman, R.V. Pouyat, M.J. McDonnell, and S.T.A. Pickett. 1995. Methane uptake and nitrogen availability in forest soils along an urban to rural gradient. Soil Biology and Biochemistry 27:281-286.

Grimmond, C. S. B. 1992. The suburban energy balance: methodological considerations and results for a mid-latitude west coast city under winter and spring conditions. .

Grimmond, C. S. B., and T. R. Oke. 1991. An evaporation-interception model for urban areas. Water Resources Research 27:1739-1755.

Grimmond, C. S. B., T. R. Oke, and D. G. Steyn. 1986. Urban water balance I: a model for daily totals. Water Resources Research 22:1397-1403.

Groffman, P. M., and G. E. Likens, editors. 1994. Integrated regional models: interactions between humans and their environment. Chapman and Hall, New York.

Groffman, P. M., D. R. Zak, S. Christensen, A. R. Mosier, and J. M. Tiedje. 1993. Early spring nitrogen dynamics in a temperate forest landscape. Ecology 74:1579-1585.

Groffman, P.M. 1996. Integration of soil science in ecological research. Pages 57-66 *In* The Role of Soil Science in Interdisciplinary Research (R.J. Wagenet and J. Bouma, editors). American Society of Agronomy, Madison, WI.

Grosjean, D., E.L. Williams, II. and E. Grosjean . 1995. Monitoring ambient ozone with a network of passive samplers: a feasibility study. Environmental pollution. v. 88 (3) p. 267-273.

Grove, J. M. 1995. Excuse me, could I speak to the property owner please? Common Property Resources Digest 35:7-8.

Grove, J. M. 1996. The relationship between patterns and processes of social stratification and vegetation of an urban-rural watershed. Ph.D. Dissertation. Yale Univsersity, New Haven.

Grove, J. M. 1997. New tools for exploring theory and methods in human ecosystem and landscape research: computer modeling, remote sensing and geographic information systems. *in* H. K. Cordell and J. C. Bergstrom, editors. Integrating social sciences and ecosystem management. Sagamore, Champaign.

Grove, J. M., and M. Hohmann. 1992. GIS and social forestry. Journal of Forestry 90:10-15.

Grove, J. M., and W. R. Burch Jr. 1997. A social ecology approach to urban ecosystem and landscape analysis. Urban Ecosystems 1.

Grove, J. M., K. Vachta, M. McDonough, and W. R. Burch Jr., editors. 1994. Vol Gen Tech Rep, NC-163: The urban resources initiative: community benefits from forestry. USDA Forest Service, St Paul.

Grove, J. M., K. Vachta, M. McDonough, and W. R. Burch. 1993. The urban resources initiative: community benefits from forestry. Pages 24-30 *in* P. H. Gobster, editor. Urban and high recreation settings. Volume Gen. Tech. Rep. NC-163. USDA Forest Service, St. Paul MN.

Grove, J. M., L. Vernegaard, and C. Rogers. 1991. Stratic plan for action for Baltimore's Department of Recreation and Parks. Joint Publication: City of Baltimore Department of Recreation and Parks and the Urban Resource Initiative, URI Working Paper #4. Yale School of Forestry and Environmental Studies, New Haven. 110 pp.

Grove, J. M., W. Zipperer, and L. R. Neville. 1995. Social indicators and classification for urban ecosystem management. Pages 9 *in* C. Kollin and R. Ricar, editors. Proceedings of the 7th annual national urban forestry conference, September 12-17, New York. American Forests, Washington, DC.

Grusky, D. B., editor. 1994. Social stratification: class, race, and gender in sociological perspective. Westview Press, Boulder.

Guest, A. M. 1977. Residential segregation in urban areas. Pages 269-336 *in* K. P. Schwirian, editor. Contemporary topics in urban sociology. General Learning Press, Morristown.

Guilden, J. M., J. R. Smith, and L. Thompson. 1990. Stand structure of an old-growth upland hardwood forest in Overton Park, Memphis, Tennessee. Pages 61-66 *in* R. S. Mitchell, C. J. Sheviak and D. J. Leopold, editors. Ecosystem management: rare species and significant habitats. New York State Museum, Albany.

Hall, J. 1993. The iceberg and the Titanic: human economic behavior in ecological models. Pages 51-60 *in* M. J. McDonnell and S. T. A. Pickett, editors. Humans as components of ecosystems: the ecology of subtle human effects and populated areas. Springer-Verlag, New York.

Hamm, B. 1982. Social area analysis and factorial ecology: a review of substantive findings. Pages 316-337 *in* A. Theodorson, editor. Urban patterns: studies in human ecology. Pennsylvania State University Press, University Park.

Hanski, I. 1994. A practical model of metapopultaion dynamics. Journal of Animal Ecology 63:151-162.

Hansson, L., L. Fahrig, and G. Merriam, editors. 1995. Mosaic landscapes and ecological processes. Chapman and Hall, New York.

Harris, C. D., and E. L. Ullman. 1945. The nature of cities. Annals of the American Academy of Political and Social Science 242:7-17.

Harvey, D. 1989. The urban experience. Johns Hopkins University, Baltimore.

Hemond, H. F., W. A. Niering, and R. H. Goodwin. 1983. Two decades of vegetation change in the Connecticut Arboretum Natural Area. Bulletin of the Torrey Botanical Club 110:184-194.

Hewlett, J. D., and W. L. Nutter. 1969. An outline of forest hydrology, rev Edition. University of Georgia Press, Athens.

Hill, O.W., W.C. Pettus and B.A. Hedin. 1990. Three studies of factors affecting the attitudes of blacks and females toward the pursuit of science and science-related careers. Journal of Research in Science Teaching. 27-4:289-314.

Hogan, K. 1994. Eco-Inquiry. A guide to ecological learning experiences for the upper elementary/middle grades. Kendall/Hunt Publishing Company, Dubuque, Iowa, USA.

Holland, M.M., D.M. Lawrence, D.J. Morrin, C. Hunsaker, D. Inouye, A. Janetos, H.R. Pulliam, W. Robertson, and J. Wilson. 1992. Profiles of Ecologists: Results of a Survey of the Membership of the Ecological Society of America. Public Affairs Office, Ecological Society of America, Washington, D.C. USA.

Hollweg, K.S. 1997. Are We Making a Difference? Lessons Learned from VINE Program Evaluations. North American Association for Environmental Education, Washington, D.C.

Hornbeck, J. W., and W. T. Swank. 1992. Watershed ecosystem analysis as a basis for multiple-use management of eastern forests. Ecological Applications 2:238-247.

Huston, M. A. 1994. Biological diversity: the coexistence of species in changing landscapes. Cambridge University Press, New York.

Johnson, A. R. 1993. Spatiotemporal hierarchies in ecological theory and modeling. Second International Conference/Workshop of Integrating Geographic Information Systems and Environmental Modeling. September 26-30, 1993 Breckeridge p 10.

Johnson, DW and SE Lindberg, eds. 1992. Atmospheric deposition and forest nutrient cycling. Springer-Verlag. New York, New York. 707 p.

