WATERSHEDS 96 **APPENDIX A** PICKETT

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.)	FOR NSF USE ONLY
☒ Topic A: Water and Watersheds ☐ Topic B: Technology for a Sustainable Environment ☐ Topic C: Decision Making and Valuation for Environmental Policy	NSF PROPOSAL NUMBER: DEB 9613158
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)	SHOW PREVIOUS AWARD NO. IF THIS IS	IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY?
22-3232968	☐ A RENEWAL OR ☐ AN ACCOMPLISHMENT-BASED RENEWAL	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
"Impact of Social Systems on Ecology and Hydrology in Small Watersheds: Integration for Restoration"

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE
$ 1,524,126.	36 months	1 January 1997

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:

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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.

CERTIFICATION PAGE

Certification for Principal Investigators and Co-Principal Investigators

I certify to the best of my knowledge that:

(1) the statements herein (excluding scientific hypotheses and scientific opinions) are true and complete, and

(2) the text and graphics herein as well as any accompanying publications or other documents, unless otherwise indicated, are the original work of the signatories or individuals working under their supervision. I agree to accept responsibility for the scientific conduct of the project and to provide the required progress reports if an award is made as a result of this application.

I understand that the willful provision of false information or concealing a material fact in this proposal or any other communication submitted to NSF is criminal offense (U.S.Code, Title 18, Section 1001).

Name (Typed)	Signature	Date
PI/PD		May 6, 1996
Co-PI/PD		May 6, 1996
Co-PI/PD		May 6, 1996
Co-PI/PD		May 6, 1996
Co-PI/PD		May 6, 1996

Certification for Authorized Organizational Representative or Individual Applicant

By signing and submitting this proposal, the individual applicant or the authorized official of the applicant institution is: (1) certifying that statements herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding Federal debt status, debarment and suspension, drugfree workplace, and lobbying activities (see below), as set forth in the *Grant Proposal Guide (GPG)*, NSF 95-27. Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U.S. Code, Title Section 1001).

In addition, if the applicant institution employs more than fifty persons, the authorized official of the applicant institution is certifying that the institution implemented a written and enforced conflict of interest policy that is consistent with the provisions of *Grant Policy Manual* Section 510; that to the best his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will been satisfactorily managed, reduced or eliminated prior to the institution's expenditure of any funds under the award, in accordance with the conflict of interest policy. Conflicts which cannot be satisfactorily managed, reduced or eliminated must be disclosed to NSF.

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Is the organization delinquent on any Federal debt? Yes ☐ No ☒

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal Department or agency? Yes ☐ No ☒

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This certification is required for an award of a Federal contract, grant or cooperative agreement exceeding $100.000 and for an award of a Federal loan a commitment providing for the United States to insure or guarantee a loan exceeding $150,000.

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The undersigned certifies, to the best of his or her knowledge and belief, that:

(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress connection with the awarding of any federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer employee of any agency, a Member of Congress, and officer or employee of Congress, or an employee of a Member of Congress in connection with Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, "Disclosure of Lobbying Activities," in accordance with its instructions.

(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of certification is a prerequisite for making or entering into this transaction imposed by section 1352, title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME/TITLE (TYPED) Joseph S. Warner, Administrator		May 6, 1996

TELEPHONE NUMBER	ELECTRONIC MAIL ADDRESS	FAX NUMBER
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PROJECT SUMMARY

In order to provide decision makers with effective tools to expose the widest array of options to ameliorate water quality, social, ecological, and hydrologic processes must be integrated. Therefore, the first goal of the proposed research is to develop a novel hydro-ecological model that integrates key social drivers at various scales. The model will be used to test whether social processes affect watershed dynamics and water quality, and whether any such effects act directly through pollutant loadings, or indirectly through the ecological structure and dynamics of the watershed. Furthermore, the model will be developed into a decision making tool by discovering how to interact with the existing decision structure, how to relate ecological variables to the spatial units of land use planning, and the hydrological implications of scenarios of change that decision makers propose.

To develop the new model, modules will be taken from two existing hydrologic models, HPSF and REHSSys. These models have complementary strengths, so that the new model can effectively simulate natural surfaces, built surfaces, and source areas of various spatial scales. In order to construct and calibrate the new model, the proposed research will collect high resolution data on soil, vegetation structure, and impervious surfaces, in fine scale spatial patches within subwatersheds of the Gwynns Falls watershed, a 17,150 ha area draining into the Chesapeake Bay. Data on water chemistry and benthic invertebrates will be collected to indicate the water quality of subwatersheds representing contrasting land use and land covers.

Social area analysis will be conducted at fine spatial scales, corresponding to neighborhoods, in order to provide the data on potential socio-economic drivers of water quality, stream biota, and watershed structure. Social data will include a variety of factors representing key resources of wealth, community structure, and access to social power, as well as specific actions that may affect water quality at the neighborhood level. The relationship of the social factors to specific land cover mosaics will be determined to provide the basis of assessing land use changes. Past land use changes will serve as the validation of the model.

The new model and the spatially explicit and temporal data bases used to construct and test the model will be used to assist decision makers who influence the management of the hydrologic system. By interacting with planners, managers, policy makers, community organizations, and local leaders, the proposed research will discover how management decisions are currently made, and how the hydro-ecological model might best be related to that structure. Input from decision makers will be important throughout the research to assure that the model, the scales it addresses, and the scenarios it can develop, are relevant to the user community.

The proposed research is significant because it can provide information that can help managers to modify social and landscape structure to reduce non-point pollution to the Chesapeake Bay, and because it will contribute to the theoretical integration of physical, social, and ecological sciences within a shared framework of hierarchically subdivided watersheds and ecologically functional land cover classes.

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For font size and page formatting specifications, see GPG Section II.C.

Appendix Items: None

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- Strayer-Pickett, May 1, 1996
- Wolman-Pickett, May 3, 1996

*Proposers may select any numbering mechanism for the proposal. Complete both columns only if the proposal is numbered consecutively.

