Annotated Bibliography on Cumulative Impact Analysis for the Midwest Natural Resource Group Cumulative Impacts Workshop

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Bass, R.E., A. I. Herson, and K. Bogdan. 2001. The NEPA Book: A Step-by-Step Guide on How to Comply with the National Environmental Policy Act. 2nd Ed. Solano Press Books, Point Arena, CA. Pp. 102-110.

The cumulative impact analysis section of this reference manual summarizes the CEQ and EPA cumulative impact handbooks for much of its content. Appendix U provides summaries of key NEPA court decisions, including two recent cases on cumulative impacts (Sylvester v. U.S. Army Corps of Engineers, 884 F.2d 394 (9th Cir. 1989) and Oregon Natural Resources Defense Council v. Marsh, 490 U.S. 360 (1980).

Buckley, R.C. 1998. Cumulative environmental impacts. *In:* Environmental Methods Review: Retooling Impact Assessment for the New Century. A.L. Porter and J.J. Fittipaldi, Ed. Army Environmental Policy Institute, the Press Club, Fargo, ND. Pp. 95-99.

Recognizing that most resources are actually cumulatively impacted by development, the author states that few laws and assessments actually conduct cumulative impact analyses. The greatest deficiencies in considering cumulative impacts is at the stage when impact analyses are triggered (whether to consider them before any development begins, or after some development has occurred within the analytic baseline), and at the decision-making stage, both of which are legal and political issues, not technical analytic issues.

Canter, L.W. 1996. Environmental Impact Assessment. 2nd Ed. Irwin McGraw Hill, Boston. Pp. 655.

This book is probably the authoritative treatise on the various types of environmental impact analysis methodologies for NEPA, although it does not focus on conducting cumulative impact analyses. Chapters 3, 4, and 5 describe the various methodologies in general and how to select an appropriate methodology. Chapters 6 through 14 discuss various methodologies specific to different resources (air quality, surface water, groundwater, noise, biological environment, habitat, historical/archaeological, visual quality, and the socioeconomic environment). Each chapter also includes summaries of the pertinent laws. Chapter 15 discusses decisionmaking methods; Chapter 16 discusses public involvement; Chapter 17 discusses writing the document; and Chapter 18 covers environmental monitoring.

Canter, L.W. 1997. Cumulative effects and other analytical challenges of NEPA. *In:* Environmental Policy and NEPA. R. Clark and L. Canter, Ed. St. Lucie Press, Boca Raton, Fl. Pp. 115-137.

This article provides a summary of the various general impact assessment methodologies, including analogous case studies, checklists, expert systems, literature reviews, GIS, photographs, quantitative models, matrices etc., and summarizes their appropriate application. The author contends that many methods used for analysis of direct and indirect impacts can also be applied to cumulative impacts, and provides examples from the US Army Corps of Engineers and the US Forest Service. Some analytic challenges identified by the author for analysis of cumulative impacts includes: lack of site-specific baseline data; defining the spatial and temporal boundaries; selecting appropriate models; identifying a few select factors for analysis rather than a broader array of multiple factors; and overcoming a single-discipline view of area specialists in favor of a more holistic, interdisciplinary approach. The final challenge is that impact predictions using various techniques must be interpreted from several perspectives, including laws, regulations, and Executive Orders while considering public values and professional judgment based on scientific methods and principles.

Clark, R. 1993. Cumulative effects assessments: A tool for sustainable development. Conf. Proc. International Association of Impact Assessment, Shanghai, China, June 1993. 11pp.

This paper, authored by a senior policy analyst at CEQ, defines cumulative effects and provides a fundamental process for considering cumulative impacts within a NEPA planning process, including having a clear purpose and need, determining spatial and temporal boundaries, establishing the environmental baseline and data needs, defining impact indicators, setting thresholds and carrying capacities, analyzing impacts of proposals and alternatives, and establishing monitoring. The author concludes that cumulative impact assessment is best undertaken at the programmatic or policy level because the decisions have not already passed the irretrievable commitment of resources milestone. The author also recommends developing a national environmental baseline database for the U.S. and conducting research on methods of assessing cumulative effects.

Contant, C.K. and L.L. Wiggins. 1993. Toward defining and assessing cumulative impacts: Practical and Theoretical Considerations. *In:* <u>Environmental Analysis: The NEPA Experience.</u> S.G. Hildebrand and J.B. Cannon, Ed. Lewis Publishers. Pp. 336-356.

The authors summarize regulations and the role of the Courts in defining cumulative impacts, and further clarify cumulative impacts to consider: 1) individually minor but repeated actions accumulating with a delayed response through an ecosystem; 2) ecosystems may not respond linearly when impacts accumulate, but may get worse at an increasing rate; 3) ecosystems may reach a threshold at which further perturbations, no matter how small, may cause a system to collapse; 4) some effects may have a synergistic nature in which effects on the system as a whole may be greater than the sum of its parts in terms of magnitude, intensity, severity, or complexity; 5) time/space crowding results in the inability of a natural system to recover from an earlier or close perturbation before a new perturbation occurs; 6) *nibbling* results from the incremental insult of repeated action on an area over time; 7) growth induction reflects the fact that the introduction of certain activities can accelerate or decelerate the rate of development of new activities or can result in a stronger interaction among environmental parameters, recognizing the precedent-setting effect of activities in stimulating even greater development than previously anticipated. The authors summarize cumulative impacts in five inherent aspects: 1) Similar and dissimilar actions can produce cumulative impacts; 2) impacts accumulate over time and space; 3) this accumulation takes place in both incremental and synergistic ways; 4) some activities may produce major changes in system behavior that either occur immediately or are delayed; and 5) some actions are growth inducing and as a result represent significant changes in the impetus for future activities.

