Tools to Minimize the Impacts of Energy Wood Harvesting on the Environment and Soil Productivity in Minnesota

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Executive Summary

Forest harvest residues, specifically the nonmerchantable tree tops and limbs associated with a roundwood harvest, have the capacity to supply substantial feedstock for energy production. Site and stand conditions (including tree species composition, timber size class, wood quality, and soil properties), and management and regeneration objectives are all key determinants of the amount of recoverable biomass volume available on a given roundwood harvest site.

The removal of additional woody material from a roundwood harvest site as a result of biomass harvesting activities has the potential to produce adverse effects on the environment and long-term forest productivity. Possible impacts to soil resources include soil compaction and rutting, erosion, and nutrient removal. The removal of vegetation associated with harvesting residual biomass may also increase soil temperature, adversely impacting organisms not resistant to desiccation. Additionally, re-entry into the forest site to harvest biomass residue has the potential to impact forest regeneration. Residual biomass harvesting can also alter vegetation within riparian areas, which helps provide woody debris that aids in retaining nutrients, stabilizing banks and shorelines, and maintaining moderate water temperatures through shading. With respect to potential impacts on wildlife, harvesting residual biomass could disturb sensitive sites and rare species, as well as alter the structural habitat requirements for certain forest wildlife.

In Minnesota, two important drivers for increasing wood energy use are rising fuel costs and Minnesota's Next Generation Energy Act. This act is an aggressive renewable energy standard mandating that by the year 2025, 25% of the total energy consumed in Minnesota be derived from renewable energy resources.

To address environmental and forest productivity concerns in light of increased interest in woody biomass as an alternative energy source, the 2005 Minnesota Legislature directed the Minnesota Department of Natural Resources (MNDNR) and the Minnesota Forest Resources Council (MFRC) to develop guidelines for the sustainable management and harvesting of woody biomass. In July 2007, Minnesota became the first state to establish voluntary Biomass Harvesting Guidelines (BHGs) to mitigate adverse environmental effects associated with woody residue harvesting. The BHGs identify a menu of best practices for harvesting woody biomass while the perpetuating the sustainability of the state's forest resources. The BHGs developed by the MFRC represent a synthesis of the best-available scientific information regarding the effects of biomass harvesting on the environment in five major areas associated with forest biomass removal: soil productivity, riparian area management, water quality, quantity and wetland protection, and wildlife habitat management. Yet, as biomass harvesting inherently removes more woody debris from the harvest site compared to a conventional roundwood harvest, care must be taken to ensure that an adequate amount of woody residue remains on site to sustain long-term forest productivity. Consequently, there is room for improved understanding of the long-term implications of applying the practices specified in the BHGs on the health and productivity of forest resources, as well as the economic implications to the loggers who ultimately implement them.

In order to gain a better understanding of the current biomass harvesting practices in Minnesota, phone interviews of Minnesota loggers identified as being biomass harvesters were conducted in July-August 2008. Twenty-six of Minnesota's 28 loggers who harvest biomass participated in the survey. The survey gathered information about their annual harvest activity, logging site configurations, interpretation of Minnesota's BHGs, perceptions of environmental issues associated with biomass harvesting, and constraints and opportunities associated with biomass harvesting. To the best of our knowledge, this is the first study to inventory and assess Minnesota biomass harvester practices, attitudes, and perceptions at a statewide scale.

Key study findings from the biomass harvesters who responded to our survey include: (1) the majority of loggers (64%), nearly always conduct a biomass harvest in conjunction with roundwood harvest (i.e., biomass harvest occurs simultaneously with a roundwood harvest 91-100% of the time); (2) half of the loggers operating a chipper only use non-merchantable tops (i.e., they do not process non-merchantable limbs and branches); and (3) important issues associated with biomass harvesting include the need for a consistent market demand, an increase in the price paid for biomass, a reduction in the distance required to deliver biomass to utilization facilities, and the ability to set-up efficient harvesting site configurations.

An important conclusion from the survey was that most biomass harvesters are not intentionally leaving a specified percentage of fine woody debris (FWD) on site as recommended in the voluntary BHGs. Yet, many commented that a sufficient amount of woody residue (often more than the 33% recommended in Minnesota's BHGs) is currently being left on harvest sites due to incidental breakage during the harvesting process. Thus, while logger recognition of the BHG residual recommendations is not widespread and explicit, current timber harvesting and biomass procurement practices result in considerable woody biomass being retained on site. Further research is needed to assess how much FWD is appropriate to foster the regeneration, retention and growth of various tree species, forest types and associated plant and animal populations. Such information is central to understanding the long-term impacts of biomass harvesting on forest productivity and sustainability. However, such research results will invariably be complicated by the fact that different plant and animal species may have quite different (negative and/or positive) responses to site disturbance and various levels of FWD and CWD and those responses may also differ in the duration of effects and the resiliency of species.

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I. Introduction

Global interest in the use of renewable energy sources such as woody biomass continues to increase as energy prices rise. Though forest inventories suggest forest land can support increased biomass harvesting, an enhanced understanding of the methods necessary to reduce or eliminate the potential negative effects of such harvesting on the environment is essential. This report is one of several being prepared as part of an international effort to enhance the understanding of the status and relevant issues associated with woody biomass harvesting, as well as methods to minimize adverse biomass harvesting impacts on the environment and, notably, soil productivity. It describes Minnesota's forest resource management structure and examines the current supply of and demand for biomass in Minnesota. Additionally, the report provides background on the development and details of Minnesota's Biomass Harvesting Guidelines (BHGs), the first of its kind to be developed by states to assist loggers and resource managers in applying best practices to mitigate adverse environmental effects that can be associated with woody residue harvesting. The report also reviews the major environmental issues that should be considered when harvesting biomass. Finally, the report examines the current state of Minnesota's biomass harvesting practices and associated issues through data collected from phone interviews with biomass harvesters.

II. Forest Resource Management In Minnesota

A. Forest Ownership Structure

The ownership of Minnesota's nearly 15 million acres of timberland[1] is diverse (Figure 1). According to Brown et al. (2007, p.1), "Non-industrial private forests (NIPF) comprise the largest ownership of timberland acreage in Minnesota (41%), followed by the state government (26%) and county governments (14%). The USDA-Forest Service owns 12% of the state's timberland, and other federal organizations own an additional 2%. Of the private timberland, NIPF landowners comprise approximately 90%; the forest industry ownership is 10%."

Currently, NIPFs are increasing their ownership share of the state's timberland base (Kilgore and McKay, 2007). This trend in the change of timberland ownership from industrial to nonindustrial owners could significantly impact the management and use of these forested lands; family and individual owners will increasingly make the ultimate decisions regarding land use and management objectives on these private lands (Kilgore and MacKay, 2007).

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[1] This report attempts to address lands classified as timberland, but in some instances data was only available for all forest land. As classified by the USDA Forest Service's Forest Inventory and Analysis (FIA) program, timberland is a subcategory of forest land. Timberland is "forest land that is producing or capable of producing in excess of 20 cubic feet per acre per year of wood at culmination of mean annual increment" and is not legally reserved from timber harvesting (Bechtold and Patterson, 2005). There are approximately 16.3 million acres of forest land in Minnesota, with nearly 15 million acres in the subcategory of timberland (USDA Forest Service, 2006).

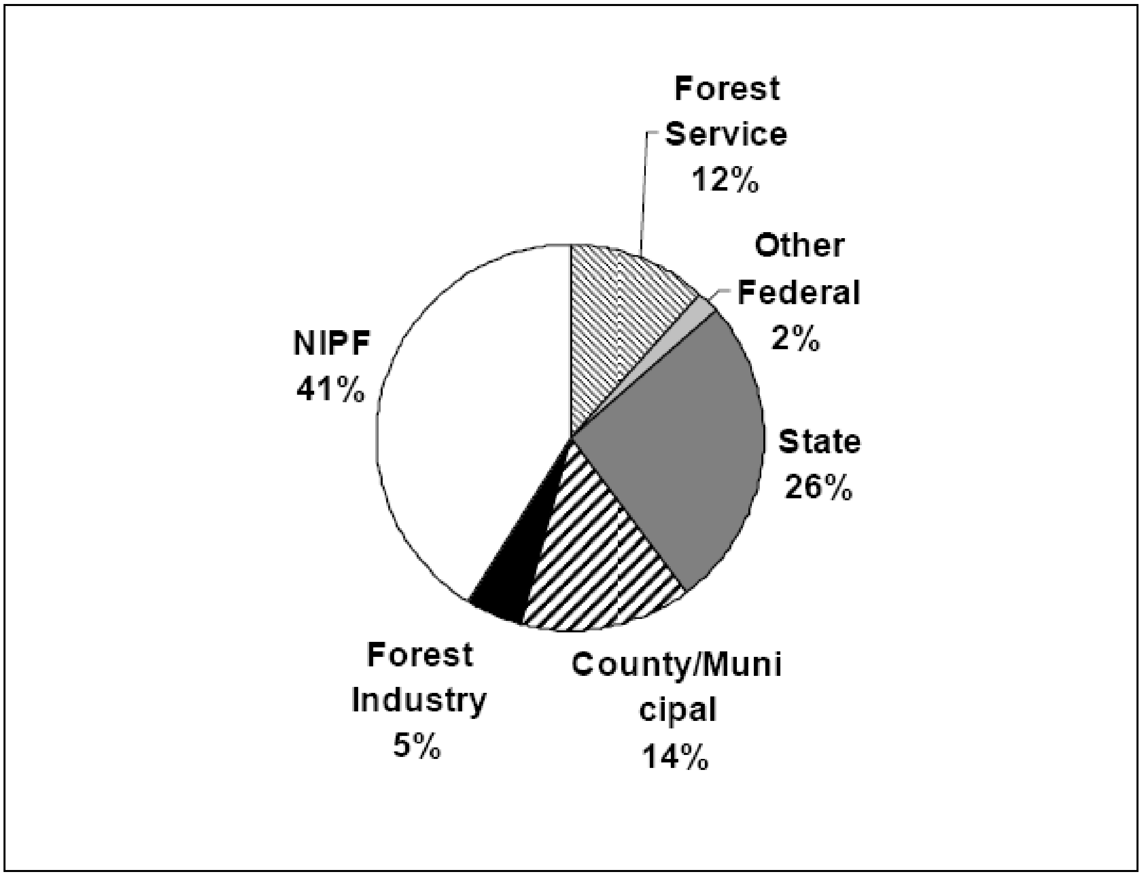

Figure 1. Distribution of Minnesota timberland by ownership group. *Source:* USDA Forest Service, 2006.

Table 1 illustrates the distribution of timberland area by ownership group and forest type (Brown et al., 2007). Covering almost 5 million acres, aspen is, by far, the predominant forest type in Minnesota (Table 1). Black spruce, northern hardwoods, and lowland hardwoods are other common forest types, each covering more than 1 million acres. The distribution of timberland area by stand size class and ownership group can be seen in Table 2 (Brown et al., 2007) using the following four diameter categories of the predominant trees (Miles et al, 2001):

- Small - < 4.9 inches dbh (seedlings/saplings).
- Medium - 5 – 8.9 inches dbh (softwoods) / 5.0 – 10.9 inches dbh (hardwoods).
- Large – 9.0+ inches dbh (softwoods) / 11.0+ inches dbh (hardwoods).
- Nonstocked – less than 10% stocked trees of any size.

Table 1. Timberland area by ownership and forest type (thousand acres).

