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Abstract

This paper provides a review and evaluation of Minnesota's experience with environmental review of forestry projects, notably using studies like the state's Forestry GEIS as a means for identifying and analyzing cumulative environmental impacts from timber harvesting and forest management. Based on this review, we recommend future cumulative impact assessments of forestry activities in Minnesota should:

- Focus on the identification and assessment of the environmental impacts of alternative levels of statewide timber harvesting and forest management activity.

- Recognize the complex dynamics of forest ecosystems and their management, and provide a thorough interpretation of findings for diverse audiences. In particular, avoid absolute determinations that are inherently based on numerous assumptions, for example, the specification of a maximum sustainable harvest.

- Build in the flexibility to evaluate environmental impacts at varying spatial scales. Some impacts are best described at statewide levels (e.g., changes in the projected habitat of rare and endangered wildlife species) whereas others are best described at multiple scales (e.g., water quality, forest age-class and covertype distributions).

- Recognize that assessments are based on sample data, models and human judgment and therefore incorporate uncertainty. As a result, great detail and accuracy is neither possible nor should it be expected for every regional, subregional, and essentially local environmental assessment.

- Focus on statewide analyses for assessing forest management and harvesting environmental impacts, reflecting the fact that woodsheds (the area from which a firm may draw timber) have grown in size in response to competition among firms, locally changing forest conditions, and improved transportation systems.

- Limit projections of forest resource conditions and associated environmental impacts to no more than 20 years into the future; projections beyond that time frame are highly speculative and time consuming in their construction.

- Limit the forest resource characterization and projections to those variables that drive future conditions and impacts, i.e., (1) forest area, (2) forest area by cover type, (3) forest area by cover type and age or stand size class, and (4) harvest by tree species, cover type and harvesting method.

- Identify and incorporate changes in forest conditions due to natural causes (e.g., decline of a cover type due to natural conversion to another type), to the extent possible, in projecting environmental change and associated impacts.

- Exclude those changes due to natural causes from any assessment of project-induced mitigation requirements.

- Evaluate a range of (preferably no less than three) statewide timber harvesting scenarios, including one scenario that reflects a reduced level of timber harvesting over what exists at the time such a study is commissioned. These scenarios should reflect, to the extent possible, realistic current and likely future conditions such as future wood fiber demand by tree species (possibly product classes), mill procurement areas, utilization practices, management and harvest policies and practices, existing laws and rules governing timber harvesting and forest management, and explicit and implicit agency environmental policies and practices.

- Recognize and clarify that none of these scenarios are a *plan* for forest management. Individual, industry and government ownerships will still seek to develop site specific and overall operational plans for their ownerships in a manner that may meet, exceed or fall short of the projected scenario results for their ownership category or overall.

- Focus on those forest resources and related values that were found in the Timber Harvesting GEIS to be most measurable and sensitive to harvesting. These include describing how harvesting activity impacts the extent (acreage), composition (covertypes and species), and structure (age-class distribution) of Minnesota's forest resources, as well as changes in the availability and quality of forest-based wildlife habitat.

- Develop an integrated data base that has explicit links between its various data components (e.g., forest inventory, future resource conditions, and wildlife habitat).

- Provide a synthesis of knowledge rather than a set of detailed research studies or resource assessments.

- Use the significance criteria developed in the Timber Harvesting GEIS as the basis for identifying significant environmental effects, with significance criteria distinguishing no less than a ten percent change in resource or environmental conditions and reviewed and updated to reflect new scientific information not available at the time it was developed.

- Emphasize the use of this study's information to improve program components (e.g., recommendations for managing riparian forests) and delivery (e.g., the correct application of site-based forestry practices). The findings from cumulative forestry impact assessments should inform forest-related research and monitoring activities. Research needs may include areas such as silviculture, forest planning tools, or policy analysis. Relevant monitoring needs include periodic assessments of the application and effectiveness of site-level timber harvesting practices, and surveys of silviculture and related forest management practices.

- Provide study results in considerably less time than the 52 months required to prepare the Timber Harvesting GEIS and at regular intervals: (1) every decade; or (2) when future statewide timber harvesting activity is projected by the state to change (either increase or decrease) by more than 25 percent over current levels and projected to be sustained at that level of change for at least a decade.

In addition to understanding global economic trends, knowledge of the cumulative environmental impacts of forestry activities is increasingly viewed as a *necessary* condition for the continued viability of a state's forest resources and forest-based industry. Formal studies of such impacts play a very important role in state forest resource policy by providing a venue for systematically quantifying possible future forest and related conditions under a range of management and investment alternatives. Additionally, considerable attention and resources need to be directed to the many components of such assessments. These components include not only the development and refinement of data, models, and related tools needed to conduct cumulative impact analyses, but also the support from a wide range of state forest resource interests for making these assessments a priority.

1 Introduction

Cumulative environmental impact is defined as the incremental effect of an action when considered within the context of other past, present, and reasonably foreseeable actions that are similar in nature (CEQ 1978, 1997). In a forestry context, cumulative environmental impacts can result from the collective activity of individual forest management and timber harvesting activities that occur across a forested landscape over time (Jaakko Pöyry 1994). Although an individual activity (i.e., a logging operation) may impose relatively benign environmental consequences, the cumulative nature of these activities in repetition over time and space can be substantial for one or more forest resources.[1]

Given the possibility for cumulative impacts to occur, it is important to assess such impact potentials in environmental review documents. One reason for doing so is that forestry projects may draw timber from many small site-specific harvesting operations located across large areas of the state and with harvesting conducted annually. For example, the current statewide annual timber harvest affects approximately one percent of the commercially-available forestland annually. Thus, the cumulative acreage affected over a decade can be substantial. A second reason is that just *how* such harvesting is conducted can increase or reduce the actual impact (i.e., harvest planning, harvesting equipment, tools and practices offer options that can avoid or provide substantial mitigation for some impacts). However, forests are complex systems with many biotic and abiotic interactions that are difficult to observe and fully quantify (e.g, forest health and diverse land ownership types with their many different management objectives).

Complicating environmental review is the fact that forests are valued in diverse ways by society. They are deemed by some as highly robust to natural and human-caused disturbances and yet highly fragile ecosystems by others. At the same time, there are few natural or widely accepted measures and standards for review of changes in forests over large areas. In fact, there are many variables or aspects of interest.

The past two decades have seen much contention over large forest based industry projects and their associated environmental review. Also, both the review processes and their duration have come under increasing scrutiny. Given this situation, the intent of this paper is to review and evaluate Minnesota's experience with environmental review of forestry projects, notably using studies like the state's GEIS on Timber Harvesting and Forest Management (Timber Harvesting GEIS) as a means for identifying and analyzing cumulative environmental impacts from timber harvesting and forest management. In Section 2.1, the legal framework for conducting environmental review in Minnesota is described. In Sections 2.3 and 2.4, we describe the Timber Harvesting GEIS. Additionally we discuss the impact this study had on state forest resource policy and program development, as well as the use of its information in facilitating environmental review of specific forest industry economic development proposals. In Section 3, we offer our observations and recommendations on how future GEIS-type studies that assess the cumulative impacts of timber harvesting and related forest management activities might be prepared. Specifically, we identify the key attributes of such a study and describe how each was

[1] **Minnesota Statutes 89.001 Definitions…"Forest resources**" means those natural assets of forest lands, including timber and other forest crops; biological diversity; recreation; fish and wildlife habitat; wilderness; rare and distinctive flora and fauna; air; water; soil; and educational, aesthetic, and historic values."

addressed in the GEIS, assess the major strengths and weaknesses of the GEIS with respect to this study attribute, and offer considerations (recommendations) for more effectively incorporating it in future cumulative impact assessments are provided. As persons who were intimately involved with the preparation of the Timber Harvesting GEIS and its subsequent uses, we comment both on the process and its effectiveness and implications from the standpoints of strengths, limitations, and unintended consequences.

2 Cumulative Forestry Impact Assessments

2.1 Legal Framework in Minnesota

Nationwide, 15 states have adopted comprehensive environmental review policies and procedures to guide economic development activities within the state (Ma 2006). In general, these state laws function similar to their national counterpart – the National Environmental Protection Act (NEPA) – in that they require an analysis and disclosure of the environmental impacts associated with proposed projects that meet minimum thresholds for development (e.g., acres affected). Such analyses are typically required prior to decisions regarding requisite building or operating permits (e.g., air and water pollution discharge).

In Minnesota, the state's guiding policy for environmental analysis and impact assessment is the Minnesota Environmental Policy Act (MEPA) (MS §116D) (Minnesota Statutes 2006). This legislation establishes a state public policy goal:

> "…to create and maintain conditions under which human beings and nature can exist in productive harmony, and fulfill the social, economic, and other requirements of present and future generations of the state's people" (MS 116D.02, subd. 1).

To achieve this goal, the act establishes a general framework for the preparation and use of environmental review documents associated with economic development actions within the state. These are typically environmental assessment worksheets (EAW—a brief document generally prepared to determine whether a more comprehensive environmental impact statement for a proposed project is needed) and environmental impact statements (EIS—a detailed document identifying and describing the environmental impacts of a proposed project and alternative measures that can be taken to mitigate significantly adverse impacts). State rules (MR Chapter 4410) specify in detail the technical and procedural aspects (e.g., actions/thresholds subject to environmental review, environmental review document form and content, and processes) associated with implementing the environmental review procedures established by MEPA. Collectively, MEPA and state administrative rules that govern its implementation provide the legal framework for environmental review for nearly all development activity in Minnesota.

Minnesota Rules (Chapter 4410.3600) also authorize the use of alternative forms of environmental review for certain types of projects where environmental impacts cannot be adequately addressed through a conventional environmental assessment worksheet or environmental impact statement. One such form is a "generic EIS" (MR Chapter 4410.3800), which can be ordered to study the types of projects that are not adequately reviewed on a case-

by-case basis. State rule specifies several criteria that are used to determine when a generic EIS is to be prepared. However, little guidance is given with respect to the form or content of a generic EIS. The criteria include:

- If the review of a type of action can be better accomplished by a generic EIS than by project specific review.
- If the possible effects on the human environment from a type of action are highly uncertain or involve unique or unknown risks.
- If a GEIS can be used for tiering in a subsequent project specific EIS.
- The amount of basic research needed to understand the impacts of such projects.
- The degree to which decision makers or the public have a need to be informed of the potential impacts of such projects.
- The degree to which information to be presented in the generic EIS is needed for governmental or public planning.
- The potential for significant environmental effects as a result of the cumulative impacts of such projects.
- The regional and statewide significance of the impacts and the degree to which they can be addressed on a project-by-project basis.
- The degree to which governmental policies affect the number or location of such projects or the potential for significant environmental effects.