Johnston, R. J. 1976. Residential area characteristics: research methods for identifying urban sub-areas -- social area analysis and factorial ecology. Pages 193-235 *in* D. T. Herbert and R. J. Johnston, editors. Spatial perspectives on problems and policies. Volume 2. Wiley, New York.

Jones, C.G., J.S. Coleman, and S. Findlay. 1994. Effects of ozone on interactions between plants, consumers and decomposers. Pages 339-363 In: R.G. Alscher and A. Wellburn (eds.). Plant Responses to the Gaseous Environment. Chapman & Hall, London.

Kolasa, J., and S. T. A. Pickett, editors. 1991. Ecological heterogeneity. Springer-Verlag, New York.

Kuchler, A. W., and I. S. Zonneveld. 1988. Handbook of vegetation science: vegetation mapping. Volume 10. Kluwer Academic Publishers, Dordrecht.

Langbein, L. I., and A. J. Lichtman. 1978. Ecological inference. Sage University Press, Newbury Park, CA.

Leopold, L. B. 1973. River channel change with time: an example. Geological Society of America Bulletin 84:1845-1860.

Lillesand, T. M., and R. W. Kiefer. 1987. Remote sensing and image interpretation, 2nd Edition. Wiley, New York.

Logan, J. R., and H. L. Molotch. 1987. Urban fortunes: the political economy of place. University of California Press, Berkeley.

Loomis, S., J. M. Grove, and L. R. Neville. 1995. Northeastern Area progress report, NA-PR-02-95: New directions in urban and community forestry: a status report on the Revitalizing Baltimore model. USDA Forest Service, Radnor, PA.

Luley, C. J., D. J. Nowak, and S. T. Rao. 1995. Evaluating air quality effects of urban trees: developing directionally sound programs for use in state ozone attianment goals. Research proposal funded by the National Urban and Community Froestry Advisory Council.

Lumb, A. M., J. L. Kittle Jr., and K. M. Flynn. 1990. Users' manual for ANNIE: a computer program for interactive hydrologic analyses and data management. US Geological Survey, Open File Report.

Machlis, G. E., and R. G. Wright. 1984. Potential indicators for monitoring biosphere reserves. Pages 50-62 *in* T. N. Vezirohlu, editor. The biosphere: problems and solutions. Elsevier Science, Amsterdam.

Machlis, G. E., J. E. Force, and S. E. Dalton. 1994. Monitoring social indicators for ecosystem management. College of Forestry, Wildlife and Range Sciences, University of Idaho, Moscow, Technical paper submitted to the Interior Columbia River Basis Project under order #43-0E00-4-9186.

Machlis, G. E., J. E. Force, and W. R. Burch Jr. 1995. The human ecosystem as an organizing concept in ecosystem management.

Machlis, G. E., W. R. Burch Jr., and J. E. Force. 1997. The human ecosystem part I: the human ecosystem as an organizing concept in ecosystem management. Society and Natural Resources.

Mackay, D. S., and L. Band. 1994. Extraction and representation of watershed structure including lakes and wetlands from digital terrain and remote sensing information. Transactions of the American Geophysical Union 75:S175.

Makse, H. A., S. Havlin, and H. E. Stanley. 1995. Modelling urban growth patterns. Nature 377:608-612.

Malanson, G. P. 1993. Riparian landscapes. Cambridge Univrsity Press, New York.

Marks, P. L., and F. H. Bormann. 1972. Revegetation following forest cutting. Mechanisms for return to steady-state nutrient cycling. Science 176:914-915.
McDonnell, M. J., and S. T. A. Pickett. 1990. Ecosystem structure and function along urban-rural gradients: an unexploited opportunity for ecology. Ecology 71:1232-1237.
McDonnell, M.J. and S. T. A. Pickett, editors. Humans as components of ecosystems: the ecology of subtle human effects and populated areas. Springer-Verlag, New York.
McDonnell, M. J., J. L. Rudnicky, J. M. Koch, and E. A. Roy. 1990. Permanent forest reference system: Pelham Bay Park and Van Cortlandt Park, Bronx, New York. Institute of Ecosystem Studies, Millbrook, NY.
McDonnell, M. J., S. T. A. Pickett, P. Groffman, P. Bohlen, R. V. Pouyat, W. C. Zipperer, M. M. Carreiro, and K. Medley. 1997. Ecosystem processes along an urban-to-rural gradient. Urban Ecosystems 1:21-36.
McPherson, E. G., D. Nowak, G. Heisler, S. Grimmond, C. Souch, R. Grant, and R. Rowntree. 1997. Quantifying urban forest sturcture, function, and value: the Chicago urban forest climate project. Urban Ecosystems 1:49-61.
Mechling, K.R., and D.L. Oliver. 1983. Activities, not textbooks: What research says about science programs. Principal. 62:40-43.
Medley, K. E., M. J. McDonnell, and S. T. A. Pickett. 1995. Human influences on forest-landscape structure along an urban-to-rural gradient. Professional Geographer 47:159-168.
Metzgar, L. H., K. Hollweg, and A. R. Berkowitz. 1994. Ecologists in pre-college ecological education. Bulletin of the Ecological Society of America 75:113-116.
Morrill, R. L. 1974. The spatial organization of society, 2nd Edition. Duxbury Press, Duxbuty.
Murcia, C. 1995. Edge effects in fragmented forests: implications for conservation. Trends in Ecology and Evolution 10:58-62.
Murdie, R. A. 1976. Spatial form in the residential mosaic. Pages 237-272 *in* D. T. Herbert and R. J. Johnston, editors. Spatial perspectices on problems and policies. Wiley, New York.
Naveh, Z., and A. S. Lieberman. 1984. Landscape ecology: theory and application. Springer-Verlag, New York.
NCTM (National Council of Teachers of Mathematics). 1989. Curriculum and evaluation standards for school mathematics. National Council of Teachers of Mathematics, Reston, VA, USA.
Neville, L. R. 1996. Urban watershed management: the role of vegetation. Ph.D. Dissertation. State University of New York, College of Environmental Science and Forestry, Syracuse.
Norby, RJ, SD Wullschleger, EG O'Neil, and MK McCracken. 1992. Productivity and compensatory responses of yellow-poplar trees in elevated CO_2. Nature. V357:322-324.
Nowak, D. J. 1993. Atmospheric carbon reduction by urban trees. Journal of Environmental Management 37:207-217.
Nowak, D. J. 1994. Urban forest structure: the state of Chicago's urban forest. Pages 140-164 *in* E. G. McPherson, D. J. Nowak and R. A. Rowntree, editors. Chicago's urban