Forest Type	Total	Forest Service	Other Federal	State	County Municipal	Forest Industry	NIPF
Jack pine	356	71	14	73	53	42	103
Red pine	562	148	15	123	50	48	177
White pine	151	47	1	17	14	6	66
Balsam fir	393	80	17	94	56	27	120
White spruce	111	26	1	41	7	14	22
Black spruce	1,334	213	19	632	221	34	215
Tamarack	868	70	11	452	139	8	188
Northern white-cedar	572	84	12	267	89	24	96
Eastern red-cedar	26	0	0	3	0	0	22
Other softwoods	6	0	0	0	0	0	6
Oak	791	2	15	92	52	7	624
Northern hardwoods	2,058	143	30	287	244	34	1,320
Lowland hardwoods	1,104	66	18	232	113	39	635
Cotton/willow	107	4	8	25	5	9	56
Aspen	4,849	531	72	1,163	858	342	1,881
Birch	999	236	19	224	164	30	326
Balsam poplar	464	23	7	128	55	34	217
Non stocked	228	16	3	95	23	6	84
Total	14,978	1,761	263	3,947	2,144	705	6,158

Source: USDA Forest Service, 2006

Table 2. Timberland area by ownership and stand size class (thousand acres).

Stand size class diameter	Total	Forest Service	Other federal	State	County municipal	Forest industry	NIPF
Large	5,057	614	56	1,691	791	394	1,511
Medium	5,688	622	124	1,445	851	210	2,437
Small	4,003	509	80	714	479	95	2,125
Nonstocked	229	16	3	95	23	7	84
Total	14,978	1,761	263	3,947	2,144	705	6,158

Source: USDA Forest Service, 2006

B. Legal and Institutional Setting for Biomass Harvesting

In 1994, a Generic Environmental Impact Statement (GEIS) was prepared in response to public concern regarding the potential impacts of increasing timber harvest levels in Minnesota (Jaakko Pöyry Consulting, Inc., 1994). The GEIS assessed the environmental impacts associated with timber harvesting at different levels statewide. The GEIS also developed recommendations to mitigate the adverse impacts of increased levels of timber harvesting (Brown et al., 2007). The suggested methods for implementing the site-level and landscape-based recommendations outlined within the GEIS became the basis for the implementation actions specified in the Sustainable Forest Resources Act (SFRA) (MN § 89A) enacted in 1995 (Minnesota Statutes, 2005). Additionally, the SFRA defined the institution responsible for coordinating achievement of the GEIS recommendations: the

Minnesota Forest Resources Council (MFRC). The SFRA also called for the development of Minnesota's Timber Harvesting and Forest Management Site-level Guidelines (TH/FM guidelines) to mitigate environmental impacts associated with timber harvesting and forest management (Dahlman and Phillips, 2004).

Requiring that Minnesota's voluntary TH/FM guidelines reflect a variety of practical and sound management practices based on the best available scientific information, (Minnesota Statutes, 2004), such guidelines were developed to foster forest ecosystem sustainability (Brown et al., 2007). Four multidisciplinary technical teams were convened by the MFRC in 1996 to develop guidelines for riparian zone management, wildlife habitat, historic/cultural resources, and forest soil productivity (Minnesota Forest Resources Council, 2005). Over a two-year period, the technical teams developed guidelines for their respective topical area, which were subsequently integrated into a single set of guidelines. An external review of the guidelines by forest managers, scientists, and loggers was conducted before the guidelines were published by the MFRC in 1998 (Minnesota Forest Resources Council, 2005).

In 2005, Minnesota legislation required public utilities seeking to fulfill the state's biomass mandate include in their use, in addition to farm-grown closed loop biomass, sustainably managed woody biomass. This legislation further specified that the Minnesota Department of Natural Resources (MNDNR) and the MFRC develop guidelines or best management practices for sustainable woody biomass harvesting by July 1, 2007. In particular, the MFRC needed to develop guidelines for harvesting and processing logging residues (nonmerchantable tops, limbs, and branches) while paying special attention to soil productivity, biological diversity and wildlife habitat concerns. Two sets of guidelines (one for brushland; one for forest land) for sustainably managing woody biomass[2] were developed. As with previous guideline development processes, a team consisting of scientists, loggers and natural resource managers developed the BHGs and appended these guidelines as a separate chapter to the state's existing TH/F guidelines.

III. Minnesota's Biomass Demand and Supply

A. Available Biomass in Minnesota

According to the MNDNR (Minnesota Department of Natural Resources, 2007a), there are a number of sources of woody biomass that can be utilized for energy in Minnesota. These include:

[2] Sustainably managed woody biomass includes: "1) brush and trees removed from rights of way, 2) upland and lowland brush harvested as part of brushland habitat, and 3) logging slash or residue created by timber harvest, Timber Stand Improvement (TSI), fuel management, or insect and disease control treatments" (personal communication with Dick Rossman, MNDNR, August 7, 2008). For the purpose of this study, logging slash or residue created by timber harvest will be the component of interest when referring to woody biomass.

- Logging Residue. Logging residue is the largest potential woody biomass resource that is largely "untapped" in Minnesota. This resource includes the nonmerchantable tops and limbs left over from commercial timber harvest operations, nonmerchantable small-diameter trees and stems, dead standing trees (snags), and down logs (CWD).[3]

- "Primary" Mill Residue. Almost all of this resource, which is waste wood material generated from primary wood product manufacturing, is presently utilized for energy.

- "Secondary" Mill Residue. A large portion of the waste wood materials generated from secondary wood product manufacturing (e.g., cabinet manufacturing) is currently utilized. Additionally, the waste stream from secondary manufacturers is much more diverse and often includes materials containing resins and finishes that can cause air quality concerns if burned.

- Dedicated energy crops. Small acreages of short rotation woody crops (SRWC) are currently being grown in Minnesota, some of which will be used for energy.

- Land clearing projects. There is a significant amount of woody material generated from powerline clearing and road construction projects. Common practices for managing this material include on-site burning, as well as chipping then spreading the material across the site.

- Biomass from brushlands. A significant potential resource, but the economics of harvesting and transporting this material need to improve before widespread use will occur.

- Precommercial thinning, timber stand improvement (TSI), fire hazard reduction vegetation management projects. A potential resource that is a byproduct of intensified forestry and wildlife management activities.

- Urban Forests. A resource from tree clearing and maintenance and storm cleanup in urban areas. Much of this wood material is chipped and sold as mulch in major metropolitan areas.

Forest harvest residues, specifically tops and limbs, have the greatest capacity to supply feedstock for energy production. FPInnovations monitored the recoverable biomass volume removed from harvest sites in Ontario and estimated that the recoverable biomass is approximately 10-16% of the roundwood volume removed from site[4]. Site conditions, tree species composition, size class, wood quality and management and regeneration objectives are all key determinants of recoverable biomass on a given harvest site. Table

[3] Fine Woody Debris (FWD) includes tops, limbs and branches and nonmerchantable small-diameter trees and stems. Coarse Woody Debris (CWD) includes down logs.
[4] Personal communication with Mark Ryans, Ontario Registered Professional Forester and Group Leader for Silviculture Operations and Bioenergy, FPInnovations, August 12, 2008.

3 estimates the additional amount of nonmerchantable biomass potentially available from various forest covertypes.

According to Berguson (2007, p.i), “An evaluation of the harvest residues shows that approximately 1 million dry tons of harvest residues are currently produced resulting from a harvest level of 3.7 million cords of pulpwood and sawtimber. Using the same ratio of harvest residues to roundwood, a harvest level of 5.5 million cords would produce approximately 1.5 million dry tons of harvest residue. Accounting for environmental mitigation, estimates of total available harvest residues are 750,000 and 1.15 million dry tons, at harvest levels of 3.7 and 5.5 million cords, respectively.” Likewise, through a variety of sources, including thinning of red pine and aspen plantations, an additional 100,000 cords (or 115,000 dry tons) above current levels could be obtained annually (Berguson, 2007).

Table 3. Appraisal of volume in top and limb wood based on cover type and diameter.

Stand cover type	DBH range (inches)	Additional amount of chips in stand as a percentage of the bolewood appraisal or scale
All hardwoods other than aspen	>9	29%
Aspen	5-9	33%
Aspen	>9	25%
Pines/Tamarack	5-9	14%
Pines/Tamarack	>9	11%
Other softwoods	5-9	33%
Other softwoods	>9	23%

Source: Minnesota Department of Natural Resources, 2007b
* Table 3 can be used to estimate slash (top and limb) biomass from standing timber volumes, based on cover type and average diameters. Additional chipped product existing in top/limb wood consists of tops and limbs that do not meet MNDNR forestry utilization standards. For cordwood material (all species), this is material less than 3” diameter, less than 6” diameter for sawtimber material in conifers, aspen, balm and birch, and less than 10” diameter for sawtimber material in other hardwoods (Minnesota Department of Natural Resources, 2007b).

B. Biomass Market and Production

Recent rising costs of petroleum-derived energy sources, such as heating oil and natural gas, have made woody biomass an economically viable energy alternative to fossil fuels (Berguson, 2007). In Minnesota, one of the largest drivers for increasing wood energy use, besides rising fuel costs, is Minnesota’s Next Generation Energy Act (Minnesota Department of Natural Resources, 2008). The Next Generation Energy Act, an aggressive renewable energy standard, mandates that by the year 2025, 25% of the total energy consumed in Minnesota be derived from renewable energy resources. Because of rising fuel costs, Minnesota’s legislative mandate, and an increased interest in renewable energy sources, woody biomass market growth is likely. However, this growth has been slow to develop in spite of increasing interest in biomass utilization facility development (Minnesota Department of Natural Resources, 2008).

Wood that cannot be used as roundwood, such as tops and limbs, small-diameter timber and lower grade material with decay, can often be used for woody biomass (Minnesota Department of Natural Resources, 2008). However, current prices paid for woody biomass resources are low, "as margins after extraction, transport, and energy production are normally pretty thin" (Minnesota Department of Natural Resources, 2008). In Minnesota, factors such as available harvesting equipment, fuel costs, landowner objectives; and roundwood market fluctuations limit the widespread removal of logging residues (per communication with Mark Ryans, an Ontario Registered Professional Forester and Group Leader for Silviculture Operations and Bioenergy for FPInnovations, August 12, 2008). Currently, Minnesota's total wood use, including roundwood demand, has been reduced substantially due to the temporary or permanent shutdowns of several large primary wood-based processing facilities. This capacity reduction has more than offset any wood use increases from energy facilities (Minnesota Department of Natural Resources, 2008c). Table 4 illustrates markets for woody biomass in Minnesota.

Potential markets for nonroundwood material include:

- Engineered Wood. The Georgia Pacific hardboard mill in Duluth and the International Bildrite insulate mill in International Falls are two engineered wood product mills in Minnesota that use bark-on wood chips.

- Special Forest Products (SFP). Markets include log furniture and material for woodcrafts. These markets are often small in volume, but high in value.

- Landscape Mulch Markets. These markets are limited in rural Minnesota, but are significant near large metropolitan areas.

- Animal Bedding. Animal bedding markets are limited in some of the state's highly forested regions due to the majority of the poultry and dairy industry being located in central and southern Minnesota.

- Energy. Energy is, by far, the largest market for woody biomass in Minnesota and continues to grow. For many years, many large and small primary woody manufacturers produced heat and, in some cases power, for their own facilities by utilizing wood residue generated from the mill's manufacturing processes. Factors such as rising fossil fuel energy prices, legislative mandates, and energy production efficiency improvements continue to expand this market (Minnesota Department of Natural Resources, 2006).