In general, a generic EIS (GEIS) differs from project-specific environmental impact statements (EIS) in the following four ways: (1) a GEIS focuses on cumulative impacts associated with a number of separate, but related activities whereas an EIS examines the environmental impacts associated with a single, proposed action; (2) preparation of a GEIS is always discretionary whereas specific thresholds exist for preparation of an EIS; (3) a GEIS focuses on developing recommendations (primarily policy and program) whereas an EIS does not recommend which alternatives it examined are preferred; and (4) the responsibility for paying for a GEIS is not specified in rule whereas the responsibility for the cost of preparing a project-specific environmental review document is that of the project proposer.

2.2 Operational Framework – The Timber Harvesting GEIS

The only cumulative assessment of forestry-related impacts that has been conducted in Minnesota was a generic-EIS on timber harvesting and forest management (Timber Harvesting GEIS). This voluntary GEIS was prepared in response to a citizen petition that was submitted to the Minnesota Environmental Quality Board (EQB) in 1989. The petition sought action to address a potential increase of nearly one million cords in annual timber harvesting activity associated with a proposed $2.2 billion increase in the state's primary wood processing plant capacity during the late 1980s (Kilgore 1992). Forestry professionals, interested citizens, and environmental activists recognized that dramatic changes might occur in Minnesota's forests as a result of such capital investments. Harvest rates were increasing, especially for aspen and oak resources. At the time, statewide forest inventory information was seriously out of date, raising uncertainties about the long-term sustainability of the state's timber harvest and certain forest conditions. The consequences of timber harvesting on the environment were also uncertain, especially for complex ecological interactions occurring over large geographically areas.

Additionally, citizen interest in the value of forests as a source of recreational opportunities, aesthetic beauty, and diverse populations of plants and animals was growing. Together, these issues heightened concern to the point of EQB action.

The EQB commissioned the GEIS in December 1989 and identified itself as the responsible government unit (RGU) in charge of overseeing its development. In doing so, the EQB identified three primary objectives for the Timber Harvesting GEIS, namely: (1) determine the extent of timber harvesting and related timber management activities in Minnesota; (2) identify and assess the environmental and related impacts of timber harvesting; and (3) recommend strategies to mitigate adverse impacts where such are found to be significant. Furthermore, the EQB was to accomplish these objectives within the context of three levels of annual statewide timber harvesting: the current level that existed in 1991 (approximately 4.0 million cords); the level expected if all plant expansions announced or under consideration became operational (4.9 million cords); and the level expected if timber harvesting rose to an assumed maximum biological yield of the state's forests (7.0 million cords).

With the aid of a citizen advisory committee and a series of public hearings around the state, the EQB identified ten major issues for analysis. These included water resources, forest soils and productivity, wildlife populations and their habitat, state and regional economic impacts, plant and animal diversity, recreational opportunities, and aesthetic and cultural resources. The GEIS was prepared by an EQB-employed consulting firm that assembled more than 60 scientists representing a wide range of academic disciplines. Thresholds beyond which timber harvesting was considered to have a significantly adverse impact on natural environments were defined through a blend of technical information and the values and perceptions of project staff and the citizen advisory committee. Additionally, numerous impact-specific mitigation strategies were identified to address those impacts that were determined to be significantly adverse.

The GEIS also identified major policy and program initiatives that would be needed to mitigate the environmental impacts projected. These included a:

- **Forest Practices Program** – to mitigate the adverse impacts of timber harvesting occurring at the site level.
- **Sustainable Forestry Program** – to sustain the integrity of large areas of forest land involving multiple owners and ecosystems through which monitoring and coordinating actions (i.e., the landscape level).
- **Forest-Based Research Program** – to provide the information required to successfully implement the forest practices and sustainable forestry programs.
- **Forest Resources Board** – to secure broad stakeholder involvement in forest policy decision-making.

The Timber Harvesting GEIS was prepared at a contract cost of approximately $1 million dollars over a five year period. The state also incurred project management and oversight costs totaling several hundred thousand dollars. The study generated the following documents:

- **Full Scoping Document (FSD)** –Identified the issues to be studied in the GEIS (prepared by the state; the remaining documents noted here were prepared by the contractor). The FSD also served as the basis for a request for proposals to conduct the work.

- **Work Plan** – Detailed the study's data sources, methodology and timelines.
- **Statewide Timber Harvesting Scenarios** – Described the three harvesting levels used to help identify probable impacts for all FSD issues.
- **Study Significance Criteria** – Specified thresholds when environmental impacts were considered to be significantly adverse, thereby necessitating the development of mitigation alternatives.
- **Technical Papers** – Nine stand-alone studies totaling approximately 3,000 pages that addressed the FSD technical issues of concern. Technical papers were developed for the following issue areas: biodiversity, economics and management issues, forest wildlife, forest health, forest soils, maintaining productivity and the forest resource base, recreation and aesthetic resources, unique historical and cultural resources, and water quality and fisheries.
- **Background Papers** – Five support studies totaling approximately 1,000 pages were prepared to address other identified areas of interest specified in the final scoping decision: global atmospheric change, harvesting systems, public forestry organizations and policies, recycled fiber opportunities, silvicultural systems.
- **Draft GEIS** – This document integrated the information contained in the various technical and background papers to identify and describe likely timber harvesting impacts at the three different timber harvest scenarios analyzed. It also identified alternative impact-specific and programmatic mitigation strategies to address the significantly-adverse impacts.
- **Final GEIS** – This document incorporated and considered extensive public comment on the draft GEIS. The resulting final document was deemed adequate (formal acceptance of Final GEIS) by the MN EQB in April 1994.

2.3 Timber Harvesting GEIS Use in Planning, Policy Development, and Environmental Review

Since its completion in 1994, the Timber Harvesting GEIS has played an extremely important role in shaping state forest resource policy and programs, as well as providing information for use in environmental review documents for several of the state's primary forest products industry expansions or modernizations.

2.3.1 Development of State Forest Resources Policy

While the Timber Harvesting GEIS provided considerable technical analysis and perspective on the ecological impacts associated with timber harvesting, it provided little strategic guidance on how such mitigation measures should be implemented in a coordinated manner. To develop further details on the implementation of the major GEIS recommendations, a roundtable of 26 state forest resource interests was convened in 1994 at the time the Final GEIS was formally accepted by the EQB. The recommendations of the roundtable for implementing the site-level and landscape-based recommendations contained in the GEIS became the basis for the implementation actions specified in the Minnesota Sustainable Forest Resources Act (SFRA) (MN § 89A) which was enacted in 1995 (Minnesota Statutes 2006). Building on the analysis and mitigation strategies recommended in the GEIS, the SFRA articulated the following four main goals for the sustainable management and use of Minnesota's resources:

- Pursue the sustainable management, use, and protection of the state's forest resources to achieve the state's economic, environmental, and social goals.
- Encourage cooperation and collaboration between public and private sectors in the management of the state's forest resources.
- Recognize and consider forest resource issues, concerns, and impacts at the site and landscape levels.
- Recognize the broad array of perspectives regarding the management, use, and protection of the state's forest resources, and establish processes and mechanisms that seek and incorporate these perspectives in the planning and management of the state's forest resources (Minnesota Statutes 2006).

The SFRA established and defined the institution responsible for coordinating implementation of the Timber Harvesting GEIS recommendations: the Minnesota Forest Resources Council (MFRC). In doing so, the act encouraged the Council to form partnerships with appropriate stakeholders whenever possible.

2.3.1.1 Comprehensive Timber Harvesting and Forest Management Guidelines

The SFRA directed the MFRC to coordinate the development of comprehensive timber harvesting and forest management site-level guidelines. Guided by this legislation, the MFRC subsequently developed guidelines for conducting timber harvesting and forest management practices in and adjacent to forest riparian zones, protecting forest soils, perpetuating forest wildlife habitat, and protecting historical and cultural resources. These new guidelines were integrated with the state's existing water quality and visual management guidelines to produce a comprehensive set of voluntary practices for protecting important forest resource uses and values when conducting timber harvesting and forest management operations (Minnesota Forest Resources Council 1999).

2.3.1.2 Forest-Based Landscape Level Planning

The Timber Harvesting GEIS recommended the development of landscape-level responses to address potential timber harvesting and forest management-related issues that may occur on a geographically large scale and/or encompass multiple forest landowners. In doing so, it defined landscape level responses as broad-based solutions to address the cumulative effects of individual site-level practices. Typical landscape level responses were those which require extensive planning and/or cross-ownership coordination to achieve intended local, regional or, in some instances, statewide objectives.

The administrative mechanism recommended for addressing landscape-level responses was the establishment of a sustainable forest resources program. The objective of this program would be to facilitate a statewide structure for: identifying existing forest resource conditions, evaluating these conditions in light of forest trends, determining the desired future forest conditions, identifying and developing specific strategies necessary to achieve those desired future forest resource conditions, and providing feedback to assess the success in achieving those objectives.

The SFRA codified the landscape-level goals and objectives recommended in the Timber Harvesting GEIS. The overarching objective of this initiative was to establish a framework that enables long-term strategic planning and landscape coordination to occur. The act specified that

regional landscape committees would be the primary vehicle for landscape planning and coordination activities. The SFRA provided direction on the composition and activities of regional committees. Specifically, they were to be inclusive of the interests of the community and serve as a forum for stakeholders to discuss forestry issues of regional significance in an open and public process. The work of regional landscape committees was to be integrated with other forest resource planning efforts, facilitate coordination of forest planning and management, facilitate public participation, set goals and strategies to achieve the goals, and communicate regional interests to the MFRC (Kilgore et al. 2005).

2.3.1.3 Forest Resources Research

The Timber Harvesting GEIS recommended development of a Forest Resources Research Program to develop information that would support effective mitigation implementation. In response, the SFRA recommended the establishment of a forest resources research advisory committee. This committee, established by the MFRC, was responsible for identifying forest resources research needs in the state, encouraging and supporting the undertaking of this research, and fostering coordination and collaboration between researchers and natural resource managers.

2.3.1.4 Monitoring

The Timber Harvesting GEIS acknowledged the need for several types of monitoring programs. Through the SFRA, several monitoring initiatives were authorized. Specific monitoring activities that have been carried out on a recurring or one-time basis include monitoring the implementation of timber harvesting and forest management guidelines, trends and conditions in the state's forest resources, timber harvesting practices and associated conditions in forested riparian areas, and silvicultural practices.