National Workshop on In-Place Resource Inventories: Principles and Practices, Orono, ME.
RRA. 1987. Procedings of the 1985 international conference of rapid rural appraisal. Rural Systems and Farming Systems Research Projects, Khon Kaen, Thailand.
Rudnicky, J. L., and M. J. McDonnell. 1989. Forty-eight years of canopy change in a hardwood-hemlock forest in New York City. Bulletin of the Torrey Botanical Club 116:52-64.
Rusk, D. 1993. Cities without suburbs. Woodrow Wilson Center Press, Washington, DC.
Rybczynski, W. 1995. City life: urban expectations in the New World. Scribner, New York.
Samuelson LJ, and JM Kelly. 1996. Carbon partitioning and allocation in northern red oak seedlings and mature trees in response to ozone. Tree Physio. V16:853-958.
Schnore, L. F. 1958. Social morphology and human ecology. American Journal of Sociology 63:620-634.
Shachak, M., and S. Brand. 1991. Relations among spatiotemporal heterogneity, population abundance, and variability in a desert. Pages 202-223 *in* J. Kolasa and S. T. A. Pickett, editors. Ecological heterogeneity. Springer-Verlag, New York.
Shachak, M., and S. T. A. Pickett. 1997. Linking ecological understanding and application: patchiness in dryland systems. Pages 108-119 *in* S. T. A. Pickett, R. S. Ostfeld, M. Shachak and G. E. Likens, editors. The ecological basis of conservation: heterogeneity, ecosystems, and biodiversity. Chapman and Hall, New York.
Shevky, E., and W. Bell. 1955. Social area analysis: theory and illustrative application and computational procedure. Stanford University Press, Stanford.
Steinberg, D. A., R. V. Pouyat, R. W. Parmelee, and P. M. Groffman. 1995. Earthworm activity and nitrogen mineralization rates along an urban-rural land use gradient. Soil Biology and Biochemistry.
Sukopp, H. 1990. Urban ecology and its application in Europe. Pages 1-22 *in* H. Sukopp, S. Hejny and I. Kowarik, editors. Urban ecology: plants and plant communities in urban environments. SPB Academic Publishers, The Hague.
Sukopp, H., and P. Werner. 1982. Nature in cities: a report and review of studies and experiments concerning ecology, wildlife, and nature conservation in urban and suburban areas. Council of Europe, Strasbourg.
Sussman, A. 1993. Science education partnerships: Manual for scientists and K-12 teachers. University of California, San Francisco, San Francisco, CA, USA.
Thompson, M., and M. Warburton. 1985. Knowing where to hit it: a conceptual framework for the sustainable development of the Himalaya. Mountain Research and Development 5:203-220.
Turner, M. G. 1989. Landscape ecology: the effect of pattern on process. Annual Review of Ecology and Systematics 20:171-197.
United Nations Population Division. 1995. World urbanization prospects: the 1994 revision. United Nations, New York.
van den Berghe, P. L. 1975. Man in society: a biosocial view. Elsevier, New York.
Vitousek, P. M. 1989. Biological invasions and ecosystem properties: can species make a difference? Pages 163-178 *in* H. A. Mooney and J. A. Drake, editors. Ecology of Biological Invasions of North America and Hawaii. Springer-Verlag, New York.

Vitousek, P.M. 1994. Beyond global warming: Ecology and global change. Ecology 75:1861-1876.

Wackernagle, M., and W. Rees. 1996. Our ecological footprint. Reducing human impact on the earth. New Society Publishers, Gabriola Island, B.C., Canada.

Walker, B. 1990. The environmental movement and African-Americans. A paper for the Environmental Defense Fund. New York, New York USA.

Weiss, M. J. 1988. The clustering of America. Tilden Press, New York.

White, G. F. 1961. The choice of use in resource management. *in* R. W. Kates and I. Burton, editors. Geography, resources, and environment: the selected writings of Gilbert F. White. Volume I. University of Chicago Press, Chicago.

Whyte, W. F. 1991. Participatory action research. Sage Publications, Newbury Park, CA.

Wiens, J. A. 1995. Landscape mosaics and ecological theory. Pages 1-26 *in* L. Hansson, L. Fahrig and G. Merriam, editors. Mosaic landscapes and ecological processes. Chapman and Hall, New York.

Wolman, M. G. 1993. Population, land use, and environment: a long history. Pages 15-29 *in* C. L. Jolly and B. B. Torrey, editors. Population and land use in developing countries. National Academy Press, WashingtonDC.

World Resources Institute. 1996. World resources: a guide to the global environment: the urban environment. Oxford University Press, New York.

Wrong, D. H. 1988. Power: its forms, bases, and uses. University of Chicago Press, Chicago.

Wullschleger,SD, PJ Hanson, GS Edwards. 1996. Growth and maintenance respiration in leaves of northern red oak seedlings and mature trees after 3 years of ozone exposure. Plant Cell and Environment, V19:577-584.

Yaro, R. D., and T. Hiss. 1996. A region at risk: the third regional plan for the New York-New Jersey-Connecticut Metropolitan Area. Island Press, Washington, DC.

Zonneveld, I. S. 1989. The land unit -- a fundamental concept in landscape ecology and its applications. Landscape Ecology 3:67-89.

SECTION 4. RESEARCH MANAGEMENT

I. Overall Project Management

The project will be run by the Project Director, Steward Pickett, and an on-site Site Manager (SM) funded by the US Forest Service. The SM will have research experience and training in one or more of the disciplines represented in the project, along with strong administrative and management skills and experience. Ideally, this will be someone familiar with Baltimore who already has connections to the important institutions, agencies and communities involved. The SM will be responsible for the day-to-day management of the project, including the coordination of the various sub-efforts and technician time, and for interfacing with Baltimore City, County and non-government organizations, and with the LTER Network Office and National Science Foundation. The project will support one half of the salary for an Assistant Site Manager (ASM), with the remainder of the support from Parks and People Foundation. This person will be responsible for logistics is support of the field research effort, organizing vehicles and equipment, and conducting site maintenance. The ASM can increase the participation of the project in community activities and assist with workshops and outreach activities with the public and policy makers. Data management will be coordinated through Dr. Timothy W. Foresman. The PD and PI's will contribute to the activities of the LTER Network.

All key decisions relating to the project - allocation of funds, research and education activities, community participation - will be made by an Executive Committee (EC) of 9 PI's (Table 4.1) plus the SM as an *ex officio* member. The EC includes PI's involved in each component of the project, and one of its key roles will be to facilitate coordination of effort and integration of results. This group already has worked well together and is focused on bringing all of our efforts to bear in addressing the three overarching questions presented earlier. Several EC members provide excellent connections to the local community (e.g., Ms. Jacqueline Carrera through Park & People Foundation and a number of city agencies, Dr. William Burch, Jr., through his long-standing community revitalization programs, and Dr. Timothy Foresman through a number of educational initiatives). The EC will meet quarterly, with more frequent voice- or video-conference calls as needed. Most of these meetings will take place on-site, while one each year will be at IES. Its specific roles will include: 1) guide each facet of the project; 2) assure that work is completed in a timely and effective manner; 3) document and evaluate project accomplishments; 4) oversee effort to make data and other results available broadly; and 5) provide a communication and feedback linkage among project components and between the project and the community at large.

The entire group of project participants (Table 4.2) will be invited to two meetings each year, held in conjunction with meetings of the EC. These will allow for careful consideration of the overall direction the project is taking, for facilitating integration among research areas and between the research, education and outreach components, and for presenting results on a frequent basis. In the long run, we envision one of these becoming a rather large annual meeting of the Baltimore Urban LTER project and other interested scientists, educators, managers and community members.

