CUMULATIVE IMPACT ASSESSMENT:

A Catalogue of Techniques to Assess Cumulative Impacts

by:

THE NEW JERSEY OFFICE OF STATE PLANNING

Herbert Simmens
Director

Thomas G. Dallessio
Project Manager

William S. Purdie
Principal Author

prepared under contract for:

THE PINELANDS COMMISSION

Terrence D. Moore
Executive Director

Larry L. Liggett
Project Manager

August 1993

Table of Contents

INTRODUCTION

This report catalogues the results of a search for cumulative impact assessment methods and applications. The New Jersey Pinelands Commission has an interest in the cumulative effects of land development within the Pinelands, and wished to research and catalogue techniques used to establish thresholds, processes, and evaluations of the impacts of large scale land uses.

The New Jersey Office of State Planning conducted a literature search for materials and related reports, and this paper reports the results of that search.

FINDINGS

DEFINING CUMULATIVE IMPACTS

There is apparently no universally-accepted definition of cumulative impacts. The most widely used is contained in the Council on Environmental Quality regulations for implementing the National Environmental Policy Act of 1969 (NEPA). Impacts come in a variety of forms, but most are included in one of the following categories: direct; additive; cross-media; synergistic; cross-boundary; and catalytic. As might be expected, there is often confusion over the use of terms, definitions and concepts. The Virginia Council on the Environment's Coastal Resource Management Program's Management of Cumulative Impacts in Virginia: Identifying the Issues and Assessing the Opportunities notes that in considering these various definitions, it becomes evident that for practical purposes, cumulative impacts management quickly merges with comprehensive environmental management.

THRESHOLDS OF CUMULATIVE IMPACT ASSESSMENT

A key attribute characterizing cumulative impacts is the concept of the threshold, or the point at which further use or activity will cause degradation. Determining thresholds of natural ecosystems is in its infancy, and attempts to set numerical threshold limits for regulatory purposes usually triggers scientific debate.

PROJECT SCALE

The scale at which cumulative impacts can be assessed is covered in several documents. Project scales range from 10,000-acre phased, major land use projects, forestry, mining and agricultural activities, to relatively small areas, like

several acres of wetlands. This report assumes that the Pinelands Commission would be interested in looking at the impacts of large land use projects on the natural environment, and, at a much smaller scale, examples of the cumulative impacts of human activities on a wetland or hardwood swamp area.

CUMULATIVE IMPACT ASSESSMENT METHODS

Since the National Enviromental Policy Act mandate to consider cumulative impacts, many methods and models have been developed. Like the confusion surrounding the definitions and types of cumulative impacts, there is a similar problem with evaluation methods. One report concludes that methods fall generally into four distinct categories. Another report categorizes methods into six types. It is clear that there is no one conceptual approach or even a set of general principles that are accepted by all scientists and managers. Some guidance is found however, in one report that sees methodology choice as dependant on key considerations, like the use of the assessment, resources available to conduct the assessment, administrative constraints, and issue significance.

PROCESSES

If an assessment is to have an effect on cumulative impacts, it must influence the decision to move forward with a proposed project or the implementation of the project. The literature provides numerous resources on process, including a source that assists planners and managers in selecting appropriate techniques to determine cumulative impacts, and, just as importantly, factors them into the decision-making process. There is also guidance on how to evaluate organizational and legal capacity to address impacts. Other sources provided information on adopting planning approaches to minimizing cumulative impacts, advocating comprehensive planning. Planning initiatives based on natural resource boundaries and performance-based planning are also discussed.

Research also turned up a discussion of management approaches in other states, with a look at permitting schemes as a way of minimizing impacts. The section concludes with a look at organizational structures that may have a bearing on management of cumulative impacts.

CONCLUSION

Many reports and documents on cumulative impacts are available. The Pinelands Commission should determine the scale at which it wants to examine cumulative impacts and decide upon a desired scale and approach. At that point, there are documents that can provide further guidance in employing an appropriate model and methodology.

Planning and management approaches to cumulative impacts, as compared to scientific methodologies are also found in the literature. The Virginia Council on the Environment's Coastal Resource Management Program's Management of Cumulative Impacts in Virginia: Identifying the Issues and Assessing the Opportunities should be reviewed for its look at methods to incorporate impact management into government review processes, and for its look at permitting and organizational ways that might manage cumulative impacts more efficiently.

CUMULATIVE
IMPACT
ASSESSMENT

INTRODUCTION

The Office of State Planning entered into a contract with the Pinelands Commission to produce a report on cumulative impact assessment techniques. The Pinelands Commission's interest in cumulative impacts has been prompted by concerns over the effects of large-scale development within Regional Growth Areas of the Pinelands Management Area, and the need to measure the impacts of all development that is theoretically possible under the Pinelands Comprehensive Management Plan.

Under the direction of Herbert Simmens, this report was authored by William Purdie. The project was managed by Thomas Dallessio. Technical assistance was provided by William Bauer, Carol Cavallo, Diane Chepega, Jill Edwards, Sandy Giambrone, Elizabeth Guididas, Denise Johnson, Steve Karp, Robert Kull, Wendy Monk, Charles Newcomb, James Reilly, Teri Schick, and Carol Schulz. For the Pinelands Commission staff, Larry Liggett was the project manager.

The objective was to research and catalogue techniques used to establish thresholds, processes, and evaluations of the off-site impacts (secondary, indirect, etc.) of large scale land uses. Of key interest to the Commission are land use demand, water resource demand, and ground and surface water quality impacts.

In preparing for the study, the New Jersey Office of State Planning staff conducted a literature search for materials related to techniques for assessing impacts of land development and their applicability to the Pinelands, and examined work already completed or compiled by other state agencies. The New Jersey Department of Environmental Protection and Energy provided a list of agency contacts and the names of several published reports on cumulative impact assessments. Many of these publications provided additional references and citations relating to other relevant cumulative impact journal articles and studies.

The Marine Law Institute provided an unpublished document that proved very useful in the literature search. "Methodology and Mechanisms For Management of Cumulative Coastal Environmental Impacts, Selected Preliminary Bibliography" listed references to general background literature, general cumulative impact literature, methodologies, federal legal authority, and state legal authority. Selected journal articles and materials referenced in the publication were borrowed from the New Jersey State Library. Other books and journal articles were obtained through inter-library loan. Stockton State College Library and the New Jersey State Library electronic catalogs enabled staff to gather lists of possible articles for examination and inclusion. Reports related to the topic of cumulative impacts and the materials reviewed are listed in the bibliography.

It is important to distinguish between the cumulative impact assessment and the cumulative impact evaluation as an analytic task, and cumulative impacts management. There are also approaches that consider impacts before a development is approved, or activity occurs (i.e., a predictive method), or after the development or activity has occurred (post hoc assessment). The majority of the literature deals with the technical aspects of cumulative impact assessments, and case-by-case, or incremental approaches to determining impacts. Much of the literature involves approaches and techniques for evaluating the cumulative impacts of various human activities. However, cumulative impacts management entails more than assessing or evaluating, and includes policies, programs and strategies to control them.

Clearly, there are many ideas and concepts about cumulative impacts, but for the purposes of this study, the more comprehensive, predictive methods are most useful. However, references to a wide range of cumulative impact assessment methodologies and literature are included in the bibliography, including planning and management approaches.

There is no set of universal terms used to describe cumulative impacts, which leads to confusion over terms and concepts. The section on definitions of cumulative impacts includes six general types. In researching the literature, impacts of all types were obtained. For further use, the Pinelands Commission will need to further define the types of impacts to be studied.

FINDINGS

DEFINING CUMULATIVE IMPACTS

The National Environmental Policy Act of 1969 (NEPA) is often cited as the starting point for analysis of cumulative impacts. Under NEPA, federal agencies were urged to consider the environmental consequences of their actions. The major provisions of this legislation included the requirement for federal agencies to prepare Environmental Impact Statements (EIS). It also created the Council on Environmental Quality (CEQ), which has the responsibility for developing national environmental policies, reviewing consequences of proposed federal programs, and promulgating the guidelines for the preparation of Environmental Impact Statements. Before federal agencies were required to comply with NEPA regulations, general definitions in the Act served as environmental guidelines for federal agencies.

NEPA defined cumulative impacts as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time." (Sec. 1508.7).