Table 4. Woody biomass energy facilities in Minnesota

Project name	Location	Project status	Type of facility
Hibbard Energy Center	Duluth	Active	CHP Plant
Laurentian Renewable Energy (LEA)	Virginia & Hibbing	Active	CHP Plant
Central MN Ethanol CMEC	Little Falls	Active	Ethanol Boiler
Central MN Ethanol CMEC	Little Falls	Proposed	Cellulosic Boiler
St. Paul District Energy II	St. Paul	Active	CHP Plant
Fibro MN	Benson	Active	Power Plant
Grand Rapids Cogeneration	Grand Rapids	Active	*
Len Busch Roses	Plymouth	Active	Heating Plant
U.S. Steel -- Minn Tac	Mountain Iron	Active	*
Xcel Energy--French Island	Lacrosse, WI	Active	Power Plant RDF Woody Chips Ground RR Ties
Ainsworth Cogeneration	Bemidji	Idle	Power Plant
Boise Paper	International Falls, MN	Active	Industrial CHP
Altrista	Cloquet, MN	*	*
Endres	Rosemount, MN	*	*
Hedstrom Lumber	Grand Marais	*	Burns Residue for Heat at Mill
Hill Wood Products	Cook	*	Provides Feedstock to Minn Tac
iLevel by Weyerhauser	Ironton	Closed	*
Itasca Power Northome Biomass Plant	Northome	Permitted	*
Marvin Windows	Warroad	*	Burns Wood as Mix of Fuels
Norbord	Solway	*	*
SAPPI	Cloquet, MN	*	Industrial CHP
Anderson Windows	Bayport, MN	*	*
Verso Paper	Sartell	*	Industrial CHP
Potlatch	Bemidji	*	Steam for Turbines and Kilns
Blandin UPM	Grand Rapids	Active	Industrial CHP
Stora Enso (new owners and name)	Duluth	*	Recently Sold
Georgia Pacific (Superwood)	Duluth	*	*
CVEC phase 1	Benson	Construction Started	Industrial Stream and CHP
CVEC phase 2	Benson	Proposed	Industrial Stream and CHP
Bio-Pellets	Deer River	Active	Wood Pellets
Valley Forest Wood Products	Marcell	Active	Wood Pellets
Minnesota Power	Hoyt Lakes	Announced	Electricity

Source: Sorensen, 2007
* Information is unknown at this time.
** The Minnesota Department of Natural Resources is currently developing a project directory of woody biomass users in the state. This document is anticipated to be available September, 2009
*** Acronym appendix for Table 4. CHP=Combined Heat and Power, CMEC=Central Minnesota Ethanol Cooperative, CVEC=Chippewa Valley Ethanol Cooperative, SAPPI=South African Pulp and Paper Industries, and UPM=United Paper Mills.

C. Future Biomass Industry

Investments in alternative energy using woody biomass can be expected in the future due to the price differential between wood and heating oil and propane. Thus, the use of woody biomass for energy will likely increase and become a significant part of the future economic landscape of Minnesota (Berguson, 2007). Even though coal remains the least expensive energy option (Table 5), permitting new coal-burning facilities is increasingly difficult due to concern over the emissions of carbon dioxide as well as other air pollutants. Consequently, the use of low CO_2 fuels, such as woody biomass, is becoming an attractive alternative energy option (Berguson, 2007). The demand for directly forest-derived woody biomass is likely to be just over 1 million green tons in 2008 for those industries purchasing wood residue on the open market (Minnesota Department of Natural Resources, 2008c). This figure is likely to increase as more facilities begin to rely on logging residue for energy (Minnesota Department of Natural Resources, 2008c).

Additionally, wood pellets are beginning to impact the energy market (Minnesota Department of Natural Resources, 2008c). Wood pellets are small dense pellets of woody material with low moisture content that are used for industrial and home heating systems. Currently, wood fuel pellets have limited regional markets in the US and Canada with a significant portion of annual production (1.56 million tons in 2006) exported to Europe (Dovetail and Ramaswamy, 2007). However, several mills that produce wood pellets for industrial or home heating have increased production and several more mills are being proposed (Minnesota Department of Natural Resources, 2008c). In 2006, fuel pellet production rose 25% over the previous year in the US (Dovetail and Ramaswamy, 2007). Wood pellets are an economical way of producing heat and have been historically favored by schools and businesses when the prices of fossil fuels have risen. Using a combination of roundwood, biomass and mill residue, wood pellets are a heating option that is emerging once again as the cost of fossil fuels continues to rise (Minnesota Department of Natural Resources, 2008c).

Table 5. Comparison of common fuels and net realized price per mmBTU.

Fuel type	$/unit	Unit	$/mmBTU	Conversion efficiency	Net cost ($/mmBTU)
Natural gas	5.60	mmBTU	5.60	.9	6.22
Heating oil	1.99	Gallon	14.21	.85	16.72
Propane	1.20	Gallon	13.10	.9	14.55
PRB coal	10.00	Ton	.57	.6	.94
Roundwood	75.00	Cord	3.83	.6	7.35
Wood chips	25.00	Green ton	2.94	.6	4.90

Source: Berguson, 2007

Minnesota's wood-based renewable energy markets have a more limited procurement range than other markets for roundwood due to the low the prices paid for chipped biomass (Minnesota Department of Natural Resources, 2008c). As markets for biomass products expand, additional Minnesota forest landowners and will likely be impacted by the increasing demand for woody biomass (Minnesota Department of Natural Resources, 2008c).

IV. Environmental Impacts of Biomass Harvesting

Currently, the BHGs developed by the MFRC (in conjunction with the TH/FM Guidelines) represent a synthesis of the best-available scientific information regarding the effects of biomass harvesting on the environment. Unless cited otherwise, the following discussion draws largely, and in some cases, directly, from this synthesis of information provided in the BHGs (Minnesota Forest Resources Council, 2007).

When used appropriately, the BHGs (in conjunction with the TH/FM Guidelines), address four major potential impacts to the environment associated with woody biomass removal: impacts to soils, impacts to riparian areas, impacts to water quality, water quantity and wetlands, and impacts to wildlife habitat.

A. Impacts to Soils

Any strategy designed to achieve sustainable forest management must first identify and reduce any negative impacts to soil resources. Overall, the BHGs are designed to "help protect the physical, chemical and biological properties of soils by minimizing the effects of soil compaction and rutting, erosion and nutrient removal that can result from woody biomass harvesting activities" (Minnesota Forest Resources Council, 2007, p.6).

Chemically and biologically, the amount of slash left as standing dead material and on the forest floor is the principal factor affecting short and long-term microbial community characteristics and nutrient availability (Belleau et al., 2006). "In most cases, evidence suggests that, if the current site-level guidelines are followed, biomass harvesting will not create additional or increased physical impacts to soil productivity, as compared to conventional forest harvesting. Where biomass harvesting may create an increased impact, compared to conventional forest harvesting, is with respect to nutrient removals. Removing more biomass from a site inevitably removes more nutrients" (Minnesota Forest Resources Council, 2007, p.13). However, results of long-term studies indicate that most mineral soils in Minnesota have a sufficient nutrient capital to tolerate a large number of harvest rotations without suffering adverse effects (Grigal, 2004). "Based on the current available information and technology, the BHGs will protect the nutrient capital of the average forested site in Minnesota" (Minnesota Forest Resources Council, 2007, p.13). However, special attention must be paid to those harvest sites with unique environmental conditions, such as sites with deep organic soils or sites with very shallow to bedrock mineral soils. "In the case of these soils, high levels of biomass removals are likely to negatively affect their productivity" (Minnesota Forest Resources Council, 2007, p.16). Additionally, it is important to note that the removal of vegetation may also increase soil temperature and may adversely impact organisms that are not resistant to desiccation (Astrom et al., 2005).

With respect to nutrient depletion, the 2005 TH/FM Guidelines were based largely on findings of the GEIS. Since that time, an update to the nutrient portion of the GEIS (Grigal, 2004) has been completed. When applied to biomass harvesting, "the update assumed 100% of the logging residue would not be removed following a conventional harvest. The material that remains would primarily be high-nutrient small branches and leaves. On average, 25% of above-ground nutrients in the pre-harvest stand would be retained following residue removal, compared to about 40% retained following conventional harvest" (Minnesota Forest Resources Council, 2007, p.14).

For all sites, including but not limited to nutrient-sensitive sites, surface soil and litter layers should not be removed as the majority of biological activity takes place in these layers. The surface soil and litter layers play key roles in nutrient supply, erosion control, water retention and rooting medium. Existing trafficking guidelines that aim to reduce the physical impacts to the soil, such as keeping equipment on trails and infrastructure, avoiding rutting, and operating on frozen ground, should be adequate for biomass harvesting. Re-entry into the forest site to harvest residue is potentially problematic and is discouraged as it may impact regeneration and disturb rehabilitated infrastructure.

B. Impacts to Riparian Areas

In general, the BHGs seek to minimize the alteration of vegetation within riparian areas. The vegetation found within a riparian area helps to provide inputs of CWD and FWD that ultimately aid in retaining nutrients, stabilizing banks and shorelines, maintaining moderate water temperatures through shading, and providing wildlife habitat.

The RMZ Guidelines (included in the TH/FM Guidelines) address issues related to the harvesting of biomass in or near RMZs. The 2005 TH/FM Guidelines allow some tree harvesting within RMZ where the tops and limbs could be used for biomass. However, the guidelines do not address specific issues related to the harvest and removal of small trees, brush or CWD within RMZs. The current BHGs note that the "...removal of additional biomass, however, must be balanced with the protection of biodiversity in these special management zones" (Minnesota Forest Resources Council, 2007, p.12).

C. Impacts to Water Quality, Water Quantity and Wetlands

The effects of forest harvest on wetlands have been shown to include: (1) change of flora from forested wetland to marsh or upland vegetation; (2) a rise in the water table due to the declining rates of transpiration and interception as a result of vegetation removal; (3) species composition shift to animals that are characteristic of marshes and meadows; and (4) an increase in the number of edge-inhabiting birds (Hutchens, Jr. et al., 2004).

Through the use of filter strips and water diversion tactics, the MFRC guidelines aim to reduce amount of sediment and nutrient movement into wetlands and other water bodies. Re-entry into timber harvest sites is discouraged as it "… increases the potential for sediment movement into wetlands through disturbance of erosion control features and rehabilitated infrastructure" Minnesota Forest Resources Council, 2007). Likewise, wetland soils are especially vulnerable to compaction and rutting as a result of logging machinery, as well alteration of soil structure that may hinder air and water movement through the soil (Rummer, 2004). It is important to note that the 2005 General TH/FM Guidelines do not address re-entry into sites for the purpose of biomass harvesting, nor do they address additional removal of stand components. As increased biomass harvesting activity increases the potential for filter strip disturbance, attention must be paid to the amount of nonmerchantable material and CWD that should be harvested or retained within filter strips. Studies have shown that patches of both CWD and FWD should be retained in order to maintain critical populations of amphibians, reptiles, and terrestrial and aquatic invertebrates (Batzer et al., 2005).

D. Impacts to Wildlife Habitat

When used properly, the BHGs are designed to, “reduce the potential for biomass harvesting activities to disturb sensitive sites, rare species, water features and unique habitats” (Minnesota Forest Resources Council, 2007). Additionally, the guidelines aim to maintain the structural habitat components needed for forest wildlife.

“While an abundance of literature demonstrates the importance of standing and down CWD in providing habitat for vertebrate species, small life forms related to FWD have not been as well studied—particularly fungi, lichens, bryophytes and arthropods, which are central to the health and productivity of forest ecosystems. Woody debris, both CWD and FWD, provides habitat for many of these species” (Minnesota Forest Resources Council, 2007, p.9). Recent work in North America has illustrated the dependence of many insect species on dead wood. Many of these species are at risk due to low volumes of CWD and require a variety of CWD conditions such as size diversity and decay class (Maritkainen et al., 2000, Latty et al., 2006).

“The relatively few studies that examined the importance of woody debris for invertebrates often reveal an immense diversity of species that require woody debris. For example, one three-year study in the Canadian boreal forest reported that 257 taxa (mostly species) of saproxylic beetles utilized decaying dead logs. Few studies, however, have quantified amount of woody debris needed to maintain specific populations, much less whole communities” (Minnesota Forest Resources Council, 2007, p.9). Credible estimates on the amounts of dead wood necessary to maintain biodiversity are needed, as long-term changes in CWD management may limit the available habitat of deadwood dependent species, such as: small mammals (Sturtevant et al., 1997), fungi (Tikkannen et al., 2006), invertebrates (Niemala, 1997), and birds (Hutto, 2006).

