2
GEIS STUDY COMPONENTS

This section provides an overview of the general structure and methodology used to conduct the GEIS study, as well as its principle outputs. A description of the study's main elements is included, as well as a chart that illustrates the organization of the study. The overall study structure was originally developed in the Feasibility Study and the methodology was developed in the Workplan. The study methodology was specifically developed to meet the study's three objectives, major assumptions, and original work schedule, and structured in a way that explicitly addresses the ten major issue areas identified in the FSD.

2.1
Study Participants

The study team of Jaakko Pöyry international consultants and local experts was organized into a core group, six specialist study groups, the preparers of five background papers, and other specialist staff. In total, more than 60 individuals were utilized by Jaakko Pöyry to help prepare the GEIS. An organizational chart identifying the subdivision of the study into the six study groups and core group is set out in figure 2.1. A brief description of the major responsibilities of the key groups is described below.

Core Group
The group was comprised of Jaakko Pöyry consultants and the local study group coordinator. It was responsible for the overall analysis, writing, and preparation of the study workproducts; preparation of the draft and final GEIS documents; presentations to the EQB, the Advisory Committee, and the public; and ongoing liaison with the state and contract administration matters.
Individuals in this group include:

- Dr. James A. McNutt, Project Manager;
- Doug G. Parsonson, Project Coordinator;
- Dr. Alan R. Ek, Study Group Coordinator; and
- Dr. Lee E. Frelich, Associate Project Coordinator.

Specialist Group
The specialist group was subdivided into six study groups to provide in-depth technical analysis of the ten issues specified in the FSD. In addition, individuals were brought to the project to develop the background papers or provide GIS and pattern analysis. The specialist study groups and their participants are as follows:

Principal Local Study Team Members

Maintaining Productivity and the Forest Resource Base
Dr. Dietmar W. Rose, Dr. Thomas E. Burk, Dr. Alan R. Ek, Dr. Howard M. Hoganson, Dr. Marc E. McDill, David K. Walters, Douglas C. Kapple

Forest Soils and Forest Health
Dr. David F. Grigal, Dr. Peter C. Bates, Jane Cummings Carlson, Dr. Deborah G. McCullough, Dr. James C. Balogh

Water Quality and Fisheries
Dr. James A. Perry, Dr. Raymond M. Newman, Dr. Kenneth N. Brooks, Dr. Nels H. Troelstrup, Jr.

Biodiversity and Wildlife
Dr. Peter Jordan, Dr. Lee E. Frelich, Dr. Gerald J. Niemi, Dr. Donald P. Christian, Joann M. Hanowski, Calvin J. Harth, Dr. Edward J. Cushing, Paul H. Glasser, Will Pitt, Kristina Miller

Recreation, Aesthetics and Cultural Resources
Dr. Dorothy H. Anderson, Dr. David W. Lime, Dr. Leo H. McAvoy, Dr. David G. Pitt, Dr. Christy A. Hohman-Caine, Wayne A. Freimund, Jerrilyn L. Thompson, Grant E. Goltz, Doug G. Parsonson

Economics and Management Issues
Dr. Allen L. Lundgren, Dr. Marc E. McDill, Donald G. MacKay, Dr. Benedict Arias

Several of the specialist study groups addressed more than one issue area. The senior members of these groups are identified in figure 2.1 and the Workplan. A number of other people also provided specific inputs to the study process.

In preparing these papers, each study group carried out the following activities: data collection, technical literature review, evaluation of the existing conditions, background analysis, and the development and evaluation of significant impacts and related mitigation measures. The methodology used for each of these components is outlined in section 2.3.3 of this document, and is set out in detail in the various technical papers.

Each study group was responsible for the preparation of one or more technical papers which, together with the background papers, address all questions stated in the ten issue areas.

BACKGROUND PAPERS

R. Pulkki, Silvicultural Systems
R. Pulkki, Harvesting Systems
J. Hacker, Major Public Forest Land Management Organizations
M. Cesar, Recycled Fibers
J. Bowyer, Consultant, Recycled Fibers
L. Frelich, Global Climate Change

CORE GROUP

J. McNutt, Project Manager
D. Parsonson, Project Coordinator
A. Ek, Study Group Coordinator
L. Frelich, Associate Project Coordinator

PATTERN ANALYSIS AND GIS

L. Queen, Specialist
M. Carlson, Specialist
1x Graduate Research Assistant

Study Group 1

Maintaining Productivity and Forest Resource Base
D. Rose, Group Leader
T. Burk, Senior Specialist
A. Ek, Senior Specialist
H. Hoganson, Senior Specialist
M. McDill, Senior Specialist
D. Walters, Specialist
D. Kapple, Graduate Research Assistant
2x Graduate Research Assistants

Study Group 2

Forest Health and Soils
Soils
D. Grigal, Group Leader
J. Balogh, Senior Specialist
P. Bates, Specialist
1x Graduate Research Assistant
Health
D. Grigal, Group Leader
J. Cummings Carlson, Senior Specialist
J. Balogh, Senior Specialist
D. McCullough, Specialist

Study Group 3

Water Quality and Fisheries
J. Perry, Group Leader
K. Brooks, Senior Specialist
R. Newman, Senior Specialist
N. Troelstrup, Jr. Specialist
3x Graduate Research Assistants

Study Group 4

Biodiversity and Wildlife
P. Jordan, Group Leader
L. Frelich, Senior Specialist
G. Niemi, Senior Specialist
D. Christian, Senior Specialist
C. Harth, Specialist
J. Hanowski, Specialist
E. Cushing, Senior Specialist
P. Glasser, Specialist
W. Pitt, Specialist
1x Postdoctoral Research Assistants
4x Graduate Research Assistants
2x Undergraduate Assistants

Study Group 5

Recreation, Aesthetics and Cultural Resources
Recreation
D. Anderson, Group Leader
D. Lime, Senior Specialist
L. McAvoy, Senior Specialist
J. Thompson, Specialist
P. Glassern, Specialist
Aesthetics
D. Pitt, Senior Specialist
W. Freimund, Specialist
Cultural Resources
C. Hohman-Caine, Senior Specialist
G. Goltz, Senior Specialist
D. Parsonson, Consultant

Study Group 6

Economics and Management
A. Lundgren, Group Leader
M. McDill, Senior Specialist
B. Arias, Senior Specialist
D. MacKay, Specialist

Figure 2.1. Study team organization.

Other individuals involved in preparing the technical and background papers and other workproducts used to develop the GEIS document are identified below. This list does not include the many people who undertook data analysis and other background work.

Jaakko Pöyry Personnel
Louis Carbonnier, Mary Cesar, Dr. Reino Pulkki, Ben Airas, Doug Gill, Scott Estey, Jan Rushing, and Sheila Parsonson

Others
Dr. James L. Bowyer, Dr. LLoyd Queen, Jan J. Hacker, and Clara M. Schreiber

2.1.1 Other Study Participants

In addition to the contractor's study team, the following groups of individuals and organizations also contributed to the study process.

Jaakko Pöyry Network Support Group: This group included Jaakko Pöyry senior management members and specialists who were available for consultation and special analyses relating to issues of policy, industry, and technology.

Minnesota Planning Office: The Minnesota Planning Office was the state's agent for administering the GEIS study. As project manager, the Minnesota Planning Office was responsible for the overall management of the study and was actively involved in all aspects of planning and preparing the GEIS. The Minnesota Planning Office assigned Dr. Michael Kilgore as the state's GEIS project coordinator and to serve as the liaison between the contractor, Jaakko Pöyry Consulting Inc., and the EQB. Dr. Kilgore also administered the GEIS Advisory Committee.

GEIS Advisory Committee: The GEIS Advisory Committee provided inputs and advice to the EQB at various stages of the study process, as discussed in section 1.3.2. The Advisory Committee played an important role in formulating the final significance criteria and selecting mitigation alternatives to be considered in the technical papers and this document. In addition, some Advisory Committee members secured technical advice in the review of draft documents by soliciting comment from independent outside experts and/or agency personnel.

Environmental Quality Board: The EQB role in the study process was to provide overall study direction as necessary and to approve workproducts. The major work of the EQB was conducted through the Board's GEIS

Committee, chaired by Dr. Paul Toren. Other committee members were Rod Sando and Robert Dunn.

Consultant-initiated Ad hoc Peer Review Group: Selected technical experts reviewed the final draft technical papers prior to their submission for approval by the EQB.

Maintaining Productivity and the Forest Resource Base
Dr. Charles Scott, USDA Forest Sciences Laboratory
Dr. Doug Brodie, Oregon State University
Dr. John Pastor, Natural Resources Research Institute

Forest Soils
Dr. Jim Bockheim, University of Wisconsin-Madison
Dr. Bill Atkinson, Dr. Hank Froehlich, and Brian Kramer, Oregon State University

Forest Health
Dr. Bill Miller and Dr. Bob Blanchette, University of Minnesota

Water Quality and Fisheries
Dr. Sandy Verry, USDA North Central Forest Experiment Station
Dr. John Clauson, University of Connecticut

Biodiversity
Dr. Malcolm Hunter, University of Maine
Dr. Thomas R. Crow, USDA Forest Sciences Laboratory
Dr. Steve Chaplin, Nature Conservancy

Wildlife
Dr. Robert Giles, Virginia Polytech Institute
Dr. Robert W. Howe, University of Wisconsin-Green Bay
Keith McCaffery, Wisconsin Department of Natural Resources

Recreation and Aesthetics
Dr. Wayne Tlusty, University of Wisconsin
Dr. John Schomaker, U.S. Fish and Wildlife Service
Dr. Herb Schroeder, USDA Forest Service

Unique Historical and Cultural Resources
Dr. Bill Lovis, Michigan State University
Gordon Peters, USDA Forest Service

Economics and Management Issues
Dr. Robin Gregory, Decision Research
Dr. Randall O'Toole, Cascade Holistic Economic Consult.

Dr. Richard Alston, Weber State University
Dr. Rebecca Judge, St. Olaf College

Independent Peer Review Group: An independent peer review of the draft GEIS was provided by a panel of objective experts prior to the public release of the draft document:

Review Coordinators
- Dr. Roger Sedjo, Resources for the Future
- Dr. Harold Burkhart, Virginia Polytech School of Forestry and Wildlife Resources
- Dr. Bill Lange, USDA Forest Service

2.2 Study Structure

The study flow chart (figure 2.2) shows how the study process was structured to integrate the work products from the various study teams. It also illustrates how opportunities were provided for input from other participants. The steps followed in the study are numbered from 1 to 19 in this figure. The figure identifies some of the preliminary documents which were instrumental in shaping the study approach. Other important factors in shaping the study included the provision of opportunities for the EQB, Advisory Committee, and the public to provide input; the internal relationships between elements of the study team; and the EQB-defined key study workproducts.