NSF FORM 1359 (7/95)

INTRODUCTION

Decision makers, planners, and managers need sound models to assess water yield and quality, and aquatic biodiversity in human-dominated landscapes. Such needs can be met through an integrated approach to watershed dynamics. Both the needs and the components of the integration are illustrated by the strategies for managing water quality. Water quality can be ameliorated 1) at the "end of the pipe;" 2) through land use changes that reduce non-point inputs; and 3) by modifying polluting actions of people through socio-economic influences. The second and third options can be exploited more effectively to improve water quality.

The proposed research develops a model to test whether socio-economic factors act as strong controls over water quality, watershed dynamics, and stream biota. The model also will test to what degree the socio-economic factors act through modifying ecological factors (e.g., clearing or planting forest patches), as opposed to acting directly through people's actions (e.g., dumping waste). The research will be conducted in the 17,150 ha Gwynns Falls watershed which runs through metropolitan Baltimore, and empties into the Chesapeake Bay.

An integrated approach to watershed dynamics and water quality is needed for several reasons. First, the Environmental Protection Agency has mandated a 40% reduction in nitrogen loading to the Chesapeake Bay. Controlling point sources of pollution has not met this mandate. Second, forest conversion and suburbanization are proceeding rapidly. This change leaves few options to mitigate water quality. Thus, a model of the interaction of the ecological and physical features of the landscape with socio-economic factors is a potential tool for managing the water quality in the Chesapeake region.

The integration of physical, ecological, and socio-economic factors required by managers also has important scientific benefits, such as linking processes across scales. Water quality may depend on processes at coarse scales, e.g., the Baltimore metropolitan region to the fine scale, such as a neighborhood. Furthermore, information gathered in the contrasting environments of a metropolitan region can help reveal causal relationships among the ecological, physical, and social factors. The control of ecosystem function and biodiversity by heterogeneity is another major ecological issue that the integration can be used to address (Huston 1994). Combining the needs of decision makers, managers, and planners with the opportunity to improve ecological understanding of watershed dynamics suggests three **goals for the proposed research**:

1. Build a novel physical-ecological watershed model to predict responses of hydrology and stream biota to changes in social patterns and processes at scales relevant to decision makers.

2. Discover the relationships between the ecological variables that are required to model the effect of the current and historical patterns of socio-economic factors on hydrology.

3. Convert the model to a practical decision making tool in collaboration with policy makers, planners, and managers.

The integration is based on fundamental concepts in ecology and hydrology. The watershed approach is common to both of these disciplines (e.g. Likens 1992). From hydrology comes the theory that cover types in a watershed influence flow path and flow rate, the runoff to precipitation ratio, and the degree of saturation (Band et al. 1993). Runoff depends on the characteristics and arrangement of patch types (Fig 1). From ecology comes the theory that the flow and water quality can be regulated by vegetation in watersheds (Malanson 1993). The watershed can be divided into patches that have different ecological and physical structures (Doppelt et al. 1993). The hierarchical nature of watersheds prompts two important questions: Is the hierarchy of patch types developed in rural watersheds effective in urban and developing regions? Does the hydrological hierarchy correspond to the hierarchy of units used by decision makers (Fig 2)?

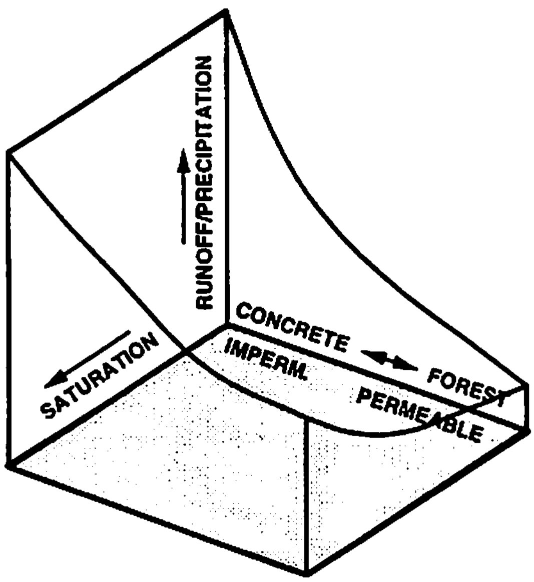

Figure 1. Prediction of runoff/precipitation ratio as a function of the permeability or flow rate and path, and saturation of substrate.

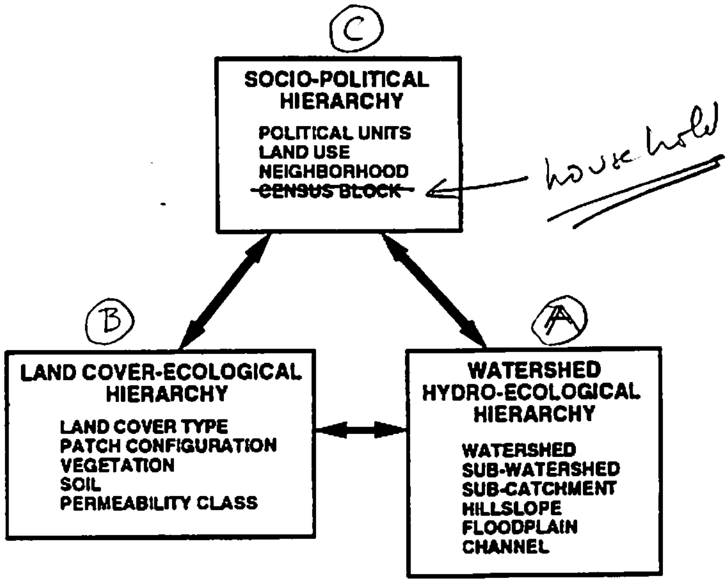

Figure 2. The three hierarchies of patch or land units to be integrated in the proposed research. Socio-political units are those defined by political or administrative entities. Watershed hydro-ecological units are those deliminated by decomposing large watersheds into smaller units that contribute runoff. The land cover-ecological hiarachy describes the specific surface features that govern the flow rate and pathway of runoff, and the degree of saturation of the substrate (cf Fig 1). The hiararchical ordering of land cover-ecological patches, vegetation, soil, and permeability classes is site specific.