Operational problems identified when these principles are applied include: 1) monitoring past and present activities and predicting future activities; 2) scientific shortcomings in understanding and predicting the behaviors of natural systems within and across media and over time; and 3) organizational, legal, and jurisdictional conflicts and limitations.

An ideal methodology for assessing cumulative impacts must accomplish several tasks: 1) monitor development activity over time and space and allow for mechanisms by which past and present development may lead to changing growth patterns over time, as well as monitor changes in environmental parameters, serving as a baseline against which new impacts can be compared; 2) provide clear and accurate models of the responses of natural systems affected by the proposed activities, describing the impact of a perturbation, the ability of a system to recover from the impact, the interactive or synergistic impacts within and across systems, and the threshold or delayed effects, as well as a justifiable forecast of probable future actions; 3) Effective management systems must evaluate cumulative developmental effects and translate into appropriate management strategies and actions.

Several approaches to cumulative impact analyses exist: 1) the programmatic approach incorporating grouped projects over a large area, then tiering site-specific analyses; 2) suitability studies which determine appropriate areas for different types of development using GIS approaches; 3) carrying capacity studies which recognize inherent thresholds or limits for many environmental and socioeconomic factors constraining the limits of development.

The authors proposed the following improvements to cumulative impact assessments: 1) monitoring actions and impacts over time and space, especially using GIS; 2) developing better models of complex natural systems; 3) managing cumulative impacts through decisions about specific actions, focusing data collection, more detailed analyses, and coordination is necessary in cases where thresholds are likely to be reached, where knowledge is lacking, and/or when policies cannot be precisely defined.

Council on Environmental Quality. 1997. Considering Cumulative Effects under the National Environmental Policy Act. 64pp. plus Appendices. Available at http://ceq.eh.doe.gov/nepa/ccenepa/ccenepa.htm

This document, prepared for the Council on Environmental Quality and involving a large number of agency and contracted experts, is considered the benchmark guidance document summarizing the concepts, principles, and methods for conducting cumulative impact analyses. The report identifies eight principles regarding cumulative impact analysis: 1) caused by an aggregate of past, present and reasonably foreseeable future actions; 2) the total effect, including direct and indirect effects on a given resource; 3) analyzed in terms of a specific resource, ecosystem or human community being affected; 4) focus analysis on impacts that are truly meaningful; 5) spatial boundaries are rarely aligned with political or administrative boundaries; 6) may result from accumulation of similar effects or interaction of different effects; 7) may last beyond the life of the project; 8) must be analyzed in terms of capacity to sustain additional effects based on its time and space parameters.

Based on the eight principles and four types of cumulative impacts (additive or interactive from multiple or repeated actions), the handbook creates an analytic framework involving scoping (identify resources affected cumulatively; the past, present, and reasonably foreseeable future actions contributing to the effect; and the spatial and temporal boundaries); describing the affected environment (characterizing the resources and their capacity to respond to stress, the stressors, and the baseline condition), and predicting the additive, countervailing, and synergistic cumulative impacts themselves (developing cause and effect relationships, determining the magnitude and significance of effects, identifying mitigation, and monitoring the effects of the selected alternative and adapt management). Chapter 5 and Appendix A describe and summarize the various cumulative impact methods that have been used and their applications (models that describe cause and effect relationships, models that analyze trends and change, and spatial overlay processes), such as questionnaires, checklists, matrices, network and system diagrams, modeling, trends analyses, carrying capacity analyses, and overlay mapping and GIS. Table 5-3 summarizes each method and their strengths and weaknesses.

Eccleston, C.H. 1999. Performing the impact analysis: Cumulative impact analysis and special issues. *In:* <u>The NEPA Planning Process: A Comprehensive Guide with Emphasis on Efficiency.</u> John Wiley and Sons, New York. Pp. 285-299.

The author provides a general process for conducting cumulative impact analyses, based on summaries of some court cases, including: scoping to focus on the important cumulative issues; determining spatial and temporal boundaries for each resource; describing the affected environment; collecting data to support the development of cause and effect relationships; and considering monitoring and adaptive management. Agencies must deal with uncertainty in ways that provide evidence that the risks of uncertainty have been balanced against the benefits of going forward with a decision.

Eccleston, C.H. 2001. Chapter 7.1: Cumulative Effects Analysis in EAs; and Chapter 8.2: Assessing Significance. *In:* <u>Effective Environmental Assessments: How to Manage and Prepare NEPA EAs.</u> CRC Press, Boca Raton, Fl. Pp.81-87, 120-122.

The author includes discussions of key court cases and the CEQ guidance on cumulative impact analysis to summarize the documented requirements for cumulative impact analysis in EAs, as well as EISs (Section 7.1). In determining if an impact is significant, he uses the CEQ regulatory definition and criterion for significance regarding cumulative impacts to outline a procedure for comparing impacts of the proposed action to the impact of the baseline (Section 8.2).