When silvicultural practices consider both biodiversity and wildlife, a general premise is that harvesting activities need to closely resemble relevant natural disturbance regimes and stand development processes (Hunter, 1999, Kohm and Franklin, 1997). One of the major differences between traditional even-aged harvesting methods and natural stand replacement disturbances is the lack of significant biological legacies (see glossary) (Lee and Crites, 1999).

“Biomass harvesting following roundwood harvesting increases the disparity between managed stands and their natural analogs by removing additional CWD, as well as slash, thus further challenging natural resource managers to manage sustainably” (Minnesota Forest Resources Council, 2007, p.9). Likewise, the harvesting of woody debris and slash for biomass reduces the amount of decaying wood on forest landscapes and changes the physical and chemical environment. The BHGs (in conjunction with the existing General TH/FM Guidelines) attempt to incorporate natural disturbance patterns and processes into harvesting activities. According to the Minnesota Forest Resources Council (2007, p.9), this effort can be accomplished by: "maintaining biological legacies through leave tree clumps and maintaining structural complexity throughout the harvest area by retaining a level of snags, down CWD and FWD."

V. Minnesota's Biomass Harvesting Guidelines

A. Introduction to Biomass Harvesting Guidelines

Minnesota does not regulate timber harvesting and forest management practices applied to woody biomass. Instead, voluntary BHGs are included as a section in the TH/FM guidelines used as a guide for the application of sustainable forest management practices (Brown et al., 2007). The BHGs apply for two types of sites in Minnesota: forested sites and brushland sites. For the purpose of this study, only the BHGs that apply to forested sites are discussed. The definition of biomass harvesting includes, "…the process of collecting and removing woody biomass from forested sites" (Minnesota Forest Resources Council, 2007, p.6). Likewise, biomass harvesting in Minnesota refers to the utilization of tops and limbs (FWD) from trees harvested in a roundwood operation, nonmerchantable small-diameter trees or stems (snags), and down logs (CWD) (Minnesota Forest Resources Council, 2007).

It is important to remember that: (1) biomass harvesting removes more woody material from a harvest site than would otherwise be removed under a traditional roundwood harvest; and (2) the BHGs are voluntary recommendations that focus on how to protect the values and functions of forest resources during woody biomass harvesting and management activities (Minnesota Forest Resources Council, 2007). The guidelines do not generally provide recommendations on how to manage specific sites or which management activities need to be applied to specific harvest sites. Instead, the guidelines seek to "…provide a menu of site-level management practices that provide for the harvesting of woody biomass while ensuring the sustainability of forest resources in Minnesota" (Minnesota Forest Resources Council, 2007, p.3).

B. Overview of the Guidelines

The BHGs are broken up into several sections depending on the nature of the harvest site and the intended harvesting objective. The following is an overview of the BHGs:

1. Biomass Harvesting on Sensitive Sites

- Review *General Guidelines* and *Timber Harvesting Guidelines*, especially those relating to checking for the presence of known endangered, threatened and special concern species (ETS), sensitive plant communities or cultural resources.

- Avoid biomass harvesting in native plant communities as described in the Minnesota Forest Resources Council Voluntary TH/FM Guidelines (2005).

    - To determine whether any of these native plant communities are known to occur on the harvest site, consult with local MNDNR forestry offices and/or the Minnesota County Biological Survey (MCBS) Native Plant Communities Geographic Information Systems (GIS) layers, which may be downloaded from the MNDNR Data Deli at http://deli.dnr.state.mn.us.
    - Biomass harvesting may still be appropriate under the following conditions:
        - If management plans specifically include strategies to maintain habitat for rare species and/or to restore degraded native plant communities.
        - If biomass harvesting is used as tool to restore degraded native plant communities (e.g., overgrown savanna plant communities).
        - If biomass harvesting is used as a management tool to assist with ecological management of the native plant community (e.g., creating a fire break as a part of burning a fire-dependent native plant community).

- Avoid biomass harvesting within specific sites where plant or animal species listed as endangered or threatened at the state or federal level are known to exist (e.g., sites identified in the DNR Natural Heritage Information System).

2. Managing Water Quality and Riparian Management Zones (RMZ)

- Review *General Guidelines* and *Timber Harvesting Guidelines* related to water quality and RMZ management.

- Avoid harvest of additional biomass from within RMZ over and above the tops and limbs of trees normally removed in a roundwood harvest under existing timber harvesting guidelines.

- Avoid additional biomass removal within 25 feet of a dry wash bank except tops and limbs of trees normally removed in a roundwood harvest under existing timber harvesting guidelines, when managing near a dry wash in southeastern Minnesota.

3. Managing Soil Productivity

- Review *General Guidelines* and *Timber Harvesting Guidelines* relating to soil productivity, including infrastructure management, nutrient conservation and avoiding impacts to physical properties.

- Avoid biomass harvesting (over and above bolewood utilization) on organic soils deeper than 24 inches that are Ombrotrophic.

- Ombrotrophic sites typically have more than 90% of the basal area in black spruce, with no alder or willow in the understory. These sites fit the Northern Spruce Bog and Northern Poor Conifer Swamp native plant communities.

- Avoid biomass harvesting (over and above bolewood utilization) on aspen or hardwood cover types with shallow soils (8 inches or less) over bedrock.

- Do not remove the forest floor, litter layer and/or root systems for utilization as biomass.

- Plan roads, landings and stockpiles to occupy no more than 1-3% of the site.

- Avoid additional biomass harvesting from erosion-prone sites (e.g., those sites on steep slopes of 35% or more) over and above the tops and limbs of trees normally removed in a roundwood harvest under existing timber harvesting guidelines.

- Ensure that landing or on-site areas used to store biomass are in a condition that favors regeneration and growth of native vegetation and trees after use.

- Install temporary erosion control devices, such as straw bales, mulch or woody debris, to help stabilize soils prior to establishment of vegetative cover. Take care to avoid introduction of invasive species in bales or mulches.

    - For soils with 8-20 inches of soil over bedrock and droughty sands, consider that the recommended retention of one-third or more of FWD on the site benefits soil productivity as well as biodiversity. FWD should be evenly distributed throughout the site.
    - Consider that biomass products piled on landing for the majority of one growing season or longer will usually reduce natural regeneration.

4. Re-entry into Previously Harvested Sites to Retrieve Biomass

- Residue from timber harvests and other forest management activities often remains piled on site after harvesting activities are completed. The preference is to remove biomass at the time of harvest. If re-entry is necessary, use caution to avoid reducing future forest regeneration and compromising infrastructure rehabilitation efforts.

- Avoid re-entry in the general harvest area of a site with a second operation for the purpose of harvesting biomass once regeneration has begun or planting has been completed.

- If re-entry is needed once regeneration has begun or planting has been completed, restrict traffic to existing infrastructure.

- Re-establish erosion control measures on roads and landings, including vegetative cover and water diversion devices, after re-entering a site for biomass harvest.

- Avoid re-entry of sites across nonfrozen wetlands.

- Retain slash piles that show evidence of use by wildlife.

5. Managing and Retaining Wildlife Habitat and Structural Diversity

- Review and incorporate leave tree, snag and CWD guidelines in *General Guidelines* and *Timber Harvesting Guidelines*:

- The intent of the BHGs is to leave all pre-existing CWD and snags possible.

  - Leave all snags possible standing in harvest areas. Snags cut for safety reasons should be left where they fall.
  - Retain and limit disturbance on all pre-existing CWD (except in skid trails or landings).

- Retain stumps and uprooted stumps.

- In filter strips, avoid removal of pre-existing CWD material from the forest floor.

- Avoid biomass harvesting in leave tree clumps, except tops and limbs of trees normally removed in a roundwood harvest under existing *Timber Harvesting Guidelines*.

- Avoid biomass harvesting from within RMZ, except tops and limbs of trees normally removed in a roundwood harvest under existing *Timber Harvesting Guidelines*.

- Retain and scatter tops and limbs from 20% of trees harvested in the general harvest area (one "average-sized" tree out of every five trees harvested).

- Avoid removing FWD resulting from incidental breakage of tops and limbs in the general harvest area.

- If harvesting brush and small trees for biomass associated with a timber harvest, leave 20% of this material on the site. This material may be run over or cut, but it should remain on the site.

- The overall goal of FWD retention is to retain about one-third of the FWD on a site. This goal is achieved by intentionally retaining 20% of the FWD (tops and limbs from one "average-sized" tree out of every five trees harvested), with an additional 10-15% achieved by incidental breakage during skidding.

6. Biomass Harvest for Fuel Reduction

- Use these guidelines when harvesting understory vegetation for the purpose of wildfire fuel reduction. It may be necessary to modify biomass utilization in some cases, such as on sites with excessive fuel loading.

- Retain understory vegetation in several reserve patches that total at least 20% of the harvest area.

- Retain snags greater than 12 inches dbh and down logs where at least one end is greater than 12 inches in diameter and six feet in length.

- Modify management activities to maintain, promote or enhance ETS species.

C. Outreach and Communication with Loggers and the Public

The Minnesota Logger Education Program (MLEP) is a nonprofit organization that was designed in 1995 to assist logging business owners with the ever-changing logging industry demands related to: sustainable forest management, transportation, safety, and business management through educational programming. In order to remain an active MLEP member, loggers are required to attend eight hours annually of logging and safety-related workshops and training sessions. Biomass Harvesting Guideline Training is one of the workshops offered by the MLEP that provides information and educational assistance to loggers and foresters in understanding how to interpret and implement the BHGs. In 2008, approximately 300 loggers attended one of two conferences that the MLEP held in April where the BHGs were a major focus of discussion[5]. Likewise, the MLEP is continually developing more workshops on how to implement the BHGs. In September, the MLEP expects to offer online training for the BHGs[8].

In addition to working with loggers and foresters, the MLEP also communicates the BHGs to the public through an informational website and by distributing landowner informational manuals that provide information on forest management and the utilization of the BHGs. The MLEP also communicates to the public which guidelines should be implemented on a private sale and which guidelines should be considered before contracting a sale[6].

D. Certification Standards

On much of Minnesota’s public forest land, forest land certification plays an influential role in the forest management decisions that are made (Brown et al., 2007). The Forest

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[5] Personal communication with Dave Chura, Director, Minnesota Logger Education Program, August 1, 2008.

[6] Personal communication with Dave Chura, Director, Minnesota Logger Education Program, August 1, 2008.

Stewardship Council (FSC) and the Sustainable Forestry Initiative (SFI) are the two major certification systems used in Minnesota. Combined, 7.1 million acres of forest land has been certified under one or both of these two systems. Most of this certified forest land is owned by state and local governments, wood-based industries, and institutional investors (i.e., real estate investment trusts and timberland investment management organizations) (Brown et al., 2007). Both the FSC and the SFI certification systems use Minnesota's TH/FM guidelines as the basis for evaluating the sustainability of timber harvesting and forest management practices on Minnesota forest lands.[7]

As the BHGs were developed as an additional chapter to the existing TH/FM guidelines, the BHGs are a complement to the existing site-level forest management guidelines for Minnesota and are entirely voluntary. On private land, it is the landowner's decision whether to apply any of the recommended BHGs. The greatest flexibility in the use of the BHGs lies in the hands of the nonindustrial private landowner. On forest land managed by state or local governments and primary forest product companies, the BHGs are often mandatory per the organization's policy. In fact, many organizations choose to uphold the BHGs in order to remain certified with the SFI or FSC.

Currently, the MNDNR is the largest owner of certified forest land in Minnesota (Brown et al., 2007). Consequently, for all timber sales on MNDNR-administered forest land, adherence to the TH/FM guidelines is a condition of keeping its forest land base certified[10]. Likewise, forest products companies such as UPM Blandin use the Minnesota TH/FM guidelines (including BHGs)as a template for timber harvesting and forest management activities conducted on its lands (Brown et al., 2007).