2.3.1.5 Education and Training

The Timber Harvesting GEIS also played an important role in highlighting the need for continuing education for the state's natural resource professionals. As directed by the SFRA, the MFRC encouraged early collaboration with the Minnesota Logger Education Program (MLEP) to establish guideline training as a continuing element of logger education. The MFRC also provided seed money to help establish the Center for Continuing Education (CCE) in the College of Natural Resources at the University of Minnesota. The stated objective for the CCE was to promote excellence in natural resource management through educational opportunities.

2.3.2 Context for Subsequent Project-Specific Environmental Review

State rule specifies that governmental units responsible for preparing environmental review documents need to consider information from an available GEIS through "tiering," a process in which information from a GEIS is incorporated into project-specific environmental documents. Incorporating information from a GEIS into project-specific environmental review documents can only occur if the GEIS is considered by the EQB to be "adequate" at the time the specific project proposal is subject to environmental review. This is separate and distinct from the procedural determination of adequacy rendered by the EQB at the time a GEIS is originally prepared. Since its completion in 1994, the Timber Harvesting GEIS has been used in the preparation of three environmental review documents associated with primary forest products industry expansion proposals in Minnesota. The first two such documents were EAWs, prepared

in conjunction with plant expansion proposals at the Potlatch OSB mill in Cook (1996) and Boise Cascade pulp and paper mill in International Falls (2000). In both cases, information contained in the Timber Harvesting GEIS was referenced or briefly discussed in the environmental review documents within the context of timber harvesting activity associated with the economic development proposal being considered. The adequacy decisions associated with both environmental review documents were subject to legal challenges, with the original adequacy decisions subsequently upheld by the courts.

The latest environmental review document to incorporate information from the Timber Harvesting GEIS was an EIS completed in 2006 for the proposed expansion of the Blandin Paper Company paper mill in Grand Rapids. In contrast to the two earlier EAWs, this document more fully integrated the information from the Timber Harvesting GEIS with respect to forest condition projections, the identification of potentially significant cumulative impacts; and recommended programmatic mitigation responses. Specifically, it: (1) compared forest condition projections (cover type and age class distributions) between the Timber Harvesting GEIS and the modeling conducted for the EIS; (2) compared forest condition projections for both its build and no-build alternatives in terms of the 17 significant impacts projected in the Timber Harvesting GEIS; and (3) assessed the sustainability of the projected harvest levels for the project's build alternative in terms of the implementation of the GEIS Strategic Programmatic Response as authorized through the SFRA and as outlined in sections 2.3.1.1 - 2.3.1.5 (HDR Engineering 2006).

3 Observations/Recommendations for Future Cumulative Forestry Impact Assessments

The Timber Harvesting GEIS represents the state's most comprehensive attempt to identify and evaluate the cumulative impacts of timber harvesting and forest management on the state's forest resources. In 2005, the EQB determined the Timber Harvesting GEIS was no longer adequate for the purposes of tiering within the context of project-specific environmental review (EQB 2005). Consequently, an update of the existing GEIS, portions thereof, or the preparation of a new GEIS-type study to assess the cumulative effects of forestry related activities on the state's forest resources, will likely be needed in the near future.

The following describes a recommended framework for preparing future GEIS-type studies that assess the cumulative affects of timber harvesting and related forest management activities. This framework is focused on key study attributes and is informed by findings of the GEIS Report Card Study (Kilgore et al., 2005), a review and analysis of the original Timber Harvesting GEIS and associated documents (e.g., scoping document, work plan, study significance criteria, and technical and background papers), and the authors' experiences with these activities. For each key study attribute considered, this report provides a description of how it was addressed in the GEIS, an assessment of major strengths and weaknesses relative to how it was addressed in the GEIS, and considerations and recommendations for more effectively incorporating it in future cumulative impact assessments.

3.1 Study Purpose

3.1.1 Timber Harvesting GEIS

As specified in the GEIS final scoping decision, the objectives of the study were to:

1. Develop a basic understanding of the status of timber harvesting and related forest management activities in Minnesota, and how this level of statewide activity relates to long-term sustainable levels of timber removals.
2. Identify and assess the environmental and related (i.e., economic and social) impacts associated with current and potential elevated levels of statewide timber harvesting and forest management activity.
3. Develop strategies to mitigate potential significant adverse impacts that are identified.

3.1.2 Assessment of Timber Harvesting GEIS Strengths and Weaknesses

The Timber Harvesting GEIS accomplished all three study objectives as described in the scoping document, although it focused primarily on the second and third objectives. With respect to objective 1, the study provided the most comprehensive study to date (and probably since) in terms of understanding the level and type of timber harvesting and forest management activity occurring across all forest ownership groups in the state. The detail developed on the status and condition of forests and timber harvesting in the state effectively elevated the discussion from conjecture about future forest resource conditions and associated management and harvesting activities to a high and technical plane of discourse. The detail was more than most stakeholders anticipated.

In responding to objective 1, the study also identified an upper level of timber harvesting activity of approximately 5.5 million cords per year that presumably could be sustained indefinitely given then current management and harvesting practices plus implementation of mitigations. However, communicating this exercise and the results proved to be problematic. Considerable confusion existed (and still exists today) regarding the assumptions associated with making this upper limit estimate (e.g., did it represent current forest productivity levels, or was it the maximum productivity possible under certain forest management investment scenarios? To what extent was level and timing of mitigation implementation crucial to support this estimate?). Because forest growth and change are dynamic, any sustainable timber harvest activity estimate will also change over time. These dynamics are a fundamental understanding among forest resource analysts. However, they are quite technical and not well understood among all audiences seeking forest growth and change information. Further, the biological and economic factors that underlie the assumptions in harvest activity estimates were simply not well understood by many stakeholders involved in the GEIS's development or its subsequent interpretation. Consequently there has been continuing confusion on this aspect of the study, i.e., long-term sustainability for various harvest levels.

3.1.3 Considerations for Future Cumulative Forestry Impact Assessments

In as much as the Timber Harvesting GEIS sought to incorporate economic and social information and related implications, such clarification proved to be problematic at best. This result was not because the economic and social information was lacking, but rather because the capacity to *integrate* economic and social impacts with environmental impacts was limited. This

capacity limitation is, in part, due to the confusion in interpreting the study results noted in the previous section (e.g., impacts on the habitat of certain wildlife species). However, even with that capacity, resolving the fundamental trade-off between economic development and environmental protection is at the core of most debates of natural resource use and protection—it is largely a value-driven examination that is best developed outside of a largely technical environmental impact study. Such was the case with the Timber Harvesting GEIS.

Additionally, in-as-much as many interest groups and policy makers wanted a "bottom-line" answer of how much timber harvesting activity in Minnesota was sustainable, future cumulative forestry impact assessments should avoid making such a pronouncement of a maximum sustainable harvest level for the reasons previously described. Even estimating the maximum level of timber harvesting that can be sustained when timber production is the sole management objective can be problematic. Incorporating complex constraints such as environmental objectives and agency management policies and practices makes developing such an estimate even more challenging. In reality, a definitive answer of what maximum level of harvest can occur while sustaining important nontimber resources and values will be elusive at best and more likely impossible. Thus, offering an estimate will lead to clarity or confusion, depending on the audience.

Given the above difficulties in conducting and conveying such studies, a clear focus and thorough articulation of findings is an imperative. Specifically, priority should be given to identifying and describing the environmental impacts of alternative statewide timber harvest levels.

3.2 Geographic Focus

3.2.1 Timber Harvesting GEIS

The Timber Harvesting GEIS considered all forest lands and resources within the state's boundaries in determining statewide cumulative environmental impacts. This included commercial forest lands (timberlands), reserved, and unproductive forests. Emphasis was on examining the cumulative impacts of timber harvesting and forest management activities occurring on all timberlands in Minnesota. This included, to the extent possible, all public forest lands owned and/or managed by federal, state, county, or municipal governments as well as forest land owned by industrial and nonindustrial private interests. Cumulative impacts were assessed statewide and, where it was possible, within each of the state's seven ecoregions. These ecoregions were geographic regions with similar physical and biophysical characteristics and were defined by the Upper Great Lakes Biodiversity Committee. At the time the study was commissioned, these were the most widely acceptable ecologically-based sub-state regions. Data availability and precision limited the extent to which impacts could be quantitatively assessed at an ecoregion level for certain issues. Additionally, some of the analysis was performed using smaller geographic units than ecoregions. When these finer scale analyses were performed, the results were aggregated and reported at an ecoregion scale. Unfortunately, as smaller areas are considered, the errors increase, yet results are typically assumed to be without error.

3.2.2 Assessment of Timber Harvesting GEIS Strengths and Weaknesses

The use of sub-state regions (ecoregions) was needed to satisfy the FSD objectives of providing a scale of resolution that was broad enough to adequately identify and describe cumulative timber harvesting effects, yet detailed enough to substantiate the analysis and to enable development of appropriate strategies to avoid and/or ameliorate the identified environmental impacts. The use of ecoregions enabled the study to present the information (conditions, impacts, mitigations) in a fairly uniform format across issue areas (e.g., wildlife habitat, water quality). In some instances, the study reported economic, social, and other related impacts using other types of regional subdivisions (e.g., counties). The use of ecoregion-level analysis also enabled a greater focus and clarity on the mitigation strategies needed to address environmental impacts. In several instances, the Timber Harvesting GEIS described environmental impacts and the associated mitigation strategies to specific ecoregions within the state where the impacts were likely to occur.

Using ecoregions to describe timber harvesting and related impacts also enabled this information to be more readily incorporated in subsequent project-specific environmental review documents. The Thunderhawk EIS, which was prepared in conjunction with the possible expansion of the Blandin Paper Company paper mill in Grand Rapids, Minnesota, was such an example. The Thunderhawk EIS integrated the Timber Harvesting GEIS impact analyses for those ecoregions likely to be impacted by wood procurement operations into its assessment of the likely environmental effect associated with the mill expansion proposal. Unfortunately, the Thunderhawk EIS perpetuated the myth that the magnitude of all of the environmental impacts identified was equally accurate, regardless of geographic scope considered, and therefore equally subject to the need to consider or not consider mitigation.