Federal Highway Administration. 1992. Position paper: Secondary and cumulative impact assessment in the highway project development process. HEP-31. 6 pp.

FHWA and the state DOTs must produce systematic interdisciplinary analyses of environmental, social and economic impacts of sponsored projects that include coverage of secondary and cumulative impacts, using methods based on cause and effect relationships. Knowledge of past and present pressures from both the proposed project and outside forces is essential to determine whether a project is expected to jeopardize threatened or endangered species. Secondary and cumulative impacts to the larger system may be "invisible" to normal environmental studies that examine only the immediate influence of an isolated project, because the affected resource functions may be removed from the project in time and space. Although this policy applies to all agency actions, FHWA will focus on construction activities, including analysis of potential for development within the area.

FHWA policy provides a general framework for consideration of secondary and cumulative impacts: 1) consideration of secondary and cumulative impacts should begin in the planning stages; 2) In areas with limited local land use planning, past history can sometimes be an indicator for future development; 3) determine trends for future development; 4) relate information on development trends to the scope of the project proposal; 5) determine the temporal scope of the analysis (design life); 6) analyze the planned and potential development of the area influenced by the project to determine indirect impacts; 7) FHWA policy is that mitigation must be reasonable and related to project impacts and within the authority and control of FHWA.

Federal Highway Administration. 2002. Toolbox for Regional Policy Analysis (http://www.fhwa.dot.gov/planning/toolbox).

The web-based toolbox includes discussions of various types of impacts, types of forecasting methods and where they have been applied, specific case studies (New York, Utah, Maryland, California, Oregon, Europe, Puerto Rico, and Iowa) and bibliography on forecasting methods, including models, software, and written resources.

Federal Highway Administration. 2003. Interim guidance: Questions and answers regarding the consideration of indirect and cumulative impacts in the NEPA process. *In:* FHWA Environmental Guidebook. 25pp.

This document offers answers based primarily on the CEQ regulations, court decisions, the CEQ's "40 Questions," and FHWA policies and guidance. It sets out FHWA policy regarding the consideration of secondary and cumulative

impacts in categorical exclusions, environmental assessments and environmental impact statements, mitigation responsibilities, strategies for streamlining and scoping, and requirements within other federal laws such as the National Historic Preservation Act, the Clean Water Act, and other laws and agency procedures. It also provides additional pertinent references, guidance and training.

Glasson, J., R. Therivel, and A. Chadwick. 1994. Introduction to Environmental Impact Assessment: Principles and Procedures, Process, Practice and Prospects. UCL Press, London. 342 pp.

In Section 4.7 of this textbook, the authors briefly summarize the different types of quantitative and qualitative analysis methods for environmental impact analysis. Brief references to cumulative impact analysis are mentioned in several other sections throughout the book.

Hunsaker, C.T. 1993. Ecosystem assessment methods for cumulative effects at the regional scale. *In:* Environmental Analysis: The NEPA Experience. S.G. Hildebrand and J.B. Cannon, Ed. Lewis Publishers. Pp. 480-493.

This author proposes that regional ecological risk assessment provides a useful approach for assisting scientists in assessing cumulative impacts. The common goals of cumulative impact assessments, programmatic EISs, and ecological risk are to support informed decisions and to protect or manage the environment for large geographic areas. The spatial and temporal boundaries depend on the resource analyzed and its heterogeneity. Cumulative impacts are best addressed on at least a regional scale, often using programmatic documents, with the definition of regional and subregional boundaries a critical component. Dose response curves, cumulative frequency distributions, and maps are important tools for communicating cumulative effects analyses. Additional helpful assessment tools include GIS, remote sensing data and landscape indices that capture landscape patterns relevant to ecological processes. The lack of availability of integrated databases hinders capabilities to conduct cumulative impact analyses.

Hunsaker, C. T. 1998. Cumulative effects assessment. *In:* Environmental Methods Review: Retooling Impact Assessment for the New Century. A.L. Porter and J.J. Fittipaldi, Ed. Army Environmental Policy Institute, the Press Club, Fargo, ND. Pp. 100-106.

The author contends that risk-based cumulative impacts are best applied at the regional scale because it is at this spatial scale and associated temporal scale that cumulative effects manifest. To address cumulative impacts effectively requires a sustained effort, including evaluation of historic information and future prediction and planning; neither science nor government has been successful at either requirement. This paper primarily and briefly references the work of others.

Irving, J.S. and M.B. Bain. 1993. Assessing cumulative impact on fish and wildlife in the Salmon River Basin, Idaho. *In:* Environmental Analysis: The NEPA Experience. S.G. Hildebrand and J.B. Cannon, ed.. Lewis Publishers. Pp. 357-372.

The Federal Energy Regulatory Commission developed the Cluster Impact Assessment Procedure (CIAP) to evaluate the cumulative impacts of numerous

hydroelectric energy projects on fish and wildlife resources. CIAP was a schedule of interactive workshops intended to determine the number of proposed projects, to identify target fish and wildlife resources for analysis, to define important components of the target resources, and to determine sources and availability of data. Cumulative impact analysis for the specific multiple projects involved a matrix-format model that developed a relative cumulative impact score for each target resource for every project configuration, with a matrix for each project, integrated using computer technology, resulting in a relative ranking of the project configurations.