This broad definition can be further defined in terms of six general types of cumulative effects:

Direct
Additive
Cross-media or Multi-media
Cross Boundary Impacts
Synergistic/Interactive
Catalytic, Indirect, or Secondary.

Taken together, these terms define most cumulative impacts. Cumulative impacts, however, are not necessarily confined to one category. For example, one housing unit in the New Jersey Pinelands will exhibit direct effects and may also, along with neighboring developments lend itself to environmental concerns over additive effects. The goal should be to take a comprehensive view of environmental management when considering cumulative effects.

Direct cumulative impacts describes growth-related effects which can be directly attributed to one event. Examples include the amount of land consumed by the construction of a single house, an airport, hotel, or large industrial complex. Each of these uses will have an individual direct effect on changes such

as jobs in construction, the tax base, land consumption, wildlife habitat, and the existing sewer system. While individually, some of these uses may not have significant direct effects, they may cause or contribute to additive direct cumulative impacts. Some direct effects are caused by past actions such as the storage and leakage associated with petroleum tanks. As petroleum does not break down, leaking tanks can cause environmental contamination for many years.

Additive cumulative impacts describe the changes associated with several individual projects that may not have significant direct effects. This type of impact has been described as "the nibbling effect" because of the repetitive nature of the action. The NEPA describes additive cumulative impacts as "individually minor but collectively significant actions taking place over time." One house, for example, in a forested area may not effect the wildlife habitat or significantly effect roads or school capacity. Fifty or one hundred proposed dwelling units located in the same forested area could have significant additive cumulative impacts on the same wildlife, road, water, and school systems. This type of cumulative impact has been described as the "gradual and incremental degradation of a resource, such as a waterbody or wildlife habitat resulting from a series of small actions."

Cross-media or Multi-media Impacts are cumulative impacts which have effects on more than one medium. The measurement of the total cumulative impact of a facility which is proposed to have, or currently has cross-media or multi-media effects, is the total impact from the facility on water, land and air. Cross-media describes a special type of multi-media cumulative impact. This type of impact describes pollutants which transfer from one medium to another. Automobile pollution is a typical example of this effect. The leakage and runoff of petroleum products contaminates both soil and water.

Cross Boundary Impacts describe cumulative impacts that affect more than one jurisdiction. For example, environmental degradation in the form of water or air pollution may cross municipal, county, state, or even national boundaries. The Canadian acid rain experience is an example of a cross-jurisdictional/cross-boundary effect. Because this type of impact covers several jurisdictions, it is difficult for governments to consider and understand the potential effects. One jurisdiction may not be aware of potential cross boundary impacts that could occur because the source is located in an adjacent jurisdiction.

Synergistic/Interactive effects describe cumulative impacts that occur as a result of two or more degrading actions. Individually, these actions may have a modest or insignificant effect, but when combined have a significant impact. In this way, the effect produced by the interaction is greater than the individual effects of each action.

Synergistic cumulative impacts are often associated with chemical contaminants reacting together to produce significant changes. Photochemical smog is an example of this cumulative impact. Pollutants such as nitrogen oxide and ozone can interact in the presence of sunlight to cause a synergistic effect. The Maine State Planning Office states that most environmental impacts involve some form of interactive cumulative impact. They observe that as wetlands are reduced, other elements of the ecosystem are also changed as a result. The Maine State Planning Office also points out that these types of synergistic effects are also "difficult or expensive to document and to manage."

Catalytic, indirect, or secondary effects are cumulative effects that are brought about or stimulated as a result of development. These terms are interchangeable. Catalytic refers to a project provoking or inducing additional impacts that are not directly generated. For example, if an airport is built, the freeway constructed to serve it is a direct effect. If in later years, other roads are constructed to the freeway and residential development occurs, this is said to be a indirect effect. Certain classic examples of land use projects will have reasonable foreseeable indirect effects. These types of land uses include significant development projects, shopping malls, and highways. These uses may induce secondary impacts such as increased development, traffic congestion, urban sprawl, and increased air pollution.

In a comprehensive work on cumulative impacts produced largely by development by Dames and Moore, Methodology for the Analysis of Cumulative Impacts of Corps Permit Activities, prepared for the U.S. Army Corps of Engineers, 1988, there is discussion of Army Corps permit actions that are potentially growth-inducing (page 4-14 - 4-24). While the report is focused on Army Corps permits, it offers a good examination of cumulative impacts induced by development, and includes Appendices that discuss regional and economic growth, infrastructure and land use, transportation and land use, and economic, spatial and population forecasting techniques. Regarding secondary impacts, the report states that the "permit processor must take into consideration how much growth is likely to be induced; the rate at which growth will occur; and the significance of this growth in the context in which it will occur--that is, the nature of the affected community or region. The same amount of growth may be either extremely significant, if it will transform a pristine environment into a commercialized area, or a small close-knit community into a boom town; or it may appear to be insignificant against a background of strong, ongoing regional growth.

The long-range outlook for growth of a region is also important in assessing the potential cumulative impacts of a general permit (development), because it will very likely influence the number of actions that may occur under the permit without further evaluation or before a reassessment is scheduled.

The nature of the growth occurring in a region is also important in forecasting cumulative impacts--whether it is predominantly industrial, commercial or residential, and whether it is "fill-in growth" or represents a long-range spatial extension of communities to encompass previously undeveloped areas. The cumulative impacts of induced growth that is commensurate with and compatible with a region's established, "natural" growth pattern will be less than the cumulative impacts of induced growth--that is radically different in nature from the established, but expanding economic base. "Exogenous" growth (that which is induced from outside the existing economic base) will be more likely to draw in a new labor force (resulting in rapid population growth), to impose additional categories of environmental stress (new pollutants), and to occur in nondeveloped areas. It is also more likely to change the character of communities by affecting existing institutions, social behavior, visual patterns, and demographic patterns.

Induced growth which represents mere expansion of dominant existing economic activities, i.e. "endogenous" growth, is usually less disruptive of lifestyle and less controversial to the inhabitants of the region. It also tends to be less environmentally stressful since it represents a change in degree rather than kind of impact.

The report also includes tables of land uses that list what their predominant impacts will be, and whether the use is growth inducing or growth accommodating. (See Pages 4-11 - 4-23).

THRESHOLDS OF CUMULATIVE IMPACTS

Before discussing the literature found on thresholds, it is important to note the conclusion reached in the Virginia Council on the Environment's Coastal Resource Management Program Report:

> There is little doubt that a major difficulty in taking a more aggressive cumulative impact approach is that the science to support it may not be fully developed. The scientific impediments are several and clearly relate to numerous other impediments mentioned here. First, many of the more significant environmental impacts of concern may be indirect, and, as a result, causal pathways are poorly understood. While we may be able to say with great certainty that uncontrolled urban development will have negative, perhaps even fatal effects on shellfish resources, it may be difficult to discern the actual impact of a single project or a single acre of development. Moreover, it may be especially difficult to determine ecological and biological thresholds; that is, amounts of degradation that will cause certain fundamental

changes in the functioning or productivity of the natural system. At what point can it be justified that enough is enough? (Page 13-14).

According to Dickert and Tuttle (Cumulative Impact Assessment in Environmental Planning, 1985), a key attribute characterizing cumulative impacts is the concept of the threshold. Although the effect of an individual project is negligible, or can be made negligible through mitigation, it is when the combined effects of several projects exceed a threshold that significant environmental damage may become evident. A carrying capacity approach identifies system threshold levels before they are reached. The capacity determination is relatively easy when dealing with systems such as water supply, wastewater or road capacity.

In contrast, techniques for determining the thresholds of natural ecosystems are in their infancy. The measurement of natural threshold levels is made difficult by the masking effects of interactions between biotic and abiotic factors, compensatory responses, natural variances, and problems of field measurement. Although natural factors have been analyzed as part of many regional planning studies e.g. Nassau-Suffolk Regional Planning Board 1976; Tahoe Regional Planning Agency 1982, other factors have been found to be more limiting. For example, in the well-known Sanibel Island (Florida) environmental study, the evacuation potential of the causeway bridge was the overriding limiting factor of development, even though a complete analysis of natural systems was conducted.

Attempts to set numerical threshold limits for regulatory purposes usually triggers intense scientific debate. It is difficult enough for scientists to agree on ambient exposure levels for materials demonstrated to be toxic laboratory. Even more difficult is the establishment of acceptable limits for naturally-occurring materials.