3.2.3 Considerations for Future Cumulative Forestry Impact Assessments

As was found in the Timber Harvesting GEIS, some impacts are best described at statewide levels (e.g., changes in the projected habitat of rare and endangered wildlife species) whereas others are best described at multiple scales (e.g., water quality, forest age-class and covertype distributions). Considerable advancements have been made in modeling and analysis technology since the Timber Harvesting GEIS was prepared 15+ years ago, which should facilitate a more flexible approach to incorporating variable spatial scales in cumulative forestry impact assessments. Yet, great detail and accuracy should not be expected for regional, sub-regional, and essentially local environmental assessments. While boundaries based on ecological constructs will likely be the major focus of any such substate analysis of environmental impacts, assessments should be flexible enough to incorporate changing boundaries and the use of boundaries that are not ecologically based. In fact, ecologically based and other boundaries are inherently human judgments—they are the product of models based on diverse data and decisions, not unchanging certainty. Importantly, ecologically based models have increasingly sought to define boundaries and regions that are so small, any modeled disturbance (human-induced or natural) would predict extreme changes in ecological conditions within these boundaries (e.g., wildlife habitat changes). Consequently, environmental analyses based upon such modeling exercises would effectively preclude any economic development activity.

Additionally, deference to statewide analyses for evaluating forest-based management and harvesting environmental impacts reflects the fact that woodsheds (the area from which a firm

may draw timber) have grown in size in response to competition among firms, locally changing forest conditions, tree species substitution in manufacturing, and improved transportation systems. With these changes, large mills today draw timber from several to many states and provinces. Thus, it may be impractical to define a wood or fiber supply area as a simple radius or otherwise precisely defined around a manufacturing facility.

Given these complex geographic considerations, future cumulative forestry impact assessments would be most instructive if they build in the flexibility to evaluate environmental impacts at varying spatial scales.

3.3 Temporal Planning Horizons

3.3.1 Timber Harvesting GEIS

All three scenarios projected the spatial and temporal distribution of timber harvesting activity that might occur across the state over a 50-year planning horizon. This included projecting what tree species might be harvested as well as when and where harvesting activity would occur. The USDA Forest Service's Forest Inventory and Analysis (FIA) database served as the primary data input for modeling these three scenarios (Jaakko Pöyry 1992). The 1990 FIA data (13,536 forested field plots and other information) provided a statistical sample of existing forest conditions including estimates for location, types and extent of tree species and covertypes present, timber volume, growth, and mortality and various site, stand, surrounding area descriptors and ownership. These data were assumed to represent Minnesota's forest resources at the time the study was conducted.

3.3.2 Assessment of Timber Harvesting GEIS Strengths and Weaknesses

The 50-year timeframe used in the study was both helpful and limiting. On the positive side, this long horizon enabled the Timber Harvesting GEIS to evaluate more fully how the state's forests would respond to a set of harvesting and management prescriptions; much more so than if a substantially shorter period of time were used. Yet, associated with this time horizon was a decrease in the precision of any estimates that were made. The GEIS Report Card Study's retrospective assessment of the accuracy of the GEIS projections of forest change (as measured by forest covertype and age class distributions) found that Minnesota's forests had responded largely as projected in the Timber Harvesting GEIS a decade earlier. Still, the dynamics associated with forest growth and change, inability to predict the occurrence of major events that can substantially alter forest conditions (e.g., windstorms, wildfire, insect and disease outbreaks), and uncertainty regarding economic conditions that impact wood products demand and harvesting patterns and practices limit the accuracy of long-term projections of forest resource conditions. Importantly, long term projections truly push the limits of modeling capability and increase the chance of estimation error from the various sources noted.

3.3.3 Considerations for Future Cumulative Forestry Impact Assessments

The fact that a computer model allows long term projections does not, by itself, make them useful. Instead they may provide a sense of knowing and certainty when there is little or no basis for such belief. Given the uncertainties involved in such modeling exercises, future cumulative forestry impact assessments for one or two decades ahead appear to offer important insights. However, longer projections become increasingly questionable. Consequently, we suggest

limiting projections of forest resource conditions and associated environmental impacts to no more than 20 years into the future. We make this recommendation, recognizing that such a study timeframe may not be long enough to capture the extent of forest change needed to fully assess the environmental effects. However, given the tradeoffs associated with short versus long-term project horizons, we believe that limiting future projections to no more than 20 years will produce reliable and accurate assessments that will also provide important direction for both mitigations and for interpretations beyond that time frame. Additionally, we suggest a limitation on forest resources characterization and projections to those variables that drive future conditions and impacts, i.e., (1) forest area, (2) forest area by forest cover type, (3) forest area by forest cover type and age or stand size class, and (4) harvest by tree species and forest cover type. If the first three do not appear to change much, then most of the change and impact will be modest. Where such changes are large and due to harvest, then the identified impacts will be large and suggest mitigation will need to be addressed. Adopting this time frame and focus on drivers will also favor modeling approaches that are simpler and faster than that used in the Timber Harvesting GEIS and thereby speed the overall assessment.

Further, changes due to natural causes (e.g., decline of a cover type due to natural conversion to another type) should be incorporated into the study, to the extent possible, in projecting environmental impacts. However, these natural changes should be excluded from any assessment of project-induced mitigation requirements. This exclusion is important since inclusion would be a violation of an important project analysis principle, namely evaluating conditions *with versus without the project* (as opposed to conditions before versus after the project). The proposer (in environmental review) should not be held responsible for environmental changes they have played no direct role in shaping.

3.4 Timber Harvesting Scenarios Examined

3.4.1 Timber Harvesting GEIS

Three harvesting scenarios were to analyze environmental and related impacts at three distinct levels of timber harvest intensity. These scenarios model the timber supplies needed to meet the existing levels of demand (4 million cords/ annum), a demand level projected to occur if all planned or announced industrial developments take place (4.9 million cords/annum); and a hypothetical high level of demand that would require harvesting 7 million cords of wood per annum statewide. These three are referred to as the *base, medium,* and *high* harvest scenarios, respectively.

All three scenarios of future timber harvesting activity were projected over the study's 50-year planning horizon. Further, each scenario had to be prepared at a scale that would yield the following categories of information for each harvesting level:

- Where and how timber harvesting and forest management activities would need to occur to meet the specified demand level associated with that scenario.
- A plausible schedule for harvesting over the 50-year study period to meet the level of timber demand assumed.
- Likely changes to the forest resource base, notably the distribution of forest age class and species composition.
- The structure of the state's forests during and at the end of the period being assessed.

- Projections of the proportion of the specified level of timber harvest that would be produced by the various forest ownership categories (i.e., federal, state, county, industry, family).

The Timber Harvesting GEIS used an analysis of the three EQB-specified levels of harvesting as a surrogate for an analysis of project-specific alternatives when assessing impacts. The base and medium harvest scenarios were derived by summing demand for wood from existing or planned industry facilities. The locations of these industry facilities and the volumes and types of wood they required was known. The high harvest scenario specified additional harvesting activity needed to reach a level that was assumed to be the long-term maximum sustainable level of harvest from the state's forests (Jaakko Pöyry 1992, 1994).

The base and medium harvesting scenarios were developed to match the demands from specific industries with the capacity of the forests to meet that demand. Harvesting operations and associated forest management activities were scheduled for individual stands in a way that made the most economic sense (i.e., least cost overall within the framework of mitigations and constraints). Constraints were then imposed by market demand, timber availability from major forest ownership groups, and legal, administrative, and environmental considerations. The data produced from the scenarios formed the basis for most of the subsequent impact analysis undertaken in the Timber Harvesting GEIS. As such, the scenarios were a critical element to being able to assess impacts for those issues of concern identified in the FSD (Jaakko Pöyry 1992).

3.4.2 Assessment of Timber Harvesting GEIS Strengths and Weaknesses

The three statewide timber harvesting scenarios enabled the study to evaluate a wide range of alternative future economic demands on the state's forest resources. We believe the number of scenarios evaluated (three) and range of annual harvest intensity each represented (from four to seven million cords) was a major strength of the study. The one criticism that was voiced during the Timber Harvesting GEIS study was that none of the three scenarios reflected a reduced level of timber harvest compared to the current level of statewide harvest (i.e., the Base Harvest Scenario). At the time, few envisioned that a reduced timber harvest level was a likely future scenario, given the number of additional wood-based plant expansions that were being contemplated for Minnesota. Additionally, the EQB described the Base Harvest Scenario as the study's "no build" alternative from which alternative "build scenarios" (e.g., the medium and high scenarios) could be judged against.

3.4.3 Considerations for Future Cumulative Forestry Impact Assessments

The information provided by cumulative forestry impact assessments is considerably enriched when a range of statewide timber harvesting scenarios are evaluated. We believe three scenarios is a manageable number to examine, but in some situations more than three may be required. Further, we recommend that one of the scenarios should reflect a reduced level of timber harvesting over what exists at the time such a study is commissioned. A reduced harvest scenario can provide insights into modeled changes in forest resource conditions, particularly those related to wildlife habitat, in the absence of disturbance through timber harvesting.

An important consideration in the development of any statewide timber harvesting scenarios is that they reflect, to the extent possible, realistic current and likely future conditions. This includes things such as future wood fiber availability and demand by tree species (possibly product classes), mill procurement areas, utilization practices, management and harvest policies and practices, existing laws and rules governing timber harvesting and forest management, and explicit and implicit agency environmental policies and practices. The degree to which cumulative forestry impact assessments have real predictive capability is, to a large measure, reflected in the degree to which these scenarios represent plausible future conditions. Conversely, we strongly discourage viewing any one of these scenarios as a plan for forest management. Individual, industry and government ownerships will still seek to develop site specific and overall operational plans for their ownerships in a manner that may meet, exceed or fall short of the projected scenario results for their ownership category or overall.

3.5 Scope of Issues Examined

3.5.1 Timber Harvesting GEIS

Through its scoping process, the Timber Harvesting GEIS identified the issues for analysis. The focus of analysis in the study was how timber harvesting and related forest management activities impacted each of the following ten issues:

- Maintaining the productivity of forests for timber production.
- Forest resource base conditions (historic, present, projected future).
- Forest soils (nutrient cycling, erosion, compaction, and overall site productivity).
- Forest health (insect and disease infestation risks).
- Plant and animal diversity in forest ecosystems (biological diversity, special concern, threatened, or endangered species, and old growth and old forests).
- Forest wildlife and fish (forest dependent species and their specific habitat requirements).
- Water quality (sedimentation and nutrient loading levels and runoff in lakes, rivers, streams, and wetlands; fertilizers, compost, sludge, and pesticides).
- Forest recreation (recreation opportunity impacts for consumptive and nonconsumptive recreation activities).
- Economics and management (direct impacts to regional and state economies, tourism and recreation industry impacts, habitats of game species and economic relationships, and timber stumpage distributions among various uses).
- Aesthetic and unique and cultural resources (visual quality and unique heritage resources found in forested areas).

Two additional issues were also identified for analysis. These issues were related to, but not dependent on, levels of timber harvesting and forest management being examined in the Timber Harvesting GEIS. One was assessing opportunities for using recycled fiber to meet additional wood fiber demand, including an evaluation of impacts of recycled fiber as a substitute input on the environment and the economy. The second issue required the identification and description of studies that addressed global warming and its possible effects on Minnesota's forests. Background papers were prepared on these two topics.