Irwin, F. and B. Rodes. 1992. Making decisions on cumulative environmental impacts: A conceptual framework. World Wildlife Fund, Washington, D.C. 54 pp.

This document is a result of a workshop held in 1990 involving the US EPA, CEQ, the National Science Foundation, U.S. National Research Council and the Canadian Environmental Assessment Research Council. The participants developed a framework to help agency managers compare the temporal and spatial boundaries of their decisions with the boundaries of the causes and effects of the problem; identify mismatches; and develop ways to overcome the institutional and technical barriers to conducting appropriate cumulative impact analyses and making decisions at more appropriate scales. The key to successful implementation of the framework is that when multiple agencies affect the same resource, they need to work together within a coordinated regional planning effort. The paper offers suggestions for components of any regional planning effort, including a flow chart for matching boundaries of decisions and of cumulative impacts and questions to ask. Appendix B compiles various definitions of cumulative impacts from the literature and Appendix C compiles the various ways that cumulative impacts are incorporated into U.S. Federal and state laws.

Jain, R.K., L.V. Urban, G.S. Stacey, H.E. Balbach and M.D. Webb. 2002. Environmental Assessment, 2nd ed. Chapter 6: Environmental Assessment Methodologies. McGraw-Hill, New York. 655pp.

This chapter in the textbook summarizes various impact assessment methods recommended by various authors, along with methods for selecting a methodology for a specific application. The section on cumulative impact analysis has been adapted from the CEQ handbook on cumulative impact analysis.

LaGory, K.E., E.A. Stull, and W.S. Vinikour. 1993. Proposed methodology to assess cumulative impacts of hydroelectric development in the Columbia River Basin. *In:* Environmental Analysis: The NEPA Experience. S.G. Hildebrand and J.B. Cannon, Ed. Lewis Publishers. Pp. 408-423.

The relatively complicated conceptual framework applied by the authors includes: 1) The premise that nonadditive cumulative effects are derived from the modification of single-project effects when other projects interact; 2) Cumulative effects can be additive (when the response is linear and equal to the sum of single-project effects; supraadditive (when the response to the total environmental change is greater than the sum of the responses to single projects); infraadditive (when the response to total environmental change is less than the sum of single project effects; 4) geographical, temporal, ecological relationships among projects must be determined; 4) Interaction coefficients are calculated and placed in impact matrices for accumulating incremental single-project effects and interactions between project pairs into a total cumulative effect of all projects acting together.

Mandelker, D.R. July 2003. <u>NEPA Law and Litigation,</u> 2nd ed, Release #1. Sections 8:41, 10:33, -10:42. West Group, Minn.

Dr. Mandelker summarizes and discusses key court cases that provide both judicial guidance and areas of confusion and contradiction related to incorporation and analysis of cumulative impacts. Court cases relating to cumulative impacts in general and those related to specific sectors (growth and development, highways and bridges, dams and reservoirs, river and water projects, forest, wilderness, and park projects, offshore oil leases, and projects in urban areas) each have their own section. The relationship of direct and indirect effects to cumulative impacts is also discussed.

MacDonald, L.H. 2000. Predicting and managing cumulative watershed effects. University of Minnesota Coll. Nat. Res. 10pp.

The author makes the case that current models need to be revised to not just consider runoff from watersheds (focusing on land management activities such as logging, grazing, ski areas, and roads), but also changes in erosion and sediment loads from forest management decisions. He states that current modeling of cumulative watershed effects is highly limited and does not really help much in making better decisions. Alternative approaches are adaptive management (limited in effectiveness by time lags, recovery rates, and difficulty of detecting change) and minimizing the on-site effects of individual actions. The author concludes: "No matter what approach is followed, the assessment and management of [cumulative watershed effects] will continue to be a difficult and contentious issue."

McCold, L. and J. Holman. 1995. Cumulative impacts in environmental assessments: How well are they considered? *The Environmental Professional.* 17: 2-8.

The authors reviewed 89 environmental assessments published in the Federal Register in 1992 (almost 60% from the Federal Energy Regulatory Commission and the Nuclear Regulatory Commission, with none from agencies which prepare a large number of EAs, such as the US Forest Service and the US Army Corps of Engineers, because most agencies do not publish notices of availability for EAs in the Federal Register) to determine the extent to which cumulative impact assessments in the EAs meet CEQ's regulations. Only 39% of the EAs provided any evidence that cumulative impacts had been considered and some EAs that mentioned cumulative impacts conducted no actual analysis. Of those EAs, most did not evaluate cumulative impacts for all resources that were directly impacted by the proposed action. Just two EAs of extremely limited scope conducted appropriate cumulative impact analyses, each for one resource (human health). Mostly, any cumulative impact analyses attempted did not provide sufficient evidence for a Finding of No Significant Impact.

Morgan, R.K. 1998. Environmental Impact Assessment: A Methodological Perspective. Kleuver Academic Publishers, Boston. P. 201-215.