SCOPE AND SCALE OF PROJECTS

The literature search included some sources that contemplated the impacts of large-scale projects such as:

Canals: In Defense of Rivers: A Citizens Workbook on Impacts of Dam and Canal Projects;

Mining, coal mining and other energy development: Procedures for Assessment of Cumulative Impacts of Surface Mining;

Beltways: The Land Use and Urban Development Impacts of Beltways
Transportation and Wastewater projects: Secondary Impacts of

Transportation and Wastewater Investments: Review and Bibliography;

Hydropower Facilities: Cumulative Impacts of Hydropower under NEPA;

The hypothetical gradual development of an ocean/bay area undergoing rapid recreational and commercial development: An Evaluation Paradigm for Cumulative Impact Analysis;

Major Land Use Projects: Methodology for the Analysis of Cumulative Impacts of Corps Permit Activities; An Evaluation Paradigm for Cumulative Impact Analysis; Growth Effects of Major Land Use Projects: Vol. 3 - Summary.

Below is a summary of the material found to be most relevant to project scope and scale.

From the Maine State Planning Office:

> Defining a scope of review to provide for adequate assessment is one of the major challenges in addressing cumulative impacts. Cumulative impact assessment goes beyond traditional environmental review of individual projects to include both temporal and spatial considerations. Moreover, cumulative impacts can encompass a variety of direct, indirect, synergistic or growth-inducing effects. Designing precise guidelines to cover all possible situations is difficult and leads to reliance on standards of "reasonableness and practicality." However, statutory language can provide guidance by requiring consideration of the temporal scope of review by explicitly mandating consideration of "past, present, and reasonably foreseeable projects," similar to NEPA's requirement. By using "reasonably foreseeable future projects," a broader scope of review is ensured than the more narrow requirement of "existing and proposed," which may overlook important developments not yet at the level of a proposed project. Spatial reviews are best guided by ecological considerations, such as watershed boundaries, but are often delineated by the phrase "in the area". To ensure that all relevant factors are considered in assessments, and to stress their importance, indirect or growth-inducing effects may be addressed separately, as in New York State's EIS and California CEQA requirements.
>
> Related to defining review boundaries, is forecasting the potential for cumulative effects. Ecological thresholds of tolerance, beyond which degradation should not be permitted, can provide guidance for the

> management of future impacts. However, given the current status of scientific knowledge and the complexity of ecological systems, identifying absolute thresholds is not possible. (Maine State Planning Office, The Cumulative Impacts of Development in Southern Maine, 1988, pg. 107)

In Vermont, under Act 250 (Environmental Control Law, 1969 Vt. Acts 250), "significant" developments must demonstrate by means of impact statements, that they meet the specific performance criteria embodying the "environment and integrity of Vermont towns". The Act defines significant development to include the construction of improvements for commercial or industrial purposes on tracts of land involving ten or more acres, or more than one acre in municipalities that have not adopted permanent zoning and subdivision laws, and includes the construction of housing projects with ten or more units. A subdivision is defined as a tract or tracts of land that have been partitioned for resale into ten or more lots. ("Development Impact Assessment Handbook and Model," Rutgers University, Urban Land Institute, 1991; Statewide Growth Management Programs in other States, Technical Reference Document, SDRP, 1987.)

Through the Florida Land and Water Management Act, the State of Florida evaluates Developments of Regional Impact to determine impacts on the environment, public transportation, economy and the municipality (Florida Statute 380, 1985). A Development of Regional Impact is defined as any development which, because of its character, magnitude, or location, would have a substantial effect upon the health, safety, or welfare of citizens of more than one county. Described as a decision-making tool that ensures the inclusion of state, regional and local concerns in significant decisions, the evaluation deals with 12 large-scale land uses. Development types reviewed include:

Airports;
Attractions and Recreation Facilities;
Electrical Generating Facilities and Transmission Lines;
Hospitals;
Industrial Plants and Industrial Parks;
Mining Operations;
Office Parks;
Petroleum Storage Facilities;
Port Facilities;
Residential Developments;
Schools;
Shopping Centers.

However, not all projects in these categories are required to be reviewed. State guidelines provide threshold and location criteria which further define projects presumed to be of regional impact (Florida Statute 380.0651).

Florida's Environmental Land and Water Management Act (Florida Statute 380, 1985) also mandates impact assessments for projects located in "areas of critical state concern." The process focuses on:

> Areas containing or having a significant impact on environmental, historic or archeological resources of regional or statewide importance;
>
> Areas significantly affected or having significant impact on existing or proposed major public facilities, or other areas of major public investment;
>
> Proposed areas of major development potential, such as new communities.

(Environmental Assessment: Approaching Maturity. Bendix and Graham, 1978.)

According to the unpublished "Development Impact Assessment: Handbook and Model," Rutgers University and the Urban Land Institute, 1991, development impact assessment is more common than the previously mentioned procedures for "significant developments" or "developments of regional impact" or cumulative impacts. For example, a traffic analysis is required in Westport, Connecticut for any project with at least 40 parking spaces or 20,000 square feet of gross floor area. Other examples are:

- Virginia Beach: some developments reviewed for traffic, fiscal and environmental impacts.
- Lawrence Township, New Jersey: Community Impact Statement must be prepared for subdivisions of 10 or more lots.

One of the more relevant reports is the USEPA study Growth Effects of Major Land Use Projects: Vols. 1 - 3. This document reports the results of a study of the Growth Effects of Major Land Use Projects (GEMLUP). While the principal objectives of the GEMLUP study were to formulate a methodology to predict air pollutant emissions, it does predict impacts from:

- two types of major land use developments (large concentrations of employment such as office or industrial parks, and large residential developments);
- land development that is induced by the two types of major land use development projects; and

- o motor vehicle traffic associated with both the major project and induced development.

The first phase of this study developed the following hypothesis of induced land use development:

Constructing a large source of employment like an industrial/office complex generates jobs which result in the nearby construction of dwelling units; these induce retail development to locate near them and generate demand for community, cultural and religious facilities (schools, recreation areas, libraries, churches, theaters, fire and police stations, etc.). All of this requires the construction of streets and highways that then improve accessibility to the area. Better access fosters continued urban development, particularly highway-oriented commercial and office land uses. Additional sources of employment come into the area as secondary (and tertiary) industry or services and locate near the original major project, spurring on another round of residential development, and so forth.

This model was specified in two separate forms to represent induced land use growth associated with large residential development, and large industrial or office parks in the following 12 land use categories:

residential	hotels/motels
commercial	hospitals
office	cultural
manufacturing	churches
highways	education
wholesale/warehouse	recreation

The models predict the land use in a 10,000 acre area of influence ten years after the construction of the Major Project. Concurrently, forty case studies were selected, based on various criteria relating to geographical location, project size and phasing, and data base availability.

As discussed previously in Defining Cumulative Impacts, the Dames and Moore report offers a good discussion of regional growth and growth patterns and demands, and the effects of transportation and infrastructure on a region.

In the report Water Quality Impacts of Land-Disturbing Activities, U.S.E.P.A., Evaluation and Development of Institutional Systems for Environmental Management, 1976, the effects of agriculture, forestry, construction, mining, recreation, stream modification, urbanization, military use and transportation on non-point source water pollution are identified, as are management techniques and recommendations.

The evaluation assumes that water quality is degraded by land-disturbing activities, and that management techniques exist, and are described in the literature. Of interest to the Pinelands Commission is the discussion of disturbances caused by agriculture (in particular, irrigated farming), forestry, construction (of roads and buildings), and mining (including sand and gravel extraction). Recommendations are included and appear on pages 71-78.

Transportation and wastewater investments are examined for secondary impacts in Secondary Impacts of Transportation and Wastewater Investments: Review and Bibliography (U.S.E.P.A.). Land use changes are derivative to economic and demographic impacts, both of which imply some conversion in the use of land. Almost every economic or demographic change of consequence involves some land use change as well. Transportation and wastewater investments affect people and businesses primarily by influencing their location decisions. Changes in locational decisions are reflected, in turn, by altered land use patterns. Changes in the amount of residential, commercial, industrial, agricultural, and vacant land are general measures of land use impacts.

Secondary impacts can be evaluated at a variety of scales, according to the report. Effects on land use, however, are usually considered in terms of relatively small areas. The review of literature is organized according to type of investment (highways, mass transit, wastewater) and where possible, according to type of secondary effect (economic, social, land use).