Rapid communication among project participants will take place over the Internet. We already have developed a Web page (http://chesapeake.usgs.gov/lter/index.html) and listserve, and these will be expanded to provide for frequent and convenient exchange of ideas, needs, etc.

Table 4.1. Members of the Baltimore Urban LTER Executive Committee and the project areas they represent.

Dr. Steward T.A. Pickett, Institute of Ecosystem Studies
    Project Leader, patch structure, exotic manipulation experiments
Dr. Alan R. Berkowitz, Institute of Ecosystem Studies
    Education and public outreach
Dr. Grace Brush, Johns Hopkins University
    Local facilities, historical perspective
Dr. William Burch, Yale University
    Social sciences, neighborhood restoration experiments
Ms. Jacqueline Carrera, Executive Director, Parks & People Foundation
    Local community relations, management applications
Dr. Robert Costanza, University of Maryland
    Ecological economics, integrated modeling
Dr. Timothy Foresman, University of Maryland - Baltimore County
    Local facilities, data management, patch structure and delineation, modeling
Dr. Peter Groffman, Institute of Ecosystem Studies
    Ecosystem function, integrated modeling
Dr. Wayne Zipperer, US Forest Service
    Patch delineation, liaison with US Forest Service

II. Project Components

Each component of the project will be carried out by a group of PI's and collaborators (Table 4.2). The groups include social, natural and physical scientists, assuring that each of these crucial perspectives will be considered as the research proceeds. We also have built in overlap in membership in these groups so that each includes people from each of the other parts of the project. This is an essential mechanism for assuring that all components of the project move ahead with full knowledge of the rest of the project, and that every opportunity is taken for conceptual and practical integration. Each group will choose its own leader on a two year cycle. The groups are responsible for prioritizing the work to be conducted within their area, making recommendations to the Executive Committee and PD for research activities and support, and for evaluating the status of research in its scope and integration within the project. The groups will assist in identifying additional funding opportunities to extend the effort of the BULTER.

Several components of the project require particular forms of coordination within the project and with the Baltimore community. Perhaps most obvious among these is the need to establish and maintain long-term plots and data collection sites. This is described in detail in the section III below. The education and outreach component of the project will require the thorough integration of students, teachers and education effort into each facet of the LTER research. The PI heading up these efforts (Dr. Alan Berkowitz) will be on the EC, and the group of PIs and collaborators working on the education component includes researchers involved in each component of the project along with representatives from the Baltimore City and County Schools (note: we will bring on an collaborator from Baltimore County Schools once they replace the retiring Math and Science Coordinator), and the Baltimore Urban Systemic Initiative (Table 4.2). Furthermore, since our education efforts will focus on collaboration with existing programs and resources, we have formed an Education Steering Committee of local educators (Table 2.8). We already have met with a portion of this Committee, and all members are enthusiastic about the prospects for genuine collaboration with and contributions from the LTER project (see Letters of Collaboration and Support). The group of PIs and collaborators, working with advice from the Steering Committee, will 1) oversee and direct all education and outreach efforts, 2) supervise the Education Coordinator, 3) evaluate and document project accomplishments, 4) write proposals for extending and expanding programs, and 5) coordinate with the rest of the project.

The experiment in neighborhood restoration will be developed in such a way that the community conceives, directs and implements the actual work involved. While we already have close connections with several of the neighborhoods that are likely to participate, these will be further strengthened during the beginning of the project. Student, teacher and community participants in the education component of the project (e.g., Tree Troops) will play a pivotal role and linkage between the LTER scientists and the community. The challenges to achieving this level of integration will be addressed through concerted effort, since achieving success in this fashion represents one of the greatest opportunities for such a long-term project.

Table 4.2. Groups of Principal Investigators (PI's) and Collaborators (Collabs) associated with each component of the Baltimore Urban LTER project.

PATCH STRUCTURE

PI's
- Steward Pickett
- Grace Brush
- William Burch
- Robert Costanza
- Tim Foresman
- Wayne Zipperer

Collabs
- Gary Lovett
- Patrick Bohlen
- M. Gordon Wolman

Charlie Nilon
Larry Band

PATCH FUNCTION

PI's
- Peter Groffman
- Larry Band
- David Nowak
- Rich Pouyat

Collabs
- Roelof Boumans
- Margaret Carreiro
- Gary Fisher
- Susan Grimmond
- John Hom
- Charles Nilon

PATCH DYNAMICS/MODELING

PI's
- Grace Brush
- Larry Band
- Robert Costanza
- Tim Foresman
- Peter Groffman
- Morgan Grove
- David Nowak
- Steward Pickett
- Wayne Zipperer

Collabs
- Richard Birdsey
- Sumner Crosby
- Robert Neville
- Michael Ratcliffe

EXOTICS EXPERIMENTS

PI's
- Steward Pickett
- Alan Berkowitz
- Grace Brush
- Peter Groffman
- Rich Pouyat

NEIGHBORHOOD REVITALIZATION EXPERIMENT

PI's
- William Burch
- Alan Berkowitz
- Jackie Carrera
- Morgan Grove

EDUCATION AND OUTREACH

PI's
- Alan Berkowitz
- Jackie Carrera
- Tim Foresman
- Morgan Grove
- Rich Pouyat

Collabs
- Ruth Andrione
- Jonathan Wilson (new science coordinator in Baltimore County schools)

III Project Facilities

The LTER site, appropriate to the dispersed nature of an urban system will itself be dispersed among publicly owned lands for which permission has been granted for access, collection of samples, and installation of experiments. The land is owned by the Baltimore Department of Recreation and Parks, and the Baltimore Department of Public Works. Permission has been granted (M. Perritt letter of DATE). Permanent plots will be marked inconspicuously but unambiguously (McDonnell et al. 1990). For rapid assessment plots, both public and private lands will be used. Access for the short term sampling and temporary placement of auxiliary meteorological stations will be sought from individual land owners. It is our experience that such permission is routinely granted based on good community relations. Security of equipment is in some cases maintained by locked and anchored housings, in other appropriate situations by secretive placement, and in other situations, placed on private property of community members whose involvement and responsibility has been cultivated.

Sample processing will be conducted in laboratory space rented from Johns Hopkins University School of Engineering. Ultimately space will be available in the newly renovated Eastern High School building. The space will include 420 sq ft. of laboratory workspace for technicians and field assistants to process samples and prepare equipment. Office space for the four technicians residing in Baltimore will be included as well as 200 sq ft office space for the Site Manager. Office and laboratory space will be provided with data drops. The USGS can provide additional space if required. The Assistant Site Manager will use LTER workspace, but because the position is split with the Parks and People Foundation, the ASM will have primary office space at the Crimea Mansion offices of Parks and People. Laboratory analyses of soil, plant, and water samples will be conducted at the Institute of Ecosystem Studies. The Analytical Laboratory, the laboratories of Groffman and Pickett, and space in the Rearing Facility are available for these functions. Data management activities are concentrated at the Laboratory of Spatial Analysis at the University of Maryland Baltimore County. Specific analyses overseen by particular PI's will be conducted in their laboratories (e.g., sediment core analyses at the laboratory of G. Brush at Johns Hopkins.). Storage space for large equipment and vehicles will be arranged with the Parks and People Foundation and the Department of Recreation and Parks. Use of the space will be overseen by the project director with input from the Executive Committee and administrative oversight by the Site Manager.