This section of a textbook summarizes the findings of several other authors, including Smit and Spaling (1995), Irving and Bain (1993), and L. Canter. The section identifies predicting cumulative impacts as a "vexatious problem" and recognizes that many approaches are qualitative, depending on professional judgment, checklists, and matrices, because of practicality and cost.

Myslicki, A. 1993. Use of programmatic EISs in support of cumulative impact assessment. *In:* Environmental Analysis: The NEPA Experience. S.G. Hildebrand and J.B. Cannon, Ed. Lewis Publishers. Pp. 373-390.

This paper provides a basis for understanding the strengths and weaknesses of using programmatic approaches for evaluation of cumulative impacts, with three case studies described. Programmatic EISs can evaluate impacts across diverse geographic areas as part of comprehensive planning, and mitigation can be developed for both site-specific and cumulative impacts often negating the need for site-specific analyses. Although they may take additional time, they can speed program implementation overall. However, programmatic EISs can provide opponents a means for stopping entire programs, and can cost more in time and money in the short term. It can also be difficult to develop appropriate methodologies for cumulatively analyzing a number of minor yet diverse actions, and to collect and use data at the cumulative level. Three difficult concerns regarding conducting cumulative impact analyses at a programmatic level are: 1) identification of potential reasonably foreseeable future actions; 2) the lack of availability of appropriate models for analyzing cumulative impacts for specific resources; 3) delays caused during development of programmatic documents, although in the long run they may actually speed up program implementation by identifying and mitigating cumulative impacts early.

National Cooperative Highway Research Program. 1991. Implementation of Geographic Information Systems (GIS) in State DOTs. *Research Results Digest*, No. 180. 32 pp.

This document summarizes the various applications and strengths and weaknesses of GIS systems as used by state DOTs (based on surveys). Some of the barriers include lack of appropriate computing environment; mismatches of spatial data; incompatibility and redundancy of non-spatial databases; difficulties in obtaining and maintaining support of management, and the inability to stay up with technical advances and networking. Some key findings of an expert panel include: 1) GIS capability is misunderstood and underused; 2) GIS may provide a basis for data integration; 3) GIS software needs to be more user-friendly; 4) incorporating GIS capabilities into existing statistical software packages would be a wonderful product; 5) detailed case studies (successes, failures, and cost savings) would be very useful; 6) GIS is applicable to project, corridor, regional,

and statewide scales; 7) different GIS software systems need to be compatible; 8) the agencies need to determine who supports, funds, and sustains GIS systems; 9) more agency people need to be able to effectively use GIS.

National Cooperative Highway Research Program. 1998. Guidance for Estimating the Indirect Effects of Proposed Transportation Projects. Report 403. National Academy Press, Washington, D.C. 209pp.

This extensive guidance document contains guidance and a framework for defining indirect (secondary) effects and describes tools for analysis. It has extensive case studies and legal cases, and the results of interviews with over 50 practitioners. The report identifies three categories of indirect effects: 1) alteration of the behavior and functioning of the affected environment caused by encroachment; 2) development effects influenced by the project; 3) effects related to project-influenced development effects. The analytic framework includes eight steps: 1) conduct initial scoping (need for action, level of effort, and location and extent of the study area); 2) identify the study area goals (timing, data collection, consistency with local and regional plans, public involvement); 3) identify resources (compile inventory, describe and map ecosystem, historic and archaeological, community facilities, and socioeconomic conditions; 4) identify impact-causing activities (actions causing land alteration, resource extraction, resource renewal, traffic changes, chemical treatment, access alteration, etc.); 5) identify indirect effects needing analysis (habitat fragmentation/degradation, ecosystem disruptions, relocations, alteration of traffic patterns/access, and projects which lead to induced growth, which support planned development, which stimulate complementary development, and which influence intraregional location decisions) using methods such as matrices, networks spatial mapping, case study qualitative inference and comparison, checklists; 6) analyze the indirect effects for no action and action alternatives (qualitative methods - literature review/comparative case analysis, scenario writing, expert panels/public involvement, trend extrapolation, carrying capacity analysis, econometric forecasting techniques; quantitative methods - simple gravity models; cost-benefit analysis/economic/fiscal impact models, integrated land use and transportation models) 7) evaluate the analysis results (uncertainty in assumptions, sensitivity to change in assumptions, risk analysis); 8) assess consequences and develop mitigation (basis for informed decisions, thresholds for unacceptable impacts, mitigation need, practicality, and responsibility.

National Cooperative Highway Research Program. 1999. Land Use Impacts of Transportation: A guidebook. NCHRP Report 423A. National Academy Press, Washington, D.C. 165pp.

This report is a compendium of the various analytic tools currently used by Metropolitan Planning Organizations (MPOs) and Departments of Transportation (DOTs) to analyze the interactions between land use and transportation projects. Chapter 1 provides an overview of the relationship between transportation and land use, including tables summarizing land use impacts associated with highway and transit investments and policies and land use policies on travel demand. Chapter 2 includes analytic tools such as comprehensive plans and land use

regulations, qualitative methods using expert knowledge, allocation rules assigning population and jobs to zones, decision rules based on local historic data or data from other locations, statistical methods, GIS, regional economic models, and formal land use models. Chapter 3 describes the behavioral frameworks underlying the process of urban growth and change by focusing on the key actors in urban development, the locational decision they make, and the factors that influence these decisions. Chapter 4 describes methods for using the behavioral framework in land use analysis for base case land use forecasts, impact assessments, and policy assessments.