VI. Biomass Harvesting Practices in Minnesota

A. Survey Methods

In order to gain a better understanding of the current biomass harvesting practices in Minnesota, phone surveys of loggers who harvested biomass in Minnesota (in 2008) were conducted between July 21, 2008, and August 14, 2008. Loggers who currently own a chipper and/or a grinder were identified through an MLEP inventory of its current members who harvest biomass.

Survey questions were developed and refined through researcher expertise and consultation with forestry and logging professionals. The final survey contained questions seeking information in several categories including: harvest information, logging site configuration, biomass guideline interpretation, environmental considerations, and constraints and opportunities.

[7] Personal communication with Dick Rossman, Minnesota Department of Natural Resources, August 7, 2008.

Three weeks before the phone surveys began, letters were sent to each logger to preface the upcoming evening phone interview. These letters explained the general nature of the questions to be asked, that the survey would not last more than 20 minutes, would not be recorded, would be administered by the senior author, and that participation was entirely voluntary. Additionally, each participant was guaranteed confidentiality. The survey's senior author administered all of the phone calls and recorded all of the responses provided. For each survey category, open-ended responses were analyzed for common themes. Where applicable, memorable quotations have also been included.

Of the 28 loggers identified by the MLEP who currently harvest biomass, 26 loggers were successfully contacted. As many as 20 attempts were made to reach the two remaining loggers for which contact was never established. Only loggers registered as members of the MLEP were contacted for this survey since the required complete contact and harvest information was readily available for this group.

B. Survey Results

1. Harvest Information

a. Number of biomass harvesters

Table 6 illustrates the number of loggers within the state of Minnesota currently harvesting biomass and the equipment that is in use.

Table 6. Breakdown of loggers and their equipment for harvesting biomass in Minnesota.

	Number of loggers	Loggers chipping	Loggers grinding	Loggers chipping and grinding
MLEP Members	28	17	3	8

Source: Minnesota Logger Education Program (MLEP)

Table 7 illustrates the breakdown of all loggers who participated in the survey and their biomass harvesting equipment. Overall, the majority of loggers harvesting biomass are using a chipper (Table 7).

Table 7. Breakdown of all participatory loggers and their biomass harvesting equipment.

No. participating loggers	No. loggers chipping	No. loggers grinding	No. loggers chipping & grinding
26	17	3	6

Figure 2 illustrates the length of time loggers have been harvesting biomass and the type of biomass processing equipment used. Most of the state's loggers who have been harvesting biomass for the longest period of time are using chippers. Loggers who indicated they are using both a chipper and grinder do not constitute a separate category in Figure 2 because often the length of time for utilizing both pieces of equipment is different. For loggers in this category, chippers and grinders were grouped into separate categories based on the number of years of operation for each piece of equipment.

Overall, the majority of loggers who are using both a chipper and grinder have only been doing so for a short period of time (less than ten years).

Survey participants were asked to estimate the amount of time (or percentage of sites) where chipping or grinding is conducted in conjunction with a roundwood harvest. For the majority of loggers (64%), a biomass harvest is almost always conducted when the roundwood harvest is occurring (i.e., roundwood and biomass harvests occur simultaneously 91-100% of the time) (Table 8). Two of the participants were unable to assign a percentage of time to this estimation for two reasons: (1) biomass harvesting is only conducted in the summer when land-clearing sales are available; or (2) this was the first season where the participant had begun to harvest woody biomass.

Figure 2. Years of operation for loggers owning a chipper or a grinder.

Table 8. Percentage of sites with chipping or grinding conducted in conjunction with a roundwood harvest.

% of sites	No. responses
0-10	2
11-20	0
21-30	0
31-40	0
41-50	2
51-60	0
61-70	1
71-80	1
81-90	1
91-100	17
Unsure	2

b. Desirable species

When asked what the most desirable tree species are for chipping or grinding, the majority of loggers said they had no preference (Figure 3). No loggers operating grinders indicated that birch or other hardwoods were the preferred tree species. Loggers who operate grinders often commented that tree specie does not matter due to the ease at which grinders process the material, though they noted that softwoods are an obvious preference as they create less wear and tear on the equipment. Loggers who operate chippers had different tree species preferences. Most loggers who favored chipping particular tree species cited the preference was due to:

- The large volume of chips that is typically gained when chipping a certain species of tree.

- The ease at which the tops and limbs of the tree line up and are processed by the chipper.

Loggers who operate chippers and said they had no preference for certain tree species indicated the nonmerchantable material leftover after a roundwood harvest determined what material was chipped, not the tree species.

Some loggers commented that tree specie of preference is entirely dependent upon the market and the types of chips the chip-consuming industries are accepting. Others noted that preference might be based upon moisture content instead of a particular tree specie.

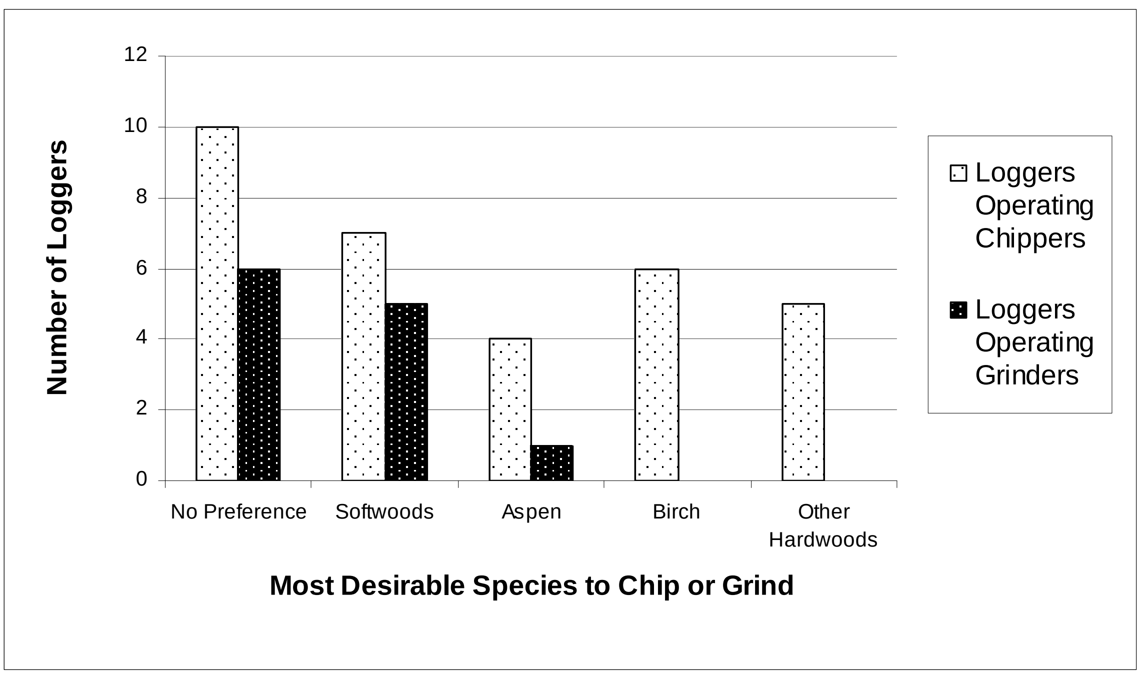

Figure 3. Most desirable tree species to chip or grind as noted by participating loggers.
* Multiple responses for this question were included when named.

When asked to identify the least desirable tree species for chipping or grinding, responses for loggers who operate grinders fell into two main categories: (1) no preference; and (2) other hardwoods (Figure 4). Loggers operating a grinder often commented that hardwoods are the most harsh on the grinder itself and are the most difficult to process. For loggers who operated chippers, the majority of responses fell into three main categories: (1) no preference; (2) softwoods; and (3) other hardwoods. For those loggers operating a chipper that noted no preference for a least desirable tree species for chipping, they often commented that the least desirable specie for chipping depends on the straightness of the top of the tree. Unlike wiry trees, straight trees are easier to line up in piles and can be fed through a chipper more efficiently.

Overall, tree specie has little or no bearing on the harvesting of biomass, though it may be important to an individual logger. Roughly half the loggers surveyed cited particular and often contradicting species of preference for biomass harvesting, while the other half noted that they had no preference. Other factors, such as the shape of the tree and the market parameters for chipped material, seemed to overshadow any species effect.

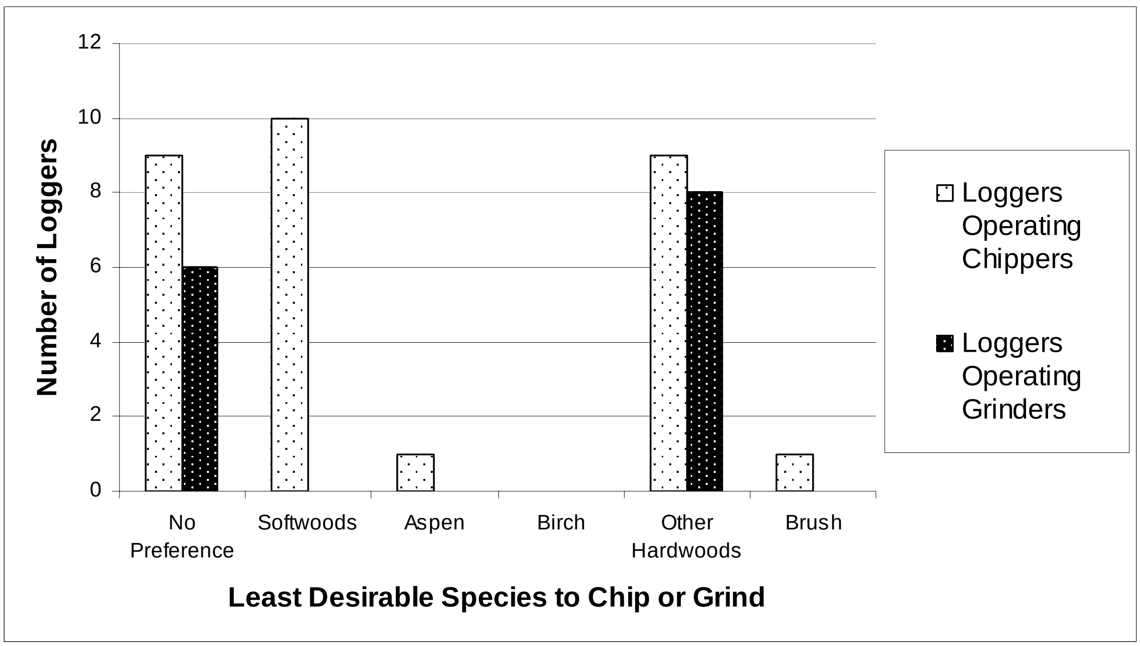

Figure 4. Least desirable tree species to chip or grind as noted by participatory loggers.
* Multiple responses for this question were included when named

c. Tree utilization

In this survey, tops were defined as the upper portion of the main stem below the usual diameter for producing roundwood. Limbs and branches were defined as the unmerchantable portions of the tree along the main stem not contained in the top.

For loggers operating chippers, stems and tops are the most commonly used parts of the tree (Table 9). Though approximately half of the loggers who chip biomass indicated they use the limbs and branches of trees for chipping, the other half noted it is not economical to process limbs and branches. Many loggers also stated that limbs and branches are difficult to chip because:

- Many of the limbs and branches are too wiry to line up and put efficiently through a chipper.

- Limbs and branches are difficult to grab onto and do not chip well.
- Limbs and branches are not economically feasible to chip due to the time and the fuel requirements associated with piling and dragging limbs and branches to the chipper.

- It is simply unnecessary to chip the limbs and branches due to the reduced number of chip loads many plants are currently accepting. These survey respondents indicated some sites have enough chip material available from chipping the tops and the stems alone.

Most loggers who operate grinders had no preference on the parts of the tree used for grinding and almost every logger mentioned that he would use all parts of the tree as grinders can easily pick up any nonmerchantable part of the tree (Table 9).

Table 9. Parts of the tree commonly utilized for biomass with chippers and grinders.