The influence of interceptor sewers on development in Fairfax County, Virginia is described in the report Suburban Growth: A Case Study (Stansbury, 1972). A major sewer interceptor into undeveloped portions of the study area was rapidly followed by sprawl type residential development. The study suggests that the particular complex set of local conditions (growth pressure, soil characteristics, zoning practices, wastewater policies) combined to make interceptor sewers the primary determinant of location and intensity of development. New development created intense pressure on public services and increased tax burdens. The study attributes these effects to poor land use planning and control, the "subsidy" that public sewers provided to developers, and the desire for increased hook-up revenues on the part of the local sewer authorities.

A discussion of identifying project boundary and scope is found in Making Decisions on Cumulative Environmental Impacts: A Conceptual Framework, (Irwin and Rhodes, 1992). The document is designed to assist program managers identify types of cumulative impact problems, understand how to select appropriate techniques for assessing cumulative effects, and evaluate organizational and legal capacity to address cumulative effects. It is premised on the mismatch between the scales at which environmental impacts occur and the

scale at which decisions are made, which presents a significant obstacle to effective management. A conceptual framework is developed to match the scope and boundary of decisions and cumulative impacts.

CUMULATIVE IMPACT ASSESSMENT MODELS

Many cumulative impact methods have been developed since the NEPA mandate, including checklists of characteristics or processes; matrices of interactions between disturbance activities and environmental conditions; nodal networks or pathways that depict probable effects of disturbances; and dynamic system models. While the literature acknowledges that cumulative impacts must be evaluated, there is no single conceptual approach, nor are there even several general principles accepted by all scientists and managers.

In the article, "General Concepts for Measuring Cumulative Impacts on Wetlands Ecosystems," (Risser, 1988) the author states that it is currently possible to develop a set of systematic approaches for detecting and quantifying cumulative impacts. He notes that the Commission on Life Sciences of the U.S. National Academy of Sciences (1986) examined the status of ecological knowledge with respect to solving environmental problems. Its approach was to evaluate a number of case studies and draw general conclusions. The report identified numerous recommendations for applying lessons learned about ecosystem behavior to solving environmental problems. While the recommendations clearly recognized the need for additional research, there were no specific recommendations about conceptual frameworks for addressing cumulative impacts.

Risser believes that further research on ecosystem behavior may eventually result in the development of a comprehensive approach. He reviews environmental impact analytical techniques and the growing understanding of ecosystem processes, and contends that general principles can predict the direction and possible magnitude of ecosystem responses. He offers a Cumulative Impacts Matrix as an interim approach and describes it as a "magnifying glass" to focus the reviewer on all possible forms of additive, synergistic and indirect impacts over time and space. Existing methods would be used to identify potential impacts, then each impact would be examined with the matrix, utilizing the most recent scientific information (page 507).

A study prepared for the US Army Corps of Engineers, An Evaluation Paradigm for Cumulative Impact Analysis (1988), asserts:

> There have been several extensive reviews of evaluation methods for assessing wetland values (US Water Resources Council 1981), cumulative impacts (US Army Institute for Water Resources 1981,

> Horak and others 1983), and environmental impact analyses (Hollick 1981, Nichols and Hyman 1982, Hobbs 1985).... None of the reviews explain the wide disparity among models, nor do they form a basis for choosing one evaluation system or one model over another. As a result, different approaches are treated as equally valid, even though the procedures and models reflect substantially different theoretical premises and evaluation philosophies (page 38).

The study further states that:

> Each method has its strengths and drawbacks. None is ideal, nor is a comprehensive, rational analytical system likely to be available in the near future, given the numerous gaps in our knowledge of ecosystem theory, economic forecasts, and environmental trends (page 39).

The Army Corps study concludes that existing methods or approaches that may potentially fulfill the conditions set for cumulative impact assessment fall into four distinct categories:

1. Valuation Methods and Models: subjective numerical measurement criteria and guidelines for direct evaluation of effects and impacts.

2. Linked Deterministic and Simulation Models: methods that link deterministic, analytically based models with more subjective simulation models and attempt to contrast desired goals with actual outcomes.

3. Unified, Holistic Theoretical Approaches: reflecting a single evaluation perspective such as econometrics or resource economics.

4. Land Use Designation Approaches: prescribed land use approaches that directly translate management objectives into environmental use constraints (pages 42-45).

Elaborating on Land Use Designation Approaches, the study says:

> These approaches rely on a predetermined designation of resource-compatible uses. They reflect a regulatory or land use zoning approach based largely on a direct translation of public values and environmental objectives into land use restrictions. Simply stated, various natural areas are classified as development compatible, as conservation zones, where only certain activities are compatible with the existing altered environment, or as preservation areas where only a few recreation and resource-extraction activities are allowed, with the idea that such restrictions are desired by the public. The Corps

> made a number of such wetlands designations in the 1970's in Oregon, and has since returned to the concept, along with the EPA, under the term Special Area Management Plans (SAMPS). The idea behind this simple approach is that local citizens must choose their destiny consistent with environmental protection objectives (page 44).

The study asserts that the ideal model must assess the interactions and feedback mechanisms between growth and environmental consequences, and offers another model, which the author calls the Heuristic Model. The Heuristic Model abstracts and idealizes goals, physical constraints, decision objectives and interactions between human activities and the environment. It allows one to directly assess cumulative environmental effects and appraise their impacts on the human environment. The method is demonstrated on a hypothetical ocean-bay area that is undergoing rapid recreational and commercial development (pages 45-62).

The study concludes that cumulative impact analysis "should not be confined solely to the ecological impacts of human activities. Nor can the cumulative consequences of a single action or project be isolated from the social, economic and environmental goals that compromise the attainment of a desired state of the human environment. Cumulative impact analysis is viewed as the requisite evaluation framework for its correlate, comprehensive planning." (page 62).

It should be noted that a goal-setting and comprehensive planning approach are advocated Planning Approaches section of the report.

In a 1984 article, A Comprehensive Review of Current Environmental Impact Assessment Methods and Techniques (Shopley and Fuggle), the authors survey methods and techniques for environmental impacts analysis including: ad hoc approaches, checklists, matrices, presentational, mathematical, networks, cartographic techniques, modeling procedures, evaluation techniques and adaptive methods. The conclusion is that most techniques are unable to address secondary impacts; however, mathematical matrices, some networks, and modeling procedures have the potential to identify and quantify secondary impacts. The fact they point out is that in the United States environmental impact analysis is usually used for post-design appraisal separate from planning and development of a project. The article concludes that inadequate attention has been given to techniques for evaluating secondary impacts.

Another work, Environmental Impact Analysis, A New Dimension in Decision-Making (Jain, Urban, Stacey 1981), provides a discussion of impact assessment methodologies by different general types, and provides illustrative examples and reviews of available methodologies in each category. Choice of

methodology is dependent on the following key considerations: Use of Assessment; Alternatives to Project; Public Involvement; Resources (to conduct assessment); Familiarity (with project); Issue Significance; and Administrative Constraints.

Various methodologies are divided into six types, based on the way impacts are identified. The book provides detailed reviews of examples of each methodology type.

> Ad Hoc: These provide minimal guidance for impact assessment, and suggest broad areas of possible impacts rather than defining specific parameters.
>
> Overlays: These rely upon a set of maps of a projects area's environmental characteristics. A composite characterization of the regional environment is made. Impacts are identified by noting the impacted characteristics within the project boundaries.
>
> Checklists: These present a specific list of environmental parameters to be investigated for possible impacts. They do not require establishing direct cause-and-effect links to project activities.
>
> Matrices: These incorporate a list of project activities with a checklist of potentially impacted characteristics. The two lists are related in a matrix which identifies cause-and-effect relationships between activities and impacts.
>
> Networks: These methodologies work from a list of project activities to establish cause-condition-effect relationships, and attempt to recognize that a series of impacts may be triggered by a project.
>
> Combination Computer-Aided: Use a combination of matrices, networks, analytical models and a computer-aided systematic approach to a) identify activities associated with implementation of federal programs; b) identify potential impacts at different user levels; c) provide guidance for abatement and mitigation techniques; d) provide analytical models to establish cause-and-effect relationships to quantitatively determine potential impacts; e) provide a methodology and a procedure to use this comprehensive information.