National Cooperative Highway Research Program. 2002. Desk reference for estimating the indirect effects of proposed transportation projects. Report 466. National Academy Press, Washington, D.C. 99pp.

This report includes the results of research included in Report 403, and updates and refines Report 403 to reflect more recent developments and new or improved tools. The updated research also involved historical case study analyses to provide an improved retrospective of indirect effects. This document updates and reviews case law, and updates the eight-step process used in Report 403. It is intended to be used for training.

National Cooperative Highway Research Program. 2002. Mitigation of Ecological Impacts: A synthesis of highway practice. NHCRP Synthesis 302. National Academy Press, Washington, D.C. 100pp.

This report synthesizes the responses of 27 transportation agencies regarding the application and effectiveness of transportation mitigation efforts, primarily aimed at wetland mitigation. It includes the regulatory framework and methodologies for impact assessment (mostly professional judgment and qualitative methods) with descriptions of primarily wetland impact analysis methods. Methods for assessing effectiveness and costs of mitigation and case studies are described.

Pescitelli, D.R. and D.L. Merida. 1993. Walking though walls: Using NEPA's cumulative impact concept to reconcile single-issue environmental statutes. *In:* Environmental Analysis: The NEPA Experience. S.G. Hildebrand and J.B. Cannon, Ed. Lewis Publishers. Pp. 424-436.

The authors present a case study of a controversial highway project that crossed the Illinois River that adversely affected two properties subject to the provisions of 4(f) of the Department of Transportation Act of 1966. Analysts considered the requirements of Section 4(f), Section 106 of the National Historic Preservation Act, the Endangered Species Act, and agricultural protection laws cumulatively to determine whether the cumulative environmental effects of each alternative considered rendered it reasonable or imprudent, rather than evaluating each alternative in terms of each law individually. This approach was a relatively novel legal argument that had not been strictly tested in the courts. However, this approach was upheld by the 7th Circuit Court of Appeals.

Saylor, R.E. and L.N. McCold. 1994. Bounding analyses in NEPA documents: When are they appropriate? *The Environmental Professional.* 16:285-291.

This paper discusses how to decide: 1) when to eliminate environmental issues from further analysis because the impacts would be insignificant; 2) when to eliminate a category of similar actions from further analysis because impacts of this group of actions would be insignificant; 3) the appropriate mitigation measures in a programmatic document; 4) Reasonable future risks of large-scale accidents. The authors basically suggest that in all cases, the appropriate "bounding" technique is to use conservative assumptions about a "reasonable worst case" scenario. If issues are still insignificant, similar actions conducted within the identified bounds would also not have a significant effect. The public can be assured that mitigation will resolve any remaining effect or that the impacts do not require mitigation. The "bounding" approach can facilitate consideration of cumulative impacts in some situations, and assist in providing prompt and efficient analyses of sufficient accuracy and detail for NEPA documents.

Senner, R.G.B., J.M. Colonell, J.D. Isaacs, S. K. Davis, S. M. Ban, J.P. Bowers, and D.E. Erikson. 2002. A systematic but not-too complicated approach to cumulative effects assessment. Proc. 22nd Ann. Conf. International Assoc. for Impact Assessment, The Hague.12 pp.

Outlines a general approach to cumulative impact analysis, including scoping (identifying and focusing on the impacted resources and their spatial and temporal boundaries); describing the affected environment (human and natural events shaping the condition of a resource up to the present); predicting direct, indirect, and cumulative impacts for each resource; screening the impacts (determine whether the potential exists for cumulative impacts); evaluation (evaluating whether significant direct or indirect impacts would occur); and mitigation, monitoring, and adaptive management.. A matrix of impacts and external influences is prepared similar to CEQ (1997). This may be a helpful organizing system (see table 2b).

Southerland, M. 1994. Evaluation of ecological impacts from highway development. *For:* U.S. Environmental Protection Agency, Office of Federal Activities. EPA 300-B-94-006. 69pp.

This detailed report prepared for the US EPA relates the goals of NEPA to ecosystem protection goals and guidance of the Federal Highway Administration. It details the primary types of adverse direct, indirect, and cumulative ecological impacts (destruction, fragmentation, and degradation of habitats, pollution, and disruption of natural processes, including natural hydrological processes) which can occur with the various phases of highway development activities (planning, design, construction, operation and maintenance). Regarding cumulative impacts, the report states that the effects of highway development accumulate when different road segments or highway systems overlap in time or space, particularly impacts on habitat fragmentation. The combined effect of these cumulative actions may exceed the sum of each individual impact or even create a qualitatively different effect on the ecosystem. These effects may be augmented or overwhelmed by secondary development (conversions to industrial or residential use), especially with capacity improvements, additional interchanges, new location construction, and creating new access to undeveloped locations.

The process for evaluation of ecological impacts includes: 1) determine the appropriate spatial and temporal scale boundaries; 2) establish ecosystem goals and objectives; 3) collect appropriate ecological data; 4) analyze direct, indirect and cumulative impacts on affected resources using appropriate methodologies, such as GIS, classification and mapping of habitats, characterization of terrestrial and aquatic habitat values, and impacts including wetlands.