Conference space will be available at the Crimea mansion, and is periodically available at Johns Hopkins University as part of the rental agreement, and available when otherwise unscheduled in the Library at the University of Maryland at Baltimore County.

Housing for a small number of PI's visiting the sites from outside the Baltimore region will be available at cost in houses owned by the Parks and People Foundation. Housing for other project staff are their responsibility, but the declining population of Baltimore makes cheap housing readily available.

LIFE CYCLE FOR BALTIMORE URBAN LTER DATA MANAGEMENT

FIGURE 5.1

SECTION 5: BALTIMORE LTER DATA MANAGEMENT PLAN

The Baltimore Urban LTER (or simply ULTER) will generate high quality ecological data and make these data available, to scientists, citizens and community groups, as well as educators and students (in partnerships with regionally and nationally organized K-12 educational programs) using state-of-the-practice data base management methods and Internet-based access technology. A goal of the site is to make data and metadata, at little or no cost, easily and widely available to these communities interested in urban ecological research. Our management focus will be upon the timely, effective, and appropriate transformation and documentation of data into information and the subsequent availability of that information via the Internet. With our substantial experience in regional, spatial-data collaboratories, we recognize that the ULTER research design requires storage and integration of a wide variety of data types, each with a wide range of temporal and spatial scales for sophisticated analytical applications. The ULTER data management system design will reflect these considerations, balancing operational activities to maintain continuous access to database resources while ensuring long-term preservation of the urban ecological datasets. We are keenly aware of, and will coordinate with, the other well established LTER sites (including the ILTER) in conjunction with the LTER Network Office and the other urban LTER (Briggs & Su, 1994).

Design and Planning

The Baltimore ULTER team views data management as a cooperative, dynamic, and interactive endeavor for all PIs (Figure 5.1). Each site-funded investigation, as well as any investigations performed under the auspices of the Baltimore ULTER, will formally incorporate a data management plan. The data manager (DM) will consult and approve these plans with each principal investigator (PI) prior to the commencement of any ULTER funded research activities. The LTER Network Office and ILTER will also be consulted for general design and protocol issues on a periodic basis (Proceedings of the 1995 LTER Network Data Managers Committee). The DM and staff will continue to monitor the nature of the data and data collection activities throughout the project life cycle to seek improvements and optimize the ULTER database.

The DM is director of the UMBC's Spatial Analysis Laboratory (SAL) and a founding partner of the Baltimore-Washington Regional Collaboratory (or Collaboratory) (www/umbc.edu/bwrdc). The Collaboratory (sponsored by NASA's Mission to Planet Earth under a five-year grant (NAGW-5040) to support a regional data distribution center) has significant experience in development and maintenance of a Internet-based research facility sharing data within the Chesapeake Region and beyond (working closely with NASA, USGS, Census, and a wide range of federal, state, and local agencies, nongovernment organizations, universities, and public schools). Previously, the DM was EPA's Project Scientist responsible for introducing GIS technology into the agency; served as the GIS Manager for Clark County, Nevada, and Nevada's State GIS Chairman; and designed and implemented land use management systems for the Department of Defense as the Navy's first research ecologist. The ULTER DM is

BALTIMORE URBAN LTER PRINCIPAL INVESTIGATOR DATA COLLECTION FLOW CHART

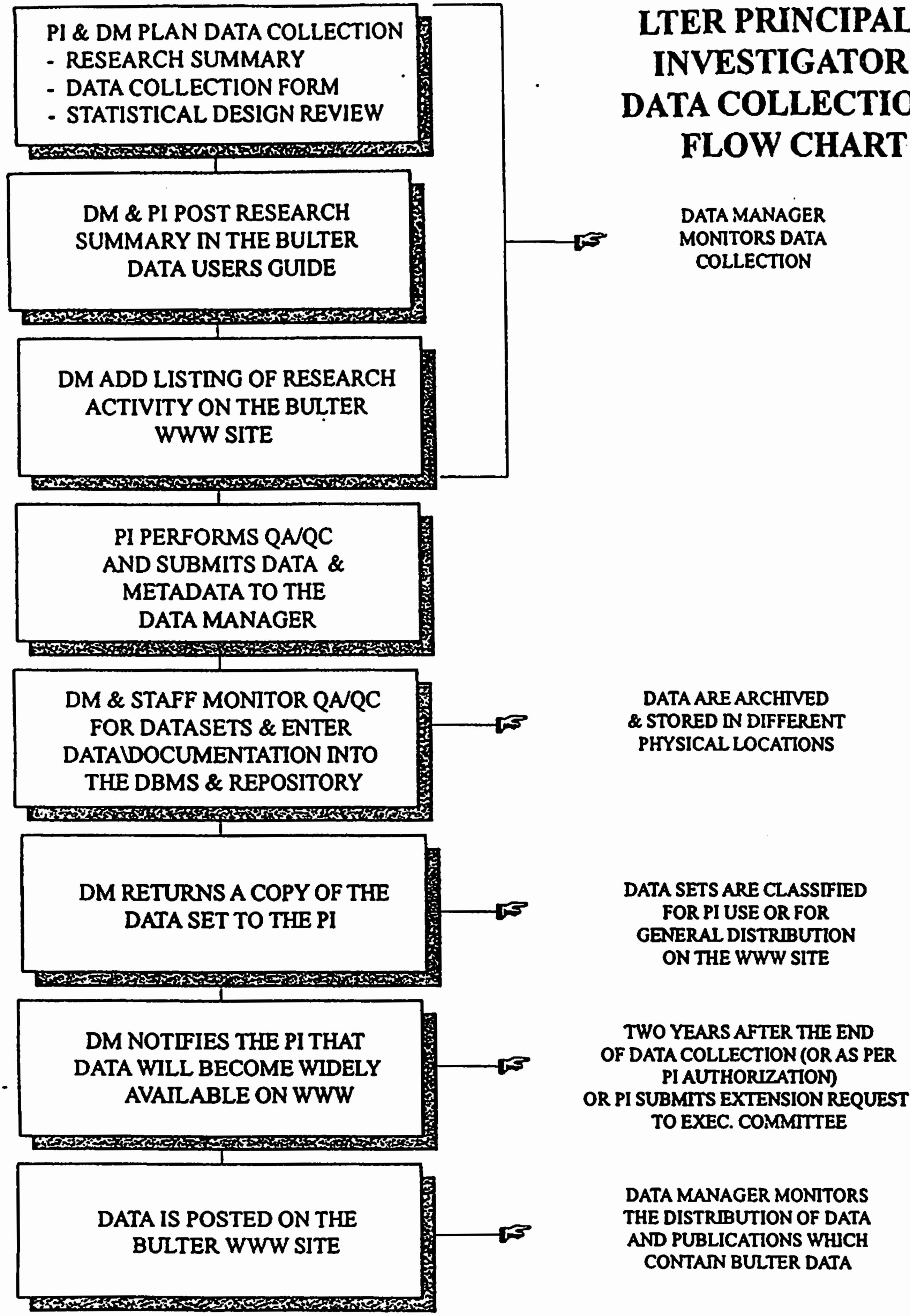


FIGURE 5.2

supported by a highly qualified and skilled data management staff with the requisite experience to manage and facilitate accessibility to the urban ecological data of the Baltimore ULTER. The DM will be assisted by SAL's systems manager who will dedicate 2/3 of his time to performing day-to-day administration of the ULTER database. Two half-time graduate students, with high-level programming experience, will also support ULTER operations. These positions and the systems manager's pay differential are funded under the DM's (Foresman) existing five-year NASA MTPE grant.