Although the major tasks of the study shared several common elements, many of these tasks were undertaken independently and combined later to create the GEIS document. This approach was adopted primarily because of the time constraints originally imposed on the study (refer to section 1.5.7). The short time frame meant that a more desirable linear study format was not possible; therefore, the parallel format was adopted, with six study groups and background paper authors working concurrently on steps 3 to 14, as shown on the study flow chart.

Aside from sharing common objectives stemming from the FSD, the common elements referred to above included using:

- the Forest Inventory and Analysis (FIA) data set from the USDA Forest Service as primary data inputs;
- ecoregions to provide uniform subdivisions of the state for analyzing/reporting impacts at a level of resolution below statewide level;
- the model run outputs from three timber harvesting scenarios as a common basis for data with which to quantitatively assess impacts;

Figure 2.2. Study flow chart.

- approved criteria to identify significant impacts, mitigation alternatives, and preferred mitigation actions;
- information on predominant silvicultural and harvesting systems and techniques used in Minnesota and the current policies, programs, and practices of Minnesota's public forestry organizations; and
- a common structure and format.

2.2.1 Data Inputs

The USDA Forest Service 1990 FIA unit data formed the basis for the harvest scenario modelling and was used by the other study groups to develop characterizations of the forests and forested areas of Minnesota. A comprehensive description of the FIA data can be found in section 4.2.1 of the *Maintaining Productivity and the Forest Resource Base* technical paper. Generally speaking, the FIA data provides the following:

- statewide coverage, reinventoried every 10 to 15 years;
- on-the-ground measurements augmented with aerial photographic interpretation;
- a statistical sample to represent existing forest conditions; and
- estimates for
  - types of tree species and covertypes present,
  - area,
  - volume,
  - growth and mortality, and
  - average annual removals.

The preliminary 1990 FIA test data set was made available to the study team by the USDA Forest Service under the terms specified in a memorandum of understanding between the USDA Forest Service and the EQB. The FIA data were structured into a relational database to facilitate retrieval of user-defined information. Where appropriate, other data were linked to the FIA plot locations to provide a consistent basis for subsequent analysis. The FIA data were examined by each study group to identify data attributes that could be used in subsequent analyses.

2.2.2 Ecoregions

The FSD called for a study that would enable the EQB to assess the cumulative impacts of timber harvesting and related forest management issues at a statewide level, over time, for the specified range of harvesting levels. In order to achieve the stated objectives, the study had to be conducted at a scale of resolution that provided this broad perspective, while still including sufficient detail to substantiate the analysis and to enable development of appropriate strategies to avoid and/or ameliorate identified impacts. A uniform format for the presentation of information was also needed. These requirements were met by subdividing the state into 7 **ecoregions** shown by figure 2.3.

Figure 2.3 Ecoregions used in the GEIS study. (Source: Jaakko Pöyry Consulting, Inc. 1992a.)

These ecoregions are geographic regions with similar physical and biophysical characteristics, and were derived from the ecoregions defined by the Upper Great Lakes Biodiversity Committee (UGLBC). Some of the
analysis was performed using smaller units than the above ecoregion subdivisions. Where possible, results from analyses undertaken at these levels of detail are aggregated and reported at the ecoregion scale.

In the technical papers, the reporting of economic, social, and other impacts was sometimes best handled using other types of regional subdivisions. The choice of the subdivisions used was governed by the form of data available and its ability to provide meaningful interpretations.

2.3
GEIS Workproducts

The following sections describe the major workproducts produced as part of the GEIS study process.

2.3.1
Statewide Timber Harvesting Scenarios

The initial harvesting scenarios were produced as the third workproduct from the study process and are shown as step 6 in the study flow chart (figure 2.2).

Three harvesting scenarios were produced in accordance with the explicit requirement set out in the FSD to analyze environmental and related impacts at three distinct levels of timber harvest intensity. These scenarios model the timber supplies needed to meet (1) the existing levels of demand (4 million cords/ annum), (2) a demand level projected to occur if all planned or announced industrial developments take place (4.9 million cords/annum); and (3) 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* scenarios, respectively. All three harvesting scenarios are projected over a 50-year planning horizon.

The base scenario for the statewide timber demand is 800,000 cords higher than the 3.2 million cord level specified in the FSD. These differences reflect more recent estimates of contemporary wood consumption levels than were available when the FSD was issued.

Details of demand levels for industrial wood and fuelwood used to compile the three scenarios are provided in section 3.5.

Harvesting Scenarios Preparation Process

Harvesting Scenarios as Alternatives: The GEIS uses 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 levels are 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 require is known. The high level of harvesting specified additional harvesting activity needed to reach a level of harvest estimated to be equal to the long-term maximum sustainable level of harvest from the state's forests.

By structuring the study alternatives in this way, the FSD required development of a methodology to allocate or schedule harvests across Minnesota's forests, and over time, to meet the specified levels of demand. The 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 imposed by market demand and the availability of particular categories of forest land for harvesting.

Data yielded from the scenarios formed the basis for most of the subsequent impact analysis undertaken by the study groups. Therefore, the scenarios were a critical element to being able to assess impacts for those issues of concern identified in the FSD.

The scenarios 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;
- a plausible schedule for harvesting over the 50-year study period;
- consequent likely changes to the age class, species composition, and structure of the state's forests during, and at the end of, the period being assessed; and
- projections of the proportion of the specified level of harvest that would be yielded by the various ownerships.

Data Requirements and Model Development: The scope of the study and the need to address the issues of concern required the collection of data describing the existing forest condition and existing and future industry demands and related factors. This information was used in the generation of scenarios that depict how, when, and where harvesting would have to take place. It was also used to depict the type of changes that would occur to the forests under the various levels of harvesting.

The previously described FIA database was selected as the most useful characterization of the state's forested lands and the starting condition of the state's forests. The FIA database contains enormous detail derived from an intensive sampling of the state's forest. Statewide 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. The forested plots were further classified into three categories: *timberlands* (productive forests potentially available for harvest); *reserved forest* (productive and unproductive forest unavailable for harvesting); and *unproductive forest*. Subsequently, only the timberlands were assumed to be available for harvest.

The plots provided a spatial approximation of the total resource and were used as the basic *units* from which the scenarios allocated timber harvesting activity. Each plot from the FIA database has an *expansion factor* that is used to convert plot characteristics to the stand scale the plot represents. As an example, most timberland plots represented 900 to 1,500 acres.

Development of computer models to generate the three scenarios was necessary to handle the amount of information required and to project the scenarios far enough into the future to insure that long-term, as well as short-term, impacts could be detected. Models were adapted and/or specifically developed to generate realistic harvesting scenarios by incorporating the most recent available data covering the following:

- the volume (by size and species), location, and ownership of wood potentially available;
- existing, planned, or potential wood-based industries and their locations;
- current costs associated with timber harvesting, transport, and forest management activities;
- the 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 (see below);
- criteria used by industries to select stands when making purchases of timber; and
- existing land management policies that influence the availability of timber for harvest.

Specific estimated timberland availability by ownership is shown in table 2.1.

Table 2.1. Availability of timberland by ownership assumed for second runs.

Ownership	Percent Available
National forests	
Chippewa	87
Superior	53
State	95
County	95
Other public	64
Forest industry	98

Other private	90

Source: Jaakko Pöyry Consulting Inc. (1992a).

In addition to these data, other important inputs were used in the modelling process. These were:

- the ability to simulate tree growth and the forest development, including forest area and land use change, that would occur during the planning period to reflect the regeneration after harvest, growth (including volume and size increments) changes in the mix of species occupying a site over time (termed *succession*); and
- the ability to alter *utilization levels*, (defined as the minimum and maximum diameters that are used to determine if a log is suitable for a particular use), on a per tree or per acre basis.

Recent and assumed forest area changes are shown in table 2.2. See section 6.12 in the Maintaining Productivity and the Forest Resource Base technical paper for more detail on actual implementation.

Table 2.2. Recent and assumed forest land area change by survey unit, 1990–2040.

FIA Unit	1977–90 (percent)	1990–2040 (percent)
Aspen-birch	-1.47	-5.7
Northern pine	-2.70	-10.7
Central hardwood	9.96	34.9
Prairie	13.57	46.0
All units	0.03	0.2

Source: Jaakko Pöyry Consulting, Inc. (1992a).

Two timber harvest and forest management planning models were also incorporated in the development of the statewide timber harvesting scenarios. These models were:

1. RxWRITE: a set of programs used to develop options for how each area of forest or stand (as represented by the plots) might be managed at each of the 10-year planning decision points used in the study, and
2. DTRAN: a forest management scheduling model that *optimizes* harvesting and management activities by selecting from the options available.

Examples of the types of options produced for a stand old enough for harvesting might include: clearcutting; thinning a certain proportion of the stand; selective harvesting; or no harvesting. For a stand that has just been harvested, the choices might be to allow the stand to naturally regenerate, or to plant it and develop a forest consisting of different species than those occupying the site prior to harvest. Thus, the range of options changed either as the stand aged, or in response to changes brought about by choices made in earlier periods. The range of options available branches out over time and is referred to as a *decision tree*, illustrated by figure 2.4.

Figure 2.4 Example of a Decision Tree. (Source: Jaakko Pöyry Consulting, Inc. 1992a.)

The most appropriate option for each stand at each ten-year decision point was selected by the forest management scheduling model, as it matched demand for a product with the stand or forest best able to supply that product. Demand was aggregated into six *market centers* to simplify the analysis. These are shown by figure 2.5. No market centers were defined in the south of the state because demand was assumed to be comprised of many smaller enterprises.

The rotation ages for various covertypes and the covertypes themselves that were assumed in the GEIS are shown in table 2.3.

Other models were incorporated within this framework as necessary to generate data, and to modify and interpret inputs and outputs: (1) a tree growth model (GROW) was used to grow trees as part of the model that develops prescription options; (2) a regeneration model was developed to portray new stand development following harvesting; and (3) a basic geographic information system type model (GISTRAN) was incorporated into the management scheduling model to generate transport information and to allow graphic depiction of outputs from the model.

Figure 2.5. Market Centers. (Source: Jaakko Pöyry Consulting, Inc. 1992a.)

All together, the above collection and linkage of models was termed the *Forest Change and Scheduling Model*.

Table 2.3. FIA covertypes and minimum nominal rotation ages assumed in the GEIS.