The Timber Harvesting GEIS also conducted surveys of Minnesota's public forestry organizations and policies, as well as the use of various timber harvesting systems and silvicultural practices in the state. The results of these surveys were described in background papers.

3.5.2 Assessment of Timber Harvesting GEIS Strengths and Weaknesses

The scope of issues addressed in the Timber Harvesting GEIS was extensive. This breadth of issue analysis that was conducted resulted in the most thorough study of environmental and related impacts on Minnesota's forest resources ever conducted—possibly the most extensive analysis of forest resources ever conducted at a state level. Consequently, while data deficiencies and modeling limitations existed, the development of policy and program responses to address adverse environmental impacts was strongly aided by the availability of considerable information.

The one drawback related to the broad scope of issues addressed in the Timber Harvesting GEIS was the extensive amount of time and resources that were required. From start to finish, the study spanned 52 months and cost in excess of $1 million, the latter of which was considered at the time to be extremely costly for an environmental forestry study. The wide-ranging coverage of issues in the Timber Harvesting GEIS was a major reason for the considerable amount of time needed to complete the study. Most involved with the study (study consultant and its contractors, EQB, stakeholders) would likely agree that it was difficult to maintain a high level of interest among stakeholders over such a long period of time.

3.5.3 Considerations for Future Cumulative Forestry Impact Assessments

The Timber Harvesting GEIS' thorough treatment of a range of issues was extremely important in identifying those forest resources and associated values that are most sensitive to timber harvesting and forest management. In effect, the study itself was a scoping process in that it helps guide the focus of future cumulative forestry impact assessments. The GEIS documented that some issues (e.g., water quality) were not greatly impacted by timber harvesting and related activities, at least not in Minnesota when examined from a cumulative impact standpoint. Unless resource conditions and/or harvesting activity changes dramatically, the treatment of such issues in future assessments would not be warranted. Others issues (e.g., cultural resources, outdoor recreation resources) lacked sufficient data to make definitive conclusions about the environmental effects of timber harvesting. Unless sufficiently new data and/or analysis methods become available, these issue areas should also be a low priority for future cumulative forestry impact assessments. Further, scoping the issues to be evaluated in future cumulative forestry impact assessments needs to pay particular attention to the ability to discern practically important differences in the "with" and "without" scenario conditions, as well as the time and cost associated with doing so. Some analyses may be technically feasible, but impractical given resource and, in the case of the GEIS, data limitations.

Future cumulative forestry impact assessments should focus on those forest resources and related values that were found in the Timber Harvesting GEIS to be most measurable and sensitive to harvesting. Specifically, we recommend describing how harvesting activity impacts the extent (acreage), composition (covertypes and species), and structure (age-class distribution) of Minnesota's forest resources, as well as changes in the availability and quality of forest-based

wildlife habitat. A major insight from the GEIS was that forest conditions (i.e., extent, composition, and structure) are *the* primary determinants of environmental conditions and associated impacts for nearly all forest-dependent resources and values. As such, they should be the focus of any future cumulative forestry impact assessments. Habitat value estimation was a particularly important derivative of forest conditions. However, as discussed in the next section, the construction of detailed projections of wildlife habitat values or population levels for each and every species at spatial scales smaller than statewide was fraught with uncertainty in data and models and thus interpretation.

3.6 Data, Analysis and Modeling

3.6.1 Timber Harvesting GEIS

The USDA Forest Service's Forest Inventory and Analysis (FIA) database contained enormous detail derived from a statewide sampling of the state's forestland. This database for 1990 provided records from 13,536 field checked plots classified as "forest." Additionally, the database contained 760 plots classified as nonforest land with trees. Ultimately the 1990 FIA data formed the basis for the harvest scenario modeling in the Timber Harvesting GEIS, which characterized the current and future forests and forested areas of Minnesota. These characterizations also served as the primary input in identifying and evaluating environmental and related impacts for each level of timber harvesting activity associated a given scenario. The FIA data contained the following desirable attributes that enabled its use in the Timber Harvesting GEIS:

- Statewide forest plot coverage that historically had been re-inventoried every 10 to 15 years, and annually since 1999 (Miles et al. 1995, 2004, USDA Forest Service 2003).
- On-the-ground measurements of forest plots that the study was able to augment using aerial photography.
- A statistically-based sample of that represented existing statewide forest conditions.
- Estimates, by types of tree species and covertypes present, of area, volume, growth and mortality, and average annual removals.

The FIA plots provided a spatial approximation of the total forest resource and were used as the basic unit for allocating timber harvesting activity. The details of the FIA and other data usage are described in the Timber Harvesting GEIS, notably the technical paper on maintaining productivity and the forest resource base (Jaakko Pöyry 1992). Each plot from the FIA database had an expansion factor that was used to convert plot characteristics to the stand scale the plot represented—most timberland plots represented 900 to 1,500 acres. A computer based model of forest growth, change and harvest was then used as the basis for generating the three timber harvesting scenarios. The models were specifically developed to generate realistic harvesting scenarios by incorporating the most recent available data such as:

- The volume (by size and species), location, and ownership of wood potentially available.
- Existing, planned, or potential wood-based industries and their locations.
- Costs associated with timber harvesting, transport, and forest management activities.
- Regional transport network to link the wood supplies with the processing facilities.

- Forest management practices and the implications of these on the structure and species composition of the forests and yields of timber in the short- and long-term.
- Criteria used by industries to select stands when making purchases of timber.
- Existing land management policies that influence the availability of timber for harvest.

Beyond the core statewide FIA database, the study relied on several sources for the data that was used in the study, including:

- Primary data collected as part of the study (e.g., silvicultural and harvesting practices).
- Published research documents.
- Public agency documents and statistical data reports.
- Unpublished public agency data and studies.
- Data provided by the consultant from its network of databases, studies, and reports.
- Unpublished research materials.
- Data, reports, and models from researchers at the University of Minnesota and in the Minnesota Department of Natural Resources.

The computer based model of forest growth, change and harvest used for scenario generation was a large forest planning model that utilized an existing forest growth model from the USDA Forest Service. This forest growth model component was an individual tree based tool designed in part for use with FIA data. The overall planning model was then modified by adding components and refinements to improve its utility for the study, e.g, to include natural succession of tree species and covertype change. Subsequently the overall planning model was used as the core tool to generate the three detailed timber harvesting scenarios. As the forest was projected into the future, harvesting and associated forest management activities were scheduled by submodels that addressed individual stands in a way that made the most economic sense, given the mitigations and constraints on the various locations and ownerships. Model outputs were then analyzed each decade to assess covertype change as described by forest growth and stand dynamics.

The model runs also incorporated ownership constraints and environmental mitigations that reflected current and prospective management procedures and policies applied by the major forest land ownership categories. Examples on constraints and mitigations include:

- Extending the minimum rotation ages by 50 percent for approximately 20 percent of the timberland on state and USDA-Forest Service lands.
- A greater use of uneven-aged management applications.
- The designation and reservation of old growth and old growth replacement acreage.
- The use of best management practices, such as partial harvesting or extended rotation forestry within 100 feet of water.
- The use of wildlife buffers, such as modeling only partial harvest practices within 200 feet of water on the state's two national forests and in the southeastern part of the state.

In addition, estimates of the actual availability of timberlands for harvest or management, developed separately for each major forest ownership group, were used to set aside a portion of the timberland as not available for various economic, environmental and social concerns.

Other components that were incorporated within this framework as submodels provided forest response data and helped in modifying and interpreting inputs and outputs. Examples included a regeneration submodel (to portray new forest stand development following harvesting) and a basic geographic information system type component (to generate transport information and to allow graphic depiction of outputs from the model).

Output from the model runs included plots and associated acreage harvested by ten-year planning period, the type of harvesting, the products harvested and their cost, and assumed management activities. FIA plot expansion factors were then used to convert this to stand, ecoregion and state level descriptions of the forest and outputs. The GEIS study groups used various parts of this output, depending on their specific requirements for conducting environmental impact assessments for the scoped issues. For example, the forest soils study group required information on the amount of timber removed by covertype and the frequency of harvest activity, whereas the wildlife group required data on the presence or absence of certain key tree species, the age and size class structure of stands, and any changes in covertype extent. The output from the scenarios formed the basis for most of the subsequent impact analysis.

Examples of harvest and management options modeled for stands included: clearcutting, thinning, selective harvesting, or no harvesting. After harvest, the choices included natural regeneration or planting. The most appropriate option for each stand at each decision point was selected by a scheduling model that matched demand for a product with the stand or forest area best able to supply that product and in consideration of mitigations and other constraints. Forest and timberland area change from 1990 to 2040 was also implemented gradually throughout the 50-year period using estimates of annual change rates.

3.6.2 Assessment of Timber Harvesting GEIS Strengths and Weaknesses

The GEIS' level of spatial coverage, modeling complexity, and breadth and depth of issue analysis could not have occurred without access to the statewide FIA database. Clearly, the availability of this data set was critical to successfully undertaking the Timber Harvesting GEIS, as it formed the basis for the harvest scenario modeling and was used by the study scientists to develop characterizations of the forests and environmental impacts. The USDA-Forest Service provided the EQB access to the 1990 inventory data before it was officially released—thus facilitating the consultant's work on the project. This early access to the FIA data was a major contribution to the study's success.

The GEIS was a technically intensive effort. However, the data and models used in the study have been interpreted as highly precise and accurate when that was not always the case. Thus, some of the study results have been attributed greater accuracy than actually was the case. Corresponding interpretations, impact assessments and mitigations have likewise been treated as essentially without error rather than the more appropriate "approximate." In fact, the study data and models and their application have five inherent sources of error in estimation that are especially important for interpretation in any such study effort:

- Specification
- Sampling
- Modeling

- Multiplication
- Projection or scenario development

Specification
These errors are illustrated by focusing on forest wildlife habit quantification. It is typically assumed that total forest area is well defined. In fact, the usual forest inventory data consisting of maps or many field plot observations (in the case of statewide FIA estimates) is assumed to provide an accurate characterization of forest area. However, in practice, such inventories must define (specify) just what constitutes forest acreage. It is not always obvious on the ground, particularly when deciding if a specific area should be considered forest or nonforest cover (e.g., one might consider the minimum size of a forest patch and type or growth stage of the vegetative present). Consequently, FIA and other forest inventories have developed specifications for classifying land as forest. These are not a major problem for total forest area, but such error can increase with breakdowns by forest cover type or further. For example, when is an aspen stand no longer classified as an aspen forest type? There are 12-20 forest cover types recognized in typical forest inventories, each with specifications for composition based on some measure of dominance of a particular tree species or group of species. With FIA, those specifications are most important in identifying mixed forest stands. Most field plots and associated stands in Minnesota have 2-6 or more tree species on them. Consequently, rules (specifications) are devised to assign forest cover types based on the percentage of composition by tree species according to some arbitrary measure. A question might then be: is a plot with 51 percent aspen by measure really different than a balsam fir stand with 49 percent aspen, or a balsam fir stand that is 29 percent aspen and 29 percent paper birch? The simple assumption of a covertype label as identifying very similar conditions can be misleading—a form of specification error. Such error is important to all covertypes, but especially those areas of mixed tree species composition, i.e., much of Minnesota. Furthermore, this specification error has important implications for estimating other important stand-level attributes e.g., habitat value will vary within stands classified as balsam fir.