The report Ecosystem Impacts of Urbanization Assessment Methodology (Office of Research and Development, U.S.E.P.A., 1977), provides a review of existing ecosystem models and the impacts of urbanization on natural ecosystems. It states that it has long been recognized that infrastructure

development such as highways and wastewater treatment facilities affect the rate of urbanization. The placement of trunk sewers and highways affects the pattern of development and the capacity of these systems affects the rate of development in urban areas. The Institute of Ecology was asked to review the International Biological Program's biome models to determine their usefulness in predicting ecological effects associated with urbanization, and to the extent possible, to develop simplified models to make such predictions.

The results of the work showed that at this point there is no model, no matter how sophisticated, that can be used to predict the ecosystem effects of urbanization. There are, however, models which are useful in predicting specific effects from specific perturbations. The report attempts to prepare and document a methodology that integrates the models of the ecologist into the decision-making process. It provides a review of various modeling efforts that can become a nucleus for additional effort. Some of the literature describing impacts on ecosystems is reviewed and an expansion of the proposed methodology is detailed. Several case studies (Adirondacks, Texas Woodlands) are presented to suggest ways the methodology and the report may be used.

The report advocates the Cumulative Impact Matrix method, which recommends the use of several existing methods, and recognizes complex ecosystem interactions and processes. It permits the use of existing methods, whether they be models, nodal pathways, interaction matrices, or checklists.

In the "Development Impact Assessment: Handbook and Model," prepared jointly by Rutgers University and the Urban Land Institute, a development impact analysis is described as the process of estimating and conveying the effects of residential and non-residential construction. The effects take numerous forms: physical, market, environmental, fiscal, economic, traffic and social. It may be either prospective or retrospective, short-term or long-term (page 2). The paper offers a development impact model which consists of a series of input data and output information. The inputs are based on readily available data as well as incorporated model factors. The outputs comprise a series of linked findings across numerous dimensions in impact assessments. The outputs include the following:

> Legal and administrative considerations; Physical and site analysis; Market analysis; Social impact analysis; Environmental impact analysis; Economic impact analysis; Fiscal impact analysis; Traffic impact analysis; Shared infrastructure costs (capital needs).

Land Development and the Natural Environment, (The Urban Institute, 1976), provides information on key issues in evaluating development impacts, and the relative merits of methodologies, and offers the following general appraisal of existing techniques for estimating impacts in several environmental categories:

Water Quality and Quantity: The estimation of impacts frequently requires the use of more than one technique or model. Water pollution impacts can be estimated fairly accurately for a very few pollutants and under limited conditions. Value estimations for the preferred measure require the use of complex models, and judgements of the implications for water use. Some produce relatively accurate results, all are expensive to reproduce. Water quality assessments are made with pollution techniques.

Wildlife and Vegetation: Although accurate baseline documentation of existing conditions is possible, techniques for producing quantitative estimates of impacts are not available. Instead, informal judgements of experts familiar with the local environment are usually necessary.

Detailed analyses of these methods, including advantages and disadvantages are included in the book.

In the article Defining and Analyzing Cumulative Environmental Impacts (Contant and Wiggins, 1981), the authors suggest an approach for analyzing the cumulative impacts of an individual project that will produce a more comprehensive assessment than existing methods. It involves considering the cumulative impacts of a development in two contexts: the relationship to other development activities, and effects upon multiple natural systems. It offers a new comprehensive analysis approach which stresses the importance of monitoring environmental conditions and past development activities, and modeling development patterns and natural system responses.

In another journal article, the authors (Contant and Ortolano, 1985) describe a cumulative impact assessment approach, based in part on a carrying capacity analysis, which was implemented on a trial basis by the Army Corps of Engineers for projects in the Oakland Estuary. The study design describes a systematic evaluation for cumulative impact assessments which was tested and applied in a typical regulatory context. The article, Evaluating a Cumulative Impact Assessment Approach attempts to evaluate the effectiveness of the approach, but lack of permit applications left them unable to fully evaluate it.

Impact Standards and Measurements

As was discussed before, cumulative impact assessment suffers from a lack of scientifically-grounded standards. This is not just a practical difficulty, it is also a legal difficulty, as it makes it difficult to defend standards. Nonetheless, the search yielded several sources of published standards for measuring impacts. Elsewhere in the literature, it was frequently noted that no generally accepted set

of standards can be applied to all developments equally. It is very difficult to find a consensus on what standard should be used, as values are often arbitrary and unjustifiable.

In Methodology for the Analysis of Cumulative Impacts of Corps Permit Activities (Dames and Moore, 1988), Appendix B provides a source list of criteria for estimating effects. "Supplemental Information for Estimating the Significance of Biological Effects" includes the following parameters: Water quality; Organism responses to general water quality changes; Suspended solids and turbidity; Organism abundance and diversity; Habitat loss; Species of special status; Special land use.

Canter, Atkinson, and Leistritz (1984) in their book Impact of Growth: A Guide for Socio-Economic Impact Assessment and Planning (1985) offer a number of measures for estimating impacts, particularly in the area of urban growth, including public service impacts, standards for school facilities, health care and social services, and police and fire facilities and standards.

The Urban Land Institute was cited in some texts as a source for impact standards. The ULI regularly publishes urban and community development standards and guidelines. One text, Management and Control of Growth Vol. II, Land Development: Measuring the Impacts, highlighted measures for evaluating impacts in the following areas: Local economy; Natural environment; Aesthetics and cultural values; Public and private services; Housing and social conditions.

Measures for evaluating land development impacts are included in Measuring the Impacts of Land Development: An Initial Approach (Schaenman, Muller, 1974). Grouped under five broad headings (Local Economy; Natural Environment; Aesthetics and Cultural Values; Public and Private Services; and Local Transportation), numerous impact areas are given a measure by which the impact can be assessed.

Environmental Impact Analysis: A New Dimension in Decision Making (Jain et al, 1981) includes a lengthy appendix that again lists broad categories like air, water, land, ecology, sound, economics, etc., and then lists what are called "attributes" for measuring impacts on each category. For example, under Water, attributes listed include: Aquifer safe yield; Suspended solids; Dissolved solids; Flow variations; Nutrients; Biochemical oxygen demand; Aquatic life.

The land category includes: Erosion; Natural hazards; and Land use patterns.

Each attribute is then detailed in discussions under the following headings: Definition of the Attribute; Activities that Affect the Attribute; Source of Effects; Variables to be Measured; How Variables are Measured; Data Sources; Skills

Required; Instruments; Evaluation and Interpretation of Data; Geographical and Temporal Limitations; Mitigation of Impact; Secondary Effects.

A final source on development impact standards is the "Development Impact Assessment: Handbook and Model," prepared jointly by Rutgers University and the Urban Land Institute. The document lists standards for the following areas:

> Social Impact Assessments: schools; libraries; elderly care; handicapped; daycare; health services; emergency medical services; police; fire; open space; and municipal personnel needs;
>
> Environmental Impacts: water consumption; solid waste generation; sewage generation;
>
> Traffic Impacts: trip generation by land use types;
>
> Economic Impacts.

PROCESSES FOR DEALING WITH IMPACTS

The Decision-Making Process

If an assessment is to be effective it must influence the decision to move forward with a proposed project or how and if the project is implemented. In its cumulative impact report, the Virginia Council on the Environment says that in order to combat the tendency to view impact statements only as "information documents" some states have sought ways to increase the consideration given to environmental impacts.

The State of California requires formal findings relating environmental impact assessment-identified impacts to the project approval decision. State agency determinations must be based on substantial evidence.

The State of Connecticut requires the submission of an assessment to a review committee for approval and recommendations. This review is concerned both with procedural and substantive matters, and is believed to cause project sponsors to better address the environmental ramifications of proposed projects.

As discussed previously, in Florida, Regional Impact Assessments are required for major development projects. The state has the authority to deny a project based on the assessment. Any project that would have a significant effect on the health, welfare or safety of citizens of more than one county must obtain a development order. This order requires the preparation of an Impact Assessment, submitted to the Bureau of State Planning. Although the assessment is primarily

concerned with infrastructure and socio-economic conditions, the environmental effects of the project are considered as they relate to the health, welfare and safety of the citizens. This process is detailed in Section 380.06 of the Statute.

The literature search yielded a document, also discussed previously, that assists planners and managers in selecting appropriate techniques to determine cumulative impacts and factor them into the decision-making process. Irwin and Rhodes (1992) also show how to evaluate organizational and legal capacity to address impacts.