FIA Code	Description	Nominal minimum rotation age*
1	*Jack pine.*—Forests in which jack pine comprises a plurality of the stocking. (Common associates include eastern white pine, red pine, aspen, birch, and maple.)	50
2	*Red pine.*—Forests in which red pine comprises a plurality of the stocking. (Common associates include eastern white pine, jack pine, aspen, birch, and maple.)	60
3	*White pine.*—Forests in which eastern white pine comprises a plurality of the stocking. (Common associates include red pine, jack pine, aspen, birch, and maple.)	60
12	*Black spruce.*—Forests in which swamp conifers comprise a plurality of the stocking with black spruce in the most common. (Common associates include tamarack and northern white-cedar.)	60
13	*Balsam fir.*—Forests in which balsam fir and white spruce comprise a plurality of stocking with balsam fir the most common. (Common associates include aspen, maple, birch, northern white-cedar, and tamarack.)	50
14	*Northern white-cedar.*—Forests in which swamp conifers comprise a plurality of the stocking with northern white-cedar the most common. (Common associates include tamarack and black spruce.)	70
15	*Tamarack.*—Forests in which swamp conifers comprise a plurality of the stocking with tamarack the most common. (Common associates include black spruce and northern white-cedar.)	60
16	*White spruce.*—Forests in which white spruce and balsam fir comprise a plurality of the stocking with white spruce the most common. (Common associates include aspen, maple, birch, northern white-cedar, and tamarack.)	60
50	*Oak-hickory.*—Forests in which northern red oak, white oak, bur oak, or hickories singly or in combination, comprise a plurality of the stocking. (Common associates include jack pine, elm, and maple.)	60
70	*Elm-ash-soft maple.*—Forests in which lowland elm, ash, red maple, silver maple, and cottonwood, singly or in combination, comprise a plurality of the stocking. (Common associates include birches, spruce, and balsam fir.)	60

Table 2.3. continued.

FIA Code	Description	Nominal minimum rotation age*
80	*Maple-basswood.*—Forests in which sugar maple, basswood, yellow birch, upland American elm, and red maple, singly or in combination, comprise a plurality of the stocking. (Common associates include white pine, elm, and basswood.)	70
91	*Aspen.*—Forests in which quaking aspen or bigtooth aspen, singly or in combination, comprise a plurality of the stocking. (Common associates include balsam poplar, balsam fir, and paper birch.)	40
92	*Paper birch.*—Forests in which paper birch comprises a plurality of the stocking. (Common associates include maple, aspen, and balsam fir.)	50
94	*Balsam poplar.*—Forests in which balsam poplar comprises a plurality of the stocking. (Common associates include maple, aspen, and balsam fir.)	40

* The full set of harvest and treatment options and ages are considerably more complex than indicated by this column. For example, ERF rotations are longer than those specified here. See appendix 1, Jaakko Pöyry Consulting, Inc. (1992a), for details.

Assumptions

Development and application of the models generating the three timber harvesting scenarios required certain assumptions generally relating to:

- the use of FIA plots and their associated expansion factors as an adequate approximation of the state's forest resource;
- growth of trees and changes in forests over time and regeneration of trees after harvesting;
- costs of timber harvesting and forest management activities; and
- availability of timberlands for harvest, and applicability of management practices for the different ownerships.

With respect to forest growth, the model used (GROW) is an individual tree-based model that projects individual tree growth and mortality on each FIA plot. The rates of growth and mortality are developed from submodels which themselves were calibrated by USDA Forest Service NCFES researchers and others using data from remeasured and other field plots. The growth and mortality estimated by the model are a function of tree species, size, crown development, site quality, stand density, and to some extent stand treatment. These calibrations and hence the precision and accuracy of estimates reflect the level of disturbance in the calibration data itself. Given that catastrophic disturbances such as fires, windstorms, and insect and disease outbreaks are difficult to incorporate in such databases, we suspect that overestimates of growth are still possible for some forest types. Consequently, for the second model runs, adjustments developed by FIA researchers were also employed with the net effect being to reduce forest growth estimates (see section 4.10.1 of Jaakko Pöyry Consulting, Inc. 1992a). The model also assumed site quality (site index) would remain stable over the 50-year projection period.

For the second runs, covertype changes were developed on an individual plot basis in two ways, that due to harvest and that due to succession or stand dynamics. The first type of change occurred at harvest (clearcut) and was developed from (1) decision trees for planting and (2) in the case of natural regeneration from covertype change matrices developed separately by FIA unit from changes in harvested plots over the period 1977–90 (see section 4.10.1 and appendix 2 of Jaakko Pöyry Consulting, Inc. 1992a). The second type of covertype change was developed from the GROW model results at ten-year intervals over the study period. Covertype change or succession was evaluated by applying the covertype algorithm to the projected FIA plot tree list (the list of trees on the plot and their associated characteristics) at that time and reclassifying the plot by covertype as appropriate. Thus the differing projected tree size, mortality and thinning by species determined the covertype and thus any change. Preliminary comparisons of this approach to actual FIA plot covertype changes over the period 1977–90 suggested this rather direct approach seemed to capture the direction of covertype change.

More specific assumptions for each of the three harvesting levels are discussed in sections 5, 6, and 7. A detailed discussion of all such assumptions can be found in the Maintaining Productivity and the Forest Resource Base technical paper.

Information on predominant harvesting and silvicultural systems, along with the policies of the state's public forestry organizations, were used to develop a detailed profile of the current methods of forest management, silviculture, and timber harvesting practices in Minnesota. Methods with potential application in Minnesota were also considered. Using this information, profiles of typical operations were developed for a range of operations, covertypes, and ownerships and incorporated into the management alternatives used in the forest change and scheduling model. These alternatives describe the silvicultural and harvesting systems that are assumed to apply to each category of operation, covertype, and ownership. This included assessments of the availability of timberlands over time (see below).

Model Runs

Two model runs were made for each of the three timber harvesting scenarios, creating two sets of harvesting scenarios. The major differences between the model runs was the incorporation of covertype dynamics and the assumed availability of timberlands for harvest.

The first model runs assumed that stands retained their original covertype designation throughout the study period, regardless of harvesting or other factors. The second runs incorporated model refinements to include (1) possible covertype change with harvesting, and (2) succession to other covertypes associated with aging and stand dynamics.

In the first model runs, an important assumption was that all timberlands in the state were available for harvesting. The only exceptions were those within legislatively designated reserve areas and those designated as unproductive. The first model runs also assumed that management objectives for all available lands included the possibility of timber harvesting, therefore ignoring and/or simplifying some of the constraints imposed by the various ownerships. The second model runs introduced ownership constraints and mitigations. These constraints and mitigations reflect current and prospective management procedures and policies applied by the major forest land managers. Examples include:

- extended rotation forests (ERF), i.e., rotation for a given forest covertype lengthened, usually by 50 percent, compared to minimum rotation ages. Approximately 20 percent of the timberland on state and USDA Forest Service ownerships to be managed under an ERF prescription (note that the Superior National Forest does not currently have an ERF program);
- greater use of uneven-aged management;
- designation and reservation of old growth and old growth replacement acreage;
- best management practices (BMPs), i.e., thinning or ERF within 100 feet of water; and
- wildlife buffers (thinning only within 200 feet of water) on the national forests and in the southeastern part of the state.

Old growth forest designation was implemented by identifying approximately one to two plots over 120 years old in each covertype (younger when necessary, but no less than 90 years old) and one replacement plot from an adjacent younger age class. Such plots comprised 57,500 acres of old growth and a similar acreage of replacement forest. These plots were then reserved from harvest for the duration of the study period. Much of this acreage was located on state and federal lands.

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

Other model changes for the second runs included refinement of thinning options, notably to reflect desired practice within buffers and for approximating and encouraging uneven-aged management. Forest and timberland area change from 1990 to 2040 was also implemented gradually throughout the 50-year period using estimates of annual change rates (see section 5.2.1 for a description of those rates). The second runs also applied the USDA Forest Service allowable cut limits for yields from national forest timberlands for the base and medium scenarios. National forest cut limits were relaxed for the high scenario. Additionally, a technological change assumption was that northern hardwoods could be substituted for aspen. Section 4.10 of the Maintaining Productivity and the Forest Resource Base technical paper provides a detailed discussion of the second model runs formulation and constraints.

Inclusion of the model refinements described here including stand dynamics, ownership constraints, and mitigations means that the second runs are a reasonable depiction of current and future timber availability.

More runs and more detailed alternatives might have been developed. However, it must be noted that the GEIS is not an agency-specific planning exercise, rather it is an attempt to assess impacts of specified levels of harvesting at an ecoregion and state level across ownerships.

The outputs from the model runs were in the form of plots harvested by planning period; the type of harvesting (clearcutting and thinning); the products harvested; products delivered and their cost; and assumed management activities (aside from harvesting). These outputs were used as an input into the forest change model which generated depictions of the forest condition on each plot over time. Depictions of changes on each plot were created at an individual tree level of resolution. The tree and plot expansion factors and stand acreage were then used to convert this to stand level and ecoregion changes.

The study groups used various parts of this output, depending on their specific requirements for conducting environmental impact assessments. For example, the forest soils study group required information on the volume of timber removed by covertype and the frequency of harvests; whereas the wildlife group required data including the presence or absence of certain key tree species, the age and size class structure of stands, and any changes in covertype.

The forest changes projected under the scenarios were then used to develop and characterize impacts affecting the issues of concern for each of the three harvesting scenarios.

Descriptions of the study group analyses using the model outputs are set out in more detail in subsequent sections of this document.

2.3.2 Study Criteria Development

There are three types of criteria developed for the GEIS:

1. *significant impacts* criteria;
2. *mitigation alternatives* criteria; and
3. *mitigation strategies* criteria.

These criteria were prepared as the major component of the fourth work product of the study process, which corresponds to step 10 in the study flow chart (figure 2.2).

The criteria were developed to facilitate input from the Advisory Committee and EQB into the study process. The first category was developed to assess the significance of each of the impacts identified in the study process. For those impacts identified as significantly adverse, a second set of criteria was developed to identify potentially suitable mitigation alternatives. Finally, the third set of criteria was developed (to select between mitigation alternatives) to identify appropriate strategies for policy development.

The criteria developed were critical work tools that ensured the study remained focused on the process needed to develop the best set of mitigation strategies to address cumulative, statewide impacts. Key issues and objectives in this process were:

- to comprehensively identify all potential impacts;
- to develop a systematic approach for assessing impacts in order to identify those which are considered significant;
- to develop intellectually sound/objective alternatives to minimize those impacts identified as significant;
- to facilitate two-way feedback between the GEIS study team and the EQB Advisory Committee on development of these criteria; and
- to develop a framework for identifying practical mitigation strategies that have the uniform support of all parties involved.

Criteria Development Process

A sequential process was used to develop the criteria. The initial or first run timber harvesting scenarios were analyzed to identify impacts, by issue area, that could occur at the three levels of timber harvesting. Technical criteria were developed that identify (in most cases) threshold levels that indicate when impacts were considered to be significant. These levels were developed using existing standards where appropriate, and from the literature or based on expert judgement where standards do not exist. In practice, very few standards had been previously developed to address the issues examined in the GEIS. Consequently, expert opinion and judgements were dominant factors in shaping the significance criteria.

The criteria, which have been approved by the EQB, reflect input from the EQB, based partly on advice from the GEIS Advisory Committee. The GEIS study team provided draft, technically-based criteria, and the Advisory Committee added a social dimension. This two-stage approach to criteria development reflects the identified role of the Advisory Committee and EQB (and its staff) (FSD section IV.C) to determine those issues where significant impacts could result from timber harvesting.