Part of the tree	Loggers chipping	Loggers grinding
Stems	15	6
Tops*	22	8
Limbs and branches	12	9
Other**	2	1

* "Tops" refers to the upper portion of the main stem below the usual diameter for producing roundwood
** "Other" may include brush or all material included in a land-clearing site
*** Multiple responses were included when given

d. Volume removed

Loggers were also asked to estimate how much chip material is removed from the harvest site for each acre harvested (Table 10). While responses to this question came in a variety of metrics, all volume responses were converted to tons per acre. For this conversion, average stand volume (20 cords per acre) and green ton weight was assumed. The standard conversion of 2.3 green tons per cord was used.

The majority of loggers surveyed were unable to estimate the amount of chip material removed for every acre harvested (Table 10). This uncertainty stems from the remarks that loggers were either new to the industry or unable to make a good estimate due to the variation in the types of stands harvested. Production variables such as the size of the logging operation, operation of a chipper compared to the operation of a grinder, logger utilization of the limbs and branches, and logger preference in species for chipping and various site prescriptions all affect the amount of chipped material removed as a percentage of a roundwood harvest. Also, many of the loggers surveyed are chipping for a variety of purposes (e.g., both for energy and primary product manufacturing). These factors and the variation between harvest sites may account for the large discrepancy between the amount of wood residue removed and what the DNR suggests is available for biomass utilization (Table 11 and Table 12). Additionally, many of these variables were noted by loggers as explanations why they were unsure how much biomass material is removed during a harvest.

Table 10. Average amount of chip material removed for every acre harvested as reported by survey participants.

Amount of chip material	No. responses
5-15 tons/acre	2
16-35 tons/acre	1
36-45 tons/acre	0
46-70 tons/acre	2
> 70 tons/acre	1
0-25% of available biomass	4
26-50% of available biomass.	2
Unsure	13
25-30 loads on a 1000 cord site	1

Likewise, considerable biophysical variation exists between harvest sites and may account for the large variation in responses to the amount of biomass removed for every acre harvested (Table 10). Variables such as tree species composition, age class of the stand, season, and the density of the trees all affect the volume of chipped woody material removed from the site. Numerous loggers commented that for mixed stands containing a high percentage of hardwood trees compared to aspen, a larger amount of chipped material is often removed due to the density of available biomass. All of these reasons influence the variability in responses to the amount of chip material removed from a harvest site.

Table 11. Amount of coarse and fine woody debris residue available by harvest type.

	Cubic feet/acre	Cords/acre	Green tons/acre	% Fine woody debris/acre
Clear-cut	523	5.75	12.9	25
Clear-cut with reserve	499	5.48	12.3	27
Partial cut	491	5.40	12.2	26
Unknown	397	4.36	9.8	36.7

Source: Sorensen, 2006

Table 12. Amount of coarse and fine woody debris residue available by cover type.

	Cubic feet/acre	Cords/acre	Green tons/acre	% Fine woody debris/acre
Aspen	519	5.70	12.8	28
Other hardwoods	686	7.54	19.2	20
Lowland conifers	391	4.30	9.5	35
Upland conifers	429	4.71	10.9	31
Unknown	557	6.12	13.8	20

Source: Sorensen, 2006

e. Chipping products

According to the loggers surveyed, the average volume of chipped woody biomass loaded in a chip van is between 25 and 30 tons. Respondents indicated such vans typically take between 16 and 30 minutes to fill (Table 13), although some loggers were unsure about the amount of time it took to fill a chip van. These latter loggers remarked that the time it takes to fill a chip van varies with the species of tree being chipped, whether a piled and ready source of biomass is constantly available for chipping, and the part of the tree being chipped. All of these factors can alter the speed and efficiency of the chipping process.

Table 13. Chip van size and the amount of time required to fill a chip van according to surveyed loggers.

Size of chip van (tons)	No. responses	Time to fill a chip van (minutes)	No. responses
< 25	7	0-15	2
25-30	16	16-30	11
31-40	1	31-45	5
> 40	0	46-60	4
Do not own a chip van	2	> 60	1
		Unsure	3

2. Logging Site Configuration

a. Description of the harvest process

For facilities that use wood-based material to generate energy, some require the material: (1) be within a specified size range; (2) be below a maximum moisture content value; and (3) not contain contaminated material (RE Consulting and Innovative, 2007). From an operations perspective, the greatest challenge lies in finding the most economic approach to converting trees and harvesting residue into a suitable product, and delivering this product to a wood-energy facility (Figure 6) (RE Consulting and Innovative Natural Resource Solutions, 2007).

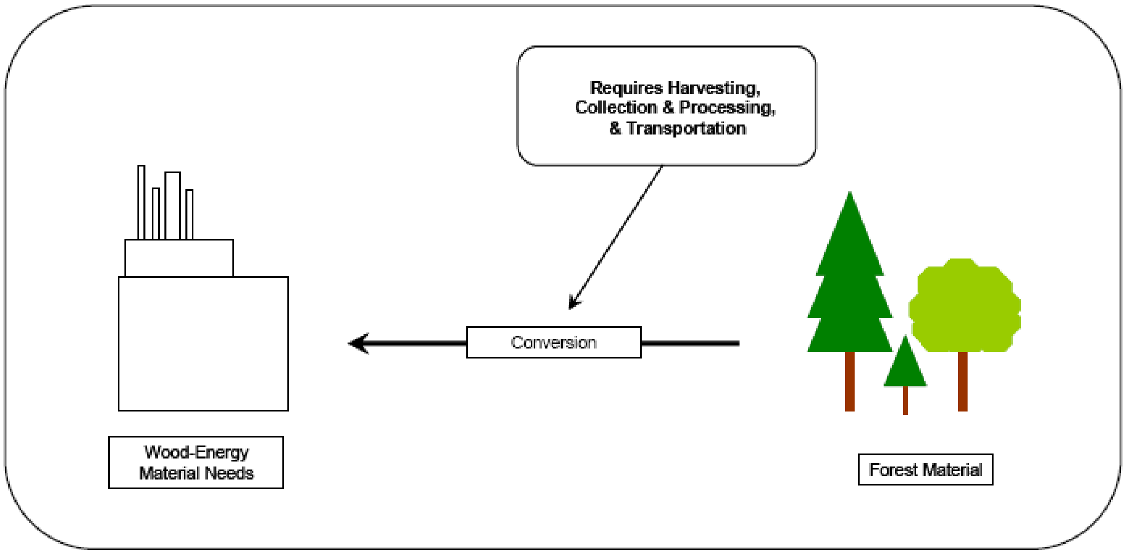

Figure 5. Overview of the in-woods biomass supply issue.
Source: RE Consulting and Innovative Natural Resource Solutions, 2007

In Minnesota, given a roundwood harvest, there are two variants to the process by which loggers utilize additional woody material (i.e., woody biomass). These alternative procurement strategies are differentiated by the utilization of: (1) tops, limbs and branches for biomass; or (2) only the tops of the trees for biomass. Note that tops are the upper portion of the main stem with a diameter smaller than minimum merchantable roundwood standards. If the tops, limbs, and branches are used for biomass, the biomass harvesting process typically mimics that of a conventional whole-tree roundwood harvest operation. The conventional harvesting system is described as a whole-tree harvest operation that processes the tree and the residual biomass (limbs and tops) at the harvest landing. Once at the landing, the unmerchantable portions of the tree (limbs and top) are processed by a chipper or a grinder. If chipped, the biomass is then transported to the mill in a chip van. Few energy wood facilities in Minnesota accept biomass residue that has been processed by a grinder; these woody materials are typically used by the landscaping industry.

If the limbs and the branches are to remain on site (either because of the site prescription or because of landowner preference) and only the top portion of the tree is to be used for biomass, then delimbing is conducted in the woods, and whole-tree skidding back to the landing does not occur. In this scenario, limbs and branches are typically scattered throughout the site or may be occasionally piled to be burned later by the landowner.

b. Harvesting equipment

Loggers were asked to describe their logging equipment configurations at the harvest site. Of those surveyed, 16 (61%) indicated they are using a fellerbuncher together with whole-tree skidding to the landing (Table 14). Four loggers indicated that they are using a cut-to-length system and delimbing at the stump.

Table 14. Logging site configurations for surveyed loggers harvesting biomass.

Logger operation setup	Cut-to-length/ forwarder configuration	Feller bunchar/skidder/slasher configuration*
Chipping	4	16
Grinding	1	2
Chipping and Grinding	2	6

* This configuration includes one logger using a hand feller

** For logging operations with a variety of site configurations, all responses were reported

c. Delimbing location

Loggers were asked to identify where the majority of the delimbing occurs. Eleven loggers who process biomass (50%) indicated that delimbing is done next to where the chipper or grinder is located (or will be located if the chipping or grinding takes place after the roundwood harvest), while eight biomass loggers (36%) responded that delimbing occurs at the stump (Table 15).

Table 15. Location of delimbing for surveyed loggers.

Number delimbing next to chipper/grinder	Number delimbing in the woods	Number who responded "depends"	Number not applicable
11	8	3	4

* Not applicable loggers consist of those who only conduct roundwood harvests

Loggers who are delimbing next to where the chipper or the grinder is located responded that they are doing so because:

- Landowners prefer this method to contain the debris and make the site more aesthetically pleasing.
- All portions of the tree will be chipped (including limbs and branches); thus, it is more efficient to delimb next to where the chipper is located.

Those loggers who are not delimbing next to where the chipper or the grinder is located responded that they are doing so because:

- The delimbing equipment works best in the woods or is part of the in-woods harvesting equipment.
- The limbs and branches are not chipped; thus, it is easier to delimb in the woods and skid only the portions of the tree back to the landing that will be harvested.
- Some MNDNR sales will not allow the delimber to be located at the landing.

- Landing space is not large enough to contain a delimber; it becomes too congested.

- If the limbs and branches must be scattered in the woods (due to a site prescription or landowner preference), then it is easier to delimb at the stump and leave the branches where they fall.

Three loggers that responded “it depends” to the question of where the delimbing is done (Table 15) responded so because one of the loggers uses a chainsaw for delimbing and the others said the variability is based on the size of the landing (larger landing areas allow for delimbing to be done next to where the chipper or the grinder is located).

d. Disposition of remaining limbs and branches

For the surveyed loggers not processing the limbs and branches as part of a biomass harvest, the majority are scattering the limbs and branches across the site (Table 16). For limbs and branches that are piled either at the landing or on the site, the majority of the loggers surveyed indicated these piles are burned (Table 17). Loggers commented that the decision to burn is entirely up to the landowner and/or site prescription and thus, varies between sites, is not the loggers’ responsibility, and happens after the logger is finished with the harvest.

Table 16. Disposition of the limbs and branches that are not utilized as a part of a biomass harvest.

Fate of remaining limbs and branches	No. responses
Piled across the site	7
Piled at the landing	6
Scattered across the landing	17
Not applicable	4

* Not applicable loggers consist of those loggers who consistently harvest the limbs and branches
** For loggers that gave multiple responses, all responses are listed

Table 17. Disposition of the piled limbs and branches according to surveyed loggers.

Branches burned?	No. responses
Yes	14
No	2
Unsure	10

e. Time of biomass harvest

Of the loggers surveyed, 14 (54%) indicated biomass harvesting is conducted concurrently with the harvesting of roundwood, while nine loggers 35%) stated biomass is typically harvested only after all of the roundwood has been harvested and removed from the harvest site (Table 18).

Table 18. Time of occurrence of biomass harvest for surveyed loggers.

No. harvesting biomass simultaneously with roundwood	No. harvesting biomass after roundwood harvest	No. loggers who responded "depends"
14	9	3

The loggers that harvest biomass simultaneously with a roundwood harvest offered several explanations for doing so:

- Chipping is a more efficient process when it is done simultaneously with a roundwood harvest.

- Some slashers are set up to transfer the wood directly to the chipper or the grinder.

- Owning a small amount of harvesting equipment requires that all harvests be done simultaneously; equipment cannot occupy multiple sites at the same time.