Sampling
Beyond the difficulty of imprecision in estimates of habitat value by cover type, there lies the issue of sampling error, i.e., that variation due to basing the proportion of forest in each cover type as determined from that sample of field plots (e.g., if 40 percent of 6,000 field plots are classified as aspen, we assume 40 percent of the forest is of the aspen cover type). Sampling error formulas allow us to estimate the sampling variation inherent in such estimates; they also confirm that such error is real. While sampling errors for forest covertype area are small for aspen statewide, they are considerable for aspen in a small ecoregion or for a less common forest covertype like white pine. In brief, the practical realities of having to sample for such forest area estimates preclude high precision and accuracy at regional and local levels. Alternatively, suggestions of simply mapping these areas are fraught with issues of timely aerial imagery, specification error, and the vagaries of imagery interpretation and mapping technologies. There is no magic estimation or mapping approach that is free of error for forest area or habitat.

Modeling
Given data that can be used to describe relationships between variables of interest (e.g., tree size and growth; stand age class and habitat value), estimation efforts use these data to develop

models of the relationship and subsequently employ these models to predict present or future values of the variable of interest given input of other (predictor) variable. Of course, those models have specification and sampling error inherent in the data, plus error due to model construction, i.e., failure of the model to fit the data perfectly. Thus the models provide at best good approximations—not perfect descriptors of habitat.

Multiplication

A particularly important aspect of environmental review of forestry projects is the use of estimates of forest cover type area, current or projected, as the basis for quantifying wildlife population numbers or habitat values over large areas and thereby changes that might be important impacts. In such cases we see the use of forest cover type area estimates (with associated error) multiplied by corresponding (to that habitat) habitat values (corresponding to population levels and with their own specification and sampling errors). Note the transient nature of wildlife makes such estimates more prone to such error than forest area data. Assuming the estimates of forest covertype area and wildlife habitat values are independent (i.e., constructed from independent estimation efforts, the usual case), the error of the product of the estimate of area times the estimate of habitat value leads to an even larger error for the result, i.e., the total value of such habitat.

For projections, the combined full set of errors in habitat value estimates includes assumptions about future conditions i.e., the assumptions for the scenario do not change over time and the models hold for future points in time, sometimes decades ahead. In our experience, the interpretation of the precision and accuracy of estimates based on this full set of errors is often interpreted far beyond the capabilities of the data and available methodology. Consequently, we argue for simplification in scenario development and the interpretation of scenarios.

The GEIS provided a lot of useful information. Yet it did stretch the capability of estimation where several to many sources of error were present. Much of the impact information in terms of forest area, area by covertype and covertype by age class was fundamentally useful, as there were few and but modest sources of error involved in such estimation. However, where small areas were considered and/or when numerous models and/or assumptions were involved, precision and accuracy fell off dramatically. Unfortunately, quantifying this error was impossible or impractical within the scope of the study. Consequently, over interpretation of the projected impacts was difficult to avoid.

3.6.3 Considerations for Future Cumulative Forestry Impact Assessments

The Timber Harvesting GEIS attempted to create an integrated database that would be used to analyze environmental effects by linking other data to the FIA plot locations to provide a consistent basis for subsequent analysis. Additionally, the FIA data attributes that could be used in subsequent analyses were identified by project scientists in the various fields of investigation (e.g., wildlife). As an example, the study scientists that examined the impacts of timber harvesting on soil nutrient depletion used FIA-modeled information on the volume of timber removed by covertype and the frequency of harvests. Similarly, the project's wildlife scientists focused on FIA-derived output that described the presence or absence of certain key tree species and changes in the extent, age, and size class structure of forest covertypes, as well as the aerial extent of forest stands.

While this attempt at data integration was largely *ex post*, it greatly aided the identification and quantification of timber harvesting effects on various aspects of the forest resource. Ideally, future cumulative forestry impact assessments should be based on an integrated data base that has explicit links between its various data components (e.g., forest inventory, future resource conditions, and wildlife habitat values). Building the architecture of such a database is no small task, requiring considerable time and resources. Given existing state agency priorities and resources, it is unlikely an integrated forest resource database of the type envisioned will be developed.

As a note of caution about the use of FIA data in cumulative forestry impact assessments, certain data collection protocol changes have been made in the FIA program since the 1990 inventory. Examples include changing definitions (e.g., forest covertype), covertype classification algorithms, and field observation protocols (e.g., distance to water). As a result, some of the variables that had been collected are no longer part of the field plot data collection protocol, which could limit the ability of FIA data to describe certain aspects of forest impact and change that occurred in the Timber Harvesting GEIS.

The authors also want to disabuse the notion that a map-based cumulative forestry impact assessment should be given higher priority over a sample based assessment. While map-driven assessments may appear appealing from a variety of viewpoints (visually instructive, spatially explicit findings), in reality such an approach has considerable technical difficulty. Chief among these difficulties is the tremendous variability in map data and mapping standards for forests and related resources. The incompatibilities among base maps often require substantial effort to make them comparable spatially and temporally. Even when base maps can be made compatible, projecting maps into the future is fraught with additional statistical problems.

Finally, the focus of cumulative forestry impact assessments should be a synthesis of knowledge rather than set of detailed research studies. As was documented in the Timber Harvesting GEIS, important gaps in the data are common. If an issue is not researchable due to a lack of data or analytic techniques, it should be identified as a priority area for future research or monitoring efforts rather than questionable estimation in the assessment itself. In fact, assessments might begin with the question of feasibility of quantifying various issues.

Further, as described in the previous section, the concepts of precision and accuracy in characterizing the growth and change of forests, the activities that might occur within them (e.g., harvesting), and the accuracy of projections or scenarios, is difficult for many to fully appreciate. Many stakeholders expected a level of precision and detail in resource description and accuracy in scenarios that is simply not achievable. Such cases include results that depend on numerous other estimations, e.g., the estimation of certain wildlife habitat values and their change for small area breakdowns. Additional cases were described by the Kilgore et al. Report Card Study (Kilgore et al. 2005) which pointed out factors such as large windstorms and insect epidemics that are difficult to predict and incorporate with any precision and timber market conditions that can vary widely in any year and decade, e.g., 1990-2000. In this last case, market conditions in that decade fell short of GEIS projections and the resulting harvest never reached the anticipated 5 million cord level.

3.7 Thresholds of Significance

3.7.1 Timber Harvesting GEIS

The environmental impacts identified in the Timber Harvesting GEIS varied considerably in their extent and longevity. Consequently, criteria were developed to evaluate the significance of the major categories of environmental impacts, as well as the scope of mitigation responses that were identified in the study. These "significance criteria" were used to evaluate each major scoped issue of concern from the perspective of cumulative impacts geographically and over time. They were also used to facilitate input from the study's advisory committee and EQB into the study process, as in most cases definitive rules on what constituted a significant impact did not exist.

Eighteen categories of environmental impacts were discussed, based on the ten issue areas identified in the study's final scoping decision. For each significance criterion developed, background information was used to determine levels or thresholds when impacts were to be considered significant. These background factors were provided to support the significance assessment and/or to provide insight as to the basis for the specified threshold. Along with the criteria itself, background information was provided on the severity and spatial extent of the impact, the certainty of the impact, the duration (and irreversibility) of the impact, the existence of guidelines and standards, and biological and economic implications associated with possible mitigation alternatives. Similarly, criteria were developed to identify possible mitigation measures and to select preferred environmental mitigation strategies.

3.7.2 Assessment of Timber Harvesting GEIS Strengths and Weaknesses

The criteria developed were an extremely important component of the Timber Harvesting GEIS. Their use helped ensure the study remained focused on the process needed to develop the best set of mitigation strategies to address cumulative, statewide impacts. Specifically, the significance criteria enabled the study process to:

- Comprehensively identify all potential environmental impacts.
- Develop a systematic approach for assessing impacts in order to identify those which are considered significant.
- Develop scientifically sound and objective alternatives to minimize those impacts identified as being significantly adverse.
- Facilitate two-way discussion and feedback between the Timber Harvesting GEIS consultants and the EQB's advisory committee in the development of these criteria.
- Develop a framework for systematically identifying practical, effective, and broadly supported strategies for mitigating adverse environmental impacts.

In practice, very few standards were available to address the issues examined in the Timber Harvesting GEIS. Consequently, expert opinion and judgments played an important role in shaping the significance criteria used in the study. The interaction that occurred between the consultant's scientists, advisory committee representing a range of different forest resource interests, and EQB in the development of the significance criteria was extensive. The fact that this interaction occurred within the framework of a defined process was also a major attribute of the study.

3.7.3 Considerations for Future Cumulative Forestry Impact Assessments

Future cumulative forestry impact assessments should benefit from the significance criteria developed in the Timber Harvesting GEIS. We encourage their use as the basis for identifying significant environmental effects. However, prior to their use, each criterion should be reviewed and updated to reflect new scientific information not available at the time it was developed. Additionally, significance criteria should seek to distinguish no less than a ten percent change in resource or environmental conditions. Thresholds smaller than ten percent belie the precision of the data used in these studies and their associated sources of error. This is particularly true for the smaller components of the forest landscape (e.g., red or white pine stands), where a low natural frequency of occurrence precludes the ability of meaningful identification of various associated long-term trends. Importantly small and rare features of the landscape are extremely difficult and costly to observe and might best be handled as an exception, i.e., monitoring and mitigation by education for avoidance.

3.8 Mitigation Strategies

3.8.1 Timber Harvesting GEIS

Numerous strategies were identified in the Timber Harvesting GEIS to mitigate the significant impacts projected to occur at the base, medium, and high harvest scenarios. These recommended mitigations were organized and presented in three categories which reflect their main focus:

Site-level Responses: Strategies in this category were intended to modify operational procedures used in the planning and execution of timber harvesting and forest management activities on an individual site or local scale. The mitigation practices recommended were identifiable, focused on achieving specific resource objectives, and tactical in nature (i.e., they typically specified on-the-ground land practices designed to reduce and/or eliminate environmental problems associated with harvesting or forest management).