Section 5.3 focuses on evaluation of cumulative impacts including the following steps, consistent with FHWA framework for considering the incorporation of secondary and cumulative effects into the highway development process: 1) define goals of assessment; 2) set spatial and temporal boundaries; 3) establish the environmental baseline; 4) select the important factors to evaluate; 5) identify the role of impact thresholds; 6) analyze the impacts of the alternatives/proposed action relative to the baseline; 7) recommend mitigation and monitoring.

Finally, ecological mitigation measures are recommended for each of the four phases of highway development.

Southerland, M.T. 1994. Methods, techniques, and tools for analyzing cumulative effects. Conf. Proc. New Dimensions of EA Practice Panel: Concept and Approaches to Cumulative Effects. 14th Ann. International Association of Impact Assessment. Quebec City, Quebec, Canada. 24 pp.

Cumulative effects analysis should be viewed as a richer and more comprehensive environmental impact analysis than that for direct or indirect impacts, using the same types of methodologies, and not as a separate process. Developing a conceptual model for cumulative impact analysis generally involves qualitative methods (scoping), including information gathering techniques, checklists, mapping, identifying past present and future actions, and identifying cause and effect pathways and networks. The primary methods for determining impacts include models, matrices, tables, map overlay techniques, and remote sensing. More advanced methods include carrying capacity analysis, ecosystem analysis, synoptic landscape approach, economic impact assessment, and social impact assessment. Tools for illustrating and communicating the results of cumulative impact analyses include dose-response curves, cumulative frequency distribution, and maps. Tools for aiding in conducting cumulative effect analyses include landscape indices that capture ecological and social pressures, habitat evaluation procedures, and expert systems. In general, there is an inverse relationship between the simplicity of the method and sensitivity to detail. Two remaining challenges to improving cumulative impact analysis are developing relevant and precise measures of effects that accumulate to resources and systems, and developing accurate methods of summarizing and evaluating the total cumulative effect on these resources and systems. Table 1 presents the fifteen primary methods and tools discussed in the paper with the strengths and weaknesses of each method.

Smit, B. and H. Spaling. 1995. Methods for cumulative effects assessment. *Environmental Impact Assessment Review*. 15:81-106.

The authors identify two broad approaches to analyzing and assessing cumulative impacts and evaluate the capacity of various methods to address the main components of the conceptual framework: 1) analytic approaches, including spatial analysis, network analysis, biogeographic analysis, interactive matrices, ecological modeling, and expert opinion; 2) Planning approaches, including multi-criteria evaluation, programming models, land suitability evaluation, and process guidelines.

Methods identified as potentially useful include: 1) Geographic information systems for analysis of spatial and to a more limited degree temporal analysis of cumulative environmental change; 2) landscape analysis for spatial and temporal analysis of cumulative impacts within a landscape boundary (requiring detailed inventory data on ecological components and processes); and 3) simulation modeling for providing a simplified emulation of the behavior of a dynamic, complex ecological system. All methods are evaluated considering their capabilities related to spatial and temporal impact accumulations, types of perturbation, and functional and structural change.

Treweek, J. and P. Hankard. 1998. Ecological Impact Assessment. *In:* Environmental Methods Review: Retooling Impact Assessment for the New Century. A.L. Porter and J.J. Fittipaldi, Ed. Army Environmental Policy Institute, the Press Club, Fargo, ND. Pp. 263-272.

Strategic Ecological Assessment (SEA; basically, a term in the United Kingdom for taking a regional or ecosystem-based approach to planning) provides a basis for considering cumulative impacts in a pragmatic way.

U.S. Environmental Protection Agency. 1999. Consideration of cumulative impacts in EPA review of NEPA documents. EPA 315-R-99-002. 22pp. Available at: http://www.epa.gov/compliance/resources/policies/neap/cumulative.pdf

This guidance, prepared by EPA for their Section 309 reviewers, is a practical approach to conducting a thorough review of the adequacy of cumulative impact analyses in NEPA documents. The guidance also provides the requirements for preparing adequate cumulative impact analyses. It covers: 1) how do determine if the appropriate resources have been analyzed; 2) determining spatial and temporal boundaries; 3) identifying and incorporating past, present, and reasonably foreseeable future actions; 4) describing the affected environment; and 5) using thresholds to assess resource degradation. Brief examples are also included.

U.S. Environmental Protection Agency. 2000. Projecting land-use change: A summary of models for assessing the effects of community growth and change on land use patterns. EPA-600-R-00-098. 260 pp.

This guide summarizes 22 computer modeling tools (including point of contact information for each model) applicable to assessing the impacts of community actions and policies on land use and the reciprocal effect of land-use changes on certain community characteristics. The intent is to help planners select the appropriate land use modeling tool to help accomplish Smart Growth planning, focusing on land-use change models. The five-step process for selecting the best land-use model includes: 1) understanding the proposed action; 2) asking the right

questions related to scope and potential direct, indirect, and cumulative impacts; 3) identifying information needs; 4) assessing internal capabilities, including financial, staff, and computer resources available; 5) choosing the right model using factors such as relevancy, sufficiency of available resources, support of the model, technical expertise, data requirements, accuracy, resolution, temporal capabilities, versatility, potential for linkage to related models, public accessibility, transferability to other locations, degree of testing in the "real world."