The ULTER will own and support a dedicated server with site data storage and metadata plus appropriate backups and off-site archival (Figure 5.3). The DM is fully supported for the proposed ULTER by UMBC's Computing Center for all requisite mass data storage and archiving, Novell network, Oracle technical support, and Internet functionality.

PIs will submit data continuously to the DM electronically, via the internet, in ASCII, GIS, or raster formats (Figure 5.2). Upon receipt of data, the data management staff will check datasets for standard quality assurance and quality control documentation and assist PIs with normalization and entity relationship assessments. The ULTER DM is well versed in scientific and legal liability issues for centralized database management, security, and structure (Edwards and Foresman, 1990) and will ensure implementation of a "Standards Policy" for the following protocols:

- naming conventions
- access privileges & security
- library management
- data transfer
- applications development test environment
- backups \ archiving
- quality assurance \ control
- recovery plans
- disk management
- world wide web interface

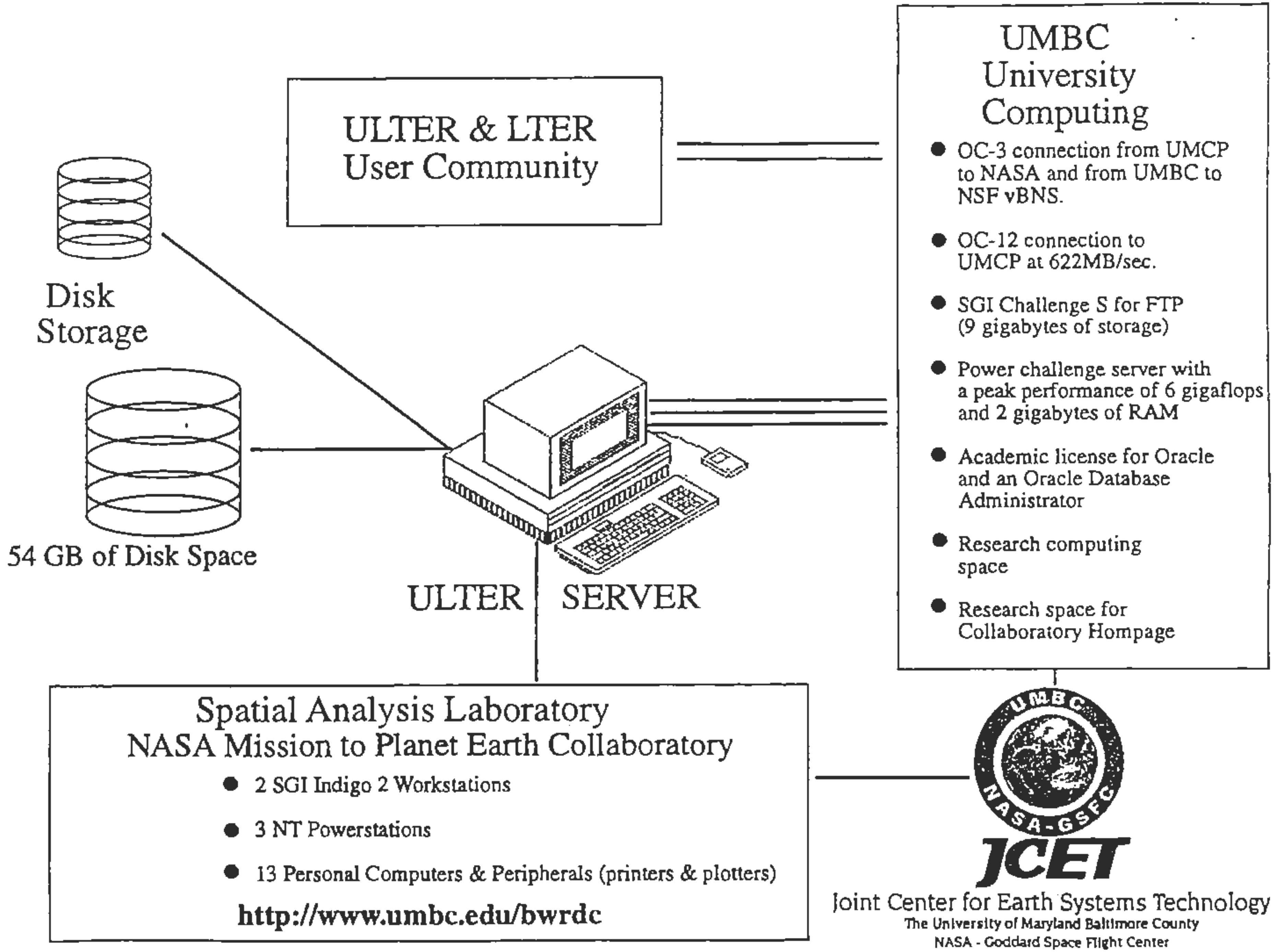
Data Access, Distribution, and Website Management

The ULTER DM will instruct all PIs in techniques for automated submission of data/metadata to the DM via the Internet. The data will be made available for free to all interested parties on the ULTER homepage, barring specific short-term restrictions as spelled out under the PI data types. Free access is based on the five-year NASA grant. After this period, the executive committee will promulgate a costing policy for data access and reimbursement of resources. PIs conducting research under LTER funding will be contractually obligated to comply with these data submission protocols. Additionally, the any research performed under the auspices of the ULTER will be accepted

Data Management \ Backup Policy

The standard for the ULTER will be to make quality data easily available to all interested parties on the ULTER homepage in a timely fashion (Figures 5.2, 5.3, & 5.4). Only under special circumstances, approved in writing by the executive committee, will data be withheld from wide distribution beyond the LTER Network standard (i.e., two years from the collection of the last datum). PIs will have a reasonable opportunity to have first use of the data they collect but have the obligation to submit their data to the site database, and to publish the data in a timely fashion. The ULTER will request that PIs receive adequate acknowledgment for the use of their data by other researchers and provide copies of any publication containing site data to ULTER PIs. The ULTER

Figure 5.3: UMBC Baltimore-Washington Collaboratory Computer Support



maintains that site data will not be sold or redistributed by the recipient. ULTER data will be made available on a long-term basis, even if an investigator leaves the project through transfer or death, and stored on a long-term basis using state-of-the-practice procedures. Efforts and resources will be dedicated to ensuring that long-term archival storage of data is maintained. The Baltimore ULTER data management policy will dictate that the ULTER database will be backed up on a bi-weekly, monthly, and yearly basis and that two copies of data will exist at different physical locations to ensure physical security. Each investigator will retain a copy of all data they collect.