Landscape-level Responses: These mitigations were typically long-term or broad-based solutions requiring extensive analysis and/or planning to identify and achieve the intended objectives of developing regional or, in some cases, statewide responses. They did not typically relate to certain practices on a given harvest site, but rather encompassed geographically large areas spanning multiple ownerships, and served to address landscape-level forest resources goals. Unlike tactical mitigations that are often realized in a relatively short period of time simply through alternative harvesting and/or management practices, these more complex mitigations often take an extended period of time to implement and require the cooperative and coordinated efforts of many different land management organizations and resource managers.

Forest Resources Research: Strategies in this category were focused on obtaining information needed to undertake strategic and operational planning, monitor changes at the landscape- and site-level, or provide the basis for developing management direction and planning tools. They were intended to provide resources managers and policymakers with better information regarding specific resource characteristics and trends.

Additionally, as a means of focusing and integrating the various mitigation options into a comprehensive policy strategy, the Timber Harvesting GEIS recommended establishment of a:

- **Forest Resources Practices Program** – to serve as an umbrella structure for the implementation of a wide range of specific management prescriptions.
- **Sustainable Forest Resources Program –** to mitigate landscape-level impacts from timber harvesting and forest management activities.
- **Forest Resources Research Program –** to facilitate extension, technology transfer, and continuing education activities.
- **Implementation Coordination** – A nonregulatory state forest resources board to serve as the administrative structure for coordinating the implementation of the three major mitigation programs recommended in the Timber Harvesting GEIS.

3.8.2 Assessment of Timber Harvesting GEIS Strengths and Weaknesses

The Timber Harvesting GEIS presented a variety of mitigation recommendations at each of the three alternative levels of statewide timber harvest. While tactical mitigations described and recommended in the GEIS were extremely important and useful study outcomes, the GEIS also served the broader purpose of providing direction on the types of policy (programmatic) strategies the state should consider to help verify and effectively address and implement these recommended mitigations. The various mitigation options were organized such that they could be integrated into a comprehensive set of policy and program strategies that would be the focus of mitigation implementation efforts.

3.8.3 Considerations for Future Cumulative Forestry Impact Assessments

For a state like Minnesota, which has a comparatively well-defined and comprehensive forest resource policy and associated program framework, the importance of defining mitigation alternatives in a cumulative forestry impact assessment is secondary to identifying and quantifying cause-effect relationships between timber harvesting and related aspects of forest resources. In these situations, emphasis should be placed on using the study findings to improve program components (e.g., recommendations for managing riparian forests) and delivery (e.g., the appropriate application of site-based forestry practices). Additionally, the findings from cumulative forestry impact assessments should inform forest-related monitoring activities, such as monitoring the application and effectiveness of site-level timber harvesting and forest management practices.

3.9 Study Timeframes and Update Frequency

3.9.1 Timber Harvesting GEIS

Commissioned in late 1989, the Timber Harvesting GEIS took over four years to prepare, with the EQB making a determination of the study's adequacy in April 1994. The Timber Harvesting GEIS Report Card Study was initiated approximately 11 years after the release of the GEIS. Its purpose was to assess the ability to predict future forest resource conditions and to describe the status of mitigations in the form of forest management practices relative to the GEIS recommendations. The Report Card Study also represented the first attempt to conduct a formal and systematic post-hoc evaluation of the Timber Harvesting GEIS findings and recommended actions.

3.9.2 Assessment of Timber Harvesting GEIS Strengths and Weaknesses

The Timber Harvesting GEIS was considered to be the most comprehensive assessment ever undertaken of the long-term impacts of timber harvesting and forest management on state's forest resources. The four plus years it took to prepare the study was too long. Major obstacles that were encountered in the preparation of this study which substantially impacted its development progress included:

- Delays in securing the funding needed for the study (note the study totaled nearly $1 million in consultant fees).
- Difficulty acquiring and/or assembling critical data sets and models that were required to conduct the analysis (this was particularly true for wildlife-related data and models).
- The time needed to develop and test the full complex of models that were used to project future forest resource conditions using FIA data.
- Extensive oversight by the GEIS Advisory Committee in nearly all aspects of the study development process.
- Modifications to the original scope of work such as conducting a consultant-initiated external review of all technical papers prior to their approval by the EQB. Note these technical papers also served as part of the basis for identifying and describing the environmental impacts associated with timber harvesting and forest management activities.

Although interest by the EQB, state forest resource stakeholders, and policymakers did not wane during the study's preparation, it is doubtful that such attention will follow future cumulative forestry impact assessments.

3.9.3 Considerations for Future Cumulative Forestry Impact Assessments

Future cumulative forestry impact assessments need to be prepared in considerably less time than was required to prepare the Timber Harvesting GEIS. This time rule is essential for the results to be truly instructive and useful. Additionally, such studies should be prepared at regular intervals – we recommend: (1) every decade; or (2) when future statewide timber harvesting activity is projected by the state to change (either increase or decrease) by more than 25 percent from current levels *and* projected to be sustained for at least a decade. Ideally, state agencies would develop the modeling and technical capacity that would allow them to conduct these assessments internally. However, given existing agency staffing levels, legislative mandates, and available resources, the development of in-house expertise and tools needed to prepare this type of assessment is unlikely to occur in the foreseeable future. Consequently such efforts are likely to be conducted by consultants. The nature of such studies further suggests deference should be given to large and highly experienced (with respect to the issues, data, and analytic tools) consulting firms, and that the contracting agency and its project oversight advisory panel have some level of specialized expertise in the subject matter to ensure full coverage of the scoped issues.

4 Summary and Conclusions

Cumulative forestry impact assessments can be a rich source of information for describing the relationship between timber harvesting and forest management activity and future forest resource conditions. These assessments can play a major role in raising the level of understanding of these relationships to a wide-ranging audience including state policy makers, special interest groups, landowners and the general public. The data generated through these processes can also be an important input to forest resource planning activities undertaken by public and private forest managers. As was experienced with the Timber Harvesting GEIS, the findings from these studies can also be invaluable in facilitating the development of new state forest policies and programs. For example, Minnesota's comprehensive timber harvesting and forest management guidelines were a direct response to a key mitigation strategy recommended in the GEIS.

Invaluable as cumulative forestry impact assessment studies are, they are difficult to fund and require considerable and wide ranging expertise to execute. Such was the case with the Timber Harvesting GEIS, where funding for the study came from several sources: state legislative appropriations, Environment and Natural Resources Trust Fund, regional economic development entities, and a private foundation. Had a broad base of support for the study not existed, it is unlikely the funding needed to carry out the study would have been available. This reality underscores the importance of developing a strong coalition that can articulate the need for conducting this type of study. Yet both of these difficulties are, in part, addressable.

In Minnesota, the Timber Harvesting GEIS created a high level of expectation for the level of insight on the cumulative nature of timber harvesting and related forest management effects on forest resources. These expectations need to be tempered with the reality that future studies will not likely provide the breadth and depth of analysis that was contained in the GEIS. Rather, subsequent studies need to focus on developing a better understanding of the cumulative impact of timber harvesting and related management practices on the two areas considered to be most pressing: (1) forest extent, composition, and structure; and (2) wildlife habitat changes. Focusing on the former is needed because unintended changes in the forest resource base have the greatest potential to create long-term, adverse conditions affecting a wide range of forest-related values and uses. Attention to the latter is required because our understanding of changing wildlife habitat conditions in response to varying levels of timber harvesting and forest management across large areas over time is still quite limited.

Finally, understanding the cumulative environmental effects of forestry activities is increasingly viewed as an antecedent condition for the continued viability of a state's wood-based industry. And for good reason. Cumulative environmental impact studies like the GEIS play a very important role in state forest resource policy by providing a venue for systematically quantifying possible future forest and related conditions under a range of management and investment alternatives. As such, considerable attention (and resources) needs to be directed to the many study aspects involved in successfully conducting these assessments. This includes not only the development and refinement of data, models, and related tools needed to conduct cumulative impact analyses, but the support from a wide range of state forest resource interests for making these assessments a priority as well as follow-up outreach efforts to help with the translation and transfer of study results and recommendations to appropriate audiences. All are needed if the

resulting information is to play a meaningful role in a state's resource protection and economic development strategy.

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6 Literature Cited and References

Literature cited

Council on Environmental Quality. 1978. CEQ – Regulations for Implementing NEPA (43 FR 56003).

Council on Environmental Quality. 1997. *Considering cumulative effects under the National Environmental Policy Act.* Washington, DC.

HDR Engineering. 2006. Final Environmental Impact Statement: UPM/Blandin Paper Mill Thunderhawk Project, Grand Rapids, MN. Minnesota Department of Natural Resources. St. Paul, MN.

Jaakko Consulting, Inc. 1994. Final generic environmental impact statement study on timber harvesting and forest management in Minnesota. Minnesota Environmental Quality Board. St. Paul, MN. 504 p.

Jaakko Pöyry Consulting, Inc. 1992. Maintaining Productivity and the Forest Resource Base. A Technical Paper for a Generic Environmental Impact Statement on Timber Harvesting and Forest Management in Minnesota. Prepared for the Minnesota Environmental Quality Board. Tarrytown, NY: Jaakko Pöyry Consulting, Inc. 305 p plus 16 appendices.

Kilgore, M. A. 1992. Government response to sensitive timber harvesting issues: Minnesota generic environmental impact statement. In: *Conference Proceedings: Forestry and the Environment: an International Perspective.* University of Alberta. Edmonton, Alberta: Canada.

Kilgore, M., A. Ek, K. Buhr, , L. Frelich, J. Hanowski, C. Hibbard, A. Finley, L. Rathbun, N. Danz, J. Lind, and G. Niemi. 2005. Minnesota timber harvesting GEIS: an assessment of the first 10 years. Staff Paper Series Number 182. Department of Forest Resources, University of Minnesota. St. Paul, MN. 178 p.

Ma, Zhao. 2006. Integrating cumulative impact assessment into state environmental review programs. Unpublished Ph.D. research prospectus. University of Minnesota, St. Paul, MN.

Minnesota Environmental Quality Board. 2005. EQB meeting minutes, Thursday, June 16, 2005, State Office Building, Hearing Room 5, St. Paul, MN. 15 p.