The sequence of how the criteria were applied, and the points where Advisory Committee and EQB input were required as part of the criteria development process are illustrated in figure 2.6.

Significant Impacts Criteria

Impacts identified in the course of this study varied in their significance and therefore in the need to develop a specific mitigation response. This was a critical stage of the study process, as these tests of significance ultimately defined the scope of mitigation responses developed by the GEIS.

Identification of an impact as being significant does not automatically prescribe a specific mitigation response. The significance criteria were developed to be inclusive rather than exclusive. Their purpose was to identify the issues and circumstances where policy initiatives were required. The range of possible policy responses, the factors used to choose between them, and the implications of selecting a particular response were all evaluated by subsequent criteria.

Criteria were developed to evaluate each of the issues of concern in the FSD. The categories of impacts to be considered are set out in the FSD within the Issues of Concern (section viii, page 8). Eighteen *categories* of impacts were identified, based on the ten issue areas in the FSD. The categories are set out in the left hand column of table 2.4.

For each significance criterion developed, several background factors were used to determine levels or thresholds when impacts are likely 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. They include:

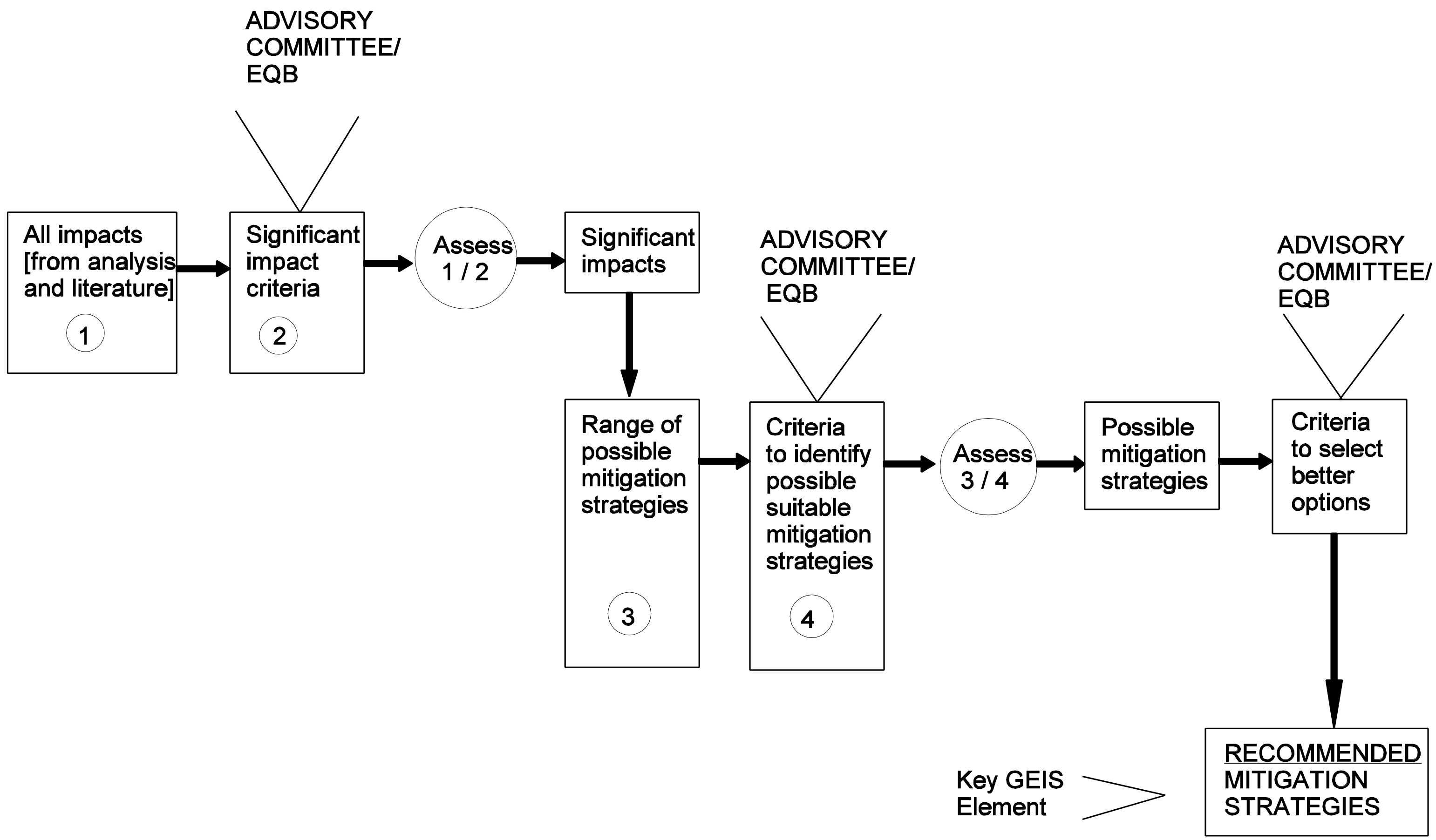

Figure 2.6. Process for criteria and mitigation strategy development. (Source: Jaakko Pöyry Consulting, Inc. 1991c.)

- severity and spatial extent of impact;
- certainty of impacts;
- duration of impact (irreversibility);
- consideration of existing guidelines and standards; and
- biological and economic implications.

The first factor identified the likely extent and severity of an impact. Impact extent varies from very localized site-specific impacts to those impacting a watershed, physiographic region, soil type, covertype, ecoregion, or the entire state. The second factor identified the degree of certainty that a predicted impact would occur. The key factors influencing certainty are identified for each criterion. The third factor incorporated the anticipated duration of the impact, and whether or not it is reversible. Duration was defined as very short-term—less than 2 years; short-term—2 to 10 years; medium-term—10 to 50 years; long-term—greater than 50 years; and irreversible. The fourth factor incorporated those existing standards and guidelines that are applicable to the respective issue areas. The fifth factor identified the key biological and economic implications of the impact.

Most of the criteria were applied to assess both positive and negative changes to the specified variable. Changes were assessed cumulatively over the 50-year study period, and in most cases, assessments were made at ten-year intervals. Most criteria were applied statewide, although some were applied to smaller geographic units, usually ecoregions.

Table 2.4 lists the significant impact criteria and the issue areas they were intended to address.

Mitigation Alternatives Criteria

These criteria were used to identify mitigation actions with the potential to address the identified significant impacts. The purpose behind this stage of the process was to identify mitigation actions which are effective and practical in a physical context, as well as in terms of the political, financial, and administrative environments in Minnesota.

Input from technical experts, the Advisory Committee, and the EQB are reflected in the final criteria. Unlike the significance criteria, the criteria to identify potential mitigation alternatives were applied uniformly across all issue areas documented in the FSD.

Major considerations used in the development of criteria to identify potential mitigation alternatives included:

- financial considerations;
- administrative considerations;

Table 2.4. Coverage of FSD issues of concern by significance criterion.

Final Scoping Decision issues of concern		Significance Criterion																				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
A1	*Descriptive**																					
2	*Descriptive*																					
3	Unsustainable harvest					X																
B1	Changes to forest area	X																				
2	Abundance, composition, spatial distribution, age class structure, genetic variability, and tree species mixture	X	X	X	X	X				X		X	X									
C1	Risk of disease and insect infestations					X	X															
D1	Biological diversity at genetic, species, and ecosystem levels-patterns of forest		X	X	X	X				X	X	X										
2	Federal and state species of special concern, threatened, or endangered species or habitats								X		X	X										
3	Old growth and old forests					X		X														
E1	*Descriptive*																					
2	Populations and habitats of ten groups of wildlife and fish		X	X	X	X					X	X	X			X						
F1	Sedimentation, nutrient and runoff													X	X		X					
2	Fertilizers, compost and sludge													X								
3	Aquatic ecosystem, wetlands and peatlands													X		X						
G1	Erosion																X					
2	Nutrient cycling, productivity																		X			
3	Compaction																	X				
4	Seasonality of harvest																	X				
H1	Recreation			X																X		
I1	. Regional and state economies . Sectors benefitting . Sectors disadvantaged																				X	
2	. Recreation and tourism industry . Segments that benefit . Segments that are disadvantages . populations and habitat of game species consumptive uses																			X	X	
3	*Descriptive*																					
4	*Descriptive*																					
J1	Cultural, historical resources																					X
2	Visual quality																			X		

Source: Jaakko Pöyry Consulting, Inc. (1991c).

*Some issues in the FSD require description of existing conditions rather than change.

Significance Criterion and corresponding number (key to table 2.4)

KEY

1 Changes to MN forests - size and composition of forest land base
2 Changes to MN forests - patterns of forest cover in areas of mixed land use
3 Changes to MN forests - patterns of forest cover in predominantly forested areas
4 Changes to MN forests - tree species mix
5 Changes to MN forests - age class structure
6 Forest health - change in susceptibility or vulnerability
7 Old growth forests
8 Federal- or state-listed species of special concern, threatened, or endangered species or their habitats
9 Forest species - genetic variability
10 Forest dependent wildlife - habitats (lowland conifers)
11 Forest dependent wildlife - habitats
12 Forest dependent wildlife - food species
13 Lakes, rivers, streams, and wetlands - level of sedimentation/nutrient loading
14 Lakes, rivers, streams, and wetlands - runoff
15 Lakes, rivers, streams, and wetlands - aquatic ecosystems
16 Forest soil productivity - soil erosion
17 Forest soil productivity - compaction/puddling
18 Forest soil productivity - nutrient removals
19 Forest recreation and aesthetics - visual impacts
20 Regional economics - changes in economic parameters
21 Historical and cultural resources - forestwide impacts

- certainty of effectiveness; and
- social implications.

Mitigation Strategies Criteria

The criteria developed for this aspect of the process were used to identify the preferred mitigation strategies that form the basis of the tactical GEIS recommendations set forth in sections 5 to 7. Selection of preferred mitigation strategies depended on consideration of the following characteristics of each mitigation alternative:

- effectiveness—Can the mitigation alternative accomplish its intended objectives?
- feasibility—Can the mitigation be implemented?
- concomitant effects—What effects, beneficial and adverse, would the mitigation measure have on other resources values?
- implementation success—What is the likelihood that the mitigation will be successfully implemented?

As with the criteria used to identify mitigation alternatives, these criteria were applied uniformly to all mitigation actions identified in the previous stage of the process. The objective was to develop workable mitigation strategies that collectively addressed the significant impacts in an integrated fashion, thus insuring strong, workable policy options.

2.3.3 Technical Papers

The following describes the subject matter and role of the technical papers in the GEIS process. The subject matter of each paper is related to the issues of concern identified in the FSD. All the technical papers shared some common elements, and these are described here, followed by a brief synopsis of each of the papers' objectives and methodology.

Role in the GEIS Study Process

The technical papers were developed to provide an in-depth analysis wherever possible of each issue of concern identified in the FSD. Information sources are identified, and the methods used to conduct the impact analysis are explained.