The hierarchy used in planning reflects the needs of decision makers. It starts with large political units and can be decomposed into "land use" classes, neighborhoods, census block groups, and households (Fig 2). However, the patches in the socio-political hierarchy are composed of complex mosaics of land cover types that have specific hydrologic and ecological functions. The surface cover or land cover hierarchy can also be termed an ecological hierarchy, because of the functional contribution that vegetation, soil and inert surfaces make to land cover classes. Furthermore, the features of surface cover determine hydrological flow paths, rates, and saturation (Fig 1). It is such functional cover types that can be used to link the watershed-hydrological hierarchy with the socio-political hierarchy (Fig 2).

Since decision makers need to assess an area in terms of the three hierarchies, social-political, watershed-hydrological, and land cover-ecological, the relationships among the hierarchies must be discovered. We will first construct a hydrological model that predicts water quality and water yield based on the actual characteristics and configuration of surface cover. Second, we will assess the relative roles of social-economic factors, and ecological and surface features by accounting for both social and ecological driving factors within the model. This second requirement translates cover characteristics and social-economic processes to the land use classes that decision makers can use in planning. These requirements suggest three objectives.

OBJECTIVES

Objective 1: Build a novel physical-ecological watershed model incorporating the heterogeneity of the land cover types and the vegetation and ecosystem structure in metropolitan regions.

Our new model will be based on existing hydrological models that have complementary strengths. The Hydrological Simulation Program-FORTRAN (HSPF) model deals well with the nature of the surface, and provides a continuous hydrograph along with water quality (DeVries & Hromadka 1993, Anderson-Nichols 1979, Lumb et al. 1990). This model is the EPA standard and is thus of interest in the Chesapeake basin. The Regional HydroEcological Simulation System (RHESSys) is well suited to analyzing the effects of vegetation cover (Band ~~and Moore 1995~~). We will adopt portions of HSPF to represent both built and natural surfaces, and portions of RHESSys to account for vegetation and ecosystem structure of the watersheds. Our model will make predictions at different spatial scales so that responses of stream biota, water quality, and water yield can be aggregated.

Objective 2: Incorporate the socio-economic patterns and processes into the new physical-ecological model of watershed hydrology.

Here we will examine the connection between human effects and water quality, water quantity, and stream biota. This objective will improve the predictive power of the hydro-ecological model developed in Objective 1 by integrating social patterns and processes. We will determine whether socio-economic factors influence watershed dynamics, and if so, whether they operate directly through the activities of people at different spatial scales, or operate indirectly through the physical and ecological structure of the watershed landscape. This hierarchical assessment of the socio-economic processes will link them to watershed processes at different scales.

Objective 3: Use the spatially referenced ecological, hydrological, and socio-economic data along with the new model to assist in decision making in metropolitan Baltimore.

By working with decision makers in the City and County of Baltimore, the State of Maryland, the Revitalizing Baltimore Program, and other organizations (I 1-3) we will determine how to best use the model in planning, management, and restoration. We will conduct workshops throughouth the development of the model to discover what parameters and relationships between socio-political, ecological, and hydrological data decision makers actually need. Based on input from potential users, we will adjust the developing model if necessary, and determine how the simulations can be used to explore process response to past environments or development scenarios. The scenarios will address changes in capital behavior, patch tenure, spatial sensitivity or behaviors on scales from subwatershed to the whole Gwynns Falls basin.

Existing Partnerships. The principal investigators represent an ongoing collaboration between several institutions and disciplines (social ecology, plant ecology, landscape ecology, soil science, and hydrology). Working relationships with aquatic ecologists and geomorphologists will be exercised in the proposed research (I 4-5). In addition, these researchers have worked extensively with policy makers, planners, and managers from federal, state, and city agencies and from non-profit organizations and community groups (I 1-3) through both the Yale Urban Resources Initiative (8 yr) and the Revitalizing Baltimore Program (3 yr). In particular, the Revitalizing Baltimore project has built upon the Yale Urban Resources initiative to develop projects that link environmental restoration with urban revitalization on a local, watershed and regional basis and that are related ultimately to the Chesapeake Bay.

LITERATURE REVIEW

Our approach links 1) the hydrological, 2) ecological, and 3) social-economic controls on water and watersheds.

Heterogeneity and Spatial Patchiness

Watershed function depends on heterogeneity of the three controlling factors. Therefore, the first step in linking hydrological, ecological, and social phenomena in a watershed model is to discover comparable patterns within the three realms (e.g., McDonnell & Pickett 1993). Natural and social scientists independently developed systems for identifying and mapping recognizable units in their disciplines (Zonneveld 1989; Kuchler & Zonneveld 1988; Bailey 1983; Bailey 1985; Rowntree 1981). Such systems can be used to assess heterogeneity and to link comparable social and ecological units (Bailey & Mulcahy 1972); scales (Johnson 1993; Burch & Grove 1993; Daniel et al. 1993; Thompson & Warburton 1985b; Allen et al. 1984); and classification systems (Zonneveld 1989, Grove 1996).

Hydrological Heterogeneity The Variable Source Area (VSA) approach incorporates heterogeneity. Different areas, or patches, contribute variable amounts of water and nutrients to stream flow, depending upon location in the watershed and physical attributes of the soil (Hewlett 1982; Dunne and Leopold 1978). This approach represents a dynamic model of the abiotic attributes of the watershed, including seasonal fluctuations, topography, physical properties of the soil, water table, and antecedent soil moisture (Dunne and Leopold 1978). However, this model does not include regulation of the hydrologic cycles by the biotic attributes of the watershed, nor does it consider social patterns and processes.