Minnesota Forest Resources Council. 1999. Sustaining Minnesota forest resources: Voluntary site-level forest management guidelines for landowners, loggers, and resource managers. St. Paul, MN: Minnesota Forest Resources Council.
Minnesota Statutes, 2006. Chapter 89A. 2006. Sustainable Forest Resources Act. Office of the Revisor of Statutes, St. Paul, MN.
Minnesota Statutes, 2006. Chapter 116D. 2006. Environmental Policy. Office of the Revisor of Statutes, St. Paul, MN.

Additional References Not Cited

Alerich, C. L, L. Klevgard, C. Liff, and P. D. Miles. 2004. The Forest Inventory and Analysis Database: Database Description and Users. Guide Version 1.7. USDA Forest Service. See http://www.ncrs2.fs.fed.us/4801/fiadb/fiadb_documentation/FIADB_v17_122104.pdf
Arner, S. L., S. Woudenberg, S. Waters, J. Vissage, C. MacLean, M. Thompson, and M. Hansen. 2003. National algorithms for determining stocking class, stand size class, and forest type for forest inventory and analysis plots. February 13, 2001, modified May 21, 2003. 65p. USDA Forest Service, Forest Inventory and Analysis. See http://socrates.lv-hrc.nevada.edu/fia/imb/imbandindex.html#_Code_Documentation
Brand, G. J. 1981. GROW - A computer subroutine that projects the growth of trees in Lake States forests. Research Paper NC-207. St. Paul, MN: USDA Forest Service, North Central Forest Experiment Station.
Brand, G. J., M. R. Holdaway, and S. R. Shifley. 1988. A description of the Twigs and STEMS individual-tree based growth simulation models and their applications. In *Forest growth modeling and prediction*, eds., Ek, A. R., S. R. Shifley, and T. E. Burk, 950-60. Proceedings of the IUFRO conference, Minneapolis, MN, August 24-28, 1987. General Technical Report NC-120. St. Paul, MN: USDA Forest Service, North Central Forest Experiment Station.
Brown, T., J. Hanowski, G. Host, and M. White. 2005. SUSTAIN: Subsection unit sustainability analysis using indicators. http://www.nrri.umn.edu/sustain/
Cotè, S. D., T. P. Rooney, J-P. Tremblay, C. D. Dussault, and D. M. Waller. 2004. Ecological impacts of deer overabundance. *Annual Reviews in Ecology and Systematics* 35:113-147.
Dahlman, R, and M. J. Phillips. 2004. Baseline monitoring for implementation of the timber harvesting and forest management guidelines on public and private forest land in Minnesota: Combined Report for 2000, 2001, and 2002. DNR Document MP - 0904. Submitted to the Minnesota Forest Resources Council. St. Paul, MN: MN Department of Natural Resources.
Dexter, M. H., ed. 2004. Status of wildlife populations, Fall 2004. St. Paul, MN: Minnesota Department of Natural Resources, Division of Fish and Wildlife, 176pp.
Dexter, M., ed. 2001. Status of wildlife populations, Fall 2001. St. Paul, MN: Minnesota Department of Natural Resources, Division of Fish and Wildlife, 180pp.
Dolton, D. D., and R. D. Rau. 2004. Mourning dove population status, 2004. Laurel, MD: US Fish and Wildlife Service.
Forest Health Monitoring Program. 2000 Forest health highlights, Minnesota. St. Paul, MN: USDA Forest Service, State and Private Forestry, Northeastern Area. See http://www.fhm.fs.fed.us/fhh/fhh-00/mn/mn 00.htm.
Frelich, L. E., M. W. Cornett, and M. A. White. 2005a. Controls and reference conditions in forestry: the role of old growth and retrospective studies. Journal of Forestry, in press.

Frelich, L. E., C. M. Hale, S. Scheu, A. R. Holdsworth, L. Heneghan, P. J. Bohlen, and P. B. Reich. 2005b. Earthworm invasion into previously earthworm-free temperate and boreal forests. Biological Invasions, in press.

Garshelis, D., and K. Noyce. 2004. Status of black bears, 2003. St. Paul, MN: Minnesota Department of Natural Resources.

Hansen, M. H. 2005. Personal communication. USDA Forest Service, North Central Research Station. June 13, 2005.

Hansen, M. H., T. Thomas, J. F. Glover, and J. F. Kelly. 1992. The Eastwide forest inventory data base: users manual. Gen. Tech. Rep. NC-151. St. Paul, MN: USDA Forest Service, North Central Forest Experiment Station. 48 p.

Hansen, M., H., and J. T. Hahn. 1992. Determining stocking, forest type and stand-size class from Forest Inventory data. *Northern Journal of Applied Forestry* 9(3):82-89.

Jaakko Pöyry Consulting, Inc. 1994. Final generic environmental impact statement on timber harvesting and forest management in Minnesota. Prepared for the Minnesota Environmental Quality Board. Tarrytown, NY: Jaakko Pöyry Consulting, Inc.

Jaakko Pöyry Consulting, Inc. 1992(a). Biodiversity. A technical paper for a generic environmental impact statement on timber harvesting and forest management in Minnesota. Tarrytown NY: Jaakko Pöyry Consulting, Inc.

Jaakko Pöyry Consulting, Inc. 1992(b). Forest Wildlife. A technical paper for a Generic Environmental Impact Statement on Timber Harvesting and Forest Management in Minnesota. Tarrytown NY: Jaakko Pöyry, Consulting, Inc.

Lind, J., N. Danz, J. M. Hanowski, and G. J. Niemi. 2005. 2004 annual update report. Breeding bird monitoring in Great Lakes National forests: 1991-2004. NRRI/TR-2005/04.

Miles, P. D., G. J. Brand, and M. E. Mielke. 2004. Minnesota's forest Resources in 2003. Review draft dated September 20, 2004. St. Paul, MN: USDA Forest Service, North Central Forest Experiment Station.

Miles, P. D., C. M. Chen, and E. C. Leatherberry. 1995. Minnesota Forest Statistics, 1990, Revised. Resource Bulletin NC-158. St. Paul, MN: USDA Forest Service, North Central Forest Experiment Station.

Minnesota Department of Natural Resources. 2004. Minnesota's forest resources. St. Paul, MN: Department of Natural Resources, Wood Utilization & Marketing Program. Revised October 11, 2004. 72p.

Minnesota Department of Natural Resources. Various reports on fuelwood surveys. See http://www.dnr.state.mn.us/forestry/um/index.html. St. Paul, MN: Department of Natural Resources, Wood Utilization & Marketing Program.

Minnesota Department of Natural Resources. 2003. Field guide to the native plant communities of Minnesota: The Laurentian Mixed Forest Province. Ecological Land Classification Program, Minnesota County Biological Survey, and Natural Heritage and Nongame Research Program. St. Paul, MN: Department of Natural Resources.

Minnesota Forest Resources Council. 2002. Sustainable Forest Resources Act implementation in 2001: Minnesota Forest Resources Council Annual Report to the governor and legislature. Report CP-0202. St. Paul, MN: Minnesota Forest Resources Council.

Minnesota Forest Resources Council. 2001. Sustainable forest resources act implementation in 2000: Minnesota Forest Resources Council Annual Report to the Governor and Legislature. Report CP-0201. St. Paul, MN: Minnesota Forest Resources Council.

Minnesota Forest Resources Council. 2000. Sustainable forest resources act implementation in 1999: Minnesota Forest Resources Council Annual Report to the Governor and Legislature. Report CP-0200. St. Paul, MN: Minnesota Forest Resources Council.

Minnesota Forest Resources Council. 1999a. Biennial report to the governor and legislature: sustainable forest resources act implementation, 1997-98. Report to Governor and Legislature. Report CP-0299. St. Paul, MN: Minnesota Forest Resources Council.

Minnesota Forest Resources Council. 1999b. Sustaining Minnesota forest resources: Voluntary site-level forest management guidelines for landowners, loggers, and resource managers. St. Paul, MN: Minnesota Forest Resources Council.

Minnesota Forest Resources Council. 1998. Implementation goals for timber harvest and forest management guidelines. SI-1298. St. Paul, MN: Minnesota Forest Resources Council.

Minnesota Forest Resources Council. 1997a. Landscape-level planning and coordination process principles and goals. Report LP-0797. St. Paul, MN: Minnesota Forest Resources Council.

Minnesota Forest Resources Council. 1997b. Sustainable forest resource act monitoring programs: Development procedures. Report MA-0697. St. Paul, MN: Minnesota Forest Resources Council.

Monstad, Y. 2004. Minnesota frog and toad calling survey, 2004 results. St. Paul, MN: MN Department of Natural Resources, Division of Ecological Services, Nongame Wildlife Program. Web report: http://files.dnr.state.mn.us/volunteering/frogtoad_survey/mftcs_results2004.pdf

Olson, C. 2005. 2004 small mammal survey report. Technical Report #05-01. 1854 Authority. Duluth, MN: Biological Services Division.

Phillips, M. and R. Dahlman. 2002. Monitoring the implementation of the timber harvesting and forest management guidelines on public and private forest land in Minnesota: report 2001. A report by the Minnesota department of natural resources. DNR Document MP – 0902. Submitted to the Minnesota Forest Resources Council. St. Paul, MN: MN Department of Natural Resources. 47p.

Phillips, M. J. 2001. Monitoring the implementation of the timber harvesting and forest management guidelines on the public and private forest land in Minnesota: Report 2000. DNR Document MP - 0201. Submitted to the Minnesota Forest Resources Council. St. Paul, MN: MN Department of Natural Resources. 45p.

Piva, R. J.2005. Pulpwood production in the North-Central Region, 2002. Resource. Bulletin NC-239. St. Paul, MN: USDA Forest Service, North Central Research Station. 56 p.

Puettmann, K. J., C. R. Blinn, H. W. McIver, and A. R. Ek. 1998. Status of Minnesota timber harvesting and silvicultural practice in 1996. Report # MP0698. St. Paul, MN: Minnesota Forest Resources Council. 49p.

Sauer, J. R., J. E. Hines, and J. Fallon. 2004. The North American Breeding Bird Survey, Results and Analysis 1966 - 2003. Version 2004.1. Laurel, MN: USGS Patuxent Wildlife Research Center.

USDA Forest Service. 2001. Final Environmental Impact Statement for the Boundary Waters Canoe Area Wilderness Fuel Treatment. Duluth, MN: Superior National Forest.

USDA Forest Service. 2003. Forest inventory and analysis national core field guide, volume 1: field data collection procedures for phase 2 plots, version 1.7. USDA Forest Service, Washington Office. Internal report. On file with: USDA Forest Service, Forest Inventory and Analysis, 201 14th St., Washington, D.C., 20250.