The impact analyses identified cumulative impacts that could be linked to the statewide levels of timber harvesting and forest management activities developed in the three harvesting scenarios. The impacts were assessed for significance, and mitigations were identified and assessed using the EQB-approved criteria and the processes previously discussed.

Each technical paper describes the application of this process to the relevant issue area(s). The outcome of the process is an assessment of significant impacts, the range of mitigation options available (if any), and the preferred alternatives. The criteria referred to previously were used for decision making. The analysis required to apply the criteria also provides results that justify the conclusions and recommendations of each technical paper. The technical papers represent a comprehensive record of the way each issue area was addressed, why it was addressed in this way and the outcome of the analysis.

Conclusions from the technical papers are integrated into the GEIS document, together with information from the background papers, primarily in sections 3 to 7.

Common Elements
Some common elements in the technical papers were necessary in order to integrate the papers into the GEIS. These were described in section 2.2. In addition to a common structure, the technical papers used similar approaches to the literature review and background analysis.

The key elements of the technical papers and a proforma for their structure were specified in the contract for consultant services between the state and Jaakko Pöyry Consulting, Inc. This format was acknowledged in the Workplan. The specified format has been modified slightly to aid in presentation.

Literature Review
Comprehensive literature reviews were carried out by the study groups. The literature reviews were used to identify the ecological, biological, and physical processes of relevance to the study area. They were also used to identify the cause and effect relationships between these processes and timber harvesting and forest management activities. Reviews typically involved a tiered approach, focusing on ecoregions and USDA Forest Service FIA units in Minnesota, then subsequently the Great Lakes region, the United States, and where appropriate, the world.

Background Analysis
The information and data collected during the literature review were used to augment existing information held by the experts in the study groups. Data and information were used as follows:

1. to describe the types of timber harvesting and forest management activities that could be applied under the various scenarios;
2. to describe existing conditions in the natural, social, and economic environments of relevance to the ten issue areas including an analysis of the current level of industry and related harvesting activity;
3. to analyze the relevant processes and changes that have shaped present conditions, including the rate and direction of changes; and
4. to identify how timber harvesting and forest management activities

interact with the forest environment in terms that reflect the ten issue areas.

Where appropriate, models that simulate the processes of change, particularly those caused by timber harvesting and forest management activities, were examined and tested by the study groups to determine their suitability for use in the study.

A separate analysis was conducted to identify and characterize the patterns in forest cover, particularly changes resulting from timber harvesting and forest management activities. Patterns in forest cover were examined, with thirty sample sites randomly selected from the list of FIA ground plots where timber harvesting has occurred recently. Aerial photo interpretation was then used to map patterns of forest cover for the section surrounding these plots. The patterns were interpreted and mapped by land use, forest covertype, stand size, and density classes, as per FIA procedures. A ground check was made to verify this interpretation and mapping. Based on these data, profiles of the typical patterns created by the range of timber harvesting and forest management activities were generated. This information was subsequently used by various study groups to interpret the impact spatial harvesting patterns might have on specific resources. Section 4.3.3 provides a good example of how this information was used in interpreting timber harvesting impacts on riparian corridors.

Objectives and Methodology

The following section provides an overview of the objectives and methodology used by each of the study groups to address the issues of concern from the FSD, identified in section 1.5.5. Unless otherwise noted, study methods and analysis pertain to the second model runs.

Maintaining Productivity and the Forest Resource Base

Objectives: This study group had three primary objectives, which collectively were of key importance to the entire GEIS process:

1. to develop the three FSD-required timber harvesting scenarios, which describe projected future forest conditions up to 50 years based on assumed levels of timber harvesting (as described in section 2.3);
2. to assess the current productive potential and long-run sustainable yield potential of Minnesota forests; and
3. to describe the key attributes of the forest resource base, including identification of historical changes, factors affecting change, and description of the current statewide forest resource base.

Methodology: The work of this study group was of fundamental importance to the GEIS. The study group analyzed the current resource status and used this analysis to develop the harvesting scenarios discussed in section 2.3. Considerable interaction with the other study groups was required for this component of the GEIS study, and the results served as the basis for estimating the potential of the forest resource to produce various levels of timber outputs and the associated costs of producing these outputs.

The productive potential and the long-term sustainable yield potential of Minnesota forests were examined for different time periods under different levels of investments in forest management practices and for different ownerships and regions. This part of the study was carried out after the study group developed a clear understanding of the existing resource base, as well as an understanding of how it has been shaped by past actions.

Forest management schedules were simulated using the forest change and scheduling model. The specific model formulations were constructed to examine specific issues, including the impact of assumptions about forest growth and yield on predicting the productive potential of Minnesota's forests.

The analysis also examined aspects of resources management, identifying potential inefficiencies and constraints in the supply of timber by regions over time. Recommendations for improved integration and the delineation of *sustained yield* units are made, based on identified opportunities and potential cost savings. The cost of producing various levels of forest products over time is an important byproduct of the scheduling model. These production cost estimates reflect required production levels, initial inventory, and changes in the inventory over time as a result of harvest and management activities. The impacts of intensifying forest management, imposing management constraints such as buffers, and excluding certain lands for timber production is measured by the change in the production costs. This serves as an indicator of the potential tradeoffs among various management options. Management problems such as those associated with overmature aspen, low quality northern hardwood stands, stocking control, and appropriate choice of species are also discussed.

The forest management schedules for each scenario were examined to identify their impact on nontimber resources. The schedules also provided data for an economic impact assessment by identifying when, where, at what level, and at what costs certain management activities will take place under each simulated scenario. The study group provided other study groups with detailed descriptions of the harvest schedules and management for each scenario, including the timing and location of all major forest management activities. Feedback received from experts in other study groups was in the form of management constraints or mitigations to protect or enhance nontimber values of the forests. These constraints and mitigations were incorporated into the forest management scenarios used for the second runs of the forest change and scheduling model.

The Maintaining Productivity and the Forest Resource Base study group was also responsible for the evaluation of potential impacts on the timber harvesting scenarios brought about by increased uses of recycled fiber in Minnesota. Input from a background paper on recycled fiber (section 2.3.4) was used to assist in this.

Forest Soils and Health

Forest Soils

Objectives: The study group's objective was to assess the impacts of the three levels of statewide timber harvesting and forest management activities on forest soil's erosion, nutrient cycling, compaction, and overall productivity. The importance of this objective is that maintenance of site productivity is a key factor in sustainable forest management. Therefore, identifying and reducing impacts on forest soils is an essential part of any strategy to achieve sustainable forest management. Adverse impacts on soil resources are strongly linked to the other issue areas. Eroded soil can impact water quality, aquatic ecosystems, and water-based recreational and tourist uses. A decrease in site productivity could affect wildlife populations and ultimately, the level of harvesting the forest can sustain.

Methodology: To this end, this study group reviewed and summarized the current state of knowledge on the effects of timber harvesting and forest management activities on forest soil properties. This information was applied to Minnesota conditions by using a Geographic Information System (GIS) to assess the impacts of the three levels of timber harvesting on soil erosion, soil compaction, nutrient cycling, and forest productivity, as outlined in the objectives statement.

A review of the available literature, input from core group experts, and information from the harvesting systems and silviculture systems background papers were used to identify:

- timber harvesting and forest management impacts on soil properties;
- specific soil properties that are important for evaluating these impacts; and
- the spatial distribution of forest soil properties in Minnesota.

Based on the results of this review, a series of decision rules and impact assessment matrices was developed to evaluate the effects of forest management activities on Minnesota's forest soils.

The overall impact assessment was facilitated by subdividing the state into seven ecoregions, as discussed in section 2.2.1. Soil, vegetation, and climatic characteristics for each ecoregion were quantified, based on thematic layers available in the GIS.

Impacts were evaluated by running different timber harvesting and forest management scenarios through the assessment matrices. The resulting spatial and temporal distribution of harvests indicated the extent or acreage of various soils impacted, according to the type of harvesting. Each scenario was evaluated within each ecoregion. Ecoregions were aggregated in order to estimate statewide impacts. Where adverse impacts were identified, the study group worked with other study groups to develop strategies to mitigate those impacts.

Emphasis in the technical review was on Minnesota conditions; information was drawn from work done in Minnesota, states adjacent to Minnesota and neighboring Canadian provinces. The review considered timber harvesting and forest management as agents of change in forests, and compared changes due to these activities with more *natural* changes, such as those from natural plant succession and windstorms to *seminatural* changes, such as those from forest fires, and to other changes caused by human activity, such as roads, air pollution, global climate change, and increased recreational populations in forested areas.

Forest Health

Objectives: This study group's basic objective involved an assessment of the risk of insect damage and disease, as related to current and projected harvest levels, by ownership class, geographic region, tree species, and forest type. The importance of this objective is that the management of Minnesota's forests should insure the forests are sustained in a healthy condition over long periods of time and that the negative impacts of epidemic disease and insect infestations are minimized. Although endemic populations of both insects and pathogens are important components of forest ecosystems, outbreaks of pests can result in substantial ecological and silvicultural losses. Plant stress induced by moisture and nutrient depletion, climatic conditions, and timber harvesting and forest management practices contribute to insect and pathogenic infestation. In addition, elements of global atmospheric change such as air pollution and global warming may affect forest health.

Methodology: The study group assessed effects of timber harvesting and forest management on risk of pest infestation and identified factors that may contribute to, or mitigate pest damage. A review of technical and scientific literature aided in the identification of primary insect and pathogen pests associated with specific species and covertypes in Minnesota forests. Ecological and management-related factors were also surveyed to determine their influence on pest population buildup and damage. Treatments or management options for minimizing pest impact have been provided.

Effects of timber harvesting levels and forest management intensity on pest impacts were assessed by combining information derived from the technical literature review with information available in GIS form. Matrices were developed relating specific pests with important site or stand-related attributes. A hierarchical approach to database and matrix development allowed information to be aggregated on varied scales. Potential impacts of pests were subsequently evaluated on an ecoregion or statewide basis. Pest information was integrated with the timber harvest and forest management scenarios developed by other study groups using an iterative feedback, review and revision process. The potential impacts of harvesting scenarios on pest damage, practices to alleviate damage, and data or knowledge gaps that limit development of conclusions were also analyzed.

This study group focused on the following key items:

- primary insect pests and diseases for each ecoregion, covertype, and dominant forest species in Minnesota, with focus on diseases and insects currently regarded as significant problems. Where appropriate, insects and diseases were identified for specific stages of forest development; e.g., seedling establishment, seedling-sapling, sapling-mature, mature- overmature, for dominant forest species and covertypes;
- infrequent or historical outbreaks of other forest health problems and their potential future significance;
- pests not currently established in Minnesota but with potential for significant impact (e.g., gypsy moth);
- ecophysiological traits associated with epidemic and/or damaging populations of forest pests. Traits were divided into:
  - ecological variables not directly related to forest management activities, including soil, topography, and climatic variables; and
  - site or stand variables directly influenced by forest management activities including stocking, stand size, or species composition.

  Potential impacts of landowner class on risk of pest infestation were included in the analysis;
- forest management activities that may increase risk of pest infestation or damage. Forest management activities to avoid or mitigate damage from insects and pathogens were also identified for pests noted above;
- scientific literature pertaining to effects of global climate change, acid rain, and ozone on forests and associated insects and diseases. Where possible, the possible impacts of these factors on forest pests in Minnesota were considered; and
- gaps in the knowledge base. Following the literature review, gaps were noted and priority research needs have been identified.

Emphasis in the technical review was on Minnesota conditions. Information was drawn from work done in Minnesota and adjacent states and Canadian provinces. The review considered forest management as an agent of change in forests, wherein changes due to natural plant succession were compared with changes caused by management and other human activities. Examples of changes brought about by human activities include air pollution, global climate change, and increased recreational populations in forested areas.

Water Quality and Fisheries
Objectives: This study group's basic objectives included assessing the impacts of the three timber harvesting scenarios and forest management activities on:

- sedimentation, nutrient loading and runoff in lakes, rivers, streams, and wetlands;
- surface and groundwater quality as related to uses of fertilizers, compost, sludge, and pesticides; and
- forest dependent fish species, their habitat requirements, and their current status and distribution.

Methodology: This analysis of the effects of increased timber harvest was developed from literature reviews and professional experience. The analysis was conducted by a seven-member study group representing water quality, hydrology, fisheries, and ecological disciplines. The work is presented in an ecoregional framework (i.e., changes are presented for each of three harvest scenarios, by ecoregion), based on the seven ecoregions of Minnesota. This analysis focuses on the two largest and most forested ecoregions, but it also includes comments on the other ecoregions. While all lakes, streams, and wetlands were considered within an ecoregion framework, the analysis focused on first through third order streams and 10- to 50-acre lakes as these were the most likely to be impacted by harvesting.

The study focusses on the potential impacts of the three harvesting scenarios on more than 15 water resource variables. The impact of each scenario on each variable is described with the following four qualifiers:

1. indications of direction of change;
2. indications of magnitude or severity of change;
3. indications of uncertainty due to variability in time and space; and
4. indications of uncertainty due to data considerations.

The fish community has been divided into coldwater species (e.g., salmonids, sculpins) and coolwater-plus-warmwater species (e.g., percids, centrarchids, cyprinids). Impacts on those communities are stratified by lake and stream strata because of variations in the type and degree of impact. Waterbodies are stratified by size and location in the basin. Impacts from timber harvesting and forest management activities vary with waterbody size strata. The small and low order systems receive more direct impact, while larger lakes and higher order streams receive more indirect impact. Background data on water quality, the fish community, and fish habitat vary predictably with ecoregion, thus facilitating the identification and predictability of impacts.

The forest change and scheduling model via changes in FIA plot characteristics produced the spatial and temporal distributions for the various harvest intensity scenarios. These change data, in turn, served as driving variables for water resources and fisheries analyses. Significant impact assessment criteria and appropriate strategies to mitigate impacts were developed in conjunction with the other study groups.

Biodiversity and Wildlife
Biodiversity
Objectives: This study group's objectives focused on assessing the impacts of timber harvesting and forest management on biodiversity, and the resulting technical paper complements the Forest Wildlife technical paper. Specifically, the objectives were to assess impacts on:

- biological diversity in forests at genetic, species, and ecosystem levels;
- forest dependent federal and state species of special concern, threatened, or endangered species or habitats; and
- old growth and old forests.

Methodology: In considering how timber harvesting and forest management may impact forest plants and endangered, threatened, or special concern animal species the emphasis was on the habitats of species, rather than the populations themselves. The forest management practices analyzed in the GEIS affect species primarily through altering forest type and age class. This in turn comprises the substrate, and cover required by the animals and smaller plants. Habitat matrices, based on research by study group members, were applied to the endangered, threatened, or special concern animal species in the state. However, there is not sufficient data to construct habitat matrices for understory plant species in Minnesota. Consequently, given the lack of data for analysis of individual plant species habitat, it was assumed that small plant diversity—as well as moss, fungi, and insect diversity—is dependent on structure at the community and ecosystem level. Further, it was assumed that the best way to maintain regional biodiversity and prevent species extinction, is to maintain *examples* of all natural community types recognized by the Minnesota Natural Heritage Program in the context of a fairly natural landscape pattern.

The technical assessment of timber harvesting and forest management impacts on biodiversity was undertaken using a variety of information sources and synthesis processes. Initially, each study group member thoroughly examined the technical literature on relationships between forest land animals or plants and the forest communities that are their habitats, particularly as these are affected by forest management changes. This review was used together with input from the background papers on harvesting systems and silvicultural systems to identify: (1) known habitat attributes for plant species that would be impacted by changes in age, composition, and spatial patterns of forest stands; (2) case studies in which timber harvesting and forest management activities have led to changes in plant communities; and (3) specific information on rare or endangered species associated with any forest system within the state.

Because information summarized from the USDA Forest Service's FIA plots was the only systematic, statewide source on forest habitat data available, this study group attempted to tie the analyses of old forests and abundance of plant species of interest to the extent of specific forest types and age classes, as designated within the FIA system.

The potential impact of timber harvesting and forest management on wildlife and plant species of interest was evaluated for the three levels of harvest—base, medium, and high. The Maintaining Productivity and the Forest Resource Base study group supplied projections of Minnesota's forest resource base for each of the next five decades under each of these three harvesting levels. These projections included postcutting acreages and age class distributions of each FIA covertype, in each of the seven ecoregions.
These data were used to estimate the amount of habitat available for communities, old forests, and species of interest.

This input was then used to assess significance of projected impacts and appropriate mitigation strategies against the EQB-approved criteria. The Biodiversity study group worked very closely with the Wildlife study group to assure the best possible technical results in achieving both groups' goals.

Wildlife
Objectives: The group's objectives were to:

- identify the forest dependent species of wildlife, their specific habitat requirements, and their current status and distribution; and
- determine to what extent timber harvesting and forest management will impact populations and habitats of eight broad groupings of wildlife as outlined in the FSD.

Methodology: This study group assessed the potential impacts of base, medium, and high levels of timber harvesting and related forest management activities on Minnesota's forest wildlife over a 50-year planning period. Impact analyses were done by four separate subgroups—small- and medium-sized mammals, large mammals, birds, and herptofauana (amphibians and reptiles). For each of these four subgroups, species of interest (those species that depend on forested habitat or survival) were selected for analyses. Species of interest included 22 small- and medium-sized mammals, 5 large mammals, 138 birds, and 12 herptofauana. Analyses of wildlife populations were performed statewide and for each ecoregion within Minnesota for virtually all species. These analyses were closely coordinated with work of the Biodiversity study group, which assessed the impact of timber harvesting and forest management on all plant species and wildlife or plant species that are endangered, threatened, or of special concern.

As specified in section 2.3.2, the three timber harvesting scenarios incorporated various ownership constraints, notably constraints on availability, and mitigations including ERF, uneven-aged management, reservation of old growth, BMPs, wildlife buffers, and modelling refinements that estimated forest area and covertype change for 1990–2040.

The eight broad wildlife groupings identified by the FSD were all analyzed: forest ungulates, forest grouse, forest furbearers (carnivores and rodents), forest interior birds, conifer-dependent birds, hardwood-dependent birds, forest raptors, and species that require old or mature forest. Two additional categories were added by the Wildlife study group: cavity-dependent birds and riparian birds.

The three harvesting scenarios provided one major type of data that can be linked to wildlife populations. These data were the acreage and approximate location of forest by USDA Forest Service FIA forest covertype, and stand age or size class. Thus, the strategy employed by the study group to assess impacts of timber harvesting and forest management activities on wildlife populations was to link abundance of each species to specific FIA forest covertypes, and age or size classes in the existing forests of Minnesota. For each species of mammal and bird, an index of relative abundance was constructed. The indices weighted acreage of each combination of forest type/size class by its value as habitat for the species. The direction and magnitude of future population change was then estimated by examining projected acreage of forest types and size classes under each of the three harvesting scenarios. Data were more limited for herp species; consequently, the total acreage of potential habitat, both existing and in the future, was used as an index of population change for this species.

After identifying the direction and magnitude of the population changes, the study group applied the EQB-approved criteria mechanism to identify the likely significant impacts and generate the appropriate mitigation strategies.

Recreation, Aesthetics and Cultural Resources

Recreation and Aesthetics

Objectives: This section sets out the methodology used to assess impacts relating to recreation and aesthetics issues. The objective of the study group was to assess the impacts of three levels of timber harvesting and related forest management on each issue area noted here:

- to what extent are forest recreation opportunities both quantitatively and qualitatively impacted by timber harvesting and forest management;
- do such impacts vary by type of recreation; and
- to what extent does timber harvesting and forest management impact the visual quality of the state's forests?

The overall approach taken was first to assess impacts on recreation opportunity classes and the recreational activities that take place within those classes. Then the group assessed aesthetic values within each recreation opportunity class. This was followed by characterizing the visual sensitivity of sites. Subsequently, this led to an assessment of aesthetic impacts due to harvesting. The methodology has been outlined separately for recreation and aesthetics.

Recreation Methodology: Forests provide significant opportunities for a wide variety of recreational experiences. Timber harvesting operations and related forest management practices can affect the quality of the recreationist's experience and the kinds of opportunities provided. Changes in recreation opportunities as a result of harvesting are not well known or documented. Little research has been conducted to examine the relationships between timber harvesting and recreational use patterns in Minnesota.

Furthermore, on a statewide basis, little is known about how or why different landscapes appeal to different kinds of recreationists. The types of recreation opportunities provided on some public lands within the state are known, and in some cases, why visitors go to those places is also known. For example, various divisions of the MNDNR have conducted recreation surveys to find out where recreationists go, what activities they engage in, what their motives are, and what kinds of facilities/resource areas are needed to meet current and future recreation needs statewide. There is also an extensive annotated bibliography of social science research conducted in the Boundary Waters Canoe Area Wilderness (BWCAW). Findings from these and other studies were compiled to assess the range and diversity of opportunities statewide.

Since the location, number, and type of recreation opportunities existing statewide are not well defined, it is unclear whether or how timber harvesting practices diminish or enhance opportunities on the whole. Despite these limitations, the study group made a concerted effort to estimate changes in outdoor recreation opportunities expected to occur as a result of the three timber harvest level scenarios. Specifically, the group has:

- identified the range and diversity of outdoor recreation opportunities existing within the state;
- assessed the impact of timber harvesting levels on various types of recreation, recreation users, and specific recreation activities;
- identified and assessed possible changes in recreation use patterns and recreation users as a result of increased timber harvesting and forest management activities;
- assessed recreation users' attitudes toward timber harvesting and forest management practices and how these attitudes affect user behaviors; and
- assessed the quality of recreation opportunities and experiences resulting from different timber harvesting and forest management activities scenarios.

The Recreation Opportunity Spectrum (ROS) was used as the guiding framework to describe recreation opportunities within the state. Briefly, ROS describes six levels of recreation opportunities—primitive, semiprimitive nonmotorized, semiprimitive motorized, roaded natural, rural, and urban. Generally, opportunities described in the primitive range are less developed, less accessible, and less abundant. They also tend to occur in more natural areas than nonprimitive opportunities.

For each harvest level, each of the six opportunity classes identified within the ROS framework was examined to identify and assess changes in activities, setting attributes, and the value of the recreation opportunity. Changes in recreation opportunities as a result of timber harvesting activities were defined as movement of a forest area from one ROS class to another. By definition, any change in the recreation opportunity results in a change in the kinds of recreation experiences possible.

The forest recreation experience is highly dependent upon visual and other sensory stimuli. Research indicates that the quality of that experience and the ability of a forest resource to attract visitors/tourists/recreationists is closely related to the perceived quality of the view. Consequently, the recreation and aesthetics specialists worked together to coordinate the literature review in common topic areas, and to share data and conclusions in developing impact matrices. The primary areas covered included:

- resource setting attributes relevant to recreation opportunities;
- recreation activities arrayed from high visibility/high resource impact to low visibility/minimal resource impact as related to specific setting classes; and
- direct and indirect values of various recreation activities.

In addition, emphasis was given to the study of nonroaded areas and the implications of developing permanent forest roads in such areas.

Aesthetics Methodology: Conceptually, the methods used to assess visual sensitivity were similar to those used by the National Forest System. The ROS, a key component of recreation value, is used as a recreation planning and management tool on national forests. The visual management objectives that serve as the core of the USDA Forest Service Visual Management System (VMS) are analogous to visual sensitivity ranks.

The data needs and assessment procedures used in setting visual management objectives are similar to those used in assessing sensitivity rank.

Two constructs, relative forest attractiveness value and recreation value, combine to define the visual sensitivity ranks of the timberland plots. An area of high visual sensitivity possesses a high level of relative forest attractiveness, and would also be a place where many people pursue a variety of outdoor recreational activities. In contrast, an area of low visual sensitivity would have a comparatively low level of relative forest attractiveness, and few people would use the area as a recreational activity setting.

It follows that the most visually sensitive areas are where more stringent visual management prescriptions would be appropriate. The study group assumed for this exercise that failure to implement such prescriptions would produce significant adverse impacts on the recreational and aesthetic values of the harvested forest and of surrounding areas. In contrast, timber harvesting and forest management activities occurring on less sensitive plots need to conform to only the most basic visual management prescriptions. These less sensitive areas were assumed not to be particularly attractive nor would they be likely to sustain high levels of recreational use.

In summary, a total of five visual sensitivity ranks were identified:

Visual Sensitivity Rank I.—Plots or areas of this rank are a special case for lands adjacent to designated recreational areas such as state parks, national parks, wilderness areas, wild and scenic rivers, and long-distance trails. They are highly sensitive lands because of their proximity to designated recreational areas.

Visual Sensitivity Ranks II to V.—Areas in these ranks are defined by ROS class, attractiveness value, and recreation value combinations. Visual sensitivity rank V includes the lowest recreation and attractiveness values.

Once this ranking was developed for the FIA plots, the likely impacts of the three harvesting scenarios was evaluated. Subsequently, this led to the assessment of significant impacts and development of the ultimate mitigation strategies.

Cultural and Historical Resources

Objectives: Timber harvesting and some forest management activities can have direct and irreversible impacts on historical and cultural resources. The objective of this study group was to examine the extent to which such resources can be impacted by timber harvesting and forest management.

Methodology: The resources considered by the study group included cultural landscapes, standing structures, archaeological sites, cemeteries, and traditional use sites. Examples of these are Native American traditional use sites and sacred/religious sites. These resources, collectively referred to as Heritage Sites, are protected by a variety of state and federal laws. They are nonrenewable resources.

Impacts to Heritage Sites affect not only the physical Heritage Sites themselves, but also the cultural lifestyle of Native American peoples. The nature of these effects were delineated and mitigation measures suggested. Specifically, the cultural resource specialists:

- characterized the maximum impacts that could occur under the three harvest intensities identified in the FSD;
- assessed the constraints involved in compliance with relevant law and regulation under each of the harvest intensities;
- recommended management procedures based on a model of site location; and
- defined work needed to generate site locational information for a GIS and to increase accuracy of the site locational model.

The cultural resource specialists summarized potential impacts of the three management scenarios according to type of Heritage Site and ecoregion. Uncertainty due to data considerations was also addressed.

Economics and Management

Objectives: The Economics and Management Issues study group's objectives were to assess expected impacts from timber harvesting and forest management as noted here:

- to what extent are state and regional economies impacted;
- which and to what extent are specific economic sectors benefitted or adversely impacted;
- to what extent is the state's recreation and tourism industry impacted;
- which and to what extent are specific segments of the recreation and tourism industry benefitted or adversely impacted;

- how will habitats of deer and ruffed grouse, other game species, and other recreational use wildlife be affected; and how will these changes affect state and regional economies; and
- what is the current distribution of stumpage among various users; what laws, policies, and procedures influence this distribution?

Methodology: Increased levels of timber harvesting result in increased purchases and sales by timber harvesting operations, and changes in economic activity for some forest products industries and other sectors. These changes in economic activity are likely to change levels of income, sales, employment, and other measures of the economy. Increased harvest levels also result in changes to the forest resource and to forest management practices and activities by various forest landowner groups. These changes to the forest resource affect timber inventories, growth, and yield, and may also alter soil productivity, water quality, wildlife habitat, the aesthetics of forested areas, and other forest characteristics. These, in turn, may affect forest uses (e.g., various recreation opportunities) and users (e.g., hunters, hikers, cross-country skiers). Such changes in forest uses have impacts on recreation, tourism, and other economic activities in the state.

In response to increased levels of timber harvesting, forest management activities of landowners often have to be increased. Additional funding and personnel is required to: prepare and administer the timber sales required to meet the levels of timber harvest proposed; intensify silvicultural and forest management activities (site preparation, regeneration, thinning, etc.); coordinate land use planning; forest road construction and/or maintenance; and meet other land management needs. These increased management activities have economic impacts within land management organizations (e.g., budget and staffing implications), and have economic impacts outside the organization (e.g., increased purchasing of supplies and equipment, contracting for services).

The major objectives of the Economics and Management Issues study were addressed in the following three distinct steps.

1 Determine economic impacts of increased timber harvesting and management. Analyses to determine economic impacts of increased timber harvesting and forest management activities were conducted as two separate tasks: (a) to determine economic impacts of increased timber harvesting, and (b) to determine economic impacts of increased forest management activities.

The first task, determining the economic impacts of increased levels of timber harvesting and forest management activities, estimated the economic impact of three levels of timber harvesting. Economic impacts were estimated for specific sectors of the economy, for groupings of counties that represent the various ecoregions and economic regions of Minnesota using an input-output economic modelling technique (IMPLAN and IPASS models). Wherever possible the study also identified sectors that benefit and sectors that are adversely affected by the increased levels of timber harvesting and forest management activities. The base level of harvest was used as the baseline from which to estimate changes due to increased levels of timber harvesting. Measures of economic impact included expected changes in income, output, and employment over time that result from the increased timber harvests, by economic sector. Impacts were estimated as changes in regional and state economies from the base level timber harvest.

The second task, determining the economic impacts of increased timber management activities, estimated the impacts of the three levels of timber harvesting on management activities of county, state, and federal land management agencies in Minnesota over time. The impacts of these changes in management activities were also considered, specifically as they affected budgets and personnel requirements within these agencies, and employment and income for various economic sectors and regions in the state. Impacts were estimated as changes in budgets and personnel of the various public land management agencies, and resulting changes in regional and state economies, by economic sector, from what would have occurred with the base timber harvest level. Only public forest land management agencies were included in the analysis. Of federal lands, only those managed by the USDA Forest Service, were included. Of state-owned lands, only those managed by the MNDNR Division of Forestry were included. To provide a county focus, a few key sample counties in the northern part of the state were also addressed.

2 Determine timber harvesting impacts on the recreation and tourism industry, including recreational use of wildlife. The Economics and Management Issues study group found poorly documented linkages between timber harvesting levels, changes in forest composition and characteristics (e.g., timber stands, soils, water, wildlife habitat), changes in recreation activities and other nontimber uses and activities, and changes in economic impacts on the tourism industry and other related economic sectors. Unfortunately, specific quantitative data on the linkages between timber harvesting and levels of participation in various outdoor recreation activities are lacking, and could not be developed in sufficient detail for economic analysis for this study. Information to quantify how changes in recreation opportunities would affect visitor days for various types of recreation activities was unavailable, so it was not possible to directly quantify the impacts of increased timber harvesting on the recreation and tourism industry. However, it was possible to explore how various levels of assumed changes in recreation activities would affect economic sectors that are related to the recreation and tourism industry. This was done using information gathered by the state about participation and expenditure patterns for different classes of recreation and tourism. Such information was helpful in analyzing the potential importance to the economy of various levels of changes in the recreation activities that are likely to be affected by increased levels of timber harvesting, even though the exact impacts could not be determined.

3 Determine timber sale stumpage distribution among various users, and what laws, policies, and procedures influence this distribution. This issue was interpreted to mean: Who gets how much of what stumpage from where in timber sales from various land management agencies and owner groups, and what influences this distribution? That is, how much of what kinds of stumpage from various landowner groups is currently allocated or distributed through timber sales to various users of timber stumpage? Also, what laws, policies and procedures influence how this distribution takes place?

In determining stumpage distribution, consideration was given to how stumpage distribution among users varies by timber species, land ownership, and economic regions. These data were related to an analysis of whether the stumpage is purchased directly or indirectly. Two types of timber sales purchases were considered in this analysis:

1. the various kinds of primary wood-using industries, such as pulp and paper mills, structural and other particleboard mills, sawmills, pole treating plants, and others that obtain the cutting rights and subsequently use roundwood harvested from the forest as a raw material in their industrial processes; and
2. independent logging contractors who purchase cutting rights and then sell harvested timber to one or more users.

In determining what laws, policies, and procedures influence how this distribution of stumpage takes place, primary attention was given to the laws, policies, and procedures of county, state, and federal land management agencies that affect how stumpage is distributed. However, in doing so, it was recognized that economic factors within the timber industry affect the distribution of timber sales. Where competitive bidding for stumpage is effective, economic factors within the forest products industry and among individual industries strongly influence stumpage prices for any particular timber sale, and thus determine (or at least influence) the distribution of stumpage among individual loggers and mills. A comprehensive analysis of the importance of prices and economic competition in the allocation of timber stumpage was not a focus for this study.

2.3.4 Background Papers

In addition to a detailed study of the issues mentioned above, specialists were contracted to provide five background papers under the supervision of the core group and independently of the study groups. These papers were prepared to meet two distinct requirements of the study process. Two background papers, *Global Atmospheric Change* and *Recycled Fiber Opportunities* (Jaakko Pöyry Consulting, Inc. 1992i,j), were prepared to address the additional factors, outside of the issues of concern, identified in the FSD (see 1.5.5). The other three papers, *Public Forestry*

Organizations and Policies, Harvesting Systems, and *Silvicultural Systems* (Jaakko Pöyry Consulting, Inc. 1992k,l,m), provided the detailed information needed to guide the study groups through a full understanding of how timber harvesting and forest management is practiced in Minnesota.

The following sections briefly describe the content of each background paper.

Global Atmospheric Change
A survey of the general nature and conclusions of the research on possible impacts of global atmospheric change on Minnesota's forest, including changes in:

- the extent of forests;
- species that comprise them; and
- costs of management.

Recycled Fiber Opportunities
An examination of the existing and potential opportunities for utilizing recycled fiber in the wood products manufacturing process in Minnesota including:

- implications of paper and associated products currently produced in Minnesota;
- current technology;
- availability of recycled fibers to Minnesota paper industries;
- opportunities for using current technology to substitute recycled fiber for virgin wood fiber in papermaking and allied products;
- possibilities for short- and long-term use of recycled fiber by Minnesota's wood products manufacturing industries and potential environmental; and
- economic impacts of using recycled fiber in the production of paper and allied products by Minnesota's wood fiber industries.

Public Forestry Organizations and Policies
A description of public forest land management organizations in Minnesota including:

- organizational histories and structures;
- major forest management and timber harvesting policies;
- major forestry programs and activities;
- current planning and coordination efforts; and
- public participation in forest management and planning.

An examination of laws and policies for related land uses and development in order to assess the extent to which they apply to:

- timber harvesting;
- forest management; and

- nonindustrial private forest (NIPF) lands.

Additionally, this paper developed estimates of timberland availability by ownership.

Harvesting Systems
A description of harvesting systems currently used and those with potential for use in Minnesota, plus an assessment of the competitive aspects and physical impacts of possible harvesting systems through a detailed discussion of:

- harvesting systems and equipment currently used in Minnesota by forest covertype;
- harvesting systems and equipment employed elsewhere in similar conditions;
- transport systems currently used to move harvested wood from the forest to processing facilities;
- ground pressure indices for the different harvesting systems and equipment; and
- comparative productivity and cost data for the above harvesting and transport systems.

This paper also addresses one specific aspect of a major issue of concern (Economics and Management): *What level of road density, design, and construction is appropriate to provide access for all forest activities (e.g., timber harvesting and management, fire/insect/disease protection, and dispersed recreation on forest lands)?*

Silvicultural Systems
A discussion of existing and potential silvicultural systems, in terms of suitability for the range of forest covertypes and physical conditions in Minnesota including:

- a description of the types and extent of use of silvicultural systems being used in Minnesota;
- a discussion of other silvicultural systems potentially available for use in Minnesota;
- an assessment of the comparative indices of timber yields versus the yield of other forest values associated with each silvicultural system currently being used as well as those with potential for use; and
- operational costs of the various silvicultural systems.

2.4 GEIS Study Document Development

The last major activity in the GEIS process involved the development of the formal GEIS study document. The key steps for this activity were:

- preparation of the draft GEIS document;
- independent peer review of the draft GEIS document;

- submission of the revised draft GEIS document for public review and comment; and
- submission of the Final GEIS Study to the EQB.

2.4.1 Draft GEIS Document Development

Following completion and EQB approval of the nine technical and five background papers, the Core Group began the process of preparing the draft GEIS study document. The initial effort integrated information from these 14 papers. This is identified as step 15 in figure 2.2.

The Workplan and FSD both call for the draft GEIS to be "a high quality, professional document written in plain English...." This guidance was important as the Core Group's goal was to synthesize and integrate the substantially technical-type materials from the 14 papers into an easy to read, user-friendly document. In this regard, preparers of the GEIS document attempted to avoid the more complex, scientific context of the 14 papers described earlier. For a more rigorous and technical perspective, readers are referred to the 14 technical and background papers.

The draft GEIS document integrated the technical and background work, clearly identifying and describing the impacts associated with statewide timber harvesting and associated forest management activities. It also identified and described recommendations to address those impacts.

The FSD and Workplan call for the draft GEIS to include separate chapters, one for each alternative statewide timber harvesting scenario. As noted here, these chapters include the following:

- a complete description of each alternative statewide timber harvesting scenario including all assumptions;
- a clear and concise discussion of how statewide timber harvesting and associated forest management activities will impact the issues and subissues identified in section xiii of the FSD at each scenario-prescribed level of activity;
- a clear and concise description of *significant impacts* (existing or potential) identified in the analyses;
- a description of possible means (*mitigation alternatives*) of alleviating or minimizing the identified significant impacts; and
- recommendations for mitigating (*mitigation strategies*) those significant impacts including the rationale for such recommendations.

Sections 5 to 7 of the draft GEIS document were prepared in accordance with this guidance. Forest policy strategies suggested to help ensure that the collective set of mitigation recommendations identified in these sections are implemented over time are discussed in section 8.

2.4.2

Draft GEIS Document Peer Review

The FSD and Workplan call for peer review of the draft GEIS prior to its submission to the Advisory Committee and EQB. This is step 16 in figure 2.2. The goal of this technical peer review was to obtain an independent, objective, and critical review of the initial draft GEIS. The review panel selected by Jaakko Pöyry and endorsed by the EQB was identified in section 2.1.1. The guidelines used to select this review group stipulated that reviewers:

- have not substantially participated in the preparation of any work products prepared for the GEIS project;
- are knowledgeable and respected experts in the subject material addressed in the draft GEIS; and
- represent a balanced but diverse set of opinions on the subject matter addressed in the draft GEIS.

Once the peer reviews were completed, the Core Group provided the state written summaries of all comments submitted by all reviewers. Subsequently, the Advisory Committee and EQB reviewed the initial draft GEIS document and all peer reviews with the Core Group. Based on guidance from the Advisory Committee and the EQB, the Core Group then modified the draft GEIS in preparation for public review and comment.

2.4.3 Public Review and Comment

The FSD and Workplan call for a formal public review period to secure public comment and input on the draft GEIS. This is step 17 in figure 2.2. Included as part of this review are three public information meetings to explain the draft report's findings and conclusions, and to solicit public input on the draft. These meetings were originally scheduled for April 1992. However, due to the extended GEIS project timeframe (see section 1.5.7), these public meetings were subsequently rescheduled to June 1993.

Following the public meetings, the state assumed responsibility for organizing and summarizing all substantive comments provided by the public on the draft GEIS during the entire designated public comment period, which is set at a minimum of 40 consecutive days.

The state's GEIS project coordinator designated all substantive comments as either "technical" or "policy." The Core Group responded to technical matters, and the Advisory Committee and EQB responded to policy comments. The chair of the EQB has the final authority over the adequacy of responses to both technical and policy comments as reflected in the final GEIS document.

2.4.4 Final GEIS Compilation and Submission

The Core Group was responsible for incorporating all EQB approved public comment responses into the Final GEIS document. This is step 18 in figure 2.2. Once the draft GEIS was revised into the Final GEIS, it will be submitted to the Advisory Committee and EQB for final editing. This ensures that the Final GEIS document is identical in format to the draft GEIS, except for EQB-approved responses to the public comments. Approval for release of the Final GEIS study rests solely with the chair of the EQB.

2.5
Resource Information Issues

The GEIS process required an immense amount of resource-based information. Sources of information have been highly varied. They included:

- published research documents;
- public agency published documents and statistical data reports;
- Jaakko Pöyry network data base, studies, and reports;
- unpublished research materials;
- public agency files and interoffice studies and communications;
- internal UofM files, reports, models, and databases; and
- expert knowledge, etc.

The Core Group and the study groups invested a tremendous amount of time and energy scouring for information within Minnesota, the United States as a whole, and, where possible and appropriate, even globally. Yet in spite of this concerted effort, many important information needs fell short of the optimal or simply were not met.

An example of this was the type of database needed for generating the three harvesting scenarios and all of the related scenarios' outputs required by all the study groups to conduct their respective technical analyses. Key requirements were the need for an updated, pre-existing database that consistently covered all timberland on all ownerships statewide with a very wide array of data elements/variables. Unfortunately, no such database exists. The closest possibility is found in the USDA Forest Service FIA system and database. The FIA system was never designed for a GEIS-type process, but does allow for essentially statewide coverage and contains many of the data variables required by the study groups.

Another complicating factor was that the 1990 Minnesota FIA survey was not published when the GEIS process started in mid-1991. As a consequence, the GEIS work proceeded on the unpublished data. In addition, the study groups had to create new and novel techniques to meet information needs. For example, habitat typing by FIA plot for wildlife and biodiversity analyses required conducting separate technical analyses. Although inadequate in some ways, the FIA database and system were the best available, and the study groups were able to develop techniques that helped extend the database to meet most needs at this level. Without the FIA database, the GEIS process would have been severely constrained.

An example of data that was totally lacking in a form useful for the GEIS process was specific documented impacts of timber harvesting (physical site change) on the recreational experience by recreation activity. Much anecdotal information is available, as are numerous site-specific/focused studies that provide indications of relationships. However, a well-researched statewide database across all major timber harvesting and recreational issues was simply not available. As a consequence, the Recreation and Aesthetics technical paper's examination of these relationships was forced into a broad and qualitative analysis.

Another example of a major data deficiency was one which related to changes in timber harvesting levels and related forest management activities to changes in the economic aspects of the tourism (and recreation) industry. The GEIS study groups were unable to isolate a comprehensive useful database that would allow for a nonspeculative evolution of such relationships over time for various timber harvesting scenarios. The GEIS specialists know these issues are linked. However, with a charge to pursue fact-based analyses, a meaningful evaluation of these particular relationships was not possible.

One additional data deficient area involved that dealing with sites' nutrient capital. Although much data is available, good, concise knowledge on nutrient effects on forest productivity and growth are not readily available. Also, the extent to which nutrients versus other factors (temperature, moisture, etc.) are limiting factors is also not well known. As a consequence, some of the specificity desired in the soils research for the GEIS was not possible.

The key point of this discussion is to highlight two important resource information issues:

1. the GEIS process required and was based on a tremendous volume of resource related information; and
2. many information needs were either lacking in completeness or simply not available, and this affected the ability of the GEIS team to fully address all FSD-scoped issues.

These resource information deficiencies were expected and this was noted in the FSD. Where such deficiencies had a material effect on the GEIS process, the FSD and Workplan called for the Core Group to identify and outline future research needs. This topic is specifically covered in section 8 of the GEIS document.