Other examples of processes for evaluating cumulative impacts were found in Environmental Impact Analysis (Jain, et al), page 325-332, and Methodology for the Analysis of Cumulative Impacts of Corps Activities (Dames and Moore), page 4-14 to 4-24.

Planning Approaches

The Virginia Council on the Environment's Coastal Resource Management Program's report notes that project-by-project assessment amounts to incremental planning, which makes cross-project cumulative impact assessment difficult. They advocate a link to comprehensive planning. The authors state that the planning approach seeks to work backwards from identification of a desired future condition--in a sense, a desired cumulative impact--to consideration of projects that will achieve the plan. Private and public agency actions can then be judged based on consistency with the plan.

Planning approaches discussed in the Virginia report include the following:

> Planning Initiatives Based on Natural Resource Boundaries: By delineating the natural boundaries of a resource(s), the naturally-occurring ecosystem becomes the focus of protection. In plans based on natural boundaries, accumulating inputs to a particular system are inventoried and considered together. The detrimental cumulative impacts of the inputs are then more identifiable. Resource-based plans can be organized to try to assess all types of inputs to a region or they can address only the detrimental inputs of a single type to a resource. Watershed-based plans can allow for analysis of all inputs to a resource. North Carolina and Maryland currently utilize such a planning approach.
>
> Performance-based Plans: In this approach, cumulative impacts are addressed by establishing maximum limits for certain activities, and then working backwards to individual permits. The difficulties

> encountered in determining and defending these maximum limits have already been discussed, and also by Dickert and Tuttle (see below).

Dickert and Tuttle (1985) assert that, because of the difficulty in prestating system threshold limits, incrementalism has become the management approach to many cumulative impact problems. Land development projects are generally approved on a case-by-case basis following negotiations regarding onsite mitigation of on-site direct impacts. Mitigation is the primary approach of most local planning agencies, coastal zone management programs and many other programs in urban land use, water resources, and public lands management. A significant effect of the Clean Water Act 208 nonpoint source programs was the preparation by local governments of manuals for onsite erosion control. The implicit assumption in these management programs is that onsite mitigation alone will be enough to avoid later cumulative effects. That is, if mitigation eliminates project impacts, the sum of the zero impact projects should cumulatively be zero.

Dickert and Tuttle advocate a planning approach to cumulative impacts in their report, and develop a model land use planning system that consists of a set of land disturbance targets, and an erosion-susceptibility map. Also identified are issues that must be addressed in developing a planning system to incorporate a cumulative impact assessment. The report also touches on the allocation of development rights under such a planning system.

The authors conclude that reliance on mitigation measures is not enough to ensure against cumulative impacts, nor will project-by-project impact assessment provide a basis for estimating the impacts of land development. A planning system that incorporates cumulative impact assessment is necessary, and the key issues that need to be addressed are restated.

The Maine State Planning Office Report describes the merits of a planning approach:

> Whether a state employs a regulatory or a planning/regulatory system to address cumulative impacts will determine how troublesome the issues of allocation and thresholds will be. Regulatory programs which decide permit applications on an individual basis violate the underlying tenet of cumulative impacts assessment which seeks to consider impacts comprehensively and <u>before</u> ecological stress is apparent. At some point under a regulatory approach, limits of tolerance will be reached, prohibiting further development. Determining what these limits are and justifying them, however, raise difficult legal and technical questions.

> To a certain extent, comprehensive planning techniques can remedy this dilemma. By incorporating predetermined resource values into comprehensive plans, resource use decisions can be guided by ecological priorities. Specific thresholds of tolerance do not have to be proven, as may be required in a strictly regulatory system. Local plans in North Carolina and California establish resource protection values in special management areas. North Carolina not only specifies protection areas but details permissible and non-permissible uses so that applicants and permit reviewers are well aware of what is acceptable for a given area. New Jersey's coastal program also establishes resource values in a planning context, but does so at the state level. Comprehensive planning provides protection against cumulative impacts by establishing guidelines before submission of a permit application.
>
> Planning approaches can also address the small-scale, incremental development which contributes to the cumulative impact problem but may escape review under regulatory programs. However, simple implementation of comprehensive plans may be too general to provide adequate protection, unless modified to address specific resource concerns. (page 109)

Lee and Gosselink (1988), allege that cumulative effects in bottomland hardwood forests result from incremental forest loss, or nibbling, and from synergisms resulting from this nibbling. This is because of the focus on permit site evaluation, rather than on large landscapes. The paper cites the need for a landscape focus, and states that this perspective requires pre-planning, or goal-setting to establish desired conditions to be maintained in the regulated landscape unit.

The need for a landscape focus is based on the claim that there is no framework for anticipating the cumulative impacts of permit approvals on existing conditions in watershed or landscape units, and only a weak consensus among responsible regulatory agencies about the conditions that should be maintained there. Two quotations illustrate this point:

"Clearly, an anticipatory rather than a reactive approach would provide regulatory agencies with a needed tool." (page 593) "A good precedent for cumulative impact goal-setting has been the establishment of clean air and clean water standards. While water quality standards are based on the best technical understanding of the effects of changes in water quality constituents on stream biota, published specifications reflect the interplay between technical and policy sectors." (page 598)

The authors state that the importance of goal-setting cannot be overemphasized. Goal-setting is the heart of cumulative impact assessment, and determines the levels of cumulative effects that are to be interpreted as impacts. Goals drive the interpretation of the direction a proposed activity will have on maintaining the integrity of a landscape. Because the impact of most single permit requests is not detectable at the landscape level, direction of the impact with respect to the goal should be the regulatory concern, rather than just the absolute magnitude of the individual impact and its significance in contributing to degradation of flood storage, water quality, and life support functions.

Other Management Approaches

The most complete review of approaches to cumulative impact mitigation was found in the Virginia study. The various types are summarized below:

Permitting: Many feel that it is at the permit stage that breakdowns have occurred. This belief has generated much of the interest and concern over finding better methods for dealing with cumulative impacts. The permit is where impact concerns are translated into permit issuance or denial. In cooperation with the Environmental Protection Agency, several states (including New Jersey) have developed programs to examine approaches. The alternative approaches are grouped into three categories:

Facility-wide Permitting: A single multi-media permit for discharge facilities is granted, rather than single permits for water, air and waste disposal. Massachusetts and New Jersey (Pollution Prevention Act) are implementing this approach.

Stated goals of the approach are:

- Pollution Reduction: through coordination of inspection, planning and permitting.
- A holistic approach to pollution prevention, including source reduction.
- Increasing efficiency of permitting procedures and staff time.

Basin-wide Permitting: All projects in a delineated area are assessed together, creating the opportunity for better information about system loads and accumulating effects. This approach is used in North Carolina and Michigan for permit renewals in their National Pollution Discharge Elimination System programs.

Coordinated Pre-Permit Review: An informal, internal program was instituted in Illinois to improve State review of environmental impacts. The review team is made up of section heads from air, water, and land use bureaus. A key component of this process is concurrent review and coordinated issuance of permits.

Organizational Structure

According to the Virginia study, organizational structure can play a significant role in how environmental programs address cumulative impacts. An effective organizational structure that facilitates communication, coordination or joint action can assist in coordinating permit reviews and improving consideration of trans-media impacts. Consistency in permit decisions can also be a result of good coordination.

While noting that there is no single organizational structure that is better than any other under all conditions, the report points to two studies done by the States of North Carolina and Pennsylvania that studied alternative organizational approaches. The studies grouped state environmental programs into four models:

- Unconsolidated Program Model: where each agency is essentially independent.
- Health Department Model: places several, but not all, of the primary permitting departments in one location.
- EPA Model: places all of the permitting departments in one agency.
- Superagency Model: again, all of the permitting departments, and at least one natural resource or development program are placed together.

Each of these structures is reviewed for advantages and disadvantages in dealing with cumulative impacts.

Other Organizational Tools

Strategic Planning: A survey by the State of Pennsylvania determined that a strategic planning process that defined environmental priorities was needed. Such an approach has been explored in Georgia, Iowa and Wisconsin. A strategic plan can provide a common framework for agencies, regardless of organizational structure, and foster discussion of cumulative impacts.