- It is most efficient to have the same team of loggers harvest the biomass that harvested the roundwood. Harvesting processes are significantly slower when a second team of loggers comes in afterwards and begins the biomass harvest that was set up by a different team of individuals.

For the loggers harvesting biomass after roundwood harvest is completed, several explanations were offered (note that some of these comments contradict the statements made by loggers who harvest biomass simultaneously with a roundwood harvest):

- Chipping is a more efficient process when it is conducted after the roundwood harvest.

- Inconsistent markets and backups at the receiving end do not require the need for continual chipping.

- Some firms or industries pay more for chips with a reduced moisture content; chipping after the roundwood harvest allows for drying time.

- Consumer-scale pricing on some MNDNR sales requires the chipping to be done after the roundwood harvest.

- The loggers may only be running a chipping business that always harvests biomass after another logger has previously harvested the roundwood.

- A preferred method is to chip every other day between roundwood harvest loads.

- Chipping must be done after the roundwood harvest due to backups and space limitations at the landing.

Three of the loggers were unable to generalize the time that biomass harvesting takes place due to the variability in their harvest operations. These loggers indicated the size of the timber sale may determine whether chipping is done concurrently with the harvesting of roundwood—larger timber sales are more prone to a simultaneous biomass harvest. Additionally, some of the loggers surveyed do not harvest both roundwood and biomass on all sites.

f. Variation in site configuration

Of the 26 loggers surveyed, 18 (69%) said that they do not alter their plan for harvesting a site differently if they are going to chip or grind as a part of the roundwood harvest, while seven (27%) indicated they would change the site layout. One logger always chips or grinds as a part of the roundwood harvest. For those loggers that do lay out their site plans differently when harvesting biomass, the explanations are as follows:

- If chipping or grinding, the slasher and the chipper or the grinder are both located at the same landing.

- The limbs and branches will be piled neatly (as opposed to scattered throughout the site) and continually organized at the main landing if chipping or grinding is to be conducted at that location.

- If chipping or grinding, the landing will be set up so that the chipper or grinder is visible while slashing and delimbing.

3. Biomass Guideline Interpretation

Twenty-three of the 26 surveyed loggers (88%) indicated they were familiar with Minnesota's BHGs. While only half reported having attended a training session for the guidelines, many said they intend to do so in the near future.

Loggers who participated in the survey were reminded the MFRC BHGs recommend leaving 33% of the woody material on site, specifically:

> *The overall goal of FWD retention is to retain about one-third of the FWD on a site. This goal is achieved by intentionally retaining 20% of the FWD (tops and limbs from one "average-sized" tree out of every five trees harvested), with an additional 10-15% achieved by incidental breakage during skidding* (Minnesota Forest Resources Council, 2007, p.29).

Each logger was asked to identify the strategy(s) they employed to leave some woody material on site (regardless of whether this material constituted 33%). Eight loggers (31%) said they were intentionally leaving woody material on site, while the majority of loggers (18 or 69%) were not intentionally leaving woody material on site (though material may still remain on site through breakage and other aspects of the harvest process).

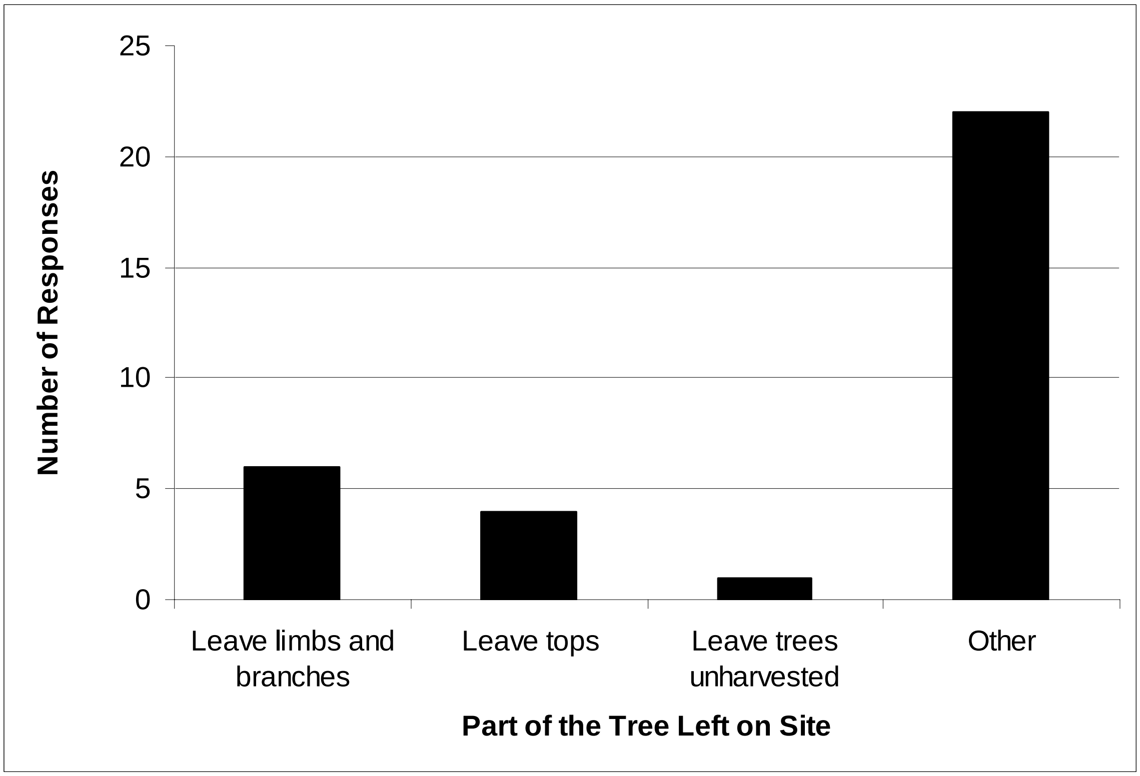

Figure 6. Breakdown of the type of woody material left on site after a biomass harvest according to surveyed loggers.
* If loggers listed multiple types of woody material left behind, all responses are given
** Other refers to woody material not listed, such as breakage

The majority of loggers in this survey are leaving "other" types of woody material on site, such as material produced through incidental breakage (Figure 7). The remaining respondents stated the residual biomass left on site comes from (in order of declining frequency) limbs and branches, tops, and leave trees.

For loggers that indicated they leave "other" types of woody material on site, there was no consensus whether this material constituted 33% of the available biomass. Many loggers commented that:

- By chipping only what makes it to the landing, one is still not leaving 33% of the woody material on site.

- Breakage alone accounts for more than 33%.

- The amount of breakage that occurs depends on the season of harvest and the age of the trees in the stand.

    - "Most of the wood on state sales is so far over mature, it would be impossible to take it all. It breaks when it hits the ground."

- More than 33% is left on site through the process of harvesting (e.g., breakage, snags, and not cleaning piles completely).

a. Additional comments for woody material left on site

When asked for additional comments regarding the BHG's recommendation to leave 33% of woody material on site, the following responses were given:

- Loggers using grinders are not leaving 33% of the material on site. "They take everything."

- Many loggers thought leaving 33% of the woody material on site was too high an amount.

    - On state or county sales, where 33% is required, this amount takes away from the profitability of chipping. "By forcing me to leave 33%, you're trying to pull the rug out from underneath me."
    - "I don't agree with 33%, we've been doing it for 20 years and everything (regeneration) was fine. It's not cost efficient to leave 33% on site."

- The amount of material left on site varies with the species present in the stand. Certain loggers have preferences for what species can be chipped.

- Concern over how to estimate what retaining 33% of the available material looks like.

    - "I have no idea (if 33% remains on site), there's crap laying everywhere."
    - "I don't know how to gauge 33%."

- The amount of material left on site varies with the landowner. State and county sales have very different site prescriptions than those of private landowners or land-clearing sites.

- Depending on the size restrictions a logger utilizes in roundwood, the amount of material left on site can be altered.

b. Suggestions for improvement

During the survey, loggers were asked to suggest improvements to Minnesota's BHGs. Of the loggers surveyed, 17 did not have suggestions for improving Minnesota's BHGs. However, nine loggers provided the following comments/suggestions:

- "Before you make any more guidelines, find out if it's economically feasible first."

- Roundwood should be available and classified as chip material. There is little use for roundwood as paper mills continue to shut down.

- The methods for critiquing or reviewing a site for biomass removal after the removal has already taken place need to be revised. There is an unfair comparison being made between the amount of biomass removed and what was available in the beginning.

- The BHGs should be made from a landscape perspective. They cannot be the same across all types of forest sites.

- Leaving 33% of the material on site is too high of an amount. The percentage should be re-evaluated and lowered.

- Pure bark that remains on some sites as the result of clean chipping should not be permitted to remain on site. "It remains on the site forever."

4. Environmental Considerations

Seventeen of the responding loggers 65%) said there were certain types of harvest sites or areas within these sites where they would not harvest biomass. When asked to describe the types of sites where loggers would not harvest biomass, the following themes in responses were given:

- Loggers' ability to harvest biomass depends on the site prescription or landowner objectives.

- Many loggers said they would not harvest biomass on sites with nutrient poor or sandy soils. Some loggers commented that they might still harvest biomass on these sites but would then leave more woody material behind to aid with soil erosion and nutrient replacement.

- The majority of the loggers interpreted this question from a production point of view. For these loggers, types of sites where biomass harvesting would not be conducted include: sites where the volume of top material is minimal and the return is small (e.g., black spruce swamps, stands consisting of all aspen or stands consisting of only jack pine), sites that are not large enough to allow for the passage of a chip van, or sites that consist solely of brush material.

Nine respondents (35%) indicated there were no situations that would prohibit them from harvesting biomass.

5. Constraints and Opportunities

a. Opportunities for biomass harvesting

Loggers were asked to identify both the greatest opportunity and the greatest constraint to biomass harvesting that will emerge in the future. As for the greatest opportunity associated with biomass harvesting, the following themes were identified:

- Increased market options. Many loggers believe that the industry will continue to grow as fuel costs continue to rise and that markets will continue to emerge, which could prove advantageous as the distance needed to transport biomass may decrease. Likewise, many loggers commented that the rising costs of fuel will add value to their end product; some noting the development and more recent need for wood pellets. However, numerous loggers noted that in order for this industry to expand, markets must become more consistent in their demand and the price paid for the end product must be competitive and increase.

    - "I think it's (biomass harvesting) the future and it's gonna happen. There needs to be a consistent demand and the prices have to adjust though."

- The growth and emergence of clean energy. Several loggers expressed excitement and optimism over the continued growth and use of biomass to produce renewable energy, and possibly at a reduced cost.

- Environmental benefits of biomass harvesting. Some loggers cited biomass as a clean environmental alternative to burning coal, while others noted the positive effects on forest health that biomass harvesting produces.

    - "I hope resource managers look at this (biomass harvesting) as a tool to improve forest health."
    - "I think it (biomass harvesting) looks better and it's good for wildlife and the environment. Let's do it!"

- Forests' ability to sustain biomass harvesting. Numerous loggers pointed to the sustainability of this industry. Some loggers believe that more stands may lend themselves to biomass harvesting in the future while others pointed to the short turn around time between harvests. Several loggers expressed the desire to chip whole trees.

    - "Running around cleaning up piles is a lot of work for a little payout."

- The growth of the biomass harvesting business as an opportunity for young and upcoming loggers. One logger pointed to the potential benefits young loggers might receive from a business with a limited number of people, while another logger pointed out that biomass harvesting improves the logging industry's public image.

    - "Biomass harvesting makes the industry look a little cleaner."

- A few loggers commented that neither benefits nor opportunities exist with biomass harvesting.