Wilkinson, C. 1998. Environmental Justice Impact Assessment: Key Components and Emerging Issues. *In:* Environmental Methods Review: Retooling Impact Assessment for the New Century. A.L. Porter and J.J. Fittipaldi, Ed. Army Environmental Policy Institute, the Press Club, Fargo, ND. Pp. 273-281.

Cumulative impact assessment from an Environmental Justice point of view emphasizes effects from multiple and cumulative exposures (exposures from multiple pollutants in one or more locations through various pathways over a period of time) from past, present, and reasonably foreseeable future actions. Analysts should be thoroughly familiar with the populations, using heightened public involvement strategies when necessary. Existing EPA databases associated with NPDES permits, ambient air quality data, and EPCRA-, RCRA-, and CERCLA-related reporting can support cumulative impact analyses.

Williamson, S.C. 1993. Cumulative impacts assessment and management planning: Lessons learned to date. *In:* Environmental Analysis: The NEPA Experience. S.G. Hildebrand and J.B. Cannon, Ed. Lewis Publishers. Pp. 391-407.

The author states that obstacles to effective cumulative impact analysis include: 1) determining appropriate timing, costs, and level of effort; 2) apportioning the cost and responsibility for the assessment and mitigation among participants; 3) coordinating assessment of different types of projects that cross agency jurisdictions; 4) selecting appropriate methods and development scenarios; 5) limited history of application of most of the methods; 6) identifying specific roles for project proponents and interested parties. A cumulative impact assessment should look at a much larger geographic area than typically used for specific projects.

The authors provide four recommendations for resolving theoretical, analytical, and institutional impediments to effective cumulative impact assessments: 1) Emphasize scientific, cause-effect understanding and communication of the overall situation, each problem, and problem interactions; 2) Stress measurable overall action toward progressive goals for each problem (stabilize or improve, rather than evade a deterioration threshold); 3) Use a generation-long, ecosystem-level, problem-solving, and solution-generating process, starting from the potential effects rather than the actions; 4) Use an interagency collaborative and interdisciplinary process toward cumulative improvement of the overall situation.

The recommended cumulative impacts assessment process should use the following steps: 1) During scoping phase, define the specific ecological situation for each resource and select a strategy for each; 2) During analysis phase, investigate and document the problems and their causes in detail using the best available data and analytical tools, then set goals for each; 3) During interpretation phase, develop and document options, estimate changes using ecological models, and develop a plan; 4) During the direction phase, implement and incrementally improve the management plan and systematically evaluate, improve, and update the problem statements, data, analytical tools, and mathematical models.

Cumulative impact assessment and management planning should not only investigate and decrease the ongoing negative effects of human actions, but should also concentrate on exploring and obtaining a more positive overall impact. Selecting a strategy (which level of mitigation identified in the CEQ regulations) involves the following considerations: 1) where the current ecological condition is below acceptable standards, restoration is appropriate; 2) where the current ecological condition is about equal to acceptable standards, impact avoidance (no net loss) is usually chosen; 3) where the current condition is above acceptable standards, allowing some decline by impact minimization may work.

U.S. Environmental Protection Agency. Web Page databases and geographic queries. Where You Live, Envirofacts Data Warehouse, Window to My Environment, EnviroMapper Storefront, Watershed Information Network, Environmental Justice Geographic Assessment Tool. http://www.epa.gov/epahome/whereyoulive.htm

This web page provides the gateway to EPA databases and map-based environmental information, all of which can be easily queried. It is a powerful tool for environmental information as the basis for cumulative impact analysis at local, regional, watershed, and statewide scales.

York, M.L. and A. Spitzer, Florida Atlantic University/Florida International University. 1998. Secondary and Cumulative Environmental Impacts of Transportation Projects; Final Report. *For:* Florida Department of Transportation. Report WPI 0510788 BA 517. 282 pp.

This extensive review of cumulative ands secondary impact analysis from a highway development point of view begins with clear and detailed descriptions of each of the four phases of highway development – planning, planning/environmental management, project development/preliminary design, and operation/development. For each phase, it provides guidance and processes for interagency coordination and public involvement. Because highway development focuses on the "footprint" of the corridor, secondary and cumulative impacts have been difficult to assess. Interviews with a variety of Florida state and federal agencies identified problems with definitions; selecting appropriate methodologies; conducting impact analyses during long range planning; the relationship of broad corridor planning and site-specific planning; developing formal procedures for early review by local governments; early interagency coordination and review (highest need); and data and funding exchanges. Table 1 provides a summary of existing methodologies and guidance documents, and their appropriate phases and agency responsibility, followed by in-depth analysis of each method. Recommendations include: clarifying the definitions of secondary and cumulative impacts; revising state policy and develop methodologies for incorporation of analyses of secondary and cumulative impacts; prepare more in-depth written guidance for conducting secondary (growth induced impacts) and cumulative impacts during the project design phase and during long range planning; develop formal processes for interagency review and conflict mediation; and develop processes for better coordination with local government and land use planning. The appendices include various definitions of secondary and cumulative impacts and case law.