Metadata

Metadata compliance is mandatory for all ULTER PIs and will be posted on the homepage (Figure 5.4). The DM working closely with the site manager and PIs will ensure complete metadata documentation to 1) allow "outside" researchers and citizens the ability to use/interpret data effectively, and 2) to enable researchers the ability to replicate the study and its data collection methods. A three-tiered Federal Geographic Data Committee (FGDC) metadata scheme, developed by UMBC to ensure national standards compliance and adopted by many Maryland State agencies, will afford ULTER spatial data users three levels of metadata complexity without sacrificing key scientific information (Foresman, et al., 1996 b; NSDI, 1996).

Community Education and Outreach

The use of urban ecological data in the education sector is highly valued by the ULTER, as demonstrated by ongoing high school field collection programs (Tree Troops of Baltimore) led by UMBC, USFS, and other ULTER partnerships (e.g., Parks and People, Revitalize Baltimore). The DM and PIs, in cooperation with educational advisors, will compile special datasets on the homepage (highlighted for student education) to be used in primary, secondary, and collegiate classrooms (Figure 5.5). Coordination with other education programs, e.g., the GLOBE program, Nature Map, the Maryland Geographic Alliance, and other NSF-sponsored activities will help ensure effective integration of these data into curriculum specific targets (see Section 4) and will allow students to collect ecological data, enter the data into a database, and perform analyses upon their own datasets as well as other ULTER data.

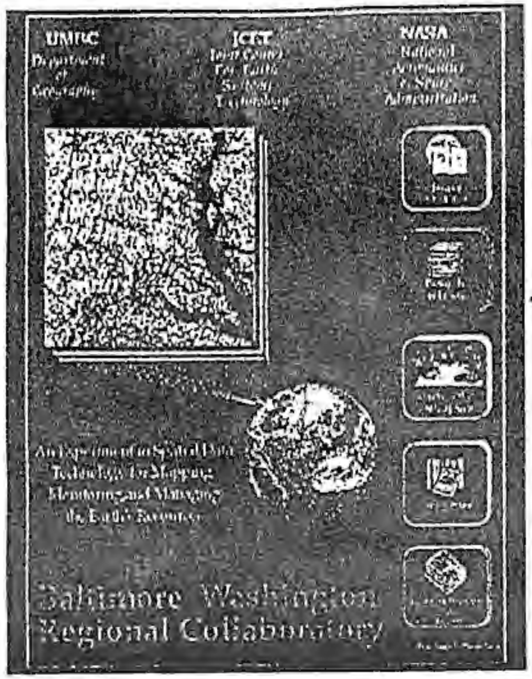
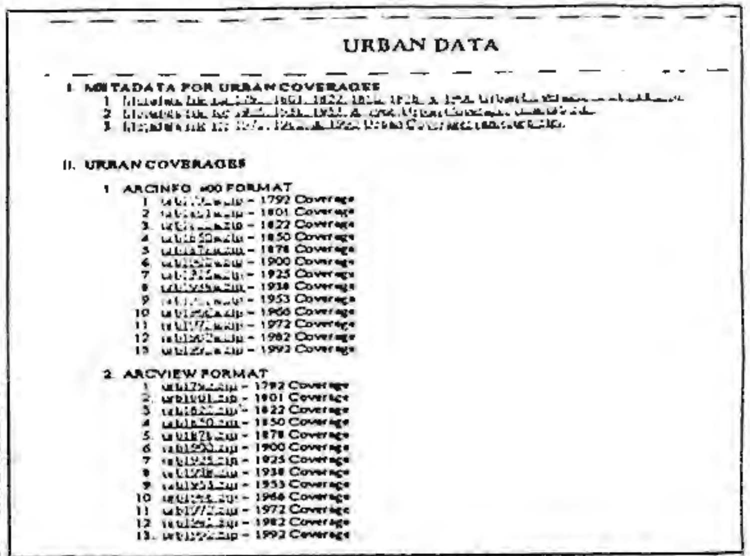
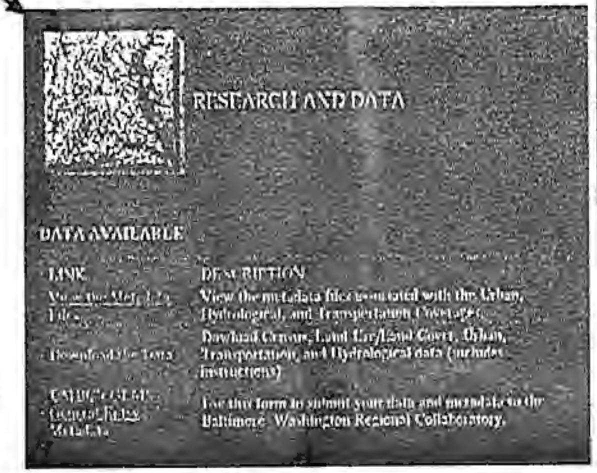
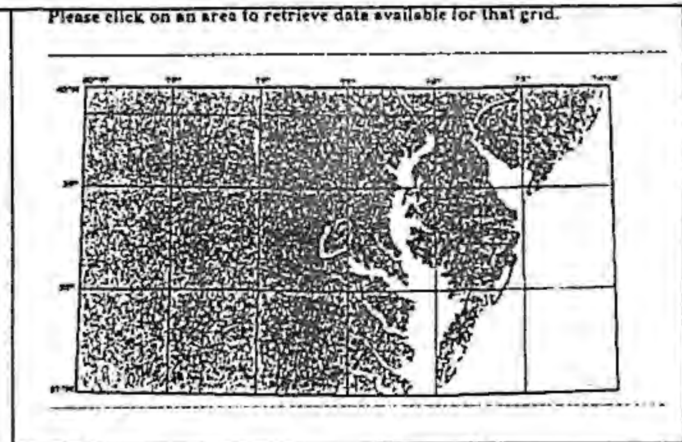