    - "I don't want to paint the picture that biomass harvesting is this great thing. For how much fuel and energy that's involved, it's a waste."
    - "I think biomass harvesting is a useless waste of time and energy. It's not efficient or effective and it's a waste of time."

b. Constraints for biomass harvesting

As for the greatest constraints associated with biomass harvesting, the following themes were identified in the responses:

- Existing markets and price paid for the end product. Many loggers noted that the combination of the small price paid for the delivered product, the lacking number of outlets for the product, and the instability of the current markets makes biomass harvesting economically infeasible in its current state.

    - "If you're going to compete dollar for dollar with western coal, you can't go out there and operate this equipment for less than $30/gr. ton and expect to make $16/gr. ton for the end product."
    - "How do you harvest something that's worth the cost of trucking to get it there?"

- The cost of equipment and the harvesting process outweighing the profits made from harvesting biomass. With an average chipper or grinder costing between $300,000-$500,000, loggers are making large, long-term investments in a market where the returns are currently minimal. Likewise, the fuel costs associated with harvesting biomass and with delivering it to the industry are also large. Some loggers expressed concern over the difficulty of small logging businesses being able to join the biomass harvesting industry due to the large initial costs.

    - "Markets are not paying near enough for the investments we've made."
    - "It's not economically feasible to harvest the slash with the current cost of fuel."
    - "Transportation costs can really eat us up right now."

- “All of us with grinders, we had a meeting today. We’re all going to get out of it in the next two weeks if prices don’t improve.”
- “I hope you…figure this dilemma out real soon.”
- “Biomass harvesting is too expensive: fuel, equipment, the entire operation.”
- “We used to leave all that wood in the woods. Now, they say it’s worth it to haul it out. But, in a lot of stands, it’s still worthless to spend that much time, equipment and energy to harvest that little bit.”
- “Distances to energy plants need to be shorter with the high costs of fuel.”

* Lack of available material for harvest. In order to make the industry profitable, many loggers pointed to the need to increase the amount of available harvestable material. For some loggers, this meant the ability to chip whole trees, for others, an increase in the amount of sales that are up for biomass harvesting.

  - “You can’t get enough material cutting the tops and the scrap. There’s not enough material even if you cut down all the houses in Minneapolis.”
  - “We should grind whole trees. We need to figure out how to use each product best for the necessary market.”
  - “New foresters are overly protective with the increased removal of wood. They don’t offer sites that really should be up for biomass harvesting.”
  - “What about people trying to use more than what they should. You know, nutrient regeneration?”
  - “I don’t know why we’re not chipping more whole trees and they’re not paying more for it. What’s the difference between cutting the tree down for roundwood versus chipping.”

* Concern over the use and development of biomass harvesting guidelines and regulations. Some loggers identified conflict between landowner objectives and the utilization of the BHGs. Others were hesitant toward further guideline development.

  - “If there are too many regulations, you lose the industry.”
  - “Many people are trying to make regulations and very few of them own any equipment. You all try to tell us what to do, yet you don’t really have any logger experience.”

* One logger had a strong adverse perception of the media’s attention to biomass harvesting. He believes this attention has driven down revenues from the product.

  - “The media and…people who are sticking your nose into our business. You … think we’re getting rich and now you want a handout. You’re cutting into our profits greatly and enabling power plants to get something for nothing.”

VII. Synthesis of Best Harvesting Practices

A. Synthesis

The BHGs developed by the MFRC (in conjunction with the General TH/FM Guidelines) represent a synthesis of the best-available scientific information regarding the effects of biomass harvesting on the environment and are considered sufficient for minimizing adverse effects to the environment. They further appear to address most if not all of the challenges in biomass harvesting with respect to sustaining long-term forest soil and overall site productivity. However, as outlined below, there are study areas where more information would be instructive to potentially further guideline development for biomass harvesting.

While literature regarding the effects of biomass harvesting on soils, water quality and wildlife exists, studies on the effects of biomass harvesting on site productivity as a whole are almost nonexistent.

A survey of the current biomass harvesting practices in Minnesota indicated that while most of the loggers are not intentionally leaving a specified percentage of FWD on site, many are leaving a sufficient amount of woody residue (often more than 33%) on harvest sites due to incidental breakage. However, this situation and a lack of methodology (for estimating the volume of residual material retained on the site post harvest) implies a potential gap between the BHGs' recommended amount (33%) of FWD to be retained and the amount of woody residue loggers are intentionally or otherwise leaving. This potential gap deserves further study with respect to its magnitude, frequency, importance and associated methodology to allow more precise estimation of material retained on sites.

With respect to operational efficiency, loggers, scientists and forest resource managers are urged to collaborate to identify efficient biomass harvesting site configurations. Though biomass harvesting is not entirely new to Minnesota, the industry itself has not been around long enough to develop harvesting site configurations that are both efficient and allow a large number of loggers to succeed. Currently, diverse site configurations suggest many loggers are just beginning to understand the most efficient ways to operate.

Finally, to the best of our knowledge, this is the first study that extensively inventoried and sought information from all loggers in a state that harvest biomass. Results clearly indicate some key economic issues such as: the need for efficient timber sale designs, a consistent demand from the market, an increase in the price paid for the delivered product, and a reduction in distance required to deliver the product to the industry. These are all important aspects of biomass harvesting that emerged from logger's responses and raise important points about the woody biomass industry. As the biomass harvesting industry evolves, a follow up on this survey may help in clarifying the above issues and with development of biomass energy policy overall.

B. Research Needs

Although the BHGs recommend leaving 33% FWD on site after harvest, few studies have examined the negative and/or positive effects on long-term forest productivity associated with retaining various levels of residual material from biomass harvesting. Associated with this concern, we urge a synthesis of existing research (e.g., in the areas of silvics and silviculture) that identifies how much FWD is appropriate to foster the regeneration, retention and growth of various tree species, forest types and associated plant and animal populations. Such information is central to understanding forest productivity and forest type sustainability.

Further research is also appropriate to assess whether the recommended amount of residual material is actually being left on site, regardless of whether the effort was intentional or not.

Finally, loggers in this study pointed to the difficulty visually judging what constitutes 33% FWD to be left on the site post harvest. Fortunately, the MNDNR has recognized this need and is currently developing visual guides for retaining FWD.

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VIII. Literature Cited

Astrom, M.M., M. Dynesius, K. Hylander, and C. Nilsson. 2005. Effects of slash harvest on bryophytes and vascular plants in southern boreal forest clear-cuts. *Applied Ecology* 42(6):1194-1202.

Batzer, D.P., B.M. George, and A. Braccia. 2005. Aquatic invertebrate responses to timber harvest in a bottomland hardwood wetland of South Carolina. *Forest Science* 51:284-291.

Bechtold, W.A., and P.L. Patterson, eds. 2005. *The enhanced Forest Inventory and Analysis program-national sampling design and estimation procedures*. USDA Forest Services, South Research Station, General Technical Report SRS-80.

Belleau, A., S. Brais, and D. Pare. 2006. Soil nutrient dynamics after harvesting and slash treatments in boreal aspen stands. *Soil Science Society of America Journal* 70:1189-1199.

Berguson, B. 2007. Minnesota's woody biomass resources and opportunities in the emerging energy industry. Unpublished Report. University of Minnesota, Natural Resources Research Institute, Duluth, MN.

Brown, R.N., A.R. Ek, and M.A. Kilgore. 2007. *An assessment of dead wood standards and practices in Minnesota*. Staff Paper Series No. 189. St. Paul, MN: University of Minnesota, Department of Forest Resources.

Dahlman, R., and M.J. Phillips. 2004. *Baseline monitoring for implementation of the timber harvesting and forest management guidelines on public and private forest land in Minnesota: combined report for 2000, 2001, and 2002*. DNR Document MP-0904. Submitted to the Minnesota Forest Resources Council. St. Paul, MN: Minnesota Department of Natural Resources.

Dovetail Partners, and S. Ramaswamy. 2007. *An assessment of the potential for bioenergy and biochemicals production from forest-derived biomass in Minnesota*. Dovetail Partners, Minneapolis, MN.

Grigal, D.F. 2004. *An update of forest soils. A technical paper for a generic environmental impact statement on timber harvesting and forest management in Minnesota.* Submitted to Laurentian Energy Agency, Virginia, MN. 32 pages. (mimeo)

Hunter, M.L., Jr. 1999. Maintaining Biodiversity in Forest Ecosystems. Cambridge University Press, Cambridge, MA. 714 pages.

Hutchens, Jr. J., D.P. Batzer, and E. Reese. 2004. Bioassessment of silvicultural impacts in streams and wetlands of the eastern United States. *Water, Air and Soil Pollution*: Focus 4:37-53.

Hutto, R.L. 2006. Toward meaningful snag-management guidelines for post-fire salvage logging in North American conifer forests. *Conservation Biology* 20:984-993.

Inman, R.L., H.H. Prince, and D.B. Hayes. 2002. Avian communities in forested riparian wetlands of southern Michigan, USA. *Wetlands* 22(4):647-660.

Jaakko Pöyry Consulting, Inc. 1994. *Generic Environmental Impact Statement (GEIS) Study on Timber Harvesting and Forest Management in Minnesota*. Minnesota Environmental Quality Board. Tarrytown, NY: Jaakko Pöyry Consulting, Inc.

Jobin, B., L. Belanger, C. Boutin, and C. Maisonneuve. 2004. Conservation value of agricultural riparian strips in the Boyer River watershed, Quebec (Canada). *Agriculture, Ecosystems and Environment* 103:413-423.

Kilgore, M.A. and D.G. MacKay. 2007. Trends in Minnesota's forest land real estate market: implications for forest management. *Northern Journal of Applied Forestry* 24(1): 37-42.

Kohm, K.A., and J.F. Franklin. 1997. *Creating a Forestry for the 21st Century: The Science of Ecosystem Management*. Washington, D.C.: Island Press. 475 pages.

Latty, E.F., S.M. Werner, D.J. Mladenoff, K.F. Raffa, and T.H. Sickely. 2006. Response of ground beetle (Carabidae) assemblages to logging history in northern hardwood-hemlock forests. *Forest Ecology and Management* 222:335-347.

Lee, P., and S. Crites. 1999. Early successional deadwood dynamics in wildfire and harvest stands. In *Fire and Harvest Residual Project: The Impact of Wildfire and Harvest Residuals on Forest Structure and Biodiversity in Aspen-dominated Boreal Forests of Alberta,* ed., Lee, P., 65-85. Vegreville, Alberta: Alberta Research Council.

Maritikainen, P., J. Siitonen, P. Punttila, L. Kaila, and J. Rauh. Species richness of colepoptera in mature managed and old-growth boreal forests on southern Finland. *Biological Conservation* 94:199-209.

Miles, P.D., G.J. Brand, C.L. Alerich, L.F. Bednar, S.W. Woudenberg, J.F. Glover, and E.N. Ezell. 2001. *The forest inventory and analysis database description and users manual version 1.0*. USDA Forest Service, North Central Research Station, General Technical Report NC-218.

Minnesota Department of Natural Resources. 2006. *The Market Place: Woody Biomass in Minnesota*. St. Paul, MN. http://files.dnr.state.mn.us/publications/forestry/marketplace/summer2006.pdf

Minnesota Department of Natural Resources. 2007a. *Minnesota's Forest Resources: Annual Report*. St. Paul, MN. http://files.dnr.state.mn.us/forestry/um/minnesotaforestresources_rt2007.pdf

Minnesota Department of Natural Resources. 2007b. The *Market Place: Woody Biomass Update*. St. Paul, MN. http://files.dnr.state.mn.us/publications/forestry/marketplace/summer2007.pdf

Minnesota Department of Natural Resources. 2008. *The Market Place: Wood Energy*. St. Paul, MN. http://files.dnr.state.mn.us/publications/forestry/marketplace/marketplace_winter0708.pdf

Minnesota Department of Natural Resources. 2008c. *The Market Place: Woody Biomass Demand Update*. St. Paul, MN. http://files.dnr.state.mn.us/publications/forestry/marketplace/marketplace_Spring2008.pdf

Minnesota Forest Resources Council (MFRC). 2006. *Scoping document for the biomass guideline committee*. St. