Appendix C

Forestry/Timber Harvesting Methodology and Future Forest Conditions Report

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1.0 BACKGROUND/CORRELATION WITH TIMBER HARVESTING GENERIC ENVIRONMENTAL IMPACT STATEMENT

Timber supply analyses for this Project updated information from the Generic Environmental Impact Statement (GEIS) on timber harvesting and management. The GEIS was conducted more than 10 years ago and was based on 1990 Forest Inventory and Analysis (FIA) statewide forest inventory. Detailed comparisons of the new inventory with either the 1990 inventory or projections made from it by the GEIS are difficult to make, due to significant differences in data collection and characterization practices utilized in creation of the FIA data sets. However, general information from the GEIS provides valuable insight regarding facets of the resource situation that are important to consider in analyses to better understand current forest resource conditions and potential future use.

The GEIS evaluated three scenarios describing future timber harvest levels. None of those scenarios corresponds closely with the resource situation today. The GEIS Base Harvest Scenario assumed a 4 million cord annual harvest level. Since the GEIS, total statewide harvest levels have declined and are now at approximately 3.7 million cords. Trends in state harvest levels do not fully reflect the actual amount of wood processing that occurs in Minnesota. At the time of the GEIS, timber imports into Minnesota were approximately equal to exports. In recent years, imports have risen substantially with imports exceeding exports by 600,000 cords or more. The GEIS also identified potential concerns related to available timber supply of aspen, even for the GEIS Base Harvest Scenario. Specifically, the GEIS analyses assumed that the harvest volume of aspen would likely need to decline, at least temporarily. All three GEIS scenarios assumed a 25 percent decline in the annual aspen harvest by 2010. To date, that level of decline has not occurred. Aspen stumpage prices have risen substantially in recent years, suggesting the available aspen supply in the market is at least temporarily a concern for forest industries dependent on it. Aspen is, by far, the most heavily utilized species in Minnesota, comprising nearly 60 percent of the harvest by volume. The aspen forest cover type is also, by far, the most common forest cover type in Minnesota. Yet, on average, the aspen forest cover type contains a mixture of tree species with stands in the aspen cover type averaging only 65 percent aspen by timber volume. For this project, it is proposed that approximately 45-50 percent of the proposed increase in wood use would be aspen (98,500 cords/yr).

Most of the timber supply analysis for the GEIS was based on a 50-year planning horizon. For the GEIS, a much longer-term timber supply analysis was also done to estimate harvest levels that could be sustained indefinitely. That analysis suggested that harvest levels over the long term could be sustained well above the 4.0 million cord level assumed for the GEIS Base Harvest Scenario. Aspen harvest levels were not a concern in the long-term analysis. Shorter-term concerns over aspen were thought to likely be a result of the existing imbalanced age distribution and the fact that existing aspen stands are not as well stocked as aspen stands regenerated today. With timber supply not a long-term concern, this study focused on timber supplies over the short term – the next forty years. No attempt was made to model regeneration after harvesting to project yields from stands regenerated during the planning horizon. In other words, it was assumed that timber supplies, needed for the next 40 years, would be obtained from stands in the existing forest inventory. Important inputs to the analyses were detailed growth and yield estimates for treatment options for the 2001 FIA inventory plots over the 40-year planning horizon.

2.0 THE FOREST INVENTORY AND ANALYSIS (FIA) DATA

2.1 Overview of the Statewide Forest Inventory

The starting point for projections of future forest cover type and age class structure is the statewide forest inventory dataset known as Forest Inventory and Analysis (FIA). FIA is a program of the U. S. Department of Agriculture Forest Service with a stated mission of estimating and reporting the status, trends, and conditions of the nation's forest resources with known confidence (Miles et al. 2005).

FIA is a statistical sample of all forestlands, productive and unproductive, on all ownerships, public and private. There are three phases to the FIA inventory. In phase 1, remotely sensed data are used to classify a sample of points by land use categories. In phase 2, a subset of the sample points from phase 1 are visited on the ground and data on forest and tree conditions are collected. In phase 3, a subsample of phase 2 plots receive an additional suite of measurements that are aimed at assessing forest health. (For more detailed information on sample design and plot layout see Miles et al. 2005 and Alerich et al. 2004).

Data from the most recently completed survey cycle are used in the modeling for this EIS. In Minnesota, an entire FIA inventory cycle takes five years to complete. The most recently completed cycle was started in 1999 and completed in 2003. Over the five-year period 5,165 phase 2 forested plots were measured with approximately 20 percent of the plots measured each year (Miles et al. 2005). The midpoint of the survey is 2001, and therefore we refer to the dataset as 2001 FIA, which is consistent with the naming convention used in the GEIS Report Card Study (Kilgore et al. 2005).

FIA is a statistical sample and therefore subject to sampling error. FIA has established guidelines on acceptable levels of sampling error. In the case of area of timberland, FIA requires a sampling error of 3 percent or less per 1 million acres of timberland at the 67 percent confidence level (see Alerich et al. 2004 for a full listing of sampling error targets). Sampling error estimate for the 2001 inventory is 0.76 percent for area of timberland. There is a two out of three chance that if the entire area of Minnesota had been inventoried, the total amount of timberland would be within 14,759.8 +/- 112.2 thousand acres (Miles et al. 2005). As the inventory data are subdivided, the sampling error increases and the reliability of the estimate decreases. For example, the estimate of aspen forest type timberland in Itasca County is 497.8 thousand acres and the associated sampling error is 4.1 (based on Miles et al. [1995] formula). For a complete listing of sampling errors for the 2001 inventory, see Miles et al. (2005).

2.2 Differences between the 1990 and 2001 Statewide Forest Inventory

Projections of future forest cover type and age class structure conducted for the DEIS are to be compared to the projections of the GEIS Base Harvest Scenario. The two sets of projections are based on different statewide forest inventories, with projections in the DEIS using the 2001 inventory and projections in the GEIS using the 1990 inventory.

Kilgore et al. (2005) reviewed the procedural changes in the inventories and assessed how they may affect comparisons. Kilgore et al. (2005) noted the following changes: survey procedure (periodic in 1990 versus annual in 2001), duration of field effort (three years in 1990 and five years in 2001), plot layout (10 subplots per plot in 1990 versus 4 subplots per plot in 2001), sampling intensity (more intensive survey in 1990 than 2001), new algorithms for forest type and stand size classification, determination of reserved status (field verified in 2001 but not in 1990), and distance to water and stand size fields (present in 1990 but dropped in 2001). They concluded that "the effect of most of these changes is increased difficulty in making highly precise comparisons of 1990 and 2001 results" (Kilgore et al. 2005 p. 80). The GEIS forest type algorithm was singled out as a major source of error when comparing 1990 and 2001 inventory statistics. The white pine and northern white cedar forest cover types were especially problematic (Kilgore et al. 2005).

Another major difference between the 1990 and 2001 inventory was the adoption of a mapped plot design in the 2001 inventory. The FIA plot layout is a cluster sample of points where the number and arrangement of points have varied over time and by FIA region. Points may straddle more than one forest condition, for example mature forest and a clearcut. Difficulties arise when one condition (forest type, stocking, etc.) must be assigned to the plot. Different methods to handle multiple conditions arose over time within FIA. Methods typically involved moving sample plots, which introduced bias, or averaging of conditions, which created unrealistic conditions (see Birdsey 1995 for a historical discussion of the "straddler plot" problem). In 1993, FIA adopted the mapped plot design, which prohibited both the movement of plot points and the averaging of multiple plot conditions.

In the 2001 inventory, forest conditions were defined as combinations of reserved status, owner group, forest type, stand-size class, regeneration status, and stand density. In the event that two or more conditions were observed on a forest plot, the separate conditions were mapped and the proportion of the plot in each determined. There were 6,250 forested plot conditions on 5,165 forested plots in the 2001 FIA. This condition information was preserved in the analysis (see discussion on Construction of 2001 Statewide Forest Inventory for this Study).

Another change in FIA procedures that occurred between the 1990 and 2001 inventories was the aggregation of all private forest plot conditions into one, undifferentiated private class. This change was necessitated by the need to protect the privacy of landowners and was mandated by the Fiscal Year 2000 Consolidated Appropriations Bill (PL 106-113). The change means that forest plot conditions on private industrial and private non-industrial could not be separated in the publicly available database.

Additional examination of the FIA dataset revealed a second issue relating to ownership. Between 1990 and 2001, the estimated amount of forestland and timberland in the state-owned class increased by 671.8 thousand acres and 1,032.5 thousand acres, respectively. The DNR estimated its total amount of commercial forestland at approximately three million acres (personal communication, Dr. C. M. Chen, DNR, May 23, 2005), which was much closer to the 1990 FIA estimate than the 2001 FIA estimate. Miles et al. (2005) pointed out that plots within reserved forest boundaries were not field verified in 1990, but assumed reserved. All forested plots were visited in the 2001 inventory, and some plots classified as reserved in 1990 turned out not to be reserve, effectively increasing the amount of timberland at the expense of reserved forestland. A second explanation by DNR staff, was the reclassification of unproductive black spruce in 1990 as timberland in 2001 and productive black spruce in 1990 as other forest types in 2001 (personal communication, Dr. Chen, DNR, May 23, 2005). A third explanation by forestry modeling personnel was the possibility that state-owned, county-managed forestland was classified as county-owned in 1990 and state-owned in 2001. A decrease in the amount of county-owned forestland and timberland between the 1990 and 2001 inventories lends strong support to the last explanation as a possible cause.

Another potentially important difference between the inventories relates to the changes in plot sizes. The inventory has gone from using smaller variable-radius plots in 1990 to “larger” fixed-radius plots in 2001. This is especially important in the building of tree lists for yield projections. Changes in plot size factors into “intensity” as well. The number of plots or number of subplots is not an adequate measure of sampling intensity.

2.3 Additions to the 2001 Statewide Forest Inventory Data for this Study

The two ownership issues were addressed through data requests to the North Central Research Station (NCRS) FIA. The first request was for the release of the identity of FIA plots on UPM/Blandin Paper Company land. This information was recorded by FIA and its release required authorization by the Blandin Paper Company. The release of this information provided the means to model UPM/Blandin Paper-specific impacts and mitigations.

The second request focused on identifying state-owned, county-managed plots. The identification of these plots required a GIS intersection of precise FIA plot coordinates with a data layer depicting state-owned, county-managed areas (MnDNR 2005). FIA provided the identity of approximately 90 percent of the plots that were listed as state-owned in the FIA database and that fell in a state-owned, county-managed area. The remaining 10 percent of plots were not released by FIA because of concerns over “plot integrity,” which was described by FIA staff as the release of information that would enable the identification of plot locations to an unacceptably small area (personal communication, Geoff Holden, NCRS, June 20, 2005). The information allowed for the consideration of owner-specific management treatment options and general availability of lands for harvest.

A third and final request of FIA was the identification of native plant community classes for FIA plots. A GIS intersection of precise FIA plot coordinates with data layers depicting native plant community classes was the source of this information. Classifications for the Minnesota-Ontario Peatlands, Northern Superior Uplands, and Drift and Lake Plains ecosections were provided by the wildlife team. FIA released the identity of approximately 95 percent of the plots intersecting the three ecosections, with the remaining 5 percent held because of concerns about plot integrity. The information allowed for more complete successional and forest productivity modeling. Linking the FIA inventory with ecological information allowed for the tracking of age distributions for NPCs over time. These age distributions were used in assessing wildlife conditions.

2.4 Construction of a 2001 Statewide Forest Inventory Dataset for this Analysis

Statewide forest inventory data were provided as FIADB Version 1.7 (Alerich et al. 2004). A Microsoft Access database was created allowing for the preparation of the data needed in the growth and yield modeling and forest management scheduling. The database was tested by comparing data generated from queries to summaries published by the Forest Service (Miles et al. 2005).

A dataset consisting of 6,250 records, one for each forested plot condition, was created for use in the forest management scheduling model. The important forest plot condition attributes were county, plot number, condition number, land class, reserve status, ownership, national forest designation, forest type, stand age, stand size class, site class, site index, site index species, stand origin, stand origin species, condition proportion (CONDPROP_CURR), area expansion factor (EXPCURR), ecological subsection, latitude (approximate), longitude (approximate), native plant community, Blandin Paper Company ownership, and state-owned county-managed status. The last three fields were not in the publicly available database, but provided by FIA (see the section Additions to the 2001 Statewide Forest Inventory Dataset for this Study).

3.0 TIMBER GROWTH AND YIELD MODELING

To address future timber supply conditions it was necessary to create the capability to predict timber yield streams under alternative management treatment options. Since it had been determined that the Minnesota FIADB from the latest annual inventory cycle (1999-2003) would be an important source of forest resource inventory data for the study, this meant implementing a yield model that could project conditions on forested FIA plots. The STEMS individual tree growth model (Miner et al. 1988) is the most widely used model for such purposes in Lake States forestry practice. The model operates at the level of the individual tree, allowing straightforward handling of the multi-species forested conditions prevalent in Minnesota. The STEMS model is the Lake-States variant of the more recent FVS implementation (Teck et al. 1996).

The STEMS model was coded using Visual Basic for Applications (VBA) within a Microsoft Access database. This allowed the model to be applied directly against the tables of the FIADB and allowed for the flexibility needed in generating an arbitrarily large number of treatment options for conditions of interest. STEMS operates on a tree list. Tree lists for each forested plot condition were generated, in terms of the tables in the FIA database, by querying the FIADB TREE table for each relevant condition in the COND table. Only trees alive and 1-inch diameter at breast height (dbh), and larger diameter at the time of the inventory were included in the tree list. Only trees on annual inventory subplots 1-4 were included. The important tree attributes were species code, dbh, crown ratio, tree condition code, tree site index, and tree expansion factor. Specifically, tree expansion was computed as TPACURR (from the TREE table) divided by CONDPROP_CURR from the COND table.

The DNR uses an alternative, stand-based model for similar purposes. DNR stand inventories do not maintain tree level data. For this analysis, a stand-based model would not provide enough resolution in terms of the multi-species nature of most forest cover types in Minnesota.

3.1 The STEMS Model

STEMS ran on an annual time step to generate the desired yield streams. Each group of species has its own parameter set in STEMS. The STEMS species groups used in this study are given in Table C-1, along with the USFS species codes for species present in the Minnesota FIADB falling into the group. Parameter values for these groups were taken from Miner et al. (1988).

Table C-1
Species Groups Used in STEMS and USFS Species Codes that Constitute the Group

STEMS Species Group	USFS Species Codes Included
Aspen	741, 746
Birch	375
Northern red oak	833
Ash	543, 544
Elm	970, 972, 977
Jack pine	105, 130
Red pine	125
Black spruce	95
White spruce	94
Balsam fir	12
Tamarack	71
Basswood	951
Sugar maple	318
White pine	129
Other softwoods	68, 70, 96, 136
Cottonwood	742
Silver maple	317
Red maple	316
Yellow birch	371
White ash	541
White oak	802, 804, 823
Other red oak	809, 837
Hickory	400, 402, 407
Bigtooth aspen	743
Other hardwoods	313, 319, 356, 372, 391, 462, 500, 552, 601, 602, 660, 682, 701, 740, 760, 761, 762, 763, 765, 766, 901, 920, 921, 922, 927, 935, 974
Non-commercial	999
Planted red pine	125 in artificially regenerated condition

For each tree, its potential dbh growth was first predicted based upon tree dbh, tree crown ratio, and condition site index (made species-specific). Potential dbh growth was then reduced by a modifier driven by the tree's dbh relative to the average tree's (on the condition) dbh, the average tree's dbh, and the basal area of live trees in the condition. Finally, an adjustment was added to the reduced growth to obtain a final prediction of annual dbh increment (Holdaway 1985).

In addition to growing a tree's dbh, each tree in the tree list has its expansion factor reduced annually to account for mortality. This is done by computing a probability of survival for each tree (based on the tree's dbh and predicted dbh growth) and interpreting the probability as a relative frequency. For example a probability of survival of 0.98 would mean that the tree's expansion factor would be reduced by two percent for that year.

While crown ratio at the time of the inventory is in the FIADB, applying the STEMS model into the future requires predicting change in crown ratio. This was done by using the STEMS crown ratio prediction equation, based on tree dbh and condition running average tree dbh, and applying it in a difference equation to predict crown ratio change.

3.2 Tree Stem Volume

STEMS predicted change in tree dbh (and numbers of trees). For timber yield streams, tree stem volume is the attribute of interest. Tree stem volume was predicted in one of two ways. In both instances, the tree height(s) required to predict volume were found using the species-specific (Table C-2) equations of Eke et al. (1984); this is currently the approach of North Carolina FIA. Both volume prediction methods provide a species-independent estimate of gross volume. That gross volume is made species-dependent by a species-specific bark adjustment. The adjusted gross volume is then converted to a net volume using species- and tree condition-specific cull percentages (Hahn 1984).

For most tree species, gross volume was computed using the standard NC FIA approach as described in Hahn (1984). This uses Stones approximation of Table 6 in Gevorkiantz and Olsen (1955) for pulpwood volume to a 4-inch top diameter (minimum tree dbh of 5 inches). Board foot volume of sawtimber-sized trees[1] to a 7-inch (softwoods) or 9-inch (hardwoods) top diameter are found using Stones equation and a board foot conversion equation due to Hahn.

For aspen, balsam fir, and white and black spruce, better utilization was assumed for pulpwood-sized trees to compute gross volume. This was implemented in the form of a 4-inch minimum dbh size limit and a 2-inch top diameter limit. These volumes were computed using Table 8 in Gevorkiantz and Olsen (1955), implemented as suggested by Burk and Ek (1999). The utilization assumed for aspen, balsam fir, and white and black spruce is based upon discussions of one analysis team member with loggers and procurement foresters. Variation in utilization certainly exists. The assumed utilization is more relevant to today's practices than what is assumed in the volume equations used by FIA analysts in the reports they publish. Those equations were fit directly to tables based on utilization standards current in the 1940s and 1950s.

[1] Sawtimber-sized trees are defined as a minimum 9-inch dbh for softwoods and minimum 11-inch dbh for hardwoods.

Table C-2
Species and Species Groups Used in Computing Tree Volumes

Volume Species Group	USFS Codes Included
Balsam fir	12
Other hardwoods	313, 356, 372, 391, 500, 552, 660, 682, 701, 760, 761, 763, 765, 766, 901, 920, 921, 927, 935, 999
Soft maple	316, 317
Hard maple	318
Yellow birch	371
Paper birch	375
Hickory	400, 402, 407
Elm and hackberry	462, 970, 972, 974, 975, 977
Black ash	543
White and green ash	541, 544
Butternut and black walnut	601, 602
Cedar	68, 241
Tamarack	71
Jack pine and other softwoods	70, 96, 105, 130, 136
White spruce	94
Black spruce	95
Red pine	125
White pine	129
Cottonwood and black willow	740, 742, 922
Bigtooth aspen	743
Quaking aspen and balsam poplar	741, 746
Black cherry	762
White oak	802, 804, 823
Northern red oak	833
Other red oak	809, 837
Basswood	951

Note that with the higher utilization assumed for aspen, balsam fir, and white and black spruce, yields predicted by FIADB are lower, on a per acre basis, than reported by many county and private organizations that track actual removals from harvested stands.

3.3 Young Forest Conditions

STEMS was applied directly to the recorded FIADB tree lists for conditions 10 years of age and older. For younger conditions, tree lists in the FIADB were assumed to be of limited applicability for use with STEMS. To enable the inclusion of these young conditions in the timber yield streams, average tree lists were generated at a fixed, future age. The average tree lists were constructed for each forest type group (Table C-3) and site index class combination using FIADB conditions in the same age class as the fixed, future age. All relevant and available FIADB data were used for this purpose in an unmodified manner. Young stands were assumed to have no volume until they reached that fixed, future age. Thereafter the development of these young stands was projected with STEMS. The dynamics of growth and mortality applied to all other conditions were thus applied to these young stands as well. As stated, STEMS is the most widely used model for such purposes in Lake States forestry practice and the dynamics STEMS predicts is the best available information to predict the development of these young stands as represented by FIADB data, given the time constraints of conducting the analysis. For aspen and planted red pine, the fixed, future age was 20 years; for other forest type groups, the fixed, future age was generally 35 years.

The alternatives to the approach used would have been to ignore the existence of these young stands or to make assumptions regarding these stands.

Table C-3
USFS Forest Type Codes included in the Group and Yield Stream Age Limits for the Group

Forest Type Group	USFS Codes Included	Yield Ages
Jack pine	101	35 – 110
Red pine	102	55 – 140
White pine	103	40 – 140
Spruce-fir	121, 122	40 – 120
Oak	401, 402, 409, 500, 501, 503, 504, 505, 506, 509, 512	40 – 120
Northern hardwoods	519, 520, 800, 801, 802, 803, 805, 807, 809, 995	40 – 120
Aspen	900, 901, 904	35 – 100
Paper birch	902	40 – 100
Lowland spruce	125	75 – 180
Tamarack	126	65 – 120
Lowland hardwoods	700, 701, 702, 703, 704, 705, 706, 707, 708, 709	55 – 120

Note that these lower yield age limits are not equivalent to minimum rotation age assumptions used in the forest management model.

3.4 Yield Stream Predictions

The methods above allowed for the prediction of yields at any future age for any plot condition. Such yields were predicted annually for every forested condition with trees, except non-stocked conditions and conditions in the northern white-cedar forest type. The northern white cedar type was not included because it is a forest cover type that is harvested infrequently. In 2002, only 0.16 percent of the statewide harvest was white cedar by volume, and estimates show no plans for a substantial increase. In addition to volume yield, trees per acre and basal area per acre were predicted to allow consideration of leave-tree management guidelines. The age range for predictions varied by forest type group (Table C-3), and was meant to include a range of potential rotation ages for the group. However, conditions were generally not projected more than 45 years from their inventory age, five years in excess of the planning horizon for this project. Conditions were projected a minimum of 15 years regardless of the circumstances.

3.5 Planted Red Pine

Conditions that were labeled as showing evidence of artificial regeneration where the stand origin species was red pine were assumed to be red pine plantations, regardless of the forest type label. Intermediate harvest treatments (thinnings) are a standard management practice for planted red pine. To include such treatment options, a thinning option was added to the VBA code. The basic parameters defining a thinning prescription are given in Table C-4. Any thinning was assumed to first remove trees other than the target species and subsequently remove any additional basal area via a row thinning; see Table C-4.

Yield streams that included one or more thinnings were generated for planted red pine. Thinnings needed to have occurred within the 45-year maximum projection length.

Table C-4
Parameters Describing how Thinning was Implemented for Planted Red Pine

Parameter	Value
Minimum age of thinning	25 years
Basal area required to thin	150 square feet per acre
Residual basal area	100 square feet per acre
Minimum years between harvests	20 years
Maximum age of thinning	90 years

4.0 TIMBER SUPPLY MODEL

A forest management scheduling model was used to analyze the forest resource situation under nine scenarios describing the resource situation. The model used is an updated version of the Dualplan model used for the GEIS (Hoganson and Rose 1984). It was used recently for analyses in developing forest plans for both of the Chippewa and Superior National Forests in Minnesota (USDA 2004). The scheduling model is based on a linear programming formulation of the forest management situation. Decision variables describe the management options available for individual forest management units (analysis areas). Dualplan uses a specialized solution technique that allows recognition of a large number of analysis areas. In defining analysis areas, each forested plot condition of the 2001 FIA statewide inventory was further subdivided into smaller areas, with additional divisions representing area differences in terms of riparian areas and availability of private land for harvest. Each analysis area represented from 1 to 7,700 acres of similar forest condition and availability for harvest. In total, over 31,000 analysis areas were represented in the model. To take advantage of recent analyses and plans developed for national forestlands in Minnesota, modeling results from those analyses were input directly into the model to represent management plans for national forestlands. This meant that projections for National Forest lands could be based on the site-specific inventory for the National Forest lands rather than the less intensive 2001 FIA sample of National Forest lands.

A potential shortcoming of analyses for the GEIS relates to assumptions describing allowable cut limits for public lands. Those limitations were not imposed in the GEIS analyses for state and county lands. For this study, allowable cut limits were included for each decade for the forest cover type groups that are generally managed using even-aged management. These limits were upper bound limits on the area that could be harvested. Constraints were not included to force some minimal harvesting level in each forest cover type.

The forest management scheduling model can be interpreted as a series of analyses, one for each stand (analysis area), where each analysis compares and selects the best management option for that stand, balancing net returns from stand-level management with stand-level contributions towards forest-wide management constraints. In these individual stand-level analyses, shadow prices are used as internal pricing mechanisms to address the forest-wide constraints. Each shadow price is an internal tax or subsidy applied in the stand-level analyses to address the stand-level impact on a forest-wide constraint. For example, consider a forest with an imbalanced age distribution with more financially mature stands and fewer young stands. If forest-wide constraints are included to force an even flow of timber over time, then shadow prices corresponding with the even-flow constraints either tax timber production (by volume harvested) in earlier periods or subsidize timber harvest volumes in later periods, so that some of the stands financially mature in Decade 1 will have their harvest delayed until a later period. Essentially the model repeats the stand-level analyses to search for the appropriate shadow prices to use in the stand-level analyses so that forest-wide constraints are satisfied when the results of all stand-level management schedules are tallied for the forest as a whole in terms of forest conditions and timber harvest flows. These shadow price estimates are useful, as they provide insight regarding the marginal cost of achieving specific forest-wide constraints. A shadow price identifies how much more or less, on a per unit basis, a forest product or forest condition needs to be valued so the forest-wide constraint corresponding with the shadow price is achieved. A discussion of shadow prices and estimates of their values for the GEIS are found in chapters 4, 5, and 6 of the technical paper on maintaining forest productivity and forest resources (Jaakko Pöyry Consulting, 1992).

Forest-wide constraints can be used to describe a wide range of possible forest management objectives involving both economic and environmental considerations. For example, for the recent plans developed for the Chippewa and Superior National Forests in Minnesota, most forest-wide constraints described objectives related to desired future conditions of the forest for major native plant community (NPC) groups. Desired future conditions for a NPC group were generally described in terms of the desired forest cover type mix for the NPC and a limit on harvesting in that NPC group in each decade.

4.1 Developing Model Scenarios

Rather than assume that the forest situation can be described completely by a single model formulation, emphasis in forest resource analyses is usually on developing a series of scenarios, with each scenario differing in terms of a few potentially key assumptions about the resource situation. For this study, this "sensitivity analysis" focused on (1) assumptions about the availability of private lands for timber harvest in the aspen forest cover type and (2) assumptions about the degree in which demand for timber shifts to tree species other than aspen by other wood users in Minnesota. Each scenario modeled can be paired with another scenario to examine potential impacts with both the Build and No-Build Alternatives, respectively. Table C-5 provides a summary of the scenarios modeled. The next section describes the details concerning specific assumptions. For each scenario, a forest management scheduling model was applied similar to the way that the GEIS Base, Medium, and High Harvest Scenarios were modeled. A total of nine scenarios were modeled for this study (Table C-5). Two series of scenarios, labeled Series A

Table C-5
Summary of the Nine Scenarios

Scenario Number	Scenario Name	Proposer Project	Availability of Private Lands in Aspen Forest Cover Type	Additional Species Substitution for Aspen	Statewide Harvest Level All Species (M cords/yr)	Statewide Harvest Level Aspen (M cords/yr)	Statewide Harvest Level Spruce-fir (M cords/yr)	Allowable Cut Limits on Public lands
1	A	No-Build	Higher	No	3,675.0	2,206.0	405.0	Yes
2	A&P	Build	Higher	No	3,872.0	2,304.5	503.5	Yes
3	A&P&SS	Build	Higher	Yes	3,872.0	2,206.0	503.5	Yes
4	A&P&HighAspen	Build	Higher	No	Unlimited	Maximize	Unlimited	No
5	B	No-Build	Lower	No	3,675.0	2,206.0	405.0	Yes
6	B&P	Build	Lower	No	3,872.0	2,304.5	503.5	Yes
7	B&P&SS	Build	Lower	Yes	3,872.0	2,206.0	503.5	Yes
8	B&P&SF	Build	Lower	Yes	3,872.0	2,107.5	602.0	Yes
9	B&P&HighAspen	Build	Lower	No	Unlimited	Maximize	Unlimited	No

Table C-6
Assumed Reductions in Private Land Available for Harvest between Scenario Series A and Scenario B

Description	Area (thousand acres)
Reduction in area first available in Decade 1	142.8
Reduction in area first available in Decade 2	97.1
Reduction in area first available in Decade 3	22.4
Reduction in area first available in Decade 4	5.2
Total	267.5

and Series B, vary in terms of assumptions describing the availability of private lands in the aspen forest cover type. Approximately 267,000 fewer acres are available for harvest over the planning horizon for Series B as compared to Series A. These acres represent only about 2 percent of the timberland area, but these acres are in the aspen forest type and contain large volumes of aspen that are financially mature.

For both Series A and Series B, a baseline scenario was modeled assuming the project would not be implemented (No-Build Alternative). These scenarios are labeled Scenario A and Scenario B. For both of these scenarios, the 2002 statewide harvesting rate of 3.675 million cords/yr was applied for all decades in the planning horizon. For both of these baseline scenarios, harvest levels of aspen are also constrained in each decade to be 2.206 million cords/yr, which was the 2002 statewide harvest level for aspen. Constraints are also included for both red pine sawlogs and spruce-fir roundwood to sustain harvest levels at the 2002 level.

Scenario A&P and Scenario B&P differ from Scenario A and Scenario B only in that the proposed project (P) has been added to create Build scenarios for Series A and Series B. In adding the proposed project, 98,500 cords of aspen and 98,500 cords of spruce-fir are added to the statewide annual harvest rates and the statewide harvest level was increased by 197,000 cords/yr after the project is implemented in year 2007.

Scenario A&P&SS and Scenario B&P&SS differ from Scenario A&P and Scenario B&P in that some future potential species substitution for aspen has been recognized for other aspen users in Minnesota. Essentially the increased aspen use by the project is assumed to be offset by projected aspen-species substitution by other aspen users. More details concerning these substitution assumptions are described in Section 4.2, Aspen Demand and Species Substitution.

Scenario A&P&HighAspen and Scenario B&P&HighAspen were included to gain more insight on the harvesting potential for aspen. Specifically, constraints were added to set aspen harvest level targets at 3 million cords/yr with no constraints on the total statewide harvest levels and no forest regulation constraints limiting harvest of county or state lands. The primary intent with these scenarios was to gain insight on the maximum potential sustainable aspen harvest levels over the planning horizon under the different private land availability assumptions without most other management constraints that might limit timber production. The three million cords/yr aspen target was expected to be infeasible, yet the intent was to see how close the model might come to sustaining that harvest level over 40 years.

Scenario B&P&SF was developed to consider the impact if the project was based on an increase in spruce-fir and not an increase in aspen. In other words, all of the 197,000 cord/yr increase in statewide harvesting as a result of the project was assumed to be in terms of spruce-fir. Also, the 98,500 cord/year species substitution away from aspen, as assumed in the species substitution scenarios, is assumed to occur under this scenario. With this scenario, future statewide aspen harvest levels drop by approximately 100,000 cords/yr compared to the estimated statewide aspen harvest level for 2002.

For all scenarios, the project was assumed to be completed in 2007 with the project requiring an increase in wood use only in the last four years of Decade 1. The base year for the scenarios is 2001, as 2001 represents the midpoint year for the recent FIA inventory. Timber harvest level volume requirements assumed for all scenarios are summarized in Table C-7.

Table C-7
Statewide Harvest Level Constraint Levels Associated with Series A Scenarios (thousand cords/yr)

Scenario	Constraint type	Decade 1	Decade 2	Decade 3	Decade 4
All Species					
A	=	3,675.0	3,675.0	3,675.0	3,675.0
A&P	=	3,753.8	3,872.0	3,872.0	3,872.0
A&P&SS	=	3,753.8	3,872.0	3,872.0	3,872.0
AB&P&Spruce-fir	=	3,753.8	3,872.0	3,872.0	3,872.0
A&P&HighAspen	None	NA	NA	NA	NA
Aspen					
A	=	2,206.0	2,206.0	2,206.0	2,206.0
A&P	=	2,245.4	2,304.5	2,304.5	2,304.5
A&P&SS	=	2,206.0	2,206.0	2,206.0	2,206.0
A&P&Spruce-fir	=	2,166.6	2,107.5	2,107.5	2,107.5
A&P&HighAspen	=	3,000.0	3,000.0	3,000.0	3,000.0
Spruce-fir					
A	>=	405.0	405.0	405.0	405.0
A&P	=	444.4	503.5	503.5	503.5
A&P&SS	=	444.4	503.5	503.5	503.5
A&P&Spruce-fir	=	483.8	602.0	602.0	602.0
A&P&HighAspen	>=	444.4	503.5	503.5	503.5

Note: The Series B scenarios use same levels.

The model used is an optimization model similar to the GEIS and not a prediction model. In theory, a perfectly competitive market with perfect information will tend to find optimal solutions. But the forest management situation is extremely complex, with few if any landowners understanding all of the information available to the model. Modeling results thus need to be viewed as "what could be" rather than a prediction of the future. Therefore, even the term "projection" is potentially misleading. Optimization models are tools capable of offering important insight regarding management opportunities. Optimization modeling is a primary topic presented in current forest management texts, with emphasis of using modeling results to gain insights about management opportunities.

A DEIS challenge was keeping model formulations simple enough to be useful while still complex enough to describe the forest resource situation. Modeling results from the GEIS served as a helpful foundation for model formulations for this study. Time constraints for this analysis forced some simplifications regarding data development. For example, with more time it would have been possible to use detailed inventory of DNR lands directly in the model rather than to rely on FIA sample plots. What follows is a brief description of the simplifying assumptions made and the complexities recognized to address important facets of the management situation.

4.2 Aspen Harvest Levels and Species Substitution

An important assumption underlying the analyses of the GEIS relates to the demand for the aspen. Aspen, as used in this DEIS and in the GEIS, includes trembling aspen, bigtooth aspen, and balm of gilead. The GEIS analyses assumed that approximately 25 percent of the statewide aspen harvest volume would shift to other species by 2010. Large net shifts in statewide aspen harvest volumes have not yet occurred, as reported in the most recent statistics for the state involving 2002 harvest levels (DNR 2004). Yet shifts are plausible involving major chemical pulp mills and oriented strand board manufacturers. A recent large mill expansion in Cloquet was based on the assumption that the bulk of the increase in wood use would involve hardwoods other than aspen. In years immediately following the GEIS, the market provided relatively little short-term incentive for wood users to shift away from aspen, as aspen stumpage prices had increased only modestly. Since the GEIS, imports of aspen from Canada have also increased substantially. Recently, aspen stumpage prices have increased substantially, providing more incentive for Minnesota wood users to consider using other species. The extent to which shifts can occur is unclear, with more shifts likely as new wood processing technologies are developed. Impacts of the shifts will likely impact both aspen imports and statewide aspen harvest levels. Recent estimates by the DNR (2004) for Minnesota in 2005 have aspen harvest levels declining by approximately 95,000 cords, primarily because of the substitution of other hardwoods. Even with this reduction, the DNR estimate of 2.1 million cords of aspen for 2005 is above the GEIS harvest level for aspen under the Medium Scenario for 2010-2040. For 2010, the GEIS analyses assumed the harvest level for aspen would be 1.8 million cords for the Base Harvest Scenario, 2.0 million cords for the Medium Harvest Scenario, and 2.3 million cords for the High Harvest Scenario (see Table 6.5 in Jaakko Pöyry Consulting, forest productivity report).

4.3 Minimum Harvest Levels by Forest Cover Type

In 2002, 60 percent of the estimated timber volume harvested in Minnesota was aspen. This is a high percentage considering that stands in the aspen forest cover type group average approximately 65 percent aspen by volume. If future timber statewide demands for timber from Minnesota forests remain at this 2002 species mix, then there will be limited opportunities to harvest in forest cover types other than aspen. This situation was generally true for the GEIS Base Harvest Scenario in Decade 1. However, over the last 30 years of the planning horizon for the GEIS Base Harvest Scenario, the aspen harvest volume was reduced to approximately 46 percent of the total statewide harvest, assuming a shift in species demand would occur. For this analysis, the overriding objective was to examine future forest conditions and timber supply potential assuming that the statewide harvest volume levels in 2002 reflect the baseline harvest volumes under the No-Build Alternative.

Historically, public land management agencies in Minnesota have used area control methods to calculate allowable cuts for each forest cover type. Public agencies have often found it difficult to harvest at the allowable cut levels for some forest cover types, because of limited demand for species associated with the cover type. Aspen stands generally contain a mixture of species. With large areas of the aspen forest cover type harvested each year, harvest volumes of other species from aspen stands contribute substantially towards the demand for most other species. Harvesting disturbances in forest cover types, such as jack pine and paper birch, are important ecologically because of the need for a disturbance regime to maintain these forest types. With aspen stands only 65 percent aspen by volume, large areas of birch and jack pine forest cover types cannot likely be harvested and still have 60 percent of the total statewide timber harvest volume be aspen. In recent forest plans for the Chippewa and Superior National Forests, emphasis was on improving ecological conditions of the forest, with aspen volumes making up approximately 40 percent of the volume harvested each decade in the management schedule associated with the plans. For this analysis, plans for the Chippewa and Superior National Forests were assumed to be implemented as modeled in the USDA Forest Service planning process. For this analysis, minimum harvest areas per decade for forest cover types were not included for other ownerships. Clearly, public land management agencies will address these issues in their plans and likely strive to harvest more in those forest cover types needing disturbance. Harvest levels in those types will likely depend on the extent to which demand for species other than aspen increases above the 2002 statewide levels assumed for the baseline (No-Build Alternative) in this analysis. For the GEIS Base Harvest Scenario, the aspen harvest level was assumed to decline by year 2010 to 1.85 million cords/yr. Under the GEIS Base Harvest Scenario, aspen comprised 46 percent of the 4.175 million cord/yr statewide timber harvest volume for years beyond 2010. Thus, the aspen harvest volumes for the GEIS Base Harvest Scenario were not nearly as large a component of the overall statewide harvest as was estimated to occur in year 2002 and assumed for the No-Build Alternative in the DEIS.

4.4 Forest Ownership

A breakdown of forestland area as represented in the forest management model is shown in Table C-8. The discussion below provides a brief description of how the different ownership groups were addressed in the modeling process.

Table C-8
Area of Forestland by Ownership Group as Recognized in the Forest Management Model *

Ownership Category	Area (M acres)
Federal -- Reserved	726
National Forest	1,760
DNR	3,706
County/Local Government	2,616
UPM/Blandin Paper Lands	138
Private Lands	6,767
Other Owners	297
Total	16,010

** Does not include 228,800 acres of forestland classified as open land.*

4.5 National Forest Lands

Both the Chippewa and Superior National Forests released new forest plans in 2004. These plans entailed a detailed analysis based on a forest management scheduling model similar to the model used for this study. Over 50,000 analysis areas were modeled for the Chippewa National Forest and over 100,000 analysis areas for the Superior National Forest. Model output files associated with the final forest plan for each forest were used as model inputs for this study to describe future timber yields and forest conditions for National Forests. Growth and yield estimates for the national forestlands were not revised based on the growth and yield models used for other forestland ownerships considered in this study. The USDA Forest Service plans used the same forest cover type and stand age classifications as used in this study. Harvest volume levels for the national forests total approximately 330,000 cords per year over the 40-year planning horizon. USDA Forest Service plans for the national forests represent approximately 1.7 million acres and do not include the Boundary Waters Canoe Area Wilderness even though the Boundary Waters Canoe Area Wilderness is managed by the Superior National Forest.

4.6 State Lands

The DNR is in the process of completing plans for DNR-managed lands in large ecological regions (subsections) of Minnesota. These plans focus on the area mix of forest cover types and the stand age distribution of each forest cover type. Emphasis is on a range of future rotation lengths for each forest cover type and controlling the area of each forest cover type older than a typical economic rotation age. Ages for these extended rotation lengths vary by forest cover type and by ecological subsection. For this analysis, the amount of area that is mature in each decade is tracked and reported for selected forest cover types on DNR lands and all forestlands. The minimum stand ages for mature forests are shown by forest cover type groups in Table C-9. These ages generally agree with minimum stand ages used by the DNR for classifying stands as effective extended rotation forestry (ERF). A stand is considered to provide effective ERF when it is older than the minimum age.

Table C-9
Minimum Stand Ages for Mature Forest

Forest Cover Type Group	Minimum Age for Mature Forest (years)
Jack pine	50
Red Pine	60
White Pine	60
Upland spruce-fir	50
Oak	60
Northern hardwoods	80
Aspen	45
Paper Birch	55
Lowland spruce	100
Tamarack	85
Lowland hardwood	80
Cedar	80

Modeling constraints were included to limit the area of regeneration harvesting each decade in each forest cover type for state lands. Regeneration harvesting was assumed to be any harvesting which changes the age of the overstory trees to age 0 after the harvest. Limits on area harvested were set considering the long-term desired future conditions for each forest cover type in terms of the percentage of timberland that is desired to be effective ERF. Specifically, for the aspen forest cover type on state lands, the effective ERF target is 12.5 percent (a DNR estimate based on current SFRMP plans and anticipated direction in plans yet to be completed). The objective is then to spread the remaining 87.5 percent of the timberland over stand age of 45 or younger, where age 45 is assumed to be the minimum rotation age for aspen. This results in a target of 19.4 percent of the aspen cover type forest to be in the 0-9 year age class in each decade. For Decades 1 and 2 of the planning horizon, it was assumed that the 0-9 year age class could be up to 10 percent greater, reflecting the imbalanced age distribution of aspen and identified needs in recent DNR plans to regenerate high-risk and low-volume stands. DNR plans to restore some harvested aspen stands to other forest cover types were not included in the model.

The DNR, in each of their subsection plans, considers in more detail the management actions desired for the short term – the next 10 years. These plans generally emphasize an objective of increasing forest-productivity through management activities to reforest poorly stocked stands and stands at high risk of mortality. As a result, the DNR generally projects to harvest more acres in the next 10 years compared to a long-term average. Short-term DNR harvest volumes for the next 10 years also tend to be higher than those projected for the following 2-3 decades. For modeling in this study, these 10-year DNR plans fall partially in both Decades 1 and 2 used for the DEIS. Decade 1 for the DEIS starts in 2001, the midpoint year of measurement for the latest FIA inventory.

The GEIS assumed 95 percent of all timberland on DNR lands is available for harvest. This same assumption was used for this study. All forestland is tracked in this study, showing an estimated 3.7 million acres of DNR forestland and approximately 3.3 million acres of DNR timberland. This area is high compared to timberland area estimates used by the DNR in developing their recent plans. Differences in area estimates are due to both FIA ownership classification procedures and FIA forestland classification procedures. Some acres in the Boundary Waters Canoe Area Wilderness are classified as state-owned lands by FIA, and some lands managed by counties are classified as state lands by FIA. The USDA Forest Service helped identify FIA plots that represent state-owned, county-managed lands, but such information was not released by the USDA Forest Service for some FIA plots because of confidentiality concerns regarding the inventory.

4.7 County Lands

Compared to state lands and national forest lands, county lands tend to be managed with more emphasis on timber production. Like the DNR, county plans tend to address plans for each forest cover type separately. Area control is generally applied to limit the area that is regeneration harvested each year. Area control is typically applied separately to each forest cover type, with some allowance for small departures in acres harvested in the short-term. For the aspen forest cover type, current harvest levels are close to estimated allowable cut for most, if not all, counties. For this analysis, area control constraints were applied to county lands for the forest cover types listed in Table C-10. Rotation ages assumed for area control estimates are also shown along with any percentage departure in area harvested allowed for Decades 1 and 2 of the planning horizon (Table C-10). Departures are generally justified by the imbalanced nature of the stand age distribution coupled with the short-lived nature of many of the trees species in the associated forest cover type. Similar to DNR lands, 95 percent of county timberlands were assumed to available for harvest.

Table C-10
Assumptions for Allowable Cut Calculations for State and County Lands

Forest Cover Type Group	State-managed Lands			County-managed Lands	
	Minimum Rotation Age Managed (years)	Long-term ERF Targets (Percent of Timberland)	Allowable Percent Increase in Harvest Area Above Allowable Cut for Decades 1 and 2	Rotation Age for Area Control Calculation (years)	Allowable Percent Increase in Harvest Area Above Allowable Cut for Decades 1 and 2
Jack Pine	50	10.5	10	50	10
Spruce-fir	50	11	5	55	5
Aspen	45	12.5	10	45	5
Paper Birch	55	13	15	50	5
Lowland Spruce	100	13	10	100	5
Tamarack	85	14.5	5	90	5
Red Pine	NA	NA	NA	90	0

4.8 Blandin Paper Company Lands

The USDA Forest Service was able to update the 2001 FIA inventory to identify 43 FIA plots representing 140,000 acres of Blandin Paper Company lands. This study assumed that 98 percent of the Blandin Paper Company lands are available for harvest. Constraints were not included to regulate Blandin Paper Company lands directly in any way. Management of these lands is impacted in the model by the forest-wide constraints limiting the total statewide harvest level each decade.

4.9 Other Private Lands

The availability of private lands for harvest was considered an important and uncertain facet of the forest resource situation. Little specific information is available in the forestry literature about the availability of private lands for harvest in Minnesota. The literature suggests that most non-industrial private forest (NIPF) lands will eventually be available for harvest, but the time frame over which it becomes available is unclear. A survey for the northeast US (Birch 1996) showed that 12 percent of all forestland owners (based on area of timberland owned) stated that they will never harvest their lands. Other studies suggest that negative landowner attitudes about harvesting may change over time. Ownership changes may eventually make most private forestlands available for harvest. However, large acreages in age classes of financially over-mature aspen suggest that objectives other than financial returns from timber production have been influencing Minnesota forest landowners. Procurement foresters and consulting foresters are well aware that a substantial proportion of landowners currently owning financially over-mature stands in northern Minnesota are unwilling to harvest. The recent large stumpage price increases for aspen in northern Minnesota also strongly suggest that the available supply of aspen is at least a short-term concern.

The GEIS assumed that 90 percent of all NIPF timber lands, regardless of stand age and forest cover type, are available for harvest. For the DEIS analyses, assumptions were defined in greater detail, recognizing that the percentage of land available for harvest might vary substantially for various forest cover type and stand age combinations. Also recognized is a time dimension, describing availability, with more area likely becoming available over time with changes in ownership and attitudes. Stumpage prices could also be a factor, with many landowners not yet aware of recent stumpage price increases.

Table C-11 lists a set of series of percentages describing alternative assumptions about the percent of forestland available for harvest each decade. For example, acres assigned to series 9 would have 70 percent of the area available for harvest in Decade 1, and by Decade 2, 85 percent would be available. Rather than use one set of percentages and apply it to all forest cover types and existing age classes, assumptions could were varied depending on forest cover type and existing age class. Table C-12 shows the assignment of the series shown in Table C-11 to specific forest cover types and age classes. The aspen forest cover type is shown in two rows of Table C-12, showing specifically how assumptions on availability were varied for the aspen forest type between the Series A and Series B sets of scenarios. Only assumptions for the aspen forest cover type group were varied between scenarios. As noted earlier, the GEIS modeling results suggested that the statewide harvest volume of aspen had reached levels in the early 1990s that were not sustainable over the planning horizon of the GEIS.

Table C-11
Assignments of Availability Assumption Series to Combinations of Private Forestland Age Class and Forest Cover Type Group

Forest Cover Type Group	Scenarios	Age Class at Start of Planning Horizon (years)									
		Age 0-9	Age 10-19	Age 20-29	Age 30-39	Age 40-49	Age 50-59	Age 60-69	Age 70-79	Age 80-89	Age 90+
Jack Pine	All	6	7	10	9	9	13	14	15	16	17
Red Pine	All	1	1	8	11	10	9	9	9	13	14
White Pine	All	16	16	16	17	17	17	18	18	18	18
Spruce-fir	All	4	4	7	6	5	9	9	13	14	14
Oak	All	4	4	8	7	6	5	9	9	9	13
Northern Hardwoods	All	1	1	4	8	7	6	5	9	9	9
Aspen	All A	8	11	10	9	5	9	30	13	13	14
Aspen	All B	19	20	21	22	23	24	25	26	27	28
Paper Birch	All	8	7	6	5	5	5	9	9	13	14
Lowland Spruce	All	1	1	1	8	8	7	6	5	5	5
Tamarack	All	1	1	8	8	7	6	5	5	5	9
Lowland Hardwoods	All	1	12	11	10	9	9	9	9	9	9
Cedar	All	1	1	1	1	1	1	1	1	1	1

Table C-12
Alternative Assumptions Used to Describe the Availability of Timberland for Harvest over Time

Assumption Series	Proportion of Harvestable Acres First Available			
	Decade 1	Decade 2	Decade 3	Decade 4
1	0	0	0	0
2	0.98	0.98	0.98	0.98
3	0.95	0.95	0.95	0.95
4	0	0	0	0.85
5	0.8	0.9	0.95	0.95
6	0	0.8	0.9	0.95
7	0	0	0.8	0.9
8	0	0	0	0.8
9	0.7	0.85	0.925	0.95
10	0	0.7	0.85	0.925
11	0	0	0.7	0.85
12	0	0	0	0.7
13	0.6	0.8	0.9	0.95
14	0.5	0.75	0.875	0.938
15	0.4	0.7	0.85	0.925
16	0.4	0.64	0.784	0.87
17	0.3	0.51	0.657	0.76
18	0.25	0.438	0.578	0.684
19	0	0	0	0.5
20	0	0	0.5	0.7
21	0	0.5	0.7	0.85
22	0.5	0.7	0.85	0.9
23	0.7	0.8	0.85	0.9
24	0.7	0.8	0.85	0.9
25	0.6	0.7	0.8	0.85
26	0.5	0.6	0.7	0.8
27	0.45	0.55	0.65	0.75
28	0.4	0.5	0.6	0.7

4.10 Ecological Areas

Each analysis area of the forest has an associated ecological classification referred to as a native plant community. Twenty-three native plant community classes were recognized. For every decade in the planning horizon, the model tracks and reports the area of each forest cover type in each 10-year stand age class and site quality class for each native plant community. Site quality is measured by site index, with 4-6 site index classes recognized for each forest cover type considered available for harvest. By tracking each of these forest condition classes separately, model formulations could later potentially be adjusted to limit the area harvested in any native plant communities if such limits seemed necessary. Age distributions by native plant community are key input for wildlife modeling and for measuring the current condition of the forest as it relates to the range of natural variability (RNV). Tracking age classes by native plant community also makes it easier to review modeling results. The USDA Forest Service, for the 2004 Chippewa and Superior National Forest plans, limited the area that could enter the age 0-9 age class each decade for each native plant community. In effect, this limited the area that could be regeneration harvested each decade using even-aged management. The constraints forced the average age of stands in each native plant community to increase over time. Age distributions tracked for native plant communities for this study add insight regarding estimated disturbances in each ecosystem and general changes in age distributions over time. Natural succession pathways vary by native plant community. Undisturbed areas will generally succeed to either spruce-fir or northern hardwoods, depending on the specific native plant community. This detail of forest succession was not modeled directly. In interpreting the results, it is important to consider this aspect qualitatively. Reforestation activities after harvest vary among native plant communities, with foresters emphasizing the importance of matching regeneration efforts with ecological conditions of the site. Modeling of reforestation was simplified since regeneration decisions were not considered. Except for National Forest lands where specific National Forest modeling results were utilized, it was assumed that areas would be regenerated to the same forest cover type after harvesting.

4.11 Riparian Areas

Riparian Areas were modeled based on current state guidelines for management**.** The 2001 FIA inventory does not identify plots as riparian areas**.** Estimates of the area of forestland in riparian areas were developed based on recent USDA Forest planning efforts for the Chippewa and Superior National Forests that explicitly recognized riparian areas in detail. Specifically, for each FIA plot, it was assumed that a proportion of its area is in a riparian area. That proportion was defined by the proportion of the associated forest cover type that is in riparian areas on USDA Forest Service lands (Table C-13). Definitions of riparian areas are based on definitions used in the Minnesota Forest Resources Council Voluntary Site-Level Forest Management Guidelines for riparian area management.

Table C-13
Proportion of each Forest Cover Type Group that is in Riparian Areas in Minnesota's National Forests *

Forest Cover Type Group	Area of National Forest Forestland (thousand acres)	Percent of Area in Riparian Areas
Jack Pine	117.0	3.50
Red Pine	149.4	1.51
White Pine	35.6	2.90
Upland Spruce-fir	194.8	3.32
Oak	10.0	5.08
Northern Hardwoods	97.3	2.43
Aspen	663.3	2.44
Paper Birch	143.9	5.24
Lowland Spruce	247.7	3.80
Tamarack	18.7	2.01
Lowland Hardwood	38.5	6.08
Cedar	44.4	4.38
Open	7.0	4.22
Total	1,767.5	3.10

** Riparian areas are as defined by guidelines from the Minnesota Forest Resources Council.*

4.12 Silvicultural Treatment Options

Projections of future harvest volumes for alternative management treatment options for each FIA inventory plot were important model inputs. Methods for projecting yields were described in detail in Section 3.0, Timber Growth and Yield Modeling. It is important to understand that treatment options were provided to the model for each analysis area, and then the model selected (scheduled) options for each analysis area based on assumptions associated with the model formulation.

Although most silvicultural treatment options applied in Minnesota involve even-aged management, uneven-aged treatment options were considered for the northern hardwoods, oak, lowland hardwoods, and white pine forest cover types. For all analysis areas, a “no-harvest” option was considered as one of the treatment options.

Silvicultural treatment options for riparian areas were limited to harvesting so at least 40 square feet of basal area per acre were retained in the stand after harvest.

Minimum rotation lengths for each forest cover type varied by ownership. For most forest cover types these lengths varied relatively little by ownership. Red Pine is a notable exception, with DNR lands using longer rotations with more emphasis on thinnings. Table C-14 lists the minimum rotation ages considered for each ownership group.

Table C-14
Minimum Rotation Age for Ownership Groups

	State-managed	County-managed	Blandin Paper Company Lands	Other Private Lands
Jack Pine	50	45	45	45
Upland Spruce-fir	50	50	50	50
Aspen	45	40	40	40
Paper Birch	55	50	50	50
Lowland Spruce	100	90	90	90
Tamarack	85	85	85	85
Red Pine	100	60	60	60

Forest stands in Minnesota generally contain a mixture of tree species, and an associated mix of forest products. Recognizing this facet of the situation is important. With aspen making up a large proportion of the market demand, much of the harvesting tends to be in aspen stands with the aspen stands providing substantial volumes of wood of other tree species. Generally, much of the demand for all tree species is met by harvesting in the aspen forest type.

Reforestation activities and changes in forest type as a result of regeneration after harvest were not considered except as described in the inputs from analyses for National Forestlands. Direct benefits from reforestation efforts would generally not be realized within the planning horizon. Investments are ongoing to increase future forest productivity through more intensified management, and these investments were generally ignored in this analysis as benefits are also generally long-term in nature with little additional timber volume produced in less than 40 years.

Forest management activities by public agencies in Minnesota are underway to increase the area of some forest cover types, and to increase the within stand diversity of some forest cover types. Efforts to restore white pine are a good example of both of these restoration activities. None of these efforts will lead directly to substantial changes in timber volumes harvested within the planning horizon for this study. Analyses developed for this project do not include any modeling of these forest restoration efforts.

The USDA Forest Service considered 17 silvicultural treatment types (USDA Forest Service 2004). For all other forest lands considered in this study, five treatment types were recognized: (1) even-aged management with thinning, (2) even-aged management without thinning, (3) even-aged management retaining 40 square feet of basal area after harvest, (4) uneven-aged management, and (5) no harvest. Treatment type (1) was considered as an option only for the red pine forest type. Treat types (1) and (2) were not considered for riparian areas. Treatment type (3), designed primarily for riparian areas, was also applied by the Forest Service to National Forest lands in areas other than riparian areas.

4.13 Planning Horizon and Ending Inventory

A 40-year planning horizon is used with four 10-year planning periods. Harvests are assumed to occur at the midpoint of each planning period and forest conditions are measured at the beginning and ending points of each planning period. The length of the planning horizon is relatively short compared to other studies. Results of the GEIS suggest that timber supply concerns and associated environmental impacts are likely to be more short-term in nature, occurring well before 2040, the ending year of the planning horizon.

Although projections of forest conditions were developed until 2040, assumptions for valuing ending inventory were needed to recognize forest values beyond the end of the planning horizon. These values were estimated separately for each site index class for each forest cover type using soil expectation values (Davis et al. 2001) based on typical economic rotation ages for the associated cover type. For cover types considered harvestable, (all but white cedar and open lands) the number of site index classes varied from as many as six for the aspen forest cover type to as few as four for the oak and lowland hardwood forest cover types. Recognizing land values associated with future rotations helps prevent management objectives for the planning horizon from dominating modeling results.

4.14 Forest Succession

Forest succession was not included in the model, as such detail would need specific assumptions about successional pathways for all native plant communities. Model outputs show areas in age classes, for short-lived species like jack pine, aspen, and birch, in age classes beyond ages when natural succession to other forest cover types would normally occur. The area in these old age classes still provides insight about the degree to which natural succession would likely be occurring. Generally, most upland stands in Minnesota, if left undisturbed, will succeed to either northern hardwoods or to spruce-fir. The age at which succession occurs also varies within the state, with succession occurring earlier in areas farther south.

5.0 MODELING RESULTS

5.1 Shadow Prices for Timber Volume Constraints

The scheduling model analyzes each FIA plot and each of its analysis areas separately. Important to those stand-level analyses are the estimated shadow prices (marginal costs) associated with the forest-wide constraints (see Section 4.0). Forest-wide constraints that were applied to all ownerships include constraints defining total statewide harvest volume by decade (across all species) and statewide volume totals for aspen and spruce-fir by decade. These shadow price estimates are marginal cost estimates; that is, they estimate how costly it is to achieve the last unit of timber output associated with the constraint. An examination of the shadow prices for the forest-wide constraints provides a general overview of the forest management situation, and insight regarding how stand-level decisions are adjusted to address forest-wide objectives. With the value of these shadow prices in mind, it is easier to understand why the model is scheduling management activities as it does at the stand-level. Generally, the magnitude of the shadow prices indicate the degree to which the forest-wide constraint is influencing stand-level decisions. Units of measure are also important to remember in interpreting magnitude of impact. Shadow prices associated with constraints involving timber volumes harvested will be expressed in $/cord and shadow prices involving area harvested will be expressed in $/acre. Shadow prices are also reported in terms of values for the decade in which they occur. In other words, in applying them in a stand level analysis, values would still need to be discounted. This is similar to the way that actual prices or costs are generally reported, with associated analyses discounting net returns to a common base year using standard financial analysis techniques.

The marginal cost estimates for the constraints that define total statewide harvest levels for all species show clear patterns (Table C-15). The consistently negative shadow prices for the total statewide harvest level constraints indicates that the model must "tax" timber production in the stand-level analyses to keep statewide timber harvest levels from being greater than the assumed levels. These taxes are greater than the stumpage prices assumed for several tree species groups (Table C-16). With taxes greater than stumpage price values, the model has little incentive to harvest in these types unless some volumes of more valuable species can also be obtained. These "taxes" on volumes harvested are higher for the Build Alternative for Series B (Scenario B&P) than for the No-Build Alternative (Scenario B). These shadow prices must be considered in combination with the shadow price estimates associated with other constraints in the formulation. Aspen production for scenario B&P is more heavily subsidized, therefore overall timber production must be taxed more heavily for this scenario to keep total statewide harvest levels from rising above the assumed statewide levels (Table C-15). Note that the shadow prices associated with the total statewide harvest level constraints are negative and relatively large compared to stumpage prices, without any clear trend in how the values change over time.

Table C-15
Shadow Prices For Total Harvest Level Constraints ($/cord)

Scenario	Decade 1	Decade 2	Decade 3	Decade 4
A	-36.28	-35.14	-34.06	-32.89
A&P	-34.34	-33.84	-33.00	-32.45
A&P&SS	-31.68	-30.54	-29.68	-28.98
A&HighAspen	NA	NA	NA	NA
B	-38.01	-37.48	-36.43	-35.71
B&P	-74.71	-79.29	-78.88	-83.98
B&P&SS	-32.88	-32.27	-31.07	-30.55
B&P&Spruce-fir	-31.79	-30.84	-30.02	-29.14
B&HighAspen	NA	NA	NA	NA

Table C-16
Stumpage Prices Assumed for Timber Product Groups

Product Group	Price ($)	Units
Red & White Pine Logs	150	MBF
Jack Pine Logs	150	MBF
Aspen Pulp	60	cord
Hardwood Pulp	30	cord
Spruce-fir Pulp	40	cord
Tamarack Pulp	15	cord
Pine Pulp	25	cord
Firewood	15	cord

The shadow price (marginal cost) estimates for the constraints that define statewide harvest levels for the volume of aspen harvest show a general increase in value over time for all scenarios except for scenarios A&HighAspen and B&HighAspen (Table C-17). Shadow prices for aspen for those two scenarios are unrealistically high adjustments to values of aspen production. Using higher values will not produce more aspen under the silvicultural systems considered in this study. The fact that such high values were estimated by the model is indicating that the associated three million cord harvest levels for aspen for these scenarios cannot be sustained over all decades. Throughout the model's solution process, shadow prices for aspen were continuously increased, but even with large increases, ways of achieving the high aspen harvest levels could not be found. The specific magnitude for these shadow prices are not important – had the model been run longer, these shadow price estimates would have increased even more. Higher shadow prices would not produce feasible solutions that satisfy all of these constraints under the assumptions of the scenario.

Table C-17
Shadow Prices for Aspen Harvest Level Constraints ($/cord)

Scenario	Decade 1	Decade 2	Decade 3	Decade 4
A	-11.35	-6.78	-2.37	2.15
A&P	0.18	8.07	14.69	22.06
A&P&SS	-16.28	-11.71	-7.04	-1.90
A&HighAspen	5,886.70	6,992.90	7,811.93	8,642.26
B	26.36	38.02	46.04	55.33
B&P	316.14	376.70	415.37	464.05
B&P&SS	20.47	32.05	39.91	49.55
B&P&Spruce-fir	-9.09	-3.25	1.68	6.74
B&HighAspen	6,192.24	7,377.54	8,173.07	9,008.45

Shadow price estimates for aspen and the other scenarios show a clear distinction between the Series A Scenarios and the Series B Scenarios (Table C-17). Under Series A, the shadow prices for aspen timber volumes are all negative in Decade 1, suggesting a need to penalize harvesting options for Decade 1 in order to hold back on harvesting in Decade 1, compared to stand-level decisions based strictly on financial analysis that compares the net present value of stand-level treatment options. Shadow prices for Series A are also consistently increasing over time, with increases generally about $4/cord each decade for Scenario A and about $7/cord each decade for Scenario A&P. Any positively-valued shadow prices ("subsidies") for Series A are less than the "taxes" applied in terms of the shadow prices associated with the limits on statewide harvesting (Table C-15). In other words, the net impact of the shadow price estimates for the Series A assumptions does not suggest a relatively high emphasis on aspen production compared to other species groups. However, market stumpage prices assumed for aspen are higher than those for most other species (Table C-16). With an overall "tax" on harvesting of over $30/cord, emphasis does shift to species that are still profitable to harvest with that level of internal tax (Table C-15).

Shadow price estimates for aspen under the Series B assumptions are positive (Table C-17), and are generally of the same magnitude as the negative shadow prices associated with the overall statewide harvest level constraints (Table C-15). They also increase substantially over time, suggesting a need to lengthen rotations to capitalize on stand growth over the planning horizon. For the Build Alternative in Series B (Scen B&P) aspen shadow prices are over $300/cord in Decade 1 and rise over time. At this level, shadow prices are adding a large subsidy to the analyses that more than quadruples the estimated value of aspen production based on market values. In contrast, for the scenario that shifts emphasis of the project to spruce-fir, the shadow price estimates for aspen suggest little about a concern for aspen supply.

Shadow price estimates for constraints describing statewide spruce-fir production are relatively low in terms of absolute value (Table C-18). They vary much less between scenarios over time as compared to shadow prices for aspen. For the No-Build Alternatives (Scenario A and Scenario B) the values are not negative because the constraint was implemented allowing spruce-fir to exceed to minimum production levels. In other words, greater volumes of spruce-fir harvest are considered acceptable so penalties (taxes) need not be applied in these scenarios. Overall, analysis for stand-level decisions for stands with primarily spruce or balsam-fir, little adjustment is needed to address impacts of statewide timber production level constraints except to include the "taxes" associated with the limits on total statewide timber harvest levels (Table C-15). For scenario B&P, the shadow prices for spruce-fir are larger and are "internal subsidies" for harvesting spruce or fir, but these values are still less than the "taxes" on harvesting associated with the constraints that limit the total statewide harvest over all species (Table C-15).

Table C-18
Shadow Prices for Spruce-fir Harvest Level Constraints ($/cord)

Scenario	Decade 1	Decade 2	Decade 3	Decade 4
A	0.00	0.00	0.00	0.00
A&P	-2.67	-1.86	-1.68	-0.80
A&P&SS	-4.92	-4.85	-4.74	-4.03
A&HighAspen	NA	NA	NA	NA
B	0.00	0.00	0.00	0.60
B&P	41.10	47.57	48.20	55.65
B&P&SS	-3.96	-3.31	-3.66	-2.77
B&P&Spruce-fir	0.86	2.31	3.04	4.54
B&HighAspen	NA	NA	NA	NA

To better understand the impact of shadow pricing on timber harvesting, consider an example involving a stand that is potentially harvestable in Decade 1 that would yield 5 cords/acre of aspen and 15 cords/acre of other hardwoods. Consider this option for just Scenario B and Scenario B&P realizing that the same approach is used for other scenarios using the shadow prices reported in Table C-15 and Table C-17. Under Scenario B, the impact of the constraint limiting statewide harvest to 3.675 million cords/yr adds a tax in the model's stand-level analysis of 20 cords/acre times $38.01/cord, which equals a $760.20/acre tax. Because aspen is produced in the process and producing 2.206 million cords/year is required for the scenario, the model is adding a subsidy of $26.36/cord times 5 cords/acre, which equals $131.80/acre. Overall, the net impact for this treatment option is a net tax of $628.40/acre ($760.20/acre less $131.80). It is a net tax because the modeling process is indicating that too much volume is being produced in relation to the added benefit of providing more aspen. Under Scenario B&P, the results are different. The tax on total volume harvested is $1494.20/acre (20 cords/acre x $74.71/cord), and the subsidy for providing aspen is $1580.50/acre (5 cords/acre x $316.14/cord), making for a net subsidy of $84.50/acre ($1580.70 - $1494.20). For the stand-level analyses conducted for this stand in the model, market values for the timber returns would also need to be included, and analyses would also need to consider treatment options for harvesting in other decades. But clearly, for Scenario B&P, the amount of aspen produced from harvesting a stand is impacting substantially the net tax or subsidy that is applied in the stand level analyses in the model to satisfy the forest-wide harvest level targets associated with Scenario B&P. This internal pricing approach is standard to all linear programming models, and understanding it can help enormously in understanding the modeling results.

5.2 Statewide Timber Levels: Volumes Harvested

The statewide timber harvest volumes resulting from model runs are summarized in Table C-19. This information displays whether the model was able to meet the targets as specified for the scenario. Note that the statewide harvest levels average over 5 million cords/year for the scenario where the statewide total harvest level was not constrained (Scenario A&HighAspen and Scenario B&HighAspen). In effect, these two scenarios reflect higher harvest levels associated with not including any negative shadow prices in the stand-level analysis for the purpose of keeping statewide harvests at the statewide 2002 level, either with the Build or No-Build Alternatives.

Table C-19
Total Wood Volume Harvested by Decade (thousand cords/yr)

Scenario	Decade 1	Decade 2	Decade 3	Decade 4	Average
A	3,671	3,683	3,666	3,677	3,674
A&P	3,761	3,881	3,867	3,890	3,850
A&P&SS	3,743	3,843	3,861	3,854	3,825
A&HighAspen	5,621	5,187	5,158	4,975	5,235
B	3,680	3,684	3,680	3,686	3,682
B&P	3,765	3,881	3,888	3,890	3,856
B&P&SS	3,738	3,871	3,856	3,872	3,834
B&P&Spruce-fir	3,740	3,870	3,877	3,872	3,840
B&HighAspen	5,412	5,092	4,949	4,870	5,081

Comparing the results of the scenarios in terms of the average annual harvest volume of aspen adds insight (Table C-20). Important to note is how close the aspen harvest levels are for Scenario A&HighAspen and Scenario B&HighAspen compared to harvest levels for the other scenarios. These two scenarios use 3 million cord targets for aspen each decade, and not surprising, those aspen volumes cannot be sustained under either scenario. However, the resulting harvest levels provide insight about what statewide levels could be sustained over the next 40 years under the assumptions of Series A and Series B describing the availability of private lands for harvest. Note that these scenarios contain few other constraints that could potentially be limiting aspen harvest levels. Specifically, they do not contain constraints for state or county managed lands that limit the area harvested in each forest cover type each decade. Without these limits and without any limits on the total statewide harvest level each decade, results suggest that a sustainable harvest level for aspen is only about 200,000 cords/yr over the No-Build Alternative under Series A assumptions. Under Series B assumptions, the increase is only about 105,000 cords/yr.

For Scenario B&P, the aspen harvest levels are not achieved, with aspen volumes falling short of target levels by about 30,000 cords annually, or about 1.5 percent below the statewide aspen harvest target levels associated with the scenario. For Scenario B&P, the model attempted to achieve the aspen targets by raising shadow prices for aspen, but even with high aspen shadow prices (subsidies) the targets could not be achieved every decade. Basically, the decades are competing with each other, driving the aspen shadow prices for each decade higher. Even with high aspen shadow prices for each decade, the model could not satisfy aspen targets in every decade.

Table C-20
Aspen Volume Harvested by Decade (thousand cords/yr)

Scenario	Decade 1	Decade 2	Decade 3	Decade 4	Average
A	2,212	2,214	2,207	2,218	2,213
A&P	2,243	2,303	2,304	2,303	2,288
A&P&SS	2,222	2,219	2,229	2,224	2,224
A&HighAspen	2,488	2,428	2,393	2,352	2,415
B	2,193	2,191	2,200	2,198	2,195
B&P	2,213	2,270	2,266	2,256	2,251
B&P&SS	2,203	2,203	2,204	2,206	2,204
B&P&Spruce-fir	2,185	2,126	2,132	2,135	2,145
B&HighAspen	2,349	2,348	2,239	2,268	2,301

Average volumes for spruce-fir harvests are reported in Table C-21. Of interest are the substantially larger spruce-fir volumes for the High Aspen scenarios. This suggests some potential to expand harvest levels for spruce-fir. However, it is important to note that rotation lengths for lowland spruce are substantially longer than the 40-year planning horizon considered.

Table C-21
Spruce-fir Volume Harvested by Decade (thousand cords/yr)

Scenario	Decade 1	Decade 2	Decade 3	Decade 4	Average
A	454	470	504	446	468
A&P	444	502	504	504	488
A&P&SS	447	504	512	511	493
A&HighAspen	781	740	714	613	712
B	450	426	458	396	432
B&P	449	501	500	501	488
B&P&SS	442	509	505	507	491
B&P&Spruce-fir	482	604	601	603	573
B&HighAspen	755	732	698	611	699

The volumes of timber scheduled for harvest by the model for state managed lands are summarized in Table C-22. Comparing Scenario A & Scenario A&P, harvest from state lands increases on average by 25,000 cords/yr. A similar comparison for Series B scenarios shows a 28,000 cord/yr increase. The increase is slightly larger for the scenarios with species substitution (SS), reflecting greater opportunity for increased harvesting on state lands in forest cover types other than the aspen type. Not surprisingly, the model has higher harvest levels on state-managed lands for the Series B scenarios, the scenarios where less private land is considered available for timber production. Compared to similar Series A scenarios, on average scheduled harvests on state lands are 20,000 cords/yr higher for Scenario B, 23,000 cords/yr higher for Scenario B&P, and 14,000 cords/yr higher for Scenario B&P&SS.

Table C-22
Volume Harvested from State Lands by Decade (thousand cords/yr)

Scenario	Decade 1	Decade 2	Decade 3	Decade 4	Average
A	631	838	769	791	757
A&P	729	809	746	845	782
A&P&SS	642	848	779	908	794
A&HighAspen	1,506	964	938	1,034	1,111
B	800	771	733	805	777
B&P	863	788	752	816	805
B&P&SS	816	806	753	858	808
B&P&Spruce-fir	773	888	786	933	845
B&HighAspen	1,474	1,023	923	1,019	1,110

Harvest volume levels for county managed lands also show about a 25,000 to 30,000 cords/yr increase in harvesting between the Build and the No-Build Alternative project scenarios (Table C-23). Comparing Series A and Series B scenarios, scheduled harvest levels for county lands are higher for scenario B, but not more than 18,000 cords/yr higher for any paired scenarios that differ only in availability assumptions for private lands.

Table C-23
Volume Harvested from County Lands by Decade (thousand cords/yr)

Scenario	Decade 1	Decade 2	Decade 3	Decade 4	Average
A	750	919	886	807	840
A&P	830	937	899	810	869
A&P&SS	776	955	961	850	885
A&HighAspen	1,487	997	1,011	838	1,083
B	883	918	864	768	858
B&P	952	879	913	744	872
B&P&SS	904	968	891	802	891
B&P&Spruce-fir	849	952	980	849	907
B&HighAspen	1,480	1,055	954	831	1,080

The modeling results suggest that most of the increase in timber harvest volumes would come from private lands (Table C-24). Comparing the Build and No-Build Alternatives, the average volume increase is 121,000 cords/ year for Series A and 123,000 cords/yr for Series B. With species substitution in the market (SS scenarios in the tables), the increase is 69,000 cords/yr for Series A and 84,000 cords/yr for Series B.

Harvest levels vary by decade between the Build and No-Build Alternatives for private landowners (Table C-24). For example, the model suggests that with the project under Series A, the harvest levels on private lands should be less in Decade 1, with increased harvesting on private land in later decades. Essentially the model is adjusting harvest timings to recognize differences in growth rates between stands and across ownerships. Overall, results for each scenario do not show large shifts in the volume of timber harvested over time from private lands. In fact, for Scenario A&P the levels are quite stable ranging from 1764 cords/yr in Decade 2 to 1886 cords/yr in Decade 4.

Table C-24
Volume Harvested From Private Lands by Decade (thousand cords/yr)

Scenario	Decade 1	Decade 2	Decade 3	Decade 4	Average
A	1,880	1,545	1,658	1,717	1,700
A&P	1,785	1,764	1,847	1,886	1,821
A&P&SS	1,907	1,657	1,763	1,751	1,769
A&HighAspen	2,204	2,816	2,808	2,732	2,640
B	1,587	1,611	1,715	1,758	1,668
B&P	1,551	1,815	1,848	1,951	1,791
B&P&SS	1,609	1,710	1,844	1,845	1,752
B&P&Spruce-fir	1,700	1,638	1,752	1,746	1,709
B&HighAspen	2,040	2,598	2,672	2,650	2,490

Table C-25 compares harvest volume projections by land ownership group for the GEIS Base Harvest Scenario to projections for the DEIS No-Build Alternative assuming the higher level of availability of land from private landowners (Scenario A). Both studies have quite similar harvest patterns by ownership group. The overall harvest level is lower for the DEIS, with private lands harvesting less in percentage terms compared to the GEIS. The area of state forestlands as represented by the 2001 FIA is slightly higher, and this explains the slightly higher percentage of harvest volume from state lands for the DEIS (20.6 percent vs. 18.1 percent).

Table C-25
Comparison of Projected Harvest by Land Ownership Group for the DEIS No-Build Alternative under the Higher Level of Availability Assumption for Harvesting on Private Lands (Scenario A to the GEIS Base Harvest Scenario)

Forest Ownership Group	DEIS Projected Average Harvest (thousand cords/yr)	DEIS Projected Harvest as a Percent of Statewide Total Volume	GEIS Projected Harvest for Ownership Group as a Percent of Statewide Area Harvested
National Forest	330	9.0	7.1
State	757	20.6	18.1
County/Local	840	22.9	22.5
All Other Lands	1,746	47.5	52.3
Total	3,674	100.0	100

Table C-26 shows the projected increase in harvest volume by ownership group for the Build versus No-Build alternatives under the higher level of availability assumption for harvesting on private lands (Scenario A versus Scenario A&P). Approximately 70 percent of the increase is from private landowners in the "other owners" group in Table C-26. The increase in harvesting on state and county lands is not in the aspen forest cover type group, as harvesting in that cover type is currently at allowable cut levels.

Table C-26
Projected Increase in Harvest Volume by Ownership Group for Alternatives under Higher Level of Availability Assumption for Harvesting on Private Lands

Ownership Group	Average Harvest No-Build Scenario (M cords/yr)	Average Harvest Build Scenario (M cords/yr)	Increase with Build Scenario (M cords/yr)	Projected Percent of Statewide Volume Increase Supplied by Ownership Group	Projected Percent Increase in Harvest Volume for Ownership Group with the Project over the 40-year Period 2001-2041
National Forest	330	330	0	0	0.0
State	757	782	25	14	3.3
County/Local	840	869	28	16	3.4
All Other Owners	1,746	1,868	122	70	7.0
Total	3,674	3,850	175	100	4.8

5.3 Statewide Timber Levels: Area Harvested

In the modeling process, except for National Forest lands, all stands following even-aged management were assumed to be regenerated as the same forest cover type, with stand age reset to the 0-9 year age class after harvest. Acres in the 0-9 age class at the end of each decade (Year 10, Year 20, Year 30 and Year 40) reflect acres that were regenerated in the decade. The area of the aspen forest cover type harvested in each decade for state-managed and county-managed lands are shown in Table C-27 and Table C-28. These tables show several important points. First, the area of the aspen forest cover type harvested on state and county lands over the planning horizon will not vary whether the project is implemented or not. Second, areas harvested on these lands are near allowable cut limits based on area control planning methods. Third, the tables show little variation between decades for all the scenarios except for the "high aspen scenarios" where infeasible harvest level targets were used. The High Aspen scenario model runs provide insight regarding the impact of forest regulation constraints along with limits on total statewide harvest. Specifically, on state lands the acres of the aspen forest type could increase, at most, from about 840,000 to 973,000 acres over the 40-year period. On county lands, the increase would be from about 936,000 acres to 982,000 acres. In the model results, these added acres harvested almost certainly involve stands with relatively smaller proportions of the stand volume producing aspen. Overall, these results for the High Aspen scenarios suggest that forest regulation restrictions on the area harvested in the aspen forest cover type for state and county lands do not substantially limit the potential to sustain a higher aspen harvest level over the 40-year planning horizon.

Table C-27
State Lands: Area of Aspen Forest Cover Type Group Age 0-9 (thousand acres)

Scenario	Year 0	Year 10	Year 20	Year 30	Year 40	Total
A	192	217	222	196	199	835
A&P	192	220	220	200	199	839
A&P&SS	192	219	217	197	201	833
A&HighAspen	192	293	226	179	275	973
B	192	223	228	204	201	855
B&P	192	221	221	201	202	844
B&P&SS	192	221	220	199	201	841
B&P&Spruce-fir	192	216	217	197	199	830
B&HighAspen	192	276	251	173	272	973

Table C-28
County Lands: Area of Aspen Forest Cover Type Group Age 0-9 (thousand acres)

Scenario	Year 0	Year 10	Year 20	Year 30	Year 40	Total
A	177	241	239	227	226	933
A&P	177	241	242	228	229	940
A&P&SS	177	239	237	227	229	932
A&HighAspen	177	306	235	211	230	982
B	177	243	240	224	232	939
B&P	177	241	240	228	228	936
B&P&SS	177	240	241	230	228	939
B&P&Spruce-fir	177	238	238	226	229	931
B&HighAspen	177	304	251	200	227	982

Area harvested by decade from the aspen forest type on private lands also adds insight for interpreting modeling results (Table C-29). All of the available acres of aspen are generally scheduled for harvest under all scenarios, regardless of whether the project is implemented or not. Under both scenario Series A and Series B, the total acres of aspen forest cover type scheduled for harvest are nearly identical for all scenarios (Table C-29). For Series A, the scenarios do not vary by more than 4,000 acres. For Series B, the variation is only 12,000 acres. In other words, for both Series A and Series B, the area of aspen scheduled on private lands does not vary by even 1 percent across all scenarios. Basically, aspen is valuable compared to other species, so acres in the aspen forest cover type are desirable to harvest if it is available for harvest. The model does vary, by scenario, the acres of the aspen forest type harvested each decade. The model uses longer rotations for aspen when the relative value of aspen is increasing more over time. This reflects a need to capture more aspen volume growth during the planning horizon.

Table C-29
Private Lands: Area of Aspen Forest Cover Type Group Age 0-9 (thousand acres)

Scenario	Year 0	Year 10	Year 20	Year 30	Year 40	Total
A	332	808	463	449	427	2,147
A&P	332	672	522	482	473	2,149
A&P&SS	332	816	468	437	426	2,149
A&HighAspen	332	430	618	554	548	2,151
B	332	540	472	448	427	1,887
B&P	332	421	519	470	471	1,881
B&P&SS	332	538	482	441	431	1,893
B&P&Spruce-fir	332	654	432	412	388	1,887
B&HighAspen	332	372	535	501	487	1,894

The area in the 0-9 age class for all ownerships under the modeling results is summarized by decade for all scenarios (Table C-30). The total area entering the aspen forest type 0-9 age class during the planning horizon suggests that few additional acres of the aspen forest cover type will be harvested with the addition of the project (Table C-30, last column). Instead, to increase aspen volume with the project harvest timings are adjusted to capture aspen growth. Additional aspen volume is also found in other forest cover types.

Model results have harvesting concentrated statewide in the aspen forest cover type. Table C-31 shows the acres statewide that are in the 0-9 age class each decade for all forest cover types. For all seven scenarios that constrain the statewide harvest, on average over the planning horizon, 73 percent to 78 percent of the area in the 0-9 age class is in the aspen forest cover type. This must be because of the need to supply relatively large volumes of aspen compared to limited demand assumed for other species.

Table C-30
All Ownerships: Area of Aspen Forest Cover Type Age 0-9 (thousand acres)

Scenario	Year 0	Year 10	Year 20	Year 30	Year 40	Total
A	798	1,365	1,012	951	938	4,265
A&P	798	1,234	1,060	999	986	4,279
A&P&SS	798	1,375	1,007	944	939	4,265
A&HighAspen	798	1,113	1,163	1,037	1,140	4,454
B	798	1,102	1,018	965	944	4,029
B&P	798	966	1,067	988	985	4,005
B&P&SS	798	1,096	1,020	959	945	4,020
B&P&Spruce-fir	798	1,209	973	918	898	3,999
B&HighAspen	798	1,033	1,124	966	1,074	4,197

Table C-31
All Ownerships: Area of the Age 0-9 age class – All Forest Types (thousand acres)

Scenario	Year 0	Year 10	Year 20	Year 30	Year 40	Total
A	1,294	1,644	1,338	1,246	1,213	5,441
A&P	1,294	1,548	1,423	1,324	1,285	5,581
A&P&SS	1,294	1,672	1,394	1,296	1,253	5,614
A&HighAspen	1,294	2,074	1,909	1,595	1,552	7,131
B	1,294	1,443	1,383	1,259	1,197	5,282
B&P	1,294	1,378	1,470	1,285	1,237	5,370
B&P&SS	1,294	1,457	1,449	1,298	1,223	5,428
B&P&Spruce-fir	1,294	1,565	1,435	1,324	1,226	5,549
B&HighAspen	1,294	1,990	1,882	1,516	1,485	6,874

Table C-32 shows the average area regeneration harvested (acres/yr) in forest cover type groups that use even-aged management for the No-Build scenario under the higher availability assumption for private lands (Scenario A). Average annual harvest levels are also shown for the GEIS Base Harvest Scenario. The last row of the table shows the percentage of even-aged, regeneration harvests that occur in aspen forest cover type each decade. The table shows that most harvesting occurs in the aspen forest cover type, with that type comprising even more of the harvest in the DEIS results than in the GEIS results. The GEIS assumed that 25 percent of the aspen demand would shift to other species. Relatively little of that shift has occurred to date. For the DEIS, uneven-aged management was assumed to be the primary management tool for the northern hardwoods, lowland hardwoods, and oak forest cover types. The GEIS assumed even-aged management was the primary silvicultural treatment type for these types, explaining the relatively large differences shown for these types in Table C-32. The DEIS shows more harvesting in the jack pine type than the GEIS, likely a result of both higher prices for jack pine and the recent emphasis in the USDA Forest Service plans for the Chippewa and Superior National Forests to harvest and regenerate older jack pine to help maintain acres of the jack pine type. The DEIS also harvested, on average, about 3,400 more acres/yr in the birch type. This is at least partially explained by the opportunity to also harvest substantial volumes of aspen from many stands in the paper birch type. The DEIS model harvests more acres in the earlier decades, reflecting opportunities to capture aspen volume from older, lower volume stands that are poorly stocked with low if not negative projected growth rates.

Table C-32
Average Area Regeneration Harvested (acres/yr) by Forest Cover Type Group for Scenario A (No-Build Scenario) and the GEIS Base Harvest Scenario

Forest Cover Type Group	DEIS Harvest Projection for Decade Starting in Year				DEIS Average (2001-2041)	GEIS Average (1990-2040)	Difference (DEIS minus GEIS)
	2001	2011	2021	2031			
Jack Pine	10,568	9,177	4,665	2,698	6,777	2,354	4,423
Red Pine	1,963	3,260	3,505	3,431	3,040	3,778	-738
Upland spruce-fir	5,658	6,852	6,387	3,808	5,676	6,674	-998
Northern hardwood	81	84	321	2,682	792	6,288	-5,496
Oak	66	84	46	38	58	9,338	-9,280
Aspen	138,760	102,809	96,160	94,556	108,071	106,362	1,709
Paper birch	6,287	9,399	12,050	12,623	10,090	6,710	3,380
Lowland spruce	890	1,855	1,326	1,311	1,346	5,638	-4,293
Tamarack	86	188	106	122	126	906	-780
Lowland hardwood	0	0	0	0	0	4,976	-4,976
Total	164,358	133,708	124,566	121,269	135,975	153,024	-17,049
Percent of area regeneration harvested that is in aspen forest cover type group	84	77	77	78	79	70	

** The last row shows percentage of all regeneration harvest occurring in the aspen forest cover type.*

5.4 Types of Harvest

The model considers four types of silvicultural treatment types. For all analysis areas, a "no harvest" option is also considered. The scheduled assignments by the model to silvicultural treatments are summarized in Table C-33 for all lands except forestland classified as open land.

Table C-33
Area Distribution of Forestland by Silvicultural Treatment Type
Assigned by Model (thousand acres)*

	Even-aged with thinning	Even-aged without thinning	Even-aged with Residual Overstory	Uneven-aged or Multi-aged	No Harvest	Total Area
Scen A	81	5,226	208	188	10,314	16,017
Scen A&P	81	5,357	217	246	10,115	16,017
Scen A&P&SS	81	5,396	211	198	10,130	16,017
Scen A&P&SS&HighAspen	82	6,851	271	2,117	6,696	16,017
Scen B	81	5,057	218	290	10,371	16,017
Scen B&P	80	5,135	228	583	9,991	16,017
Scen B&P&SS	81	5,200	221	332	10,182	16,017
Scen B&P&SF	81	5,325	218	241	10,152	16,017
Scen B&P&SS&HighAspen	82	6,599	266	2,117	6,952	16,017

* *Does not include forestland classified as open land.*

For this analysis there is a large portion of the forest assigned to the "no harvest" option. Large portions of the forest are not harvested because they contain relatively little aspen with baseline harvest volume levels defined by estimated statewide harvest levels in 2002, 60 percent of the total harvest, by volume, must be aspen. Also, in considering the large area not harvested, it is important to realize that only a 40-year planning horizon was used. The GEIS used a 50-year planning horizon and over that length, more acres would be harvested. Certainly more of the "no harvest" acres would be harvested had a longer planning horizon been used in the DEIS analyses. If a fifth decade had been considered, then acres regenerated as aspen in decade 1 would be at the minimum rotation age for aspen by Decade 5.

Generally, little uneven-aged management is selected by the model because of the limit on total statewide harvest volume. Generally, uneven-aged management is used in mixed hardwood forest cover types that contain relatively little aspen volume. A summary of uneven-aged management assignments is summarized in Table C-34. For most scenarios, most all uneven-age management that is scheduled involves capturing some aspen volume from cover types other than aspen. National Forest lands have scheduled substantially more uneven-aged management because in National Forest plans markets are assumed available for all commercial species. Substantially more uneven-aged management is also used in scenarios of this analysis where the statewide timber harvest volume is not assumed to be limiting (the High Aspen scenarios in Table C-34).

Table C-34
Area Scheduled for Uneven-aged Harvest by Ownership with a First Harvest During the 40-year Planning Horizon (thousand acres)

Scenario	National Forest Lands	DNR Lands	County/Local Government	Private Lands	Other Lands	Total
A	134	8	12	33	0	188
A&P	134	15	18	79	0	246
A&P&SS	134	8	16	39	0	198
A&P&High	134	290	261	1,398	34	2,117
B	134	23	26	105	2	290
B&P	134	70	66	294	19	583
B&P&SS	134	35	34	124	7	332
B&P&SF	134	21	18	68	0	241
B&P&High	134	290	261	1,398	34	2,117

Table C-35 shows the area of the forest assigned to different silvicultural treatment options for the No-Build and Build Alternatives for the higher availability assumptions from private lands (Scenario A and Scenario A&P). In the bottom section of the table, differences between the No-Build and Build scenarios are shown in terms of areas assigned to each of the treatment types. With the project, the area harvested at least once over the planning horizon increases from 5.7 million acres to 5.9 million acres, roughly a 3.5percent increase. Some of this increase (59,000 acres) is assigned to uneven-aged management treatment options, generally in northern hardwood stands. The intent is to capture additional aspen volumes present in some mixed hardwood stands. Most of the increase in harvesting is on private lands, about 60 percent. Increases in harvesting on both private lands and public lands are in forest types other than aspen. The model is simplified in that it does not recognize that additional acres in the aspen forest type could become available from private lands if aspen stumpage prices increase as a result of the project. Like with public lands, lands in the aspen forest cover type assumed available for harvest are generally harvested within the planning horizon regardless of whether the project is implemented.

The timber volume increase with the project is 5.4 percent. In the modeling results, the percentage increase in areas harvested is less than the percentage increase in harvest volume. Aspen volume is valued relatively high by the model with aspen values increasing more over time with the project (Table C-17). With increasing aspen values over time, rotation lengths tend to be lengthened with the added time increasing the average yields per acre at rotation. As an example, consider a stand that is currently growing at the interest rate (4 percent used in this DEIS). Under constant prices such a stand is generally financially mature. For stands in the aspen cover type, this would generally be at age 40 years. But with increasing timber values, delaying harvest by 10 years would likely be desirable. Over ten years and growing at 4 percent/yr, the volume of this stand would increase by approximately 48 percent. In general, the sequencing of stands for harvest can be an important factor for achieving management potentials.

Table C-35
Comparison of Silvicultural Treatment Types Assigned to Forestland (thousand acres) by the Scheduling Model for Scenario A (No-Build) and Scenario A&P (Build) *

	Even-aged with Thinning	Even-aged without Thinning	Even-aged with Residual Overstory	Uneven-aged or Multi-aged	No Harvest	Total Area
Scen A (No-Build Alternative)						
US Forest Service Reserved	0	0	0	0	726	726
National Forest Lands	53	475	114	134	991	1,768
DNR Lands	20	1,019	19	8	2,640	3,706
County Lands	8	1,094	23	12	1,478	2,616
UPM/Blandin Paper Lands	0	90	2	0	46	138
Private Lands	0	2,461	48	33	4,224	6,767
Other Owners	0	87	2	0	208	297
Total	81	5,226	208	188	10,314	16,017
Scen A & P (Build Alternative)						
US Forest Service Reserved	0	0	0	0	726	726
National Forest Lands	53	475	114	134	991	1,768
DNR Lands	20	1,037	21	15	2,613	3,706
County Lands	8	1,137	25	18	1,428	2,616
UPM/Blandin Paper Lands	0	90	2	0	46	138
Private Lands	0	2,529	54	79	4,105	6,767
Other Owners	0	89	2	0	206	297
Total	81	5,357	217	246	10,115	16,017
Increase With Project						
US Forest Service Reserved	0	0	0	0	0	0
National Forest Lands	0	0	0	0	0	0
DNR Lands	0	18	2	7	-27	0
County Lands	0	43	2	5	-51	0
UPM/Blandin Paper Lands	0	0	0	0	0	0
Private Lands	0	67	5	46	-119	0
Other Owners	0	2	0	0	-2	0
Total	0	131	10	59	-199	0

** Comparison includes all Minnesota forestland except those forest land acres classified as open land.*

Study areas that are assigned to uneven-aged management or to even-aged management with thinning can potentially be harvested more than once over the 40-year planning horizon (Table C-35). Table C-36 shows the acres treated each decade for Scenario A (No-Build) and Scenario A&P (Build). It also shows the difference between these scenarios reflecting the increase in acres scheduled for treatment by the model with the project. The scheduling model programs fewer acres for treatment in Decade 1 with the project (Table C-36). This decrease reflects the model's increased emphasis on increasing timber growth more with the project over the 40-year planning horizon. Without the project, the model regenerates a relatively large area in the aspen cover type in Decade 1 in an effort to improve stocking on these lands for long-term production. With the project, there is more emphasis on capturing more of the potential short-term growth from aspen stands that are relatively poorly stocked. In Decade 2 through Decade 4

Table C-36
Comparison of Projected Acres Harvested by Decade for Scenario A (No-Build) and Scenario A&P (Build)*

	Scenario A (No-Build Scenario): projected harvest area (M acres/yr) for decade starting in year:				Scenario A&P (Build Scenario): projected harvest area (M acres/yr) for decade starting in year:				Projected increase in harvest area (M acres/yr) with project for decade stating in year:				Average increase (M acres/yr)
	2001	2011	2021	2031	2001	2011	2021	2031	2001	2011	2021	2031	
Intermediate Harvests													
National Forest	5.3	5.7	6.3	7.0	5.3	5.7	6.3	7.0	0.0	0.0	0.0	0.0	0.0
DNR Lands	1.2	0.6	1.6	1.1	1.2	1.0	1.6	1.8	0.0	0.3	0.0	0.7	0.3
County/Lands	0.1	0.9	0.6	1.6	0.1	1.1	0.6	2.1	0.0	0.3	0.0	0.5	0.2
UPM/Blandin Paper	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Private Lands	0.4	1.3	1.0	2.3	0.4	1.7	1.5	6.4	0.0	0.4	0.5	4.1	1.3
Other Owners	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	7.0	8.5	9.4	12.0	7.0	9.5	9.9	17.3	0.0	1.0	0.5	5.3	1.7
Regeneration Harvests													
National Forest	15.7	15.4	14.8	13.7	15.7	15.4	14.8	13.7	0.0	0.0	0.0	0.0	0.0
DNR Lands	26.1	28.2	24.7	24.7	27.2	28.0	24.6	25.9	1.1	-0.2	-0.1	1.2	0.5
County/Lands	28.9	28.6	27.6	26.6	29.8	30.2	28.7	27.5	0.9	1.6	1.2	0.9	1.1
UPM/Blandin Paper	2.3	1.2	2.8	2.9	2.1	1.5	2.8	2.8	-0.2	0.2	0.0	0.0	0.0
Private Lands	87.2	57.8	53.7	52.3	75.5	65.4	59.6	57.8	-11.6	7.6	5.9	5.5	1.8
Other Owners	4.3	2.6	1.0	1.0	4.5	1.9	1.9	0.8	0.3	-0.7	0.9	-0.3	0.1
Total	164.4	133.8	124.6	121.3	154.8	142.3	132.4	128.5	-9.5	8.5	7.8	7.3	3.5
All Harvest Types													
National Forest	21.0	21.1	21.1	20.8	21.0	21.1	21.1	20.8	0.0	0.0	0.0	0.0	0.0
DNR Lands	27.3	28.8	26.3	25.8	28.4	29.0	26.2	27.7	1.2	0.1	-0.1	1.9	0.8
County/Lands	29.0	29.5	28.1	28.2	29.9	31.3	29.3	29.6	0.9	1.9	1.2	1.4	1.3
UPM/Blandin Paper	2.3	1.2	2.8	2.9	2.1	1.5	2.8	2.8	-0.2	0.2	0.0	0.0	0.0
Private Lands	87.6	59.1	54.7	54.6	76.0	67.1	61.1	64.2	-11.6	8.0	6.4	9.6	3.1
Other Owners	4.3	2.6	1.0	1.0	4.5	1.9	1.9	0.8	0.3	-0.7	0.9	-0.3	0.1
Total	171.4	142.3	134.0	133.3	161.9	151.9	142.3	145.9	-9.5	9.5	8.4	12.6	5.2

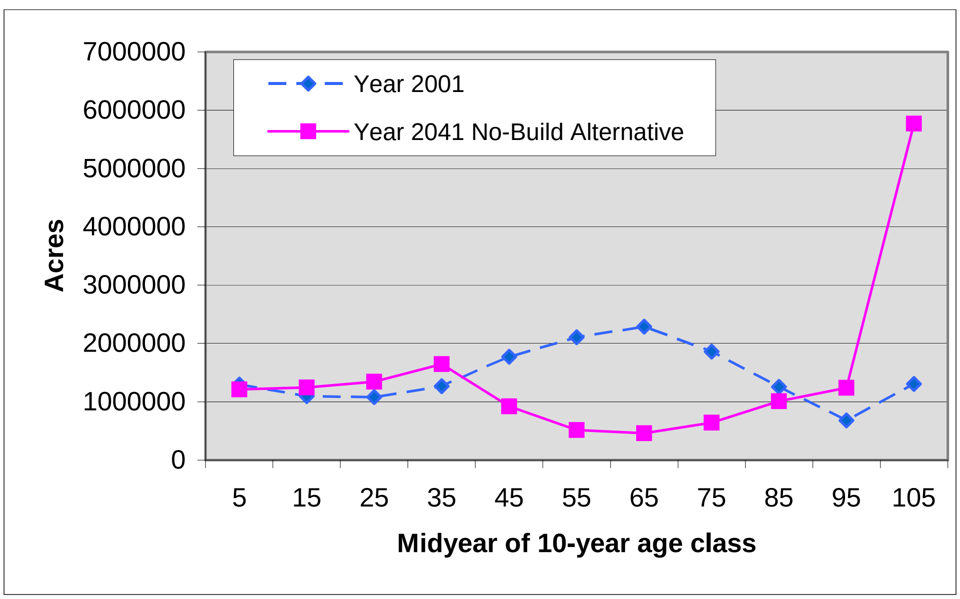
** Regeneration harvests include all harvest types that reset stand age to zero after harvest. Intermediate harvests do not result in regeneration of the overstory after harvest and are assumed to have minimal impact on the age of the overstory.*

substantially more acres are harvested with the project. It is important to note that with the project, annual harvest volume levels do not increase until the 7th year of Decade 1. The emphasis of delaying harvest in the aspen cover type with the project was also shown in area estimates for the 0-9 age class in the aspen cover type for both Series A scenarios and Series B scenarios (Table C-30). Comparing scenario A with Scenario A&P for Decade 1, the decline in the area regenerated to the aspen cover type was 131,000 acres in Decade 1 (Table C-30). The total decline in area harvested in Decade 1 is 95,000 acres (Table C-36) with the area scheduled for harvest in forest cover types other than the aspen type increasing by 36,000 acres in Decade 1with the project.

5.5 Age Class Distributions with the No-Build Alternative

Results of this analysis with the No-Build Alternative are generally similar to the GEIS findings regarding the 2040 age class distributions for forest cover types other than aspen. The GEIS describes bimodal age distributions in year 2040 for forest cover types other than aspen. In other words, in year 2040, there tends to be younger stands and older stands with fewer stands in between at ages just beyond typical rotation ages. Figure C-1 shows the statewide age class distribution for all forestland for the two No-Build scenarios. For both, the year 2040 age distributions are similar, with substantially more area in the older age classes compared to the 2001 starting condition. However, the relatively high proportion of acreage of older stands in 2041 in Figure C-1 and subsequent figures is partly an artifact of modeling. Model assumptions were simplified, especially because forest succession was not modeled. In reality, with succession the overstory of some of the oldest stands die resulting in a potentially younger overstory age (stand age), and for areas initially in cover types like aspen, paper birch and jack pine, a likely change in forest cover type to northern hardwoods or spruce-fir would occur.

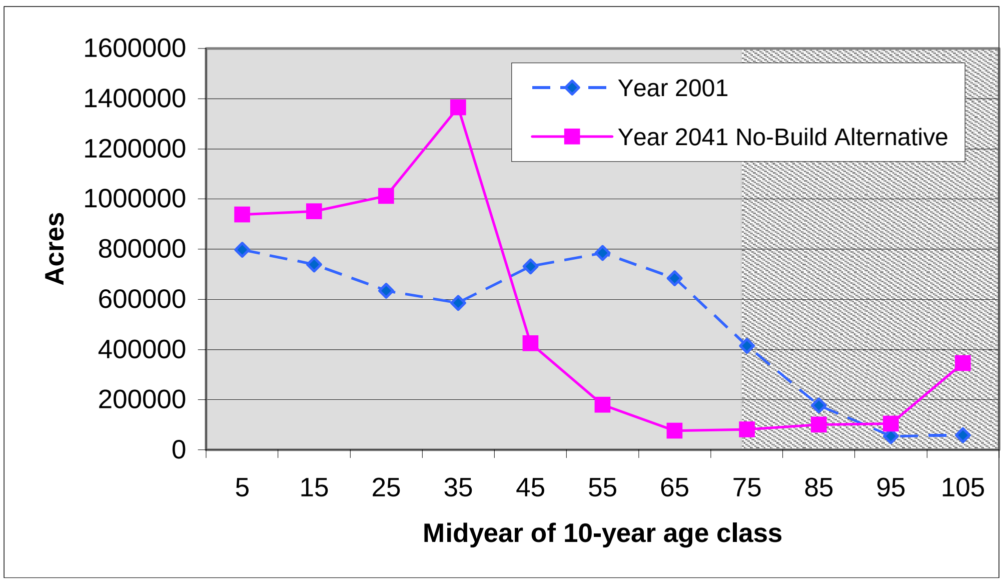
Figure C-1
All Forest Types – No-Build Alternative



Comparison of stand age class distribution of all forestland in year 2041 under the No-Build Alternative, to the stand age class distribution of all forestland in year 2001.

Changes in the age distribution over the 40-year planning horizon are quite different for the aspen forest cover type. For both scenarios, in year 2041 the area between the 40-50 and 80-90 age class is reduced substantially from the year 2001 condition (Figure C-2). The year 2041 scenarios show more acres in age classes greater than age 100, but for these older ages, natural succession will have moved many of these older stands to other forest cover types, most likely to the northern hardwoods or the spruce-fir forest cover type. In general, almost all acres in the aspen forest cover type that were assumed available for harvest were harvested by the model.

Figure C-2
Aspen – No-Build Alternative



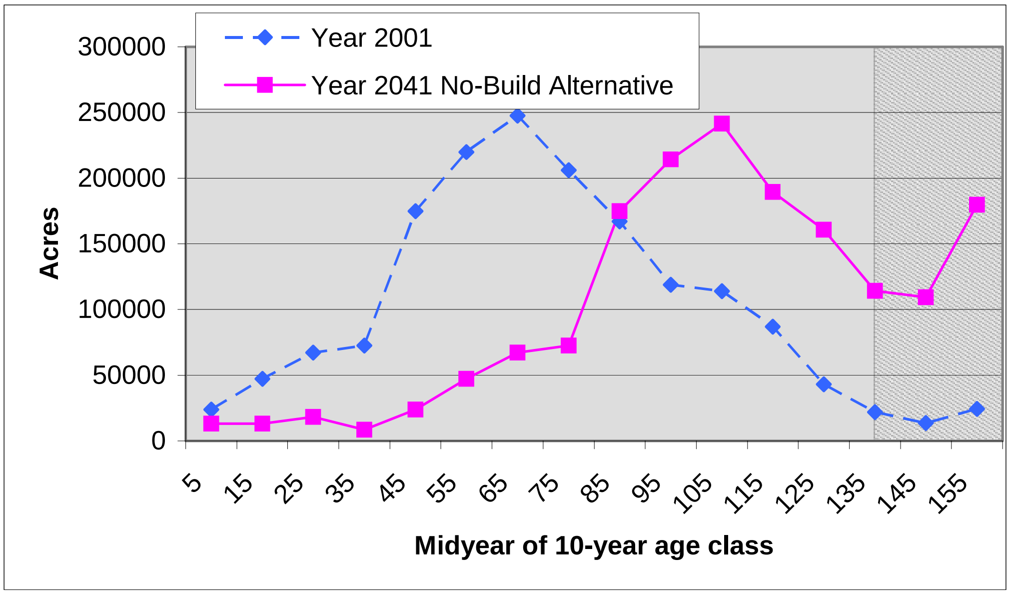
Comparison of stand age class distribution of the aspen forest cover type in year 2041, No-Build Alternative, to the aspen forest cover type stand age class distribution in year 2001. Slashed area represents those age classes where stands are beyond the maximum rotation age[2], which is defined as the maximum age at which a forest type will retain its biological ability to regenerate to the same forest type and remain commercially viable as a marketable timber sale. Stands beyond maximum rotation age are likely to succeed to other forest types.

Figure C-4 to Figure C-8 show how age classes change over time for six of the other forest cover types for the No-Build Alternative with the higher level of harvest availability assumptions for private lands (Scenario A). Differences in statewide age class distributions between Scenario A and Scenario B were not significant. A summary of implications of each age class distribution follows:

[2] The maximum rotation age offered for forest cover types evaluated in the DEIS are sourced from DNR's Subsection Forest Resource Management Planning (SFRMP) process.

Lowland Spruce – No-Build Alternative (Figure C-3): Both the year 2001 and year 2041 age class distributions for this type reflect a forest cover type with large areas of older forest. Harvesting in this forest cover type has been relatively low in the past, and the relatively little area in age classes less than age 40 in year 2041 reflects that the scheduling model scheduled relatively little of this forest cover type for harvesting. In general, the model satisfied spruce-fir demands from harvesting in the uplands, both from aspen stands and upland spruce-fir stands. Lowland spruce may offer opportunities for additional harvesting, but it involves environmentally sensitive areas with spruce regeneration after harvesting also a potential concern. Most of these areas would only be available for harvest in the winter.

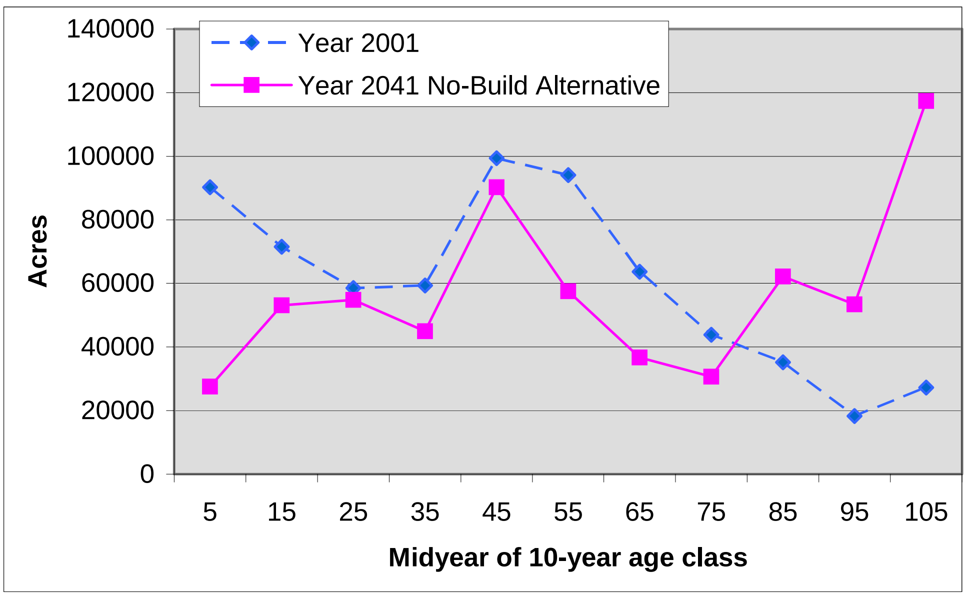
Figure C-3
Lowland Spruce – No-Build Alternative



Comparison of stand age class distribution of the lowland spruce forest cover type in year 2041, No-Build Alternative, to the lowland spruce forest cover type stand age class distribution in year 2001. Slashed area represents those age classes where stands are beyond the maximum rotation age[2], which is defined as the maximum age at which a forest type will retain its biological ability to regenerate to the same forest type and remain commercially viable as a marketable timber sale. Stands beyond maximum rotation age are likely to succeed to other forest types.

Upland Spruce-fir – No-Build Alternative (Figure C-4): The large proportion of acres in year 2001 in the youngest age class reflect the regeneration of older spruce-fir stands after spruce budworm infestations. Additional acres would likely be added to this forest cover type as a result of natural succession of older aspen, birch, and jack pine sites in some landscape ecosystems. These additions would likely occur at ages in the age 20 to age 70 age classes reflecting the shade tolerance of spruce and fir and its development in the understory of other cover types. Substantial harvesting is occurring in this forest cover type, but the area in age classes younger than age 40 does not suggest harvest levels over the planning horizon are above sustainable levels.

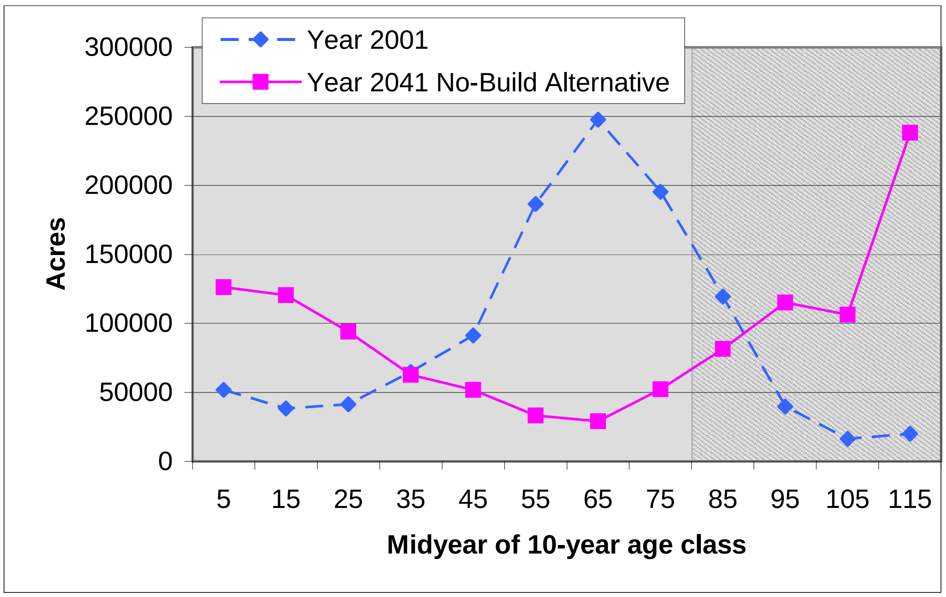
Figure C-4
Upland Spruce-fir – No-Build Alternative



Comparison of stand age class distribution of the upland spruce-fir forest cover type in year 2041, No-Build Alternative, to the upland spruce-fir forest cover type stand age class distribution in year 2001

Paper birch – No-Build Alternative (Figure C-5): The increase in the area of the youngest age classes in the year 2041 age distribution compared to the age 45 to age 75 age classes in 2041 reflects that more harvesting is scheduled by the model for this type than has occurred in recent decades. However, large areas of this type are being lost through natural succession. Birch is more abundant today than in the past. The model tends to harvest some birch stands to capture substantial volumes of aspen present in those stands. The USDA Forest Service has made regenerating birch an important objective in their recent forest plans for the Chippewa and Superior National Forests, and those plans are reflected in the age class distribution for year 2041.

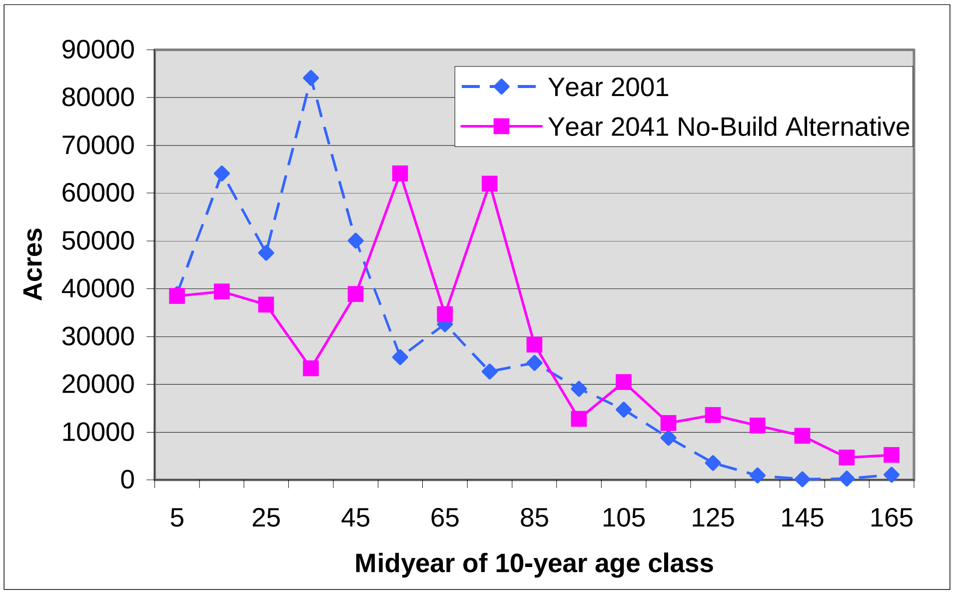
Figure C-5
Paper Birch – No-Build Alternative



Comparison of stand age class distribution of the paper birch forest cover type in year 2041, No-Build Alternative, to the paper birch forest cover type stand age class distribution in year 2001. Slashed area represents those age classes where stands are beyond the maximum rotation age[2], which is defined as the maximum age at which a forest type will retain its biological ability to regenerate to the same forest type and remain commercially viable as a marketable timber sale. Stands beyond maximum rotation age are likely to succeed to other forest types.

Red Pine – No-Build Alternative (Figure C-6): Modeling results reflect a significantly older age class distribution for red pine in year 2041 compared to 2001. The areas in the younger age classes in year 2041 reflect harvesting is scheduled for this forest cover type, but clearly not at levels that are unsustainable. Thinning was selected for some of the area in this type, especially for DNR and National Forest lands, where rotations of 100 years or more are planned. Increasing the area of older red pine is an important objective for wildlife, and modeling results suggest such changes will occur.

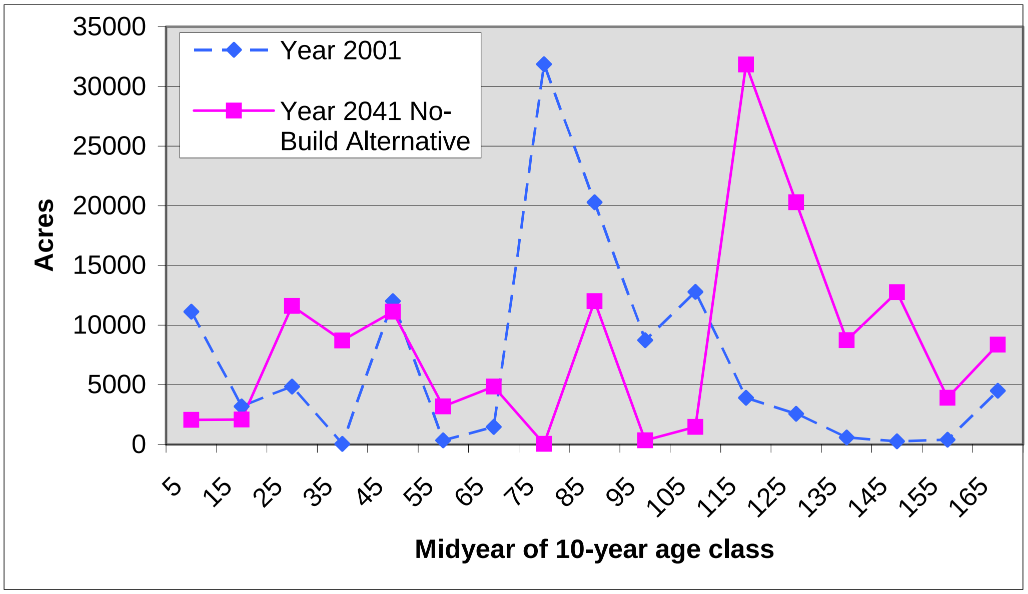
Figure C-6
Red Pine – No-Build Alternative



Comparison of stand age class distribution of the red pine forest cover type in year 2041, No-Build Alternative, to the red pine forest cover type stand age class distribution in year 2001

White Pine – No-Build Alternative (Figure C-7): Modeling results suggest that the white pine forest will simply grow older over the planning horizon. The irregularities in the shape of the age distributions reflect the relatively small area in this forest cover type. Most areas in this type will be managed using uneven-aged management. Not represented in the modeling would be the planned restoration activities by public land management agencies for this forest cover type. The area in the young age classes reflect the regeneration activities on National Forest lands included in the model.

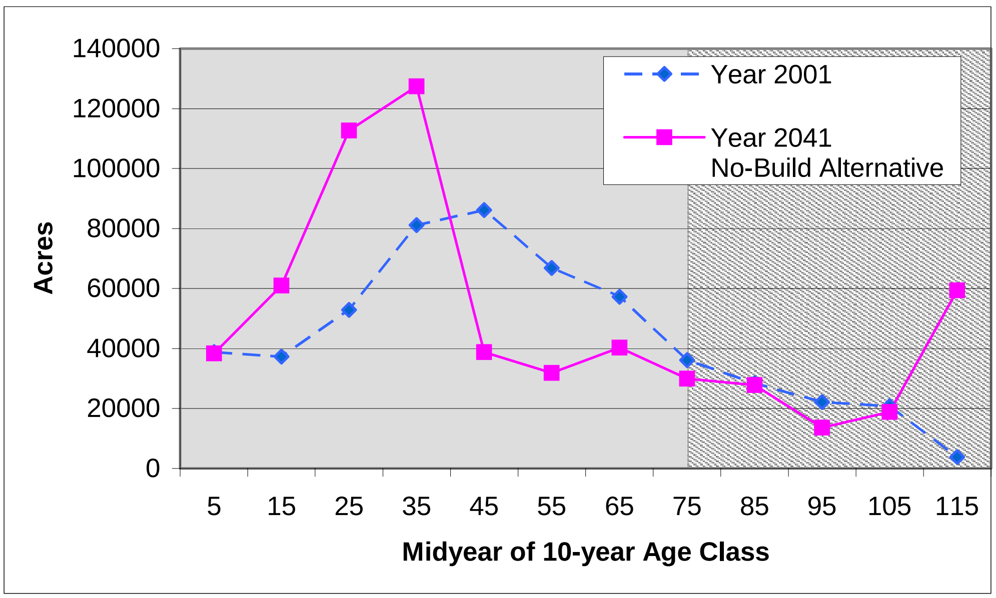
Figure C-7
White Pine – No-Build Alternative



Comparison of stand age class distribution of the white pine forest cover type in year 2041, No-Build Alternative, to the white pine forest cover type stand age class distribution in year 2001

Jack pine is a short-lived conifer that requires disturbance to regenerate (Figure C-8). In 2001, the age distributions for jack pine suggest that large areas will be lost via natural succession. This is especially true for large areas of jack pine in the BWCAW. Recent price increases for jack pine sawlogs have helped to increase harvest activities in this forest cover type. Regenerating jack pine is especially difficult in some areas, with deer browsing often a problem. The large areas of young jack pine in the 2041 are based on the assumption that areas of jack pine harvested can be regenerated to jack pine. This regeneration would likely require substantial management effort.

Figure C-8
Jack Pine – No-Build Alternative



Comparison of stand age class distribution of the jack pine forest cover type in year 2041, No-Build Alternative, to the jack pine forest cover type stand age class distribution in year 2001. Slashed area represents those age classes where stands are beyond the maximum rotation age[2], which is defined as the maximum age at which a forest type will retain its biological ability to regenerate to the same forest type and remain commercially viable as a marketable timber sale. Stands beyond maximum rotation age are likely to succeed to other forest types.

<u>Other forest cover types:</u> Age class distributions for lowland hardwoods, oak, northern hardwoods, tamarack, and northern white cedar are not shown. For all of these types, very little even-aged management was scheduled by the model. For all of these types, the areas basically age by 40 years over the planning horizon. Similar results were projected by the GEIS. Some markets for tamarack are developing, but the areas harvested are still relatively small compared to the area of this forest cover type.

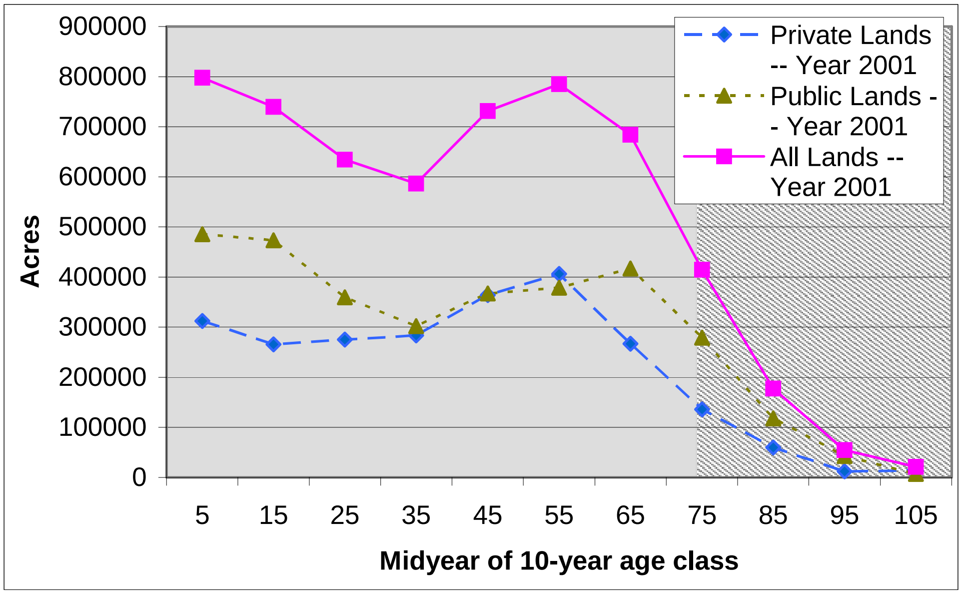
Table C-37 shows the average age of forestland acres in each forest cover type for the DEIS No-Build Alternative, assuming the higher level of availability of land from private landowners Scenario A. A similar table is shown in the GEIS (Table 5.9) for timberland acres for the GEIS Base Harvest Scenario. For both, the GEIS and the DEIS, the average age for the aspen cover type group drops from 41 years to 34 years over the planning horizon. Clearly, both the GEIS analysis and DEIS analyses are projecting a younger aspen forest cover type over time. For both the jack pine and paper birch type, the DEIS shows the average age increasing over the planning horizon, but not as much as in the GEIS. For the GEIS, the average age in year 2040 is 92 years for the paper birch type while for the DEIS it is 68 years. For the DEIS, the scheduling model is likely harvesting more birch to capture aspen volume present in many stands in the birch cover type. For jack pine, the average age increases to 50 years, versus 77 years as stated in the GEIS. Likely, more harvesting is occurring in the jack pine type to take advantage of the higher jack pine prices compared to prices at the time of the GEIS. The GEIS has average ages increasing for the oak, lowland hardwoods, and northern hardwoods cover types, but the increases are larger for the DEIS, because with the DEIS less harvesting occurs in these types and the emphasis has shifted substantially to uneven-aged management in these types.

Table C-37
Average Age of Forestland Acres per Forest Cover Type for the No-Build Alternative

Forest Cover Type	Year 2001	Year 2011	Year 2021	Year 2031	Year 2041
Jack Pine	49	44	42	45	50
Red Pine	46	51	55	58	62
White Pine	75	80	86	94	99
Upland Spruce-fir	45	50	53	57	64
Oak	69	78	88	98	108
Northern Hardwoods	65	75	85	95	104
Aspen	41	35	34	34	34
Paper Birch	61	66	68	68	68
Lowland Spruce	72	81	90	99	108
Tamarack	69	79	89	99	109
Lowland Hardwood	66	76	86	96	106
Cedar	94	104	114	123	132

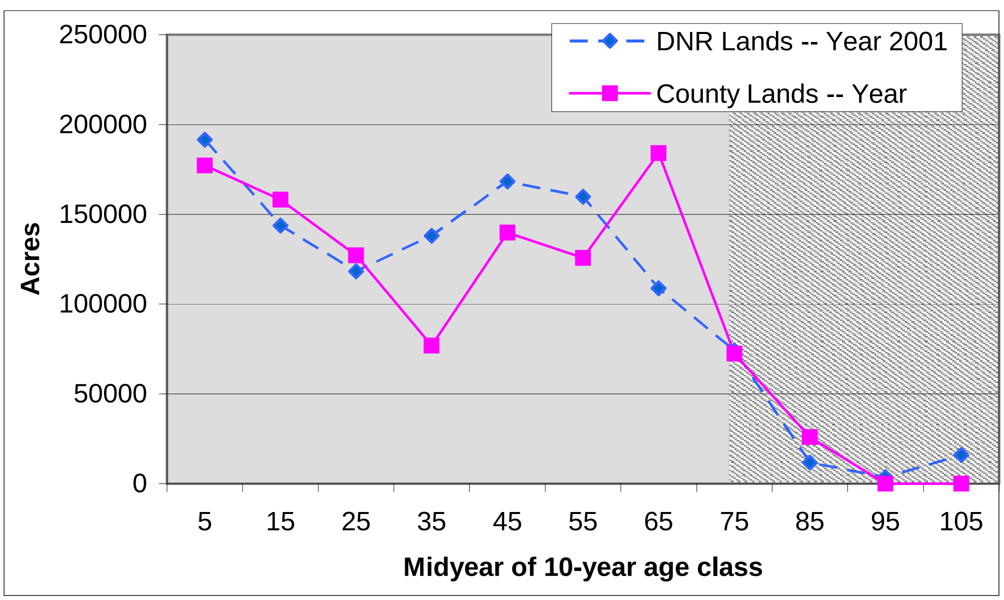
Analyses suggest that sustaining aspen supply over the planning horizon is a potential concern. This potential concern has generally been suggested as a temporary concern reflecting the imbalanced age class distribution for aspen. Figure C-9 shows the statewide aspen age class distribution and its components of public and private lands. Interestingly, much of the imbalance in the age distribution is present on public lands. For these lands, emphasis is on sustainable harvest levels over time. Public lands have plans in place that emphasize sustaining harvest levels over time without plans for large increases in areas harvested. Large increases in harvest levels over time from public lands is not expected. Their current plans generally show a constant harvest level over time. Figure C-10 shows similar and irregular aspen age class distribution in 2001 for both DNR-managed and county-managed lands.

Figure C-9
Aspen Private / Public Year 0



Stand age class distributions for the aspen forest cover type for year 2001 for private forestlands and public forestlands. Slashed area represents those age classes where stands are beyond the maximum rotation age[2], which is defined as the maximum age at which a forest type will retain its biological ability to regenerate to the same forest type and remain commercially viable as a marketable timber sale. Stands beyond maximum rotation age are likely to succeed to other forest types.

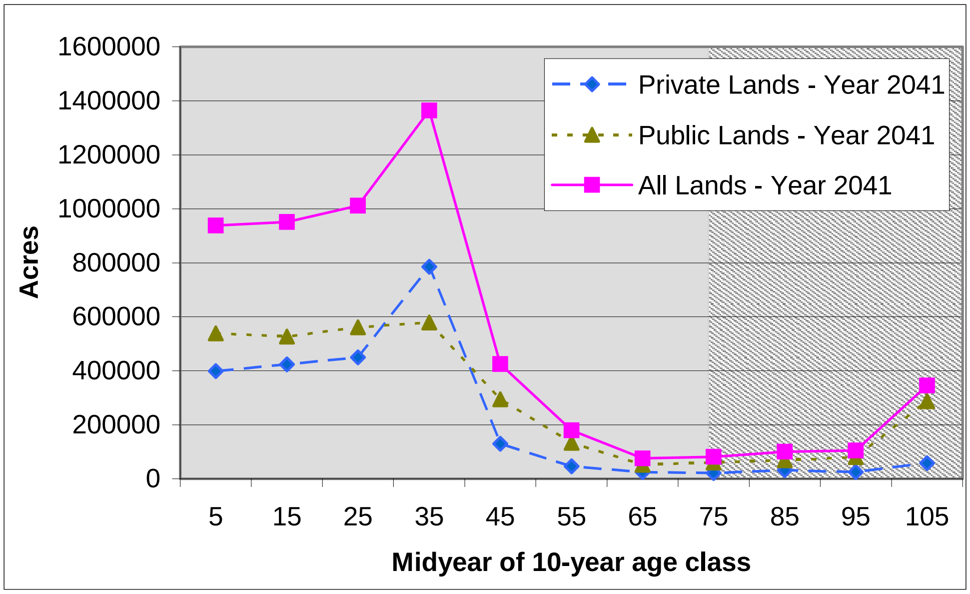
Figure C-10
Aspen DNR / County Year 0



Stand age class distributions for the aspen forest cover type for year 2001 for DNR forestlands and County forestlands. Slashed area represents those age classes where stands are beyond the maximum rotation age[2], which is defined as the maximum age at which a forest type will retain its biological ability to regenerate to the same forest type and remain commercially viable as a marketable timber sale. Stands beyond maximum rotation age are likely to succeed to other forest types.

Age class distribution of the aspen forest cover type on private lands is relatively constant for the younger age classes (Figure C-11). Under this situation large increased areas of "next rotation" aspen will not become available shortly. However, the balanced nature does not suggest that areas becoming available will decline over time. In general, it is difficult to conclude that concerns over aspen are necessarily short-term in nature. Solutions may depend on mitigative measures to better realize potentials.

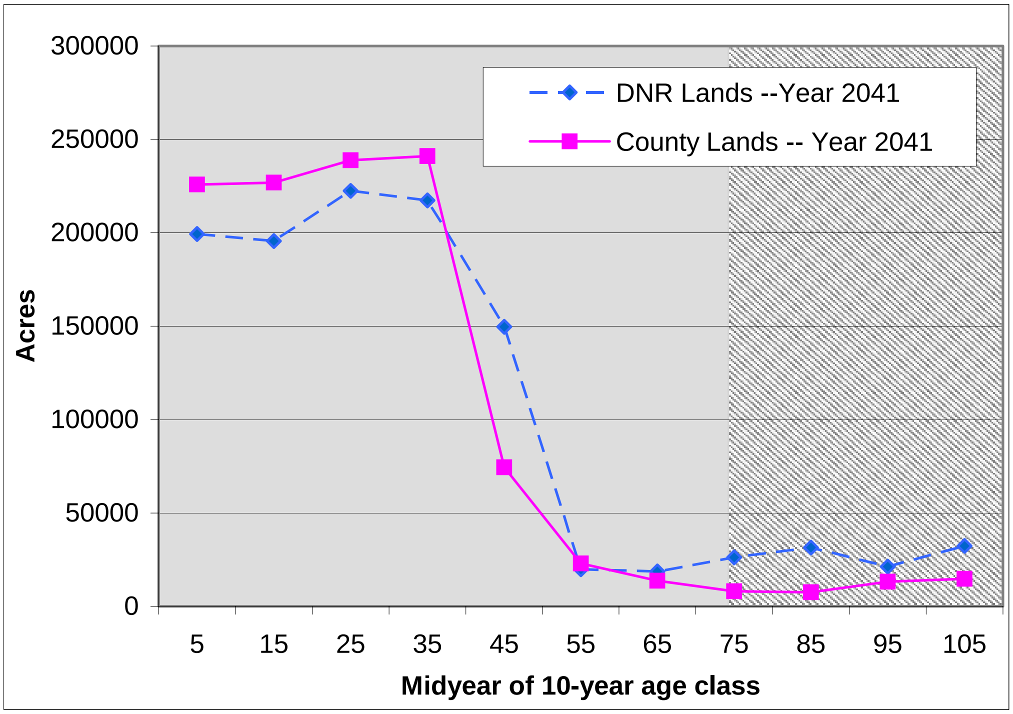
Figure C-11
Aspen Private / Public Year 40



Stand age class distributions for the aspen forest cover type for year 2041 for private forestlands and public forestlands under the No-Build scenario as modeled using the higher availability assumption for private lands. Slashed area represents those age classes where stands are beyond the maximum rotation age[2], which is defined as the maximum age at which a forest type will retain its biological ability to regenerate to the same forest type and remain commercially viable as a marketable timber sale. Stands beyond maximum rotation age are likely to succeed to other forest types.

Another potential concern related to the demand for aspen relates to the potential management of state and county lands. Some will wonder if opportunities are present for the state and county to harvest more area in the aspen forest cover type. Figure C-12 shows the age class distribution for the aspen forest cover type in year 2041 for state and county lands. State and county lands are using area control to create a more balanced age class distribution for this cover type. The DNR has a larger proportion of the area in this type in the 40-70 age classes. This reflects the desire to have areas of extended rotation forestry. Neither Scenario A&P&HighAspen nor Scenario B&P&HighAspen included forest regulation constraints for state and county lands, and potential sustainable harvest levels for aspen did not increase substantially. Overall, relaxing forest regulation constraints on state or county lands does not appear to be a viable solution to concerns over aspen supplies.

Figure C-12
Aspen DNR / County Year 40

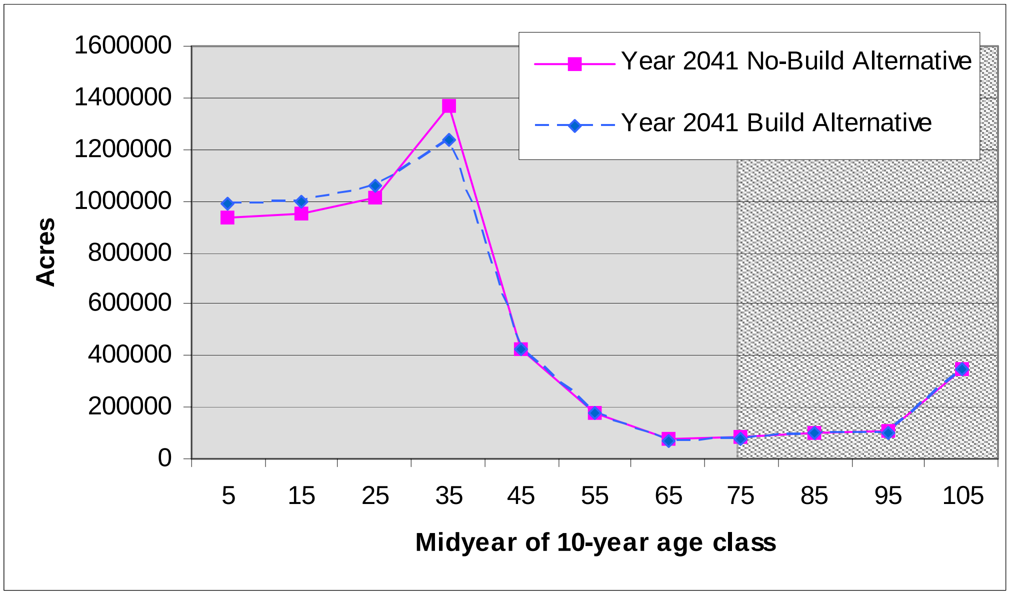


Stand age class distributions for the aspen forest cover type for year 2041 for DNR forestlands and County forestlands under the No-Build scenario as modeled using the higher availability assumption for private lands. Slashed area represents those age classes where stands are beyond the maximum rotation age[2], which is defined as the maximum age at which a forest type will retain its biological ability to regenerate to the same forest type and remain commercially viable as a marketable timber sale. Stands beyond maximum rotation age are likely to succeed to other forest types.

5.6 Age Class Distributions with the Build Alternative

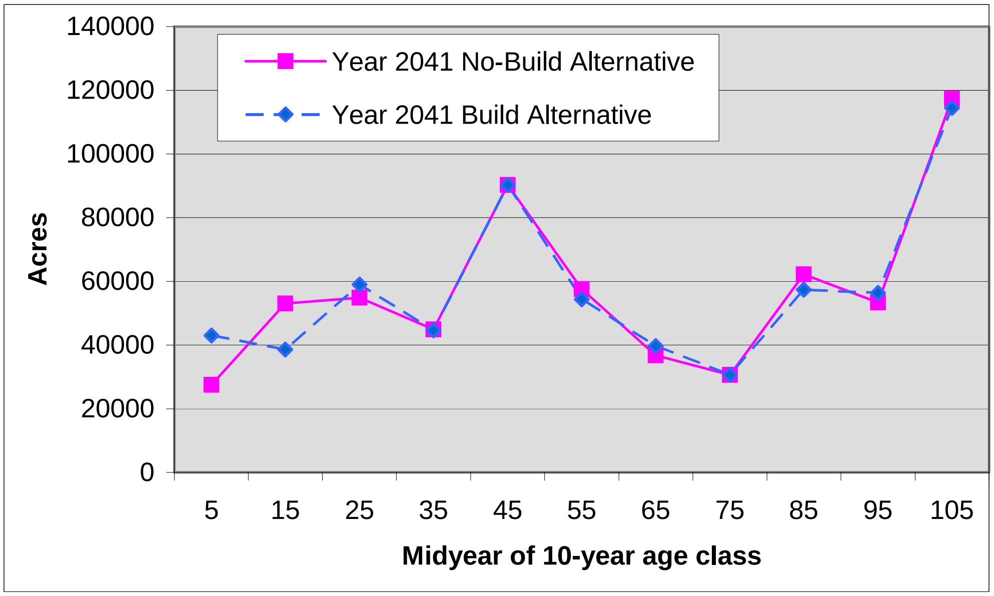
Figure C-13 through Figure C-18 compare the age class distributions for seven of the forest cover types most likely to be influenced by the project. In looking at these distributions it is difficult to identify any potential cumulative statewide impact related to age class distributions between the No-Build and Build scenarios. Figure C-19 shows forest age class distributions across all cover types for this same No-Build and Build Alternatives comparison. Time (aging) has a far greater impact on the statewide age class distributions than does the project

Figure C-13
Aspen – No-Build and Build Alternatives



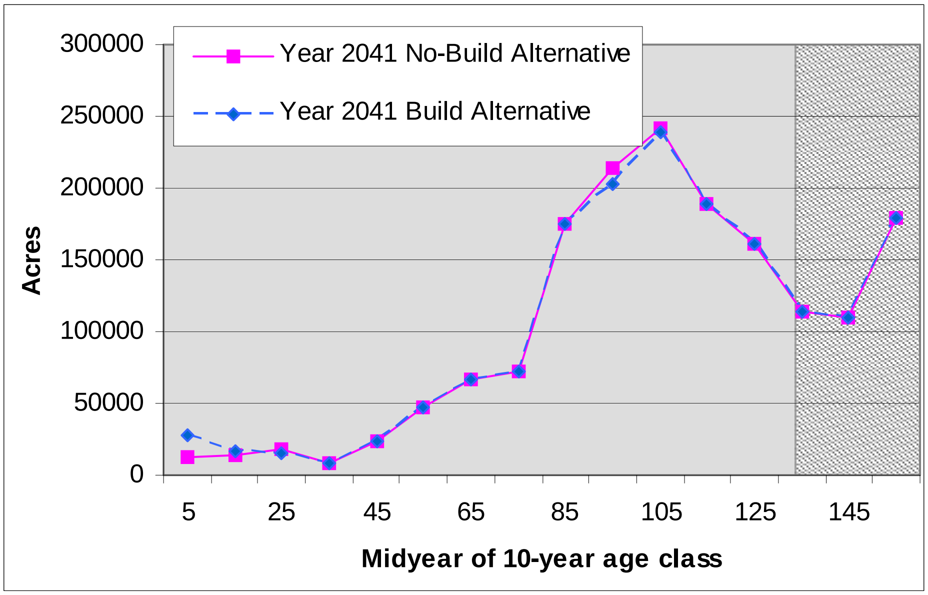
Comparison of stand age class distributions of the aspen forest cover type in year 2041, No-Build and Build Alternatives, to the aspen forest cover type stand age class distribution in year 2001. Slashed area represents those age classes where stands are beyond the maximum rotation age[2], which is defined as the maximum age at which a forest type will retain its biological ability to regenerate to the same forest type and remain commercially viable as a marketable timber sale. Stands beyond maximum rotation age are likely to succeed to other forest types.

Figure C-14
Upland Spruce-fir – No-Build and Build Alternatives



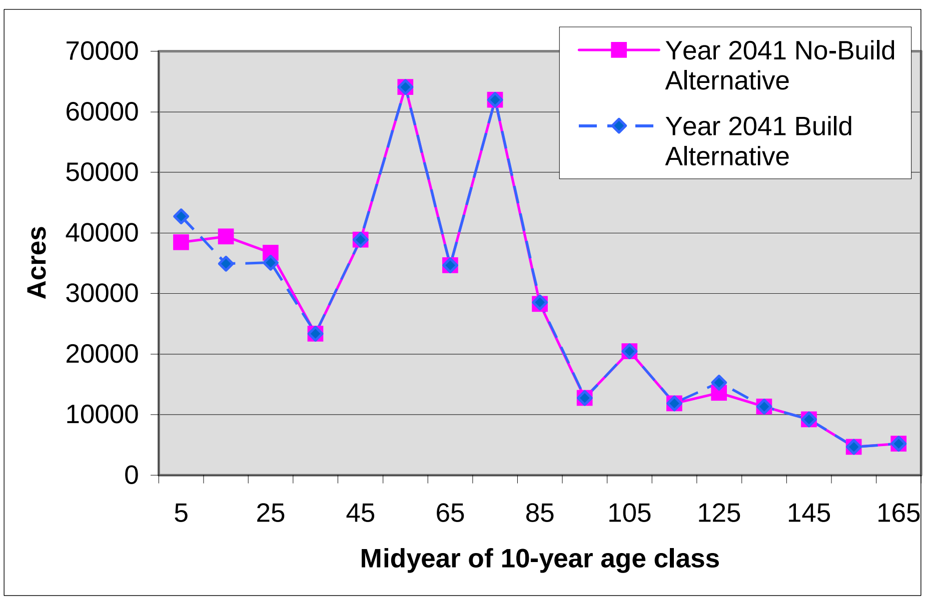
Comparison of stand age class distributions of the upland spruce-fir forest cover type in year 2041, No-Build and Build Alternatives, to the upland spruce-fir forest cover type stand age class distribution in year 2001.

Figure C-15
Lowland Spruce – No-Build and Build Alternatives



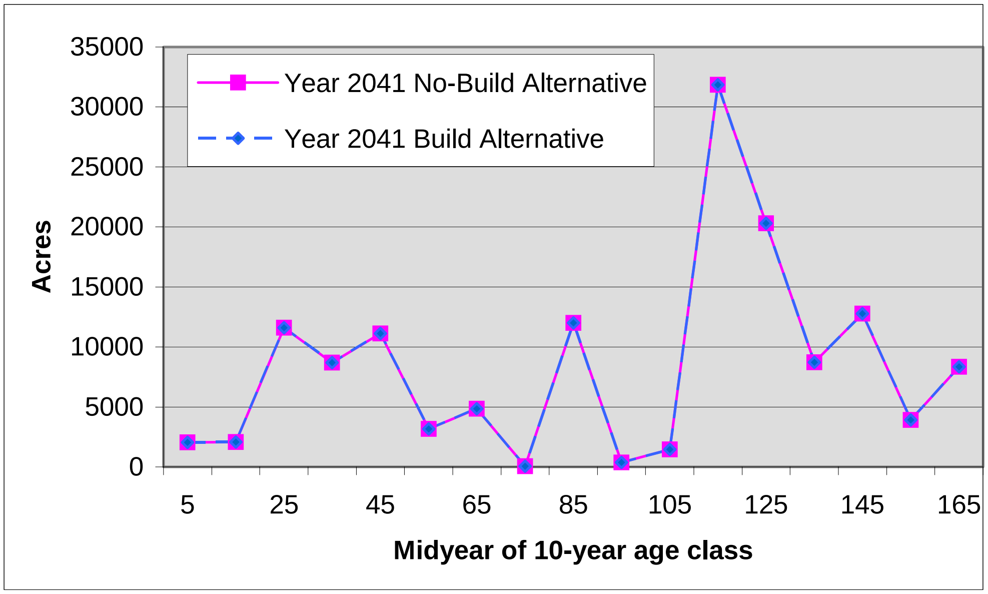
Comparison of stand age class distributions of the lowland spruce forest cover type in year 2041, No-Build and Build Alternatives, to the lowland spruce forest cover type stand age class distribution in year 2001. Slashed area represents those age classes where stands are beyond the maximum rotation age[2], which is defined as the maximum age at which a forest type will retain its biological ability to regenerate to the same forest type and remain commercially viable as a marketable timber sale. Stands beyond maximum rotation age are likely to succeed to other forest types.

Figure C-16
Red Pine – No-Build and Build Alternatives



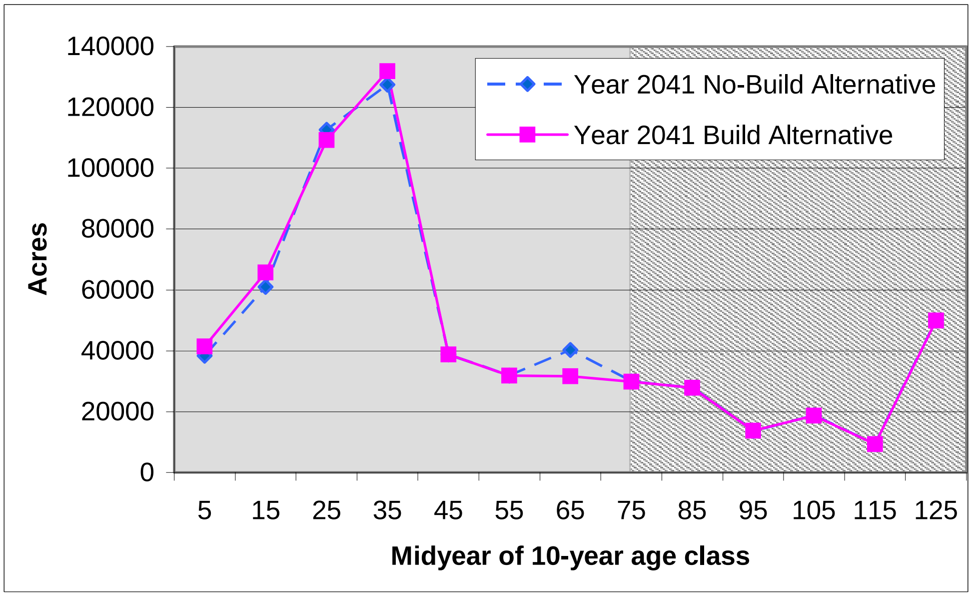
Comparison of stand age class distributions of the red pine forest cover type in year 2041, No-Build and Build Alternatives, to the red pine forest cover type stand age class distribution in year 2001.

Figure C-17
White Pine – No-Build and Build Alternatives



Comparison of stand age class distributions of the white pine forest cover type in year 2041, No-Build and Build Alternatives, to the white pine forest cover type stand age class distribution in year 2001.

Figure C-18
Jack Pine – No-Build and Build Alternatives

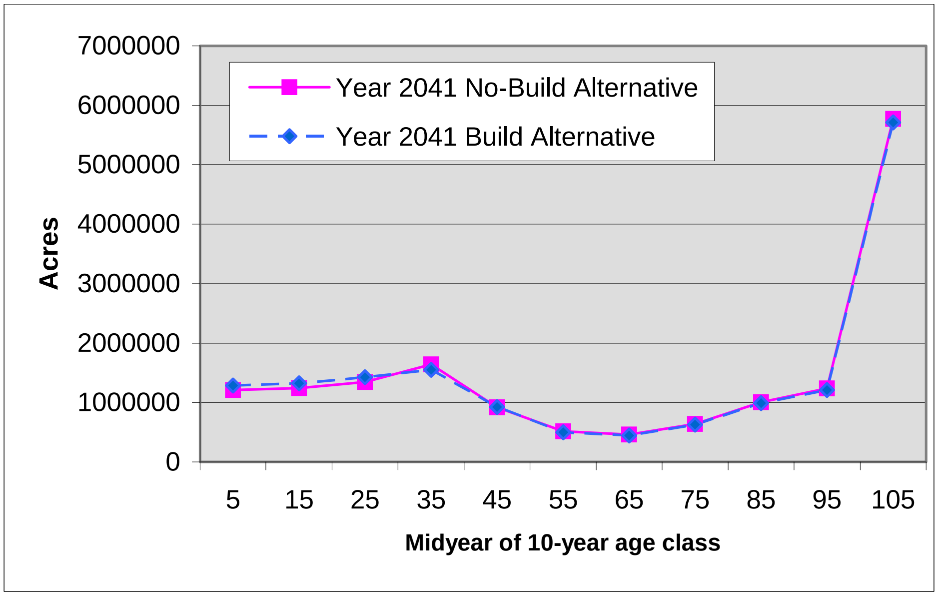


Comparison of stand age class distributions of the jack pine forest cover type in year 2041, No-Build and Build Alternatives, to the jack pine forest cover type distribution in year 2001. Slashed area represents those age classes where stands are beyond the maximum rotation age[2], which is defined as the maximum age at which a forest type will retain its biological ability to regenerate to the same forest type and remain commercially viable as a marketable timber sale. Stands beyond maximum rotation age are likely to succeed to other forest types.

This project would raise statewide harvest levels by an estimated 5.36 percent, and, as shown earlier, a substantial portion of this added volume is produced by the model through increased emphasis on the growth of aspen, increased harvested in forest cover types that also include aspen and increased use of uneven-aged management. Uneven-aged management helps maintain an older overstory canopy with the potential to harvest and still sustain the "big tree" characteristics of an older stand.

The forest stand age class distribution for the state as a whole is shown in Figure C-19, comparing both the No-Build and Build Alternative results for the higher availability scenarios in year 2041 and year 2001 distribution. The big difference is in how the forest ages over time with substantially more acres in the older age classes.

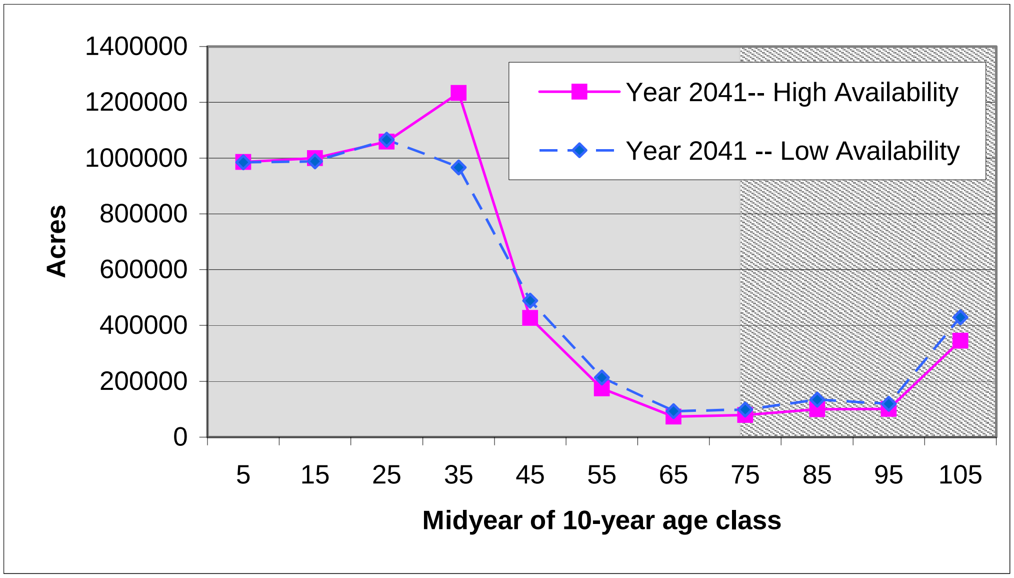
Figure C-19
All Forest Types – No-Build and Build Alternative



Comparison of stand age class distributions of all forestland in year 2041, No-Build and Build Alternatives, to stand age class distributions of all forestland in year 2001.

Figure C-20 compares the age class distribution for aspen for the higher availability and the lower availability assumptions for the Build Alternatives. Differences are not as pronounced as one might expect considering that that the higher availability assumption has 267,000 more acres of the aspen forest type available for harvest. With the lower availability assumption, much more emphasis is placed by the model on scheduling harvests to capture growth and reduce losses to aspen mortality.

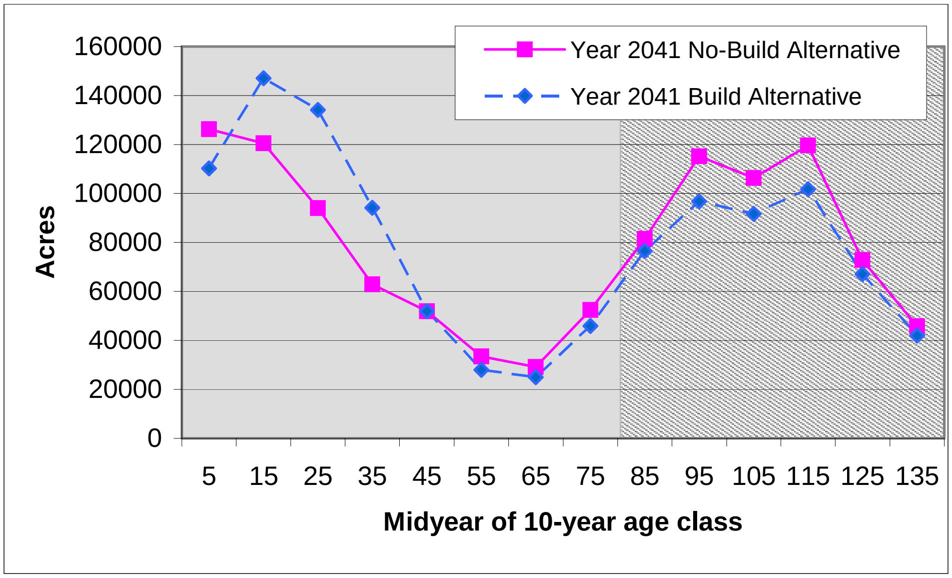
Figure C-20
Aspen – Build Alternatives, Scenarios A and B



Impact of the higher and lower availability assumption on the age class distribution of aspen in year 2041 with the project. Slashed area represents those age classes where stands are beyond the maximum rotation age[2], which is defined as the maximum age at which a forest type will retain its biological ability to regenerate to the same forest type and remain commercially viable as a marketable timber sale. Stands beyond maximum rotation age are likely to succeed to other forest types.

The age class distribution for paper birch for Scenario A&P shows that more harvesting is scheduled for the birch type with the Project (Figure C-21). Additional harvesting in the birch type occurs in the model primarily to capture more of the aspen volume found in some birch stands. Not shown in the graph, but not surprising is that slightly more young birch is being harvested and regenerated under the scenario with lower availability of the aspen cover type from private lands. Ecologically, harvesting birch is potentially important because without disturbance, acres in the birch type will succeed to other forest types. This was identified as a potential significant impact in the GEIS. Results here do not show it as nearly as large a concern. The USDA Forest Service has made regenerating birch an important objective in their recent forest plans for the Chippewa and Superior National Forests, and those plans are included in the management schedules for this study under all scenarios.

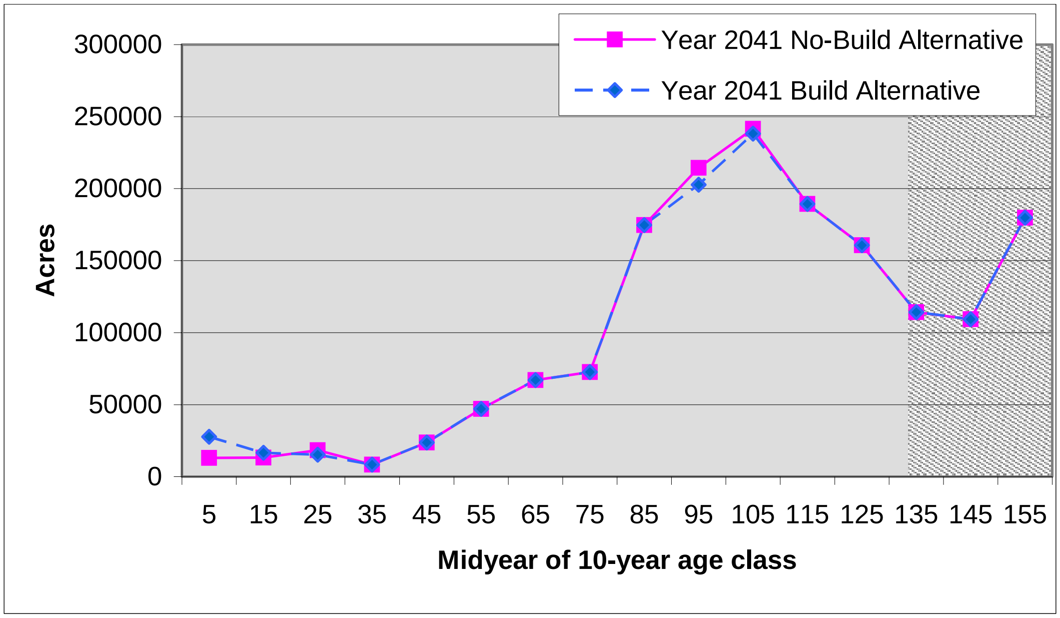
Figure C-21
Paper Birch – No-Build and Build Alternatives



Comparison of stand age class distributions of the paper birch forest cover type in year 2041, No-Build and Build Alternatives, to the paper birch forest cover type stand age class distribution in year 2001. Slashed area represents those age classes where stands are beyond the maximum rotation age[2], which is defined as the maximum age at which a forest type will retain its biological ability to regenerate to the same forest type and remain commercially viable as a marketable timber sale. Stands beyond maximum rotation age are likely to succeed to other forest types.

The age class distribution for lowland spruce shows an initial age class distribution with relatively few younger stands (Figure C-15). Generally, the model did little harvesting in this forest cover type over the planning horizon because this type contains relatively little aspen as a subspecies component. Some might wonder if UPM/Blandin Paper has opportunities to shift more of its wood use to spruce-fir (Figure C-22). That was the basis for modeling Scenario B&P&SF. The area in the younger age classes in this forest cover type are increased with Scenario B&P&SF, where a 200,000 cord/yr increase in harvesting with the project is assumed to be spruce or balsam fir volume. The resulting age distribution for lowland spruce level of harvesting in that type does not signal concern about a high unsustainable harvest level for that cover type, as the area in the younger age classes is still relatively low. It is likely that a 200,000 cord increase in spruce-fir would be available and sustainable at least over a 40-year period.

Figure C-22
High Spruce-fir – No-Build and Build Alternatives



Stand age class distributions in year 2041 for the lowland spruce forest cover type for Build Alternative scenarios that differ in terms of the amount of increase in the use of spruce-fir. Distributions for a No-Build Alternative scenario and year 2001 are also included for reference. Slashed area represents those age classes where stands are beyond the maximum rotation age[2], which is defined as the maximum age at which a forest type will retain its biological ability to regenerate to the same forest type and remain commercially viable as a marketable timber sale. Stands beyond maximum rotation age are likely to succeed to other forest types.

5.7 Mature Forest

To help monitor forest conditions, the amount of mature forest was tracked over time for all scenarios. Mature forest was defined for modeling purposes similarly to the term effective ERF (extended rotation forestry) as used by the DNR for planning on state-managed lands. For this study, mature forest was considered to be all forestland older than the stand ages shown in Table C-38. These ages are comparable to ages used by the DNR to define areas providing effective ERF. An important difference to note is that DNR objectives for ERF are based just on timberland acres and not on forestland acres. Therefore any direct comparisons of the amount of mature forest produced in the modeling results with the specific DNR's goals for ERF need to be done with caution. Also, some acres counted as mature are well beyond expected ages of survival for some species (aspen, birch, jack pine, balsam fir, etc.). In reality, these acres would succeed to another cover type. In the successional process, the age of the stand, as measured by the age of overstory trees, would be reduced. The extent of the reduction would vary by native plant community and specific stand age class structure. Generally, stands in northern Minnesota uplands succeed to northern hardwoods or upland spruce. However, the older age, as measured in the modeling process, would still reflect the time since disturbance, and often, age reductions of the overstory may be 20 years or less in the natural succession process.

For all scenarios, the amount of mature forest increases steadily over time (Table C-38). For all scenarios that limit total statewide harvesting (all scenarios except the "HighAspen" scenarios) the statewide increase is approximately two million acres over the 40-year planning horizon. Clearly, the increase in mature forest is a consequence of harvesting primarily in the aspen forest cover type with relatively little harvest elsewhere. The No-Build scenarios, the increase is larger and ranges from 2.1 to 2.6 million acres.

Table C-38
All Ownerships: Area of Mature Forest (thousand acres)

Scenario	Year 0	Year 10	Year 20	Year 30	Year 40
A	7,021	7,474	8,082	8,646	9,136
A&P	7,021	7,538	8,066	8,582	9,011
A&P&SS	7,021	7,447	7,998	8,516	8,966
A&HighAspen	7,021	7,089	7,175	7,464	7,627
B	7,021	7,625	8,202	8,790	9,282
B&P	7,021	7,685	8,188	8,753	9,210
B&P&SS	7,021	7,613	8,126	8,672	9,143
B&P&Spruce-fir	7,021	7,534	8,060	8,563	9,014
B&HighAspen	7,021	7,168	7,286	7,647	7,855

A substantial portion of the increase in mature forest occurs on private lands under all scenarios Table C-39). For all scenarios under the Build Alternative except the High Aspen scenarios, the increase is over 833,000 acres of mature forest on private lands over the 40-year planning horizon. With the No-Build Alternative, the increase ranges from 915,000 acres to over 1.1 million acres on private lands.

Table C-39
Private Lands: Area of Mature Forest (thousand acres)

Scenario	Year 0	Year 10	Year 20	Year 30	Year 40
A	2,940	3,076	3,421	3,655	3,855
A&P	2,940	3,172	3,451	3,635	3,791
A&P&SS	2,940	3,063	3,375	3,585	3,773
A&HighAspen	2,940	3,253	3,281	3,357	3,384
B	2,940	3,273	3,612	3,844	4,054
B&P	2,940	3,353	3,619	3,847	4,015
B&P&SS	2,940	3,270	3,569	3,767	3,967
B&P&Spruce-fir	2,940	3,192	3,509	3,727	3,939
B&HighAspen	2,940	3,311	3,419	3,545	3,613

The amount of forest that is mature in the aspen forest cover type declines over time under all scenarios (Table C-40). The amount of mature aspen declines from about 2.5 million acres in 2001 to 1.1 to 1.3 million acres in 2041, depending on the whether the Series A or Series B assumptions about private lands are used. The larger values for Series B are a result of the assumption that approximately 267,000 fewer acres of private lands in the aspen forest cover type are available for harvest under this series.

Table C-40
All Ownerships: Area of Mature Aspen (thousand acres)

Scenario	Year 0	Year 10	Year 20	Year 30	Year 40
A	2,541	1,897	1,494	1,258	1,103
A&P	2,541	1,996	1,554	1,291	1,088
A&P&SS	2,541	1,886	1,489	1,259	1,102
A&HighAspen	2,541	2,098	1,569	1,277	975
B	2,541	2,112	1,719	1,486	1,303
B&P	2,541	2,239	1,801	1,547	1,331
B&P&SS	2,541	2,120	1,721	1,494	1,313
B&P&Spruce-fir	2,541	2,022	1,667	1,471	1,325
B&HighAspen	2,541	2,173	1,684	1,454	1,197