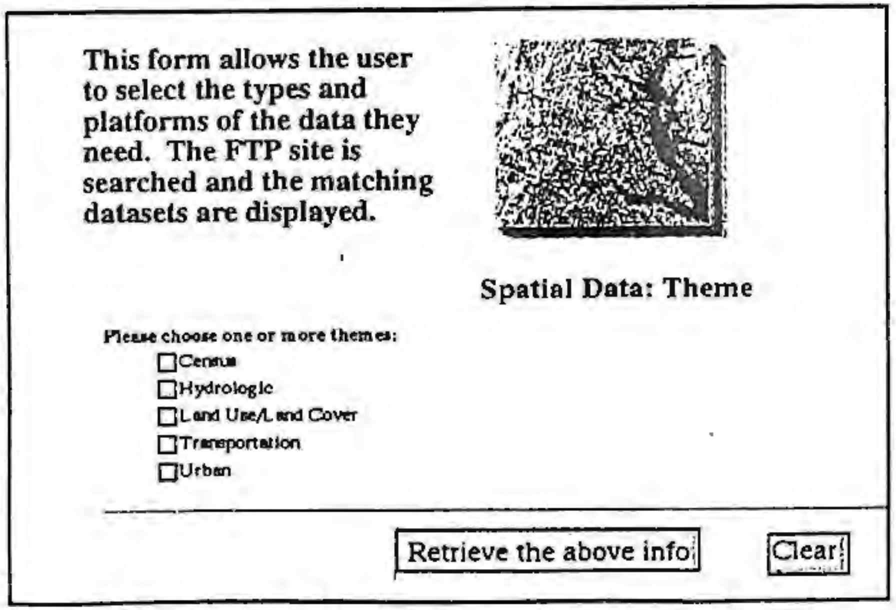
Figure 5.4 Baltimore-Washington Collaboratory Homepage: Data Search and Access Tools

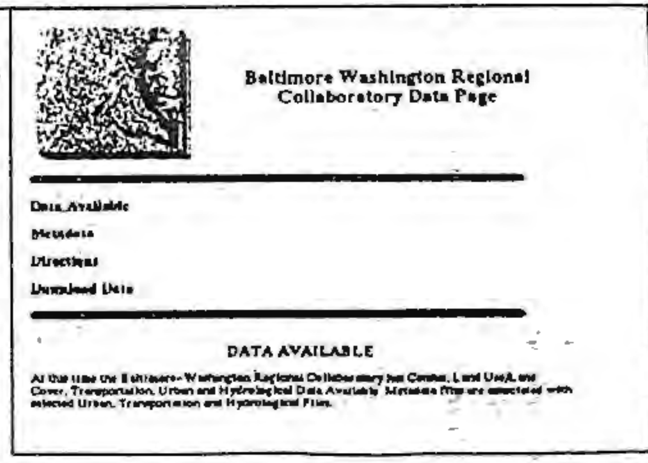






http://www.umbc.edu/bwrdc





Briggs, John M., and Haiping Su, 1994, *Development and Refinement of the Konza Prarie LTER Research Information Management Program*, in *Environmental Information Management Analysis: Ecosystem to Global Scales*. Ed. Michener, William K., James W. Brunt, and Susan G. Stafford, London: Taylor & Francis, pp 87-100.

National Spatial Data Infrastructure (NSDI), (1996). *The Baltimore-Washington Regional Spatial Data Framework Demonstration Project for Gwynns Falls Subwatershed.*

Foresman, T., H. Wiggins, and D. Porter. (1996). *Metadata Myth: Misunderstanding the Implications of Federal Metadata Standards.* First IEEE Metadata Conference. Silver Spring, MD.

Edwards, David R. and Timothy W. Foresman, (1990). *Centralized Data Management: Protecting Your Data Investment.* Proceedings of 1990 URISA Annual Conference, Edmonton, Alberta, Canada.

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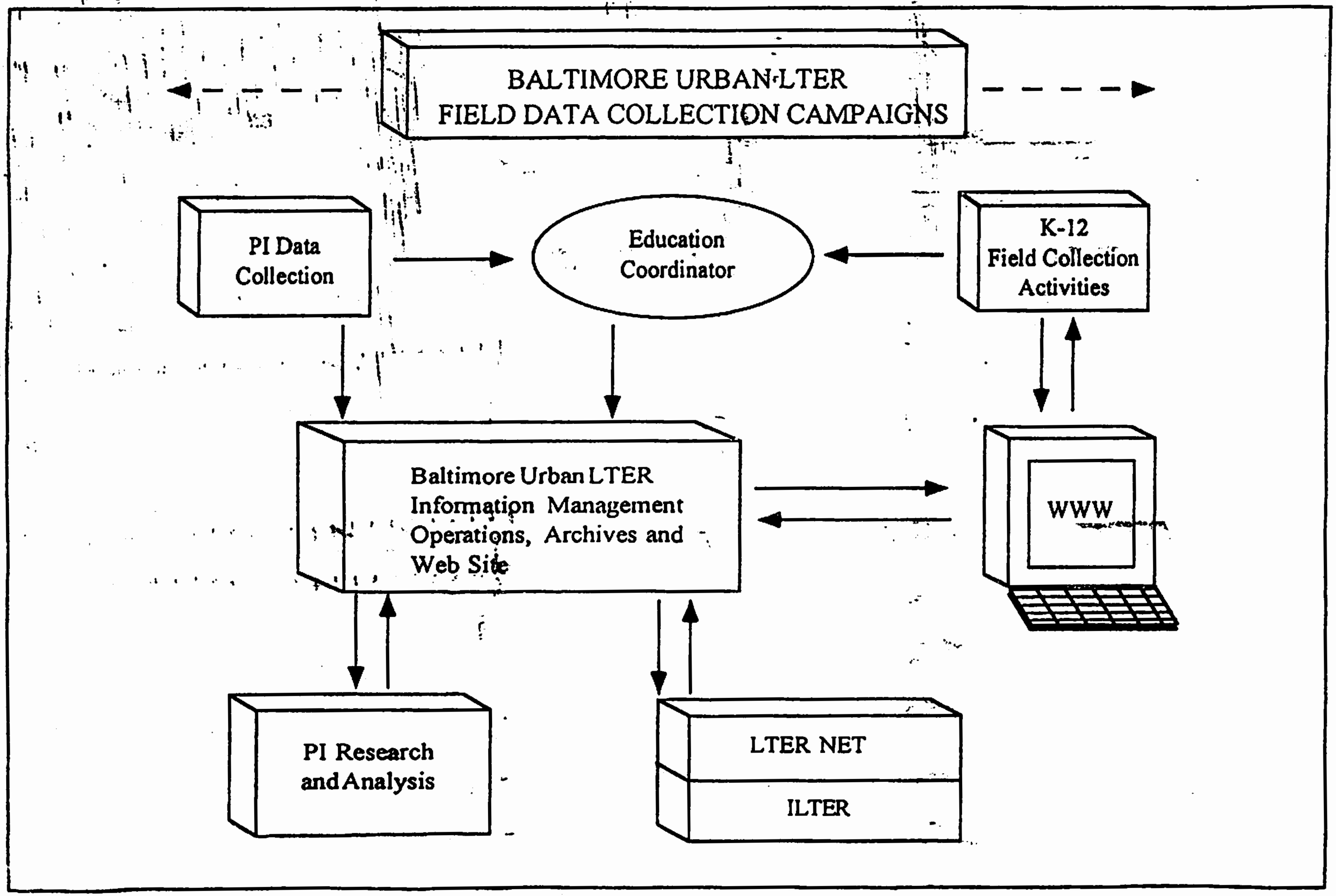

FIGURE 5.5