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 (Zhu and Band 1994). 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 (Fig 1). Fields, lawns, and other disturbed sites are intermediate. Hydrological length scales can range from a kilometer (forested tract, agricultural fields) to meters (streets, lawns, house footprints). 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 least mix, or "purest" land covers. LB(A)

Ecological Heterogeneity The watershed approach has traditionally dealt with relatively homogeneous units. However, the approach has been enhanced by considering spatial heterogeneity (Malanson 1993), which is a virtual universal in nature (Forman & 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 & Brand 1991) and nutrients (Peterjohn & Corell 1984, Groffman et al. 1993), and successional dynamics of communities (Pickett & White 1985). Patchiness is an important regulator of biodiversity (Huston 1994, Pickett 1996), and is emerging as a major theoretical organizing principle in ecology (Turner 1989, Kolasa & 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).

Point and non-point sources of nutrients and toxins can play a primary role in altering the species composition and function of stream communities (Yount and Niemi, 1990; Pitt, 1995). In addition, urbanization brings changes in physical habitat that have profound effects on stream biota. Riparian soils, stream substrates, channel and floodplain morphology, and water temperatures can all be affected by the changes in flow and sediment regimes associated with construction and the creation of impervious surfaces and storm sewer networks (Wolman 1967; Leopold, 1973). Also important are changes in the magnitude and frequency of physical disturbances (e.g. floods, droughts, channel scour) to which lotic communities are particularly sensitive (Urban et al., 1987; Reice et al., 1990). These and other effects have fundamentally altered the lotic and riparian ecology of urban streams such as the Gwynns Falls.

Socio-Cultural 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 1984; Machlis et al.1995; Fig 3). 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.

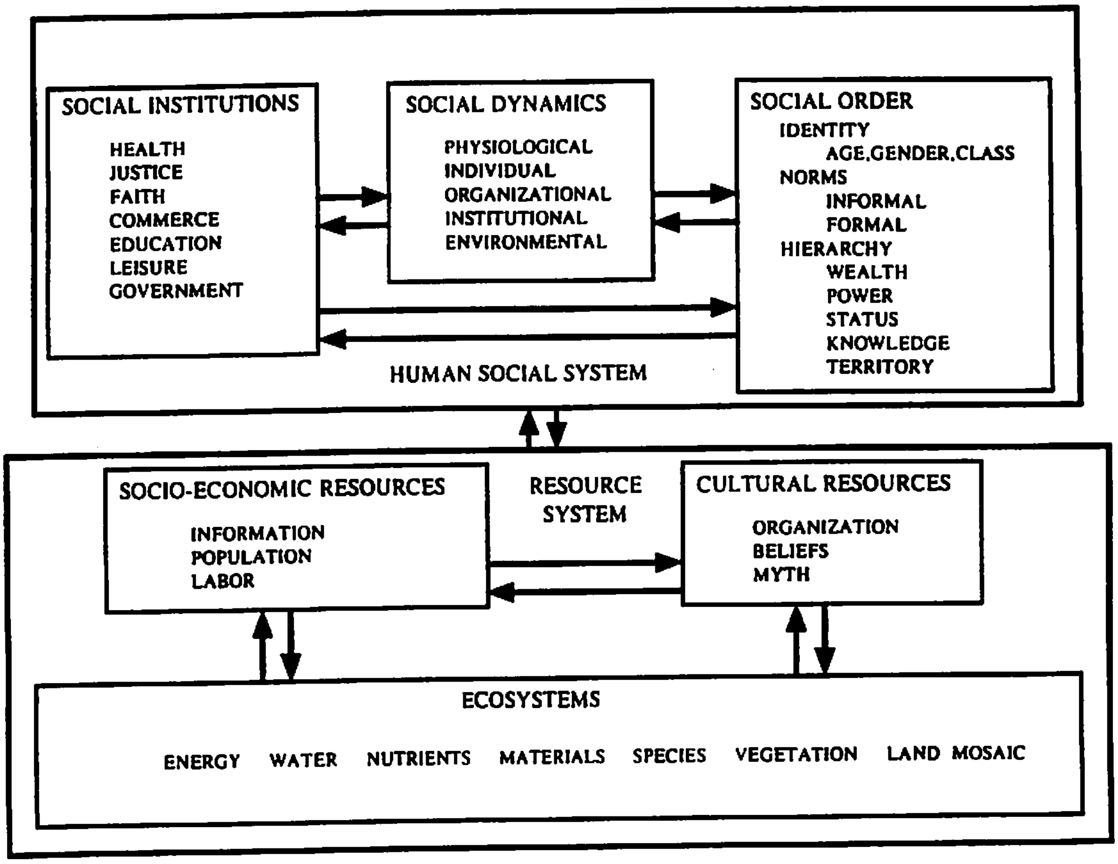

Figure 3. A human ecological systems model adapted from Machlis et al. 1995.

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 1996), social stratification within residential areas (Shevky and Bell 1955; Timms 1971; 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 Socio-political Processes

In order to understand the hydrological, ecological, and socio-economic controls on water quantity and quality, there must be a way to link the three different hierarchies. The flow of water is controlled within a heterogeneous ecological and physical landscape and socio-politically defined infrastructure. In human-dominated ecosystems, social attributes measured with a social area analysis (Shevky and Bell 1955; Johnson 1976; Hamm 1982; Frisbie and Kasarda 1988; Grove 1996) is used to extend an abiotic/biotic VSA approach in order to measure the impact of social heterogeneity on ecological patterns and processes. In essence, this represents a social-ecological VSA approach that integrates biotic, social, and physical attributes and provides the basis for a dynamic model to study the hydrologic processes of a human ecosystem and landscapes. Such integration is a pressing need (Groffman & Likens 1994).

Practical utility

With the integration of biotic, social, and physical attributes of watersheds, we can understand the 1) internal behavior and covariation of social and ecological patterns and processes, and their interactions with each other in units of critical resources such as energy, material, nutrients, population, information, labor or capital, and 2) to include a temporal dimension to examine types and rates of system change (Burch 1988). Thus, the social-ecological VSA approach will enable researchers to move beyond purely biological models, which limit researchers to investigating intermediate variables and proximate causes (McKendry & Machlis 1993), and permit researchers to address the more fundamental and significant social variables that are the basis of human ecosystems and landscapes.

Significance

The primary focus of the proposed research is to test and improve our understanding of the theoretical relationship between patterns and processes of hydrology, ecosystem structure, and social stratification and of an urban-rural watershed based upon Logan and Molotch's (1987) political economy theory of place, vegetation and ecosystem patch dynamics (Pickett and White 1985, Likens and Bormann 1995), and hydrological theory (Band ~~and Moore 1995~~). Second, it will explore a new methodological approach to enable human ecologists, ecosystem ecologists, and hydrologists to enhance their common theory and to apply forest ecosystem models to human-dominated areas. This methodology will also test a preliminary approach and parameters for developing an Integrated Regional Model (IRM) for human ecological systems (Groffman and Likens 1992). Further, this research is relevant to current environmental issues such as nutrient loadings to coastal waters, and the sustainability of ecosystems in developing regions. Specifically, this research can help solve problems of water quality that policy makers, planners and advocates must confront in order to address the dynamics of environmental equity and the linkages between environmental restoration, urban revitalization, and regional planning. This research will also explore how methods and technologies can be used in collaboration with decision makers to solve the problems they articulate.

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METHODS

Study Location

The metropolitan area of Baltimore, Maryland, will serve as the study region for this research. The region comprises three watersheds -- the Gwynns Falls, Jones Falls, and Herring Run -- and the Gywnns Falls will serve as the pilot area in which to develop and test techniques and approaches to evaluate ecological and social patterns and processes and their interactions. This watershed was chosen because of the existence of extensive field and remote sensing (satellite and aerial) data over the range of ecological and socio-economic scales collected for the Revitalizing Baltimore Project.

Gywnns Falls (76°30', 39°15') is 17,150 ha in size and contains 16 subwatersheds ranging from 460 to 1850 ha. Resident population has declined from 406,000 in 1970 to 356,000 in 1990; while urban area increased from 66.3% in 1973 to 74.3% in 1990. Population densities of sub-watersheds range from 2.5 to 19.8 people/ha. Land use varies from predominately residential/commercial/industrial at the bottom of the watershed to agriculture/forest/open space in upper proportion.

Objective 1 Construct a new physical-ecological model that assesses hydrological and biotic stream response to heterogeneity of land cover and ecological processes in metropolitan regions. In addition to constructing the model, empirical data on soils and vegetation components of the watershed landscape and their configuration are required, along with data on water quality, runoff, and stream macroinvertebrates.

Model Construction

We will develop a novel hydroecological model by hybridizing HSPF with RHESSys. HSPF model uses vegetation canopy and cover data at scales adequate to delineate minimum patch size of 900 m^2 and soil data acquired from soil surveys at a scale of 1:15,840. RHESSys uses 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 resolution. Soil variables cannot be continuously imaged as can land cover, requiring that we establish a network of field plots to characterize soil/vegetation conditions, and to observe dynamic phenology, wetness and runoff processes. Therefore, for six subwatersheds, we will deliminate 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). Within these patch types soil hydrologic and chemical properties, vegetation structure, and runoff will be measured. In addition, stream physical and ecological characteristics will be measured to determine relationships among spatial patterns of human activity, the physcial structure and dynamics of stream networks, and the spatial structure and functioning of lotic and riparian ecosystems.

Delimiting Hydrologic Units

The Gwynns Falls watershed currently has ten gauging stations operated by Baltimore City and County, in which continuous discharge data is measured along with regular sampling of N and P. The sampling scheme was set up in 1994 in response to an EPA Clean Water Act mandate, and will serve as the watershed wide quantity and quality data we will scale to. Our strategy will be to 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 watershed and subwatershed, 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. L.R. Neville (pers. com.) found 30 categories based on soil permeability, land use, and canopy cover to adequately describe samples of the Gwynns Falls watershed. Six subwatersheds, two urban, two suburban, and two rural (defined by amount of urban land cover types) will be selected to collect higher resolution data to deliminate 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 our simulation approach. We will attempt to select subwatersheds containing at least one city and county stream gauging station.

Vegetation in Hydrologic Response Units. Plots of 0.04 ha will be established in a subsample of hydrologic patch types. Sample plots (ca. 250) will be allocated among patch types proportional to the amount of area delineated for each category in the entire Gwynns Falls watershed. The surface area occupied by various human made materials, grass, shrubs, soil, herbaceous, rock, litter type and depth, water, and wood will be measured in each plot. The size and species of individual shrub masses will be recorded (length, width, height). Stem diameters of individual shrubs at 15 cm above groundline will be measured. Trees will be identified to species and measured for d.b.h., total tree height, height to base of crown, crown width, crown shape, percent of crown occupied by leaves, tree location (street-tree, yard, forest stand etc.), and condition. Estimates of tree condition will be based on foliage characteristics modified from Nowak (1994). LAI will be measured by collecting litter fall in fixed-area collectors and measuring area using a LICOR leaf area meter (Aber 1978).

Soils and Runoff. Soil samples will be taken in areas of each plot devoid of impervious materials. Infiltration rates will be determined in three locations within each plot using the ring infiltrometer method (Bertrand 1965). In addition, six undisturbed cores will be taken to a 30 cm depth from each plot. Three of the six cores will be used to determine bulk density and soil porosity at 10 cm intervals of each core. The undisturbed soil cores will be also used to measure hydraulic conductivity and permeability using the constant-head method (Klute 1965). The three remaining cores will be separated into 10 cm sections and utilized for soil textural analysis by the hydrometer method (Wilde et al. 1972). In addition to the undisturbed cores, a composite sample collected to a 15 cm depth will be used to measure soil pH, electrical conductivity, total C and N concentrations, and heavy metal and base cation concentrations.

We will sample to augment existing runoff quantity and quality data collected in larger sub-catchments by collecting more localized information on the behavior of the distinct land cover components of the HRU's. This work will concentrate on sampling within the 0.04 ha plots described above and from small drainage lines integrating over areas one to two orders of magnitude larger (e.g. curb runoff, drainage ditches). These data will be used for a combination of model diagnostics and calibration for the simulations operated at high resolution (distributed patch model described below) and lower resolution (more spatially lumped models). In each 0.04 ha plot, runoff plots of 5 to 10 m^2 will be delimited with garden edging material to collect storm totalized runoff, nitrate, total phosphorus, chloride, sulfate, and total particulates. Similar water quality measures will be taken within given storm events from curb and drainage ditch flow, depending on accessibility and storm timing. Gravimetric soil moisture and soil temperature sampling from the area surrounding the plots will be carried out weekly through the spring, summer and fall. The effectiveness of vegetation canopies in reducing net precipitation through interception will be measured by arraying 5-6 manually read gauges within each plot, along with two in a nearby clearing.

Stream Characteristics. In-channel and riparian habitat conditions will be assessed qualitatively and quantitatively throughout the watershed. Sub-basins and channel reaches within the sub-basins will be designated on the basis of land use, riparian vegetation, channel morphology, substrate characteristics, and degree of direct human modification (e.g. channelization or effluent input). Standard surveying and sedimentologic (e.g. Wolman, 1954) techniques will be employed. Hydrologic regimes, the degree of channel-floodplain connectivity, and the magnitude and frequency of disturbance by extreme flows will be assessed using available stream gage data and hydraulic modeling (HEC-2) for a sub-sample of channel reaches. All hydraulic and stream channel data will be included in the GIS database for comparison/correlation with the spatial distribution of hydrological, ecological and social factors.

The benthic macroinvertebrate community will be sampled in channel reaches selected to cover a broad range of substrate types and hydraulic conditions. Pool, riffle, littoral, and hyporheic habitats will be systematically sampled within each channel reach (Cummins, 1962). Quantitative samples will be collected using appropriate techniques for each habitat type (Merritt et al. 1984) and the sediments and animals retained for subsequent grain size analysis and taxonomic identification. Sampling will continue over a period of at least one year in order to characterize and account for seasonal variability in community composition. To augment these data, biomonitoring data from volunteer groups (e.g. Maryland Save our Streams) and government agencies (e.g. Baltimore County Department of Environmental Protection and Resource Management, Maryland Department of Natural Resources) will be used to provide additional information on recent biotic and water quality conditions. Water quality at each sampling station will be assessed. Nitrate, phosphate, chloride, sulfates, and total particulates will be analyzed.

Development of an Urban Hydroecological Index Model

The hydroecological simulation will estimate absolute or relative stormwater quantity and quality from different hydrologic patch types. High accuracy estimates of absolute discharge quantities and quality parameters at the high resolution of individual land use planning units may not be achievable for the full watershed due to limited data availability and computational capacity. Instead, we will concentrate on simulation strategies to produce quantity and quality indices so that different patch types can be ranked in order of stormwater loading.

Runoff Generation. In urban areas, the local production of runoff depends on the surface cover. The surface can be considered to be composed of hydrologic "end members" or pure patch types of such materials as concrete, bare soil, lawns, rooftops, wooded and other vegetation canopies, etc. These end members can be arranged along an axis representing relative infiltration capacity and flow-path partitioning, with an orthogonal axis of surface wetness, we can view a runoff coefficient (Rc = runoff/pcp) to be a function of static (material) and dynamic (wetness) properties (Fig. 1). The partitioning of storm events into stormflow runoff and soil and groundwater recharge is primarily dependent on the land cover materials (e.g. % impermeable surface) and the human management of more permeable materials.

Any land segment or real patch is a mixture of the static properties, and in an urban-suburban-rural landscape, the dynamic states of the surface patches are influenced by both climatic and human activities (e.g., irrigation, lawn watering, vegetation management). Very localized applications require high resolution information on surface cover and on human tenure of the patch distribution. RHESSys (Band et al. 1993) simulates a hydrologic unit (catchment, hillslope) by integrating over the distribution of distinct patches within the unit. This strategy will be extended here. Patch hydrologic process modules will be continuously operated for hydrologic balance and runoff production, including canopy interception, evaporation, transpiration, soil water redistribution and runoff, with different algorithms called for distinct hydrologic patch types. Many of the algorithms exist in RHESSys (Band et al. 1993) and HPSF (Lumb et al. 1990, DeVries and Hromadka 1993) and are being augmented for urban and agricultural conditions. A composite (areally weighted) Rc will be generated for each hydrologic unit for each storm event. Generation of runoff from irrigation (largely lawns, golf courses, fields) and other sources of applied water will be incorporated, along with a unit integrated baseflow.

Runoff Routing. In addition to surface composition, local runoff patterns can be very sensitive to the spatial configuration of patches, due to their hydrologic connectivity or drainage sequence. Runoff can be minimized in urban areas by routing water from impermeable surfaces to more permeable surfaces or detention stores where run-on infiltration or ponding can occur. Therefore, for very local applications, the high resolution information may need to incorporate the drainage connectivity of the surface through the set of patches. Information can probably only be known in detail at the landscape architecture scale (household to block or neighborhood). However, this is the scale at which community planning and redevelopment occurs, and it is also a scale at which hydrologic flowpaths, runoff generation and water quality modification can be resolved.

We will operate one set of models for the six subwatersheds (see above) at this level. This requires high resolution digital terrain information which from large scale topographic information available for much of the watershed. Drainage routing, given appropriate resolution and quality DEM is a straightforward procedure and our group has made a number of advances in this area to handle flat areas in the landscape, as well as steeper terrain (Mackay and Band 1994, 1996). Storm sewer infrastructure will also be incorporated in this system.

Index Integration. Over larger areas, our ability to route water over the set of end member patches is limited by data availability and computational capacity. We will use the higher resolution simulations just described to calibrate the Runoff Delivery Efficiency (RDE = storm runoff delivered to streams or storm sewers divided by total runoff production over all hydrologic patch types). This measure is also conditioned by the semi-permanent patch structure, and the wetness state of the system. It can be altered by human tenure of patches (e.g. lawn watering, vegetation management, drainage system maintenance, placement of coarse fill at curb overflows), and so we can incorporate alteration due to non-capital management. The RDE is also conditional on runoff magnitude as hydrologic connections may change at different water levels (curb overflow). The product of Rc and RDE can be considered an Urbanizing Hydrologic Pathway Index (UHPI) which categorizes a region in terms of its position on a gradient from recharge, slowflow dominated to surface, quickflow dominated conditions. Much of the drainage infrastructure (with the exception of detention stores and spreading basins) tends to maximize the UHPI and rapidly discharge precipitation from the basin. Note that the UHPI, as a product of Rc and RDE, is also a complex function of semi(permanent) patch structure (including storm sewer infrastructure), and dynamic wetness and storm conditions.

Water Quality Modules from HPSF will be incorporated to estimate water quality parameters of the runoff. HPSF is not specifically designed to operate at the patch level, as it uses land use averaged loading factors for sediment and pollutants. Our approach will be to use modules of HPSF to estimate relative amounts of different water quality components based on patch characteristics and the simulated hydrologic flux. We will use runoff plot measurements to provide local patch loading factors which then may be integrated to larger area loading factors based on land cover and tenure conditions. The plot measurements will expose the local conditions controlling the major variations in water quality loadings. Because our goal is to better understand the urbanizing hydrologic system to design methods to reduce contaminant loading, estimates of relative, rather than absolute, loadings should be sufficient to target landscape components and treatment strategies to achieve reductions. Convolution of the UHPI with indices of relative sediment, nutrient and contaminant loadings can be used to estimate an ordering of landscape structure and management conditions that tend to maximize or minimize stormwater export and quality under different meteorological conditions.

Extension to Larger Areas

HPSF has been successfully operated over the Gwynns Falls watershed at the low resolution at significantly larger scales (Neville 1996). The work we plan at higher resolution and within smaller, distinct subcatchments can be compared to the larger scale simulations which make use of land-use averaged loading factors and areally lumped runoff production processes. Comparison of hydrologic behavior integrated from observation and simulation over a set of smaller, distributed plot to catchment areas with lumped basin simulations which have been calibrated to the full watershed response can be used to test the internal consistency and improve the process representation of the full watershed model.

Objective 2: Incorporate the socio-economic pattern and process into the new physical-ecological model of watershed hydrology.

Social Area Analysis

Since much of the social analysis required has been conducted by Grove (1996), we will use his analysis as a foundation for this objective. Census block groups will be used as the social unit of analysis. These can be aggregated to yield higher hierarchical unity of analysis and comparison with ecological and hydrological functions. Residential areas have been identified using land use classification (above) to select all block groups lying in residential areas (Grove 1996). Census block group boundaries were obtained from the U.S. Census and digitized for 1970 and 1980. Census block group boundaries for 1990 are available in a GIS format from the US Census Bureau. Demographic and socioeconomic data from the US Census Bureau from 1970, 1980 and 1990 were matched to the block group areas as attribute data (Garson and Biggs 1992; Daniel and others 1993; Grove 1996). In 1990, there were approximately 895 block groups which averaged 9.23 hectares in size. ARC/INFO will generate social area maps and overlay maps with ecological and physical maps.

The selection of variables and indices for the classification of block groups in residential areas will use the theoretical parameters identified by Logan and Molotch (1987), Choldin (1984) and Bullard (1990) in addition to adjustments recommended by Johnston (1976), Murdie (1976) and Hamm (1982). This approach has been applied and tested previously for a number of cities in the United States (Johnston 1976; Bogue 1984; and Frisbie and Kasarda 1988). The four indices of patterns and processes of residential social stratification will include a socio-economic index, a household index, an ethnicity index and a social area index (a composite of the first three indices). The Socio-economic Index evaluates percentage of workers in professional/managerial occupations aged 16 and over; Percentage of households earning $12,500 per year or more; and Percentage of persons 25 years and over with at least a college degree. The Household Index accounts for Percentage of those aged 15 and over who are married; Percentage of households that are one-family households; and Percentage of dwellings that are owner-occupied. The Ethnicity Index includes Percentage of the population who are "black"; or "other races;" and Percentage of the population who are "foreign-born." Each index is standardized to a maximum of 100. The social area index for each block group/social area is the total of the three separate indices (Grove 1996).

Testing the importance of Social-Economic System

Our hypothesis is that human behavior, independent of the semipermanent patch configuration, may exert a significant influence on hydrologic behavior in terms of runoff quantity and quality. We will assess whether this operates at very local levels through the influence of common lawn management (irrigation and fertilization practices), salting of roads, street sweeping, etc. We will test this hypothesis through a combination of empirical observation using measured water quantity and quality parameters in association with land cover, terrain and socioeconomic variables, and by simulation. Within the simulation models we will operate a series of control runs for the different subcatchments in which variables that are set or influenced by human management (defined more formally within the project in consultation with Baltimore city, county, NGO groups) are standardized, and then compared with best estimates of the variability of these variables (or treatments) within and amongst the subcatchments.

Canonical correlation analysis and discriminant function analysis will be used to identify correlation between social area measurements (social stratification indices and social area composite) and physical and ecological attributes and to predict which physical and ecological attributes can be predicted by social area measurements. Land use configuration of social areas will be evaluated using standard landscape ecology spatial descriptions and statistics (e.g., interpatch distance; patch type, size, shape and location; patch diversity, autocorrelation of patch attributes; Turner and Gardner 1991). Spatial heterogeneity of social areas within each subwatershed will be determined by indices of patch diversity, patch size, patch shape, and patch adjacency (Turner et al. 1991). A GLM will used to regress social area measurements with physical and ecological attribute (including patch configuration) for the different hierarchical scales--block, neighborhood and land use. A discriminant analysis will be used to identify which variables are important at each hierarchy.

To incorporate the social area analysis into the hydrological model, a module will be written for RHESSys and HSPF models. These modules will predict storm water runoff and water quality and quantity based on social-economic and biophysical characteristics at different hierarchical scales (block, neighborhood, land use, and watershed). Predictive ability of these socio--biophysical models will be tested by comparing values obtained in Objective 1 and observed values obtained from the five watershed gauging stations. This step, comparing the socio-biophysical model with the biophysical model at the different hierarchical scales, will yield insights into the degree of direct and indirect influence of people on hydrologic systems and whether there are spatial thresholds of human influence .