CONCLUSIONS

Much has been written about the impacts of human activities on the natural environment. The methods and approaches range from a regional look at major land use developments of several thousand acres, to a vastly different perspective looking at the hydrologic functions of a wetland. These include both predictive and post hoc assessments. If the Pinelands Commission should decide that cumulative impacts should be further examined, it should first determine whether the impacts of individual projects will be examined, or whether a broader approach that examines development scenarios is more useful. At that point, the various approaches and methods can be narrowed down to similar cumulative impact approaches in the literature. It should be remembered that there is no one preferred method or approach, nor are there even agreed-upon standards to measure impacts against.

It is recommended that planning and organizational approaches to cumulative impact management be investigated further. The report by the Virginia Council on the Environment's Coastal Resource Management Program, Management of Cumulative Impacts in Virginia: Identifying the Issues and Assessing the Opportunities, provides an excellent summary of these approaches and the permitting process, by other states. The Pinelands Commission may be using some combination of the these approaches now. The Virginia report advocates a comprehensive planning approach in order to avoid incremental, case-by-case decision-making. This works backwards from the identification of a desired state, or set of conditions, a pre-determined cumulative impact, in a way, to consideration and encouragement of projects that will achieve the plan. The Pinelands Comprehensive Management Plan does articulate a desired state and set of conditions that is visualized for the Pinelands in the future.

It is also recommended that approaches to organizational structure as a way to better manage impacts be reviewed. Again, the Virginia report provided interesting recommendations here for more effective management.

Adamus, Paul, The Cumulative Impacts of Development in Southern Maine: Wetlands: Their Location, Functions and Value, Maine State Planning Office, Augusta, Me., 1987.

Arbuckle, Jane and Melissa Lee, The Cumulative Impacts of Development in Maine: A Study of Habitat Changes in Five Coastal in Towns, Maine State Planning Office, Augusta, ME, 1987.

Armour, Carl L., Method for Modeling Causes and Effects of Environmental Actions, Western Energy and Land Use Team, Division of Biological Services, Research and Development, Review Draft, January, 1986.

Bailey, Robert G., Land Capability Classification of the Lake Tahoe Basin, California-Nevada: A Guide for Planning, Forest Service, U.S. Department of Agriculture, in cooperation with Tahoe Regional Planning Agency, 1974.

Baskerville, Gordon, "Some Scientific Issues in Cumulative Environmental Impact Assessment," Canadian Environmental Assessment Research Council Workshop, Cumulative Impact Assessment, Vancouver, B.C., February 1985.

Beanlands, Gordon E. and Peter N. Suinker, "An Ecological Framework for Environmental Impact Assessment," Journal of Environmental Management 18 (1984): 267-277.

Beatley, Timothy and David Brower, Managing Growth: Small Communities and Rural Areas, Maine Coastal Program and Maine Department of Economic and Commercial Development, 1988.

Bedford, Barbara L., and Eric Preston, "Developing the Scientific Basis for Assessing Cumulative Effects of Wetlands Loss and Degradation on Landscape Functions: Status, Perspectives, and Prospects," Environmental Management 12, 1988.

Bell, Christopher R.et al, guided by David Brower, David Godschalk, and Edward Kaiser, Currituck County Outer Banks Carrying Capacity Study, Department of City and Regional Planning, University of North Carolina, Chapel Hill, N.C., 1983.

Bendix, Selina, and Herbert T. Graham, Environmental Assessment: Approaching Maturity, Ann Arbor Science 1978, Ann Arbor, Michigan.

Brower, David and Daniel Carol, Managing Land Use Conflicts: Base Studies in Special Areas Management, Duke University Press, Durham N.C., 1987.

Cahill Associates, Limiting Nonpoint Source Pollution from New Development in the New Jersey Coastal Zone: A Summary, prepared for the N.J.D.E.P.E., Office of Regulatory Policy, 1992.

Canter, Larry W., Samuel F. Atkinson, and Larry Leistritz, Impact of Growth: A Guide for Social-Economic Impact Assessment and Planning, Lewis Publishers, Inc. 1985, Chelsea, Mi.

CH2M Hill, Great Swamp Watershed Advisory Committee Report Vols. 1 & 2, prepared for the Great Swamp Advisory Committee to the New Jersey Department of Environmental Protection and Energy, 1993.

Clark, John, Ecosystem Management: A Technical Manual for the Conservation of Coastal Zone Resources, The Conservation Foundation, Wash., DC, New York, NY: John Wiley & Sons, Inc., 1977 (reprinted with corrections by R.E. Krieger Publ. Co. Halabar, FL 1983).

Clark, John, The Sanibel Report: Formulation of a Comprehensive Plan Based on Natural Systems, The Conservation Foundation, Wash. DC, 1976.

Comer, Robert D., "Understanding Secondary Effects of Development on Wildlife Resources in Mitigation Planning," Issues and Technology in the Management of Impacted Western Wildlife: Proc. of a National Symposium, R. Comer (ed.), 16-31, Boulder, CO: Thorne Ecological Inst., 1984.

Contant, Cheryl K. and Lyna L. Wiggins, "Defining and Analyzing Cumulative Impacts," Environmental Impact Assessment Review, 1991.

Contant, Cheryl K. and Leonard Ortolano, "Evaluating a Cumulative Impact Assessment Approach," Water Resources Research, September 1985.

Corwin, Ruthann, Patrick H. Heffernan, Robert A. Johnston, Michael Remy, James A. Roberts and D.B. Tyler, Environmental Impact Assessment, Freeman, Cooper and Company 1975, San Francisco, Ca.

Cowart, Richard H., "Vermont's Act 250 After 15 Years: Can the Permit System Address Cumulative Impacts?" Environmental Assessment Review 6, 1986.

Craig, N.J. and J.W. Day, Jr., Cumulative Impact Studies in the Louisiana Coastal Zone, Louisiana State Planning Office, Baton Rouge, LA 1977.

Creager, Clayton and Joan Baker, North Carolina's Whole Basin Approach to Water Quality Management (DRAFT), North Carolina Division of Environmental Management.

Darnell, Rezneat M, Willis E. Peqvegnat Bela M. James, Fred J. Benson, and Richard A. Detenbaugh, Impacts of Construction Activities in Wetlands of the United States, Corvallis, OR: U.S. EPA Office of Research and Development, 1986.

Dames and Moore, Inc., Methodology for the Analysis of Cumulative Impacts of Corps Permit Activities, Draft Handbook, prepared for U.S. Army Corps of Engineers, Institute for Water Resources, IWR Policy Study, 1988.

Dennis, Jeff, Joyce Noel, Debra Miller, and Caroline Eliot, Phosphorus Control in Lake Watersheds: A Technical Guide to Evaluating New Development, Maine Department of Environmental Protection, Augusta, ME., September 1989.

Dickert, Thomas G. and Andrea E. Tuttle, Elkhorn Slough Watershed: Linking the Cumulative Impacts of Watershed Development to Coastal Wetlands, Berkeley, Ca: Inst. of Urban and Regulatory Development.

Dickert, Thomas, and Andrea Tuttle, "Cumulative Impact Assessment in Environmental Planning: A Coastal Wetland Watershed Example," Environmental Impact Assessment Review, 1985.

Dominie, Hollie and Jean Scudder, Land Use and Cumulative Impacts of Development: A Study Summary, Maine State Planning Office, Augusta, ME, December 1987.

Droege, Mary F., The Cumulative Impacts of Development in Southern Maine: A Scenic Landscape Assessment: Mousam River Watershed, Maine State Planning Office, Augusta, ME., 1986.

Eco-Analysts, Inc., The Cumulative Impacts of Development in Southern Maine: Wetlands: Their Locations, Functions and Value, prepared for the Maine State Planning Office, 1988.

Estevez, Ernest D., "Techniques for Managing Cumulative Impacts in Florida's Coastal Wetlands," Proceedings: Progress in Wetlands Utilization and Management, 147-157, Orlando, FL: 1981.

Estevez, Ernest D., "Assessment and Policy Approaches to Managing Cumulative Impacts in Wetlands," Proceedings of the National Wetlands Assessment Symposium, Jon A. Kusler, and Patricia Riexlinger (eds), Portland, ME., 17 June 1985. Association of State Wetlands Managers, February 1986.

Geppert, Rollin R., Charles Lorenz, and Arthur G. Larson (eds.), Cumulative Effects of Forest Practices on the Environment: A State of the Knowledge, Washington Forest Practices Board, Olympia, WA, February 1984. Project No. 0130.