Objective 3: Use the spatially referenced ecological, hydrological, and socio-economic data along with the new model to assist decision-makers in managing the hydrological system within the Baltimore Metropolitan region.

This objective is designed to transfer the model to decision makers who influence the management of the hydrologic system of which Gwynns Falls is a part. The objective has three parts. First, we will identify the existing land-use and management decision-making process. For this, we will identify key players and constituencies, including forest, state, and local government agencies, non-profit organizations, institutional land-owners, and community representatives that influence land management decisions (I 1-3). Second, we will determine at what scale (household, blocks, neighborhoods, land use, metropolitan) are management decisions made. Third, we will work with these individuals and groups to convert our model into a decision making tool that will aid managers in making decisions about hydrologic systems within a metropolitan area. Through these steps we will identify which types of management regimes have the most impact on water quality and quantity, how management can be modified to reduce impacts, and what information is needed for policy decisions.

Management Decisions To incorporate our model into the decision making process, we will identify the legislative mandates and regulations, and the institutional histories that influence land use decisions. Through interviews with key individuals, we will determine what mandates and regulations are implemented, how they are implemented, and what are the potential benefits and impacts to the hydrologic systems. In addition, we will be able to determine what hydrological and ecological as well as other information is used in the process and what factors influence decisions.

Scale of decision Management decisions are made at different scales. These decisions will be used as categories based on scales of influence and cross-referenced to our hierarchical structure (Fig 2) thereby placing different management processes within the framework of our model. By placing existing management decision processes within the context of the model, we will be able to conduct "what if" scenarios by altering model parameters for projected or desired conditions, thus assessing the effect of the decision on the hydrologic system at different scales and providing insights into alternative decisions or mechanisms.

Developing a management tool In addition to the insights gained from the previous steps on how the model may be used for making management decision, we will work with small groups of potential users and conduct workshops to demonstrate the use of the model. We will solicit input from attendants on how the model needs to be modified to ease its usage and to create the necessary data out puts for policy decisions.

Results from Prior NSF Research

PI: Steward T.A. Pickett, Chris J. Peterson.
Award #: BSR 91-07243; Amount $131,000; Period of support:2/1/91-3-31/93
Title: "Tests of the equivalence of competitors and asymmetry of competition hypotheses in multispecies woody communities."

This project continued and extended work begun under BSR 89-06135 (PI: Pickett, D.R. Foster, G.G. Parker), "Catastrophic disturbance, patch dynamics and recovery of old growth forest" (1989-1990). This work documented the components of heterogeneity that persist from the undisturbed forest and the physical environment created by the catastrophic blowdown, and tested the interaction of advanced regeneration with invaders, new physical patch types, and herbivory by deer. Regeneration of certain species was limited in different patches by soil erosion (pits and mounds), grazing by deer, and physical environment. The presence of different kinds and amounts of debris and litter differentially limited various species. The changes in the size and quality of patch types affect the invasion, persistence and turnover of survivors and advanced regeneration. The work demonstrates the differences between regeneration in large, infrequent events that generate great heterogeneity, compared to the smaller and more frequent small gaps. Competitive equivalence was mitigated by origin and neighborhood of specific individuals. Dr. Chris J. Peterson was trained with this support.

Major publications resulting from this award:

Foster, D.R., P.K. Schoonmaker, and S.T.A. Pickett. 1990. Insights from paleoecology to community ecology. Trends Ecol. Evol. 5:119-122.
Peterson, C.J., W.P. Carson, B.C. McCarthy, and S.T.A. Pickett. 1990. Microsite variation and soil dynamics within newly created treefall pits and mounds. Oikos 58:39-46.
Peterson, C. J. and S. T. A. Pickett. 1990. Microsite and elevational influences on early forest regeneration after catastrophic windthrow. J. of Veg. Sci. 1:657-662.
Peterson, C.J. and S.T.A. Pickett. 1991. Treefall and resprouting following a catastrophic windthrow in an old growth hemlock-hardwoods forest. For. Ecol. Manage. 42:205-217.
Peterson, C.J. and S.T.A. Pickett. 1995. Evaluation of alternative models of forest regeneration: a case study in an old-growth forest catastrophic blowdown. Ecology 76:763-774.
Peterson, C.J. and S.T.A. Pickett. Tornado windthrow damage and initial revegetation of Cathedral Pines, an old-growth hemlock-white pine forest. Submitted to Oikos.
Peterson, C.J. and S.T.A. Pickett. Experimental patch dynamics: Patch type influences on components of regeneration in a catastrophic windthrow. Sumbitted to Ecology.

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 continues and analyzes the data from the Buell-Small Succession Study at the Hutcheson Memorial Forest Center. This long-term data set, begun in 1958, is the longest, continuous yearly record of oldfield vegetation change in North America. The award has permitted stabilizing plot marking, assembly of data from the 13,920 plot-years as a computerized data set on which spatial and temporal analyses are under way. Current findings are that the initial condition has persistent effects through the first decade of succession, and that novel patterns of spatial and temporal patchiness, based on life form and growth strategy determine community structure. The training of Dr. Randall W. Myster and Mr. James W. Baxter has resulted from this award.

Major publications resulting from this award:
Pickett, S.T.A. and J. Kolasa. 1989. Structure of theory in vegetation science. Vegetatio 83:7-15.
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. and M.J. McDonnell. 1989. Seed bank dynamics in temperate deciduous forest. pp 123-147 In *Ecology of Seed Banks*. R.L. Simpson, M.A. Leck and V.T. Parker, eds. Academic Press, Orlando.

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. 1990. Initial conditions, history and successional pathways in ten contrasting oldfields. Am. Midl. Nat. 124:231-238.

Facelli, J.M. and S.T.A. Pickett. 1991. The dynamics of litter. Bot. Rev. 57:1-32.

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Myster, R.W. and S.T.A. Pickett. 1992. Effects of palatability and dispersal mode on spatial patterns of trees in oldfields. Bull. Torrey Bot. Club 119:145-151.

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