Godschalk, D.R., Carrying Capacity Applications in Growth Management: A Reconnaissance, Office of Policy Development, Department of Housing and Urban Development, Washington, D.C., 1977.

Good, James W., "Mitigating Estuarine Development Impacts in the Pacific Northwest: From Concept to Practice," Northwest Environmental Journal 3, no. 1 (1987): 93-113.

Gosselink, James G, Lyndon C. Lee, and Thomas A. Muir, (eds), Ecological Processes and Cumulative Impacts: Illustrated by Bottomland Hardwood Wetland Ecosystems, Chelsea, MI: Lewis, 1990.

Hamman, Richard, Wetlands Loss in South Florida, Center for Governmental Responsibility, University of Florida College of Law, September 1982.

Hegenbarth, Jane L., "A Carrying Capacity Study of Hatteras Island," Coastal Zone 85, 1848-1854, 1985 vol. 2.

Horak, Gerald C. and Evan C. Vlachos, "Cumulative Impacts and Wildlife," R.D. Comer 9ed.) Issues and Technology in the Management of Impacted Western Wildlife 7 -13, Thorne Ecological Inst., Boulder, CO, 1982. Tech. Publ. No. 14.

Harris, Larry D., "The Nature of Cumulative Impacts on Biologic Diversity of Wetland Vertebrates," Environmental Management 12, 1988.

Hemond, Harold F., and Janna Benoit, "Cumulative Impacts on Water Quality Functions of Wetlands," Environmental Management 12, 1988.

Hunsaker, Carolyn T., and Robin L. Graham, Glen W. Suter, Robert V. O'Neill, Lawrence W. Barnhouse, Robert H. Gardner, "Assessing Ecological Risk on a Regional Scale," Environmental Management 14, 1990.

Irwin, Frances and Barbara Rhodes, Making Decisions on Cumulative Environmental Impacts: A Conceptual Framework, World Wildlife Fund, Washington, D.C., 1992.

Jain, R.K., L.V. Urban, G.S. Stacey, Environmental Impact Analysis: A New Dimension in Decision Making, Van Nostrand Reinhold Company 1981, New York, N.Y.

Jones, Jody, The Cumulative Impacts of Development in Southern Maine: Important Wildlife Habitats, Maine State Planning Office, Augusta, ME, 1986.

Keyes, Dale L., Land Development and the Natural Environment: Estimating Impacts, The Urban Institute 1976, Washington, D.C.

Kozlowski, J. and J.T. Hughes, Threshold Analysis, The Architectural Press 1971, New York, N.Y.

Kusler, Jon A., Regulating Sensitive Lands, Wash., DC Environmental Law Institute, 1980.

Land Use Consultants, Inc., Coastal Policy Study: Cumulative Impacts of Incremental Development on the Maine Coast and Appendices, Governor's Advisory Committee on Coastal Development and Conservation, Augusta, ME, February 1978. Draft for technical review.

Lee, Lyndon, and James Gosselink, "Cumulative Impacts on Wetlands: Linking Scientific Assessments and Regulatory Alternatives," Environmental Management 12, 1988.

Leibowitz, Scott G, Brooke Abbruzzese, Paul R. Adamus, Larry E. Hughes, and Jeffrey T. Irish, A Synoptic Approach to Cumulative Impact Assessment: A Proposed Methodology, Corvallis, OR: US EPA Environmental Research Laboratory, 1992.

Maine State Planning Office, The Cumulative Impacts of Development in Southern Maine: Management of Cumulative Impacts: An Analysis of Legal and Policy Issues, Marine Law Institute, Center for Research and Advanced Study, University of Southern Maine, 1988.

Mann, Diana, "Loss of Wildlife Habitat from Site Location of Development in Cumberland County, Maine 1970 to 1979," 24 January 1980.

McGilvray, Laurie J., Glen D. Anderson, and Niels West, "Managing Coastal Development: An Evaluation of the Transfer of Development Rights Approach," Coastal Zone Management Journal, 13, no. 1 (1985): 25-47.

Nassau-Suffolk Regional Planning Board, Integration of Regional Land Use Planning and Coastal Zone Science: A Guidebook for Planners, 1976.

O'Brien, Arnold L., "Evaluating the Cumulative Effects of Alteration on New England Wetlands," Environmental Management 12, no. 5 (1988) 627-636.

Office of Research and Development, U.S.E.P.A., Secondary Impacts of Transportation and Wastewater Investments: Review and Bibliography, Washington, D.C., 1975.

Office of Research and Development, U.S.E.P.A., Ecosystem Impacts of Urbanization Assessment Methodology, Corvallis, Or., 1977.

Office of Air and Waste Management, Office of Air Quality Planning and Standards, U.S.E.P.A., Growth Effects of Major Land Use Projects: Vol. 3 - Summary, Research Triangle Park, NC, 1976.

Palmer, Arthur E., "Environmentally Bases Land Use Planning and Regulation." Pace Environmental Law Review 2, no. 1 (1984).

Pennsylvania Department of Environmental Resources (DER), DER Organization Study, Task Report: Interstate Study, 1990.

Preston, Eric, and Barbara L. Bedford, "Evaluating Cumulative Impacts on Wetlands Functions: A Conceptual Overview and Generic Framework," Environmental Management 12, 1988.

Rieser, Alison and Josie Quintrell, Managing the Cumulative Effects of Development on the Maine Coast: An Analysis of Legal and Policy Issues, Maine State Planning Office, Maine Coastal Program, Augusta, ME., 13 November 1986.

Risser, Paul G., "General Concepts for Measuring Cumulative Impacts on Wetland Ecosystems," Environmental Management 12, 1988.

Rutgers University, Center for Urban Policy Research, and the Urban Land Institute, Development Impact Assessment: Handbook and Model, 1991.

Scott, Randall W., Ed., Management and Control of Growth, Vol. 11, the Urban Land Institute 1975, Washington, D.C.

Schaenman, Phillip S. and Thomas Muller, Measuring Impacts of Land Development, The Urban Institute, 1974, Washington, D.C.

Schneider, Devon M., David R. Godschalk, and Norman Axler, The Carrying Capacity Concept as a Planning Tool, Planning Advisory Service Report No. 338, American Planning Association, 1978, Chicago, Ill.

Shopley, J.B., and R.F. Fuggle, "A Comprehensive Review of Current Environmental Impact Assessment Methods and Techniques," Journal of Environmental Management 18, 1984.

Siemon, Larsen, Mattlin & Purdy, Statewide Growth Management Programs in Other States, prepared for the New Jersey Office of State Planning, Trenton, NJ, 1987.

Soule, Michael., "Lane Use Planning and Wildlife Maintenance: Guidelines for conserving Wildlife in and Urban Landscape," American Planning Association Journal (June 1991): 313-323.

Southern Maine Regional Planning Commission, Summary of Findings of Southern Maine Regional Planning Commission CAM - Cumulative Impacts Study, May 1986.

Stakhiv, Eugene Z., "An Evaluation Paradigm for Cumulative Impact Analysis," Environmental Management 12, 1988.

Stakhiv, Eugene Z., "Cumulative Impact Analysis for Regulatory Decisionmaking," Wetlands Symposium Portland, Me., June 1985.

Stansbury, Jeffery, "Suburban Growth: A Case Study," Population Bulletin, 28, 1972.

U.S.E.P.A., Evaluation and Development of Institutional Systems for Environmental Management: Water Quality Impacts of Land-Disturbing Activities, 1976

Tahoe Regional Planning Agency, Study Report for the Establishment of Environmental Threshold Carrying Capacities, 1982.

U.S.E.P.A., The Ecological Impacts of Wastewater on Wetlands: an Annotated Bibliography, 1984.

U.S.E.P.A., Evaluation and Development of Institutional Systems for Environmental Management, Water Quality Impacts of Land-Disturbing Activities, 1976.

Virginia Council on the Environment's Coastal Resource Management Program, Management of Cumulative Impacts in Virginia: Identifying the Issues and Assessing the Opportunities prepared by the Institute for Environmental Negotiation, University of Virginia, 1991.

Weller, Milton, W., "Issues and Approaches in Assessing Cumulative Impacts on Waterbird Habitat in Wetlands," Environmental Management, 12, no. 5 (1988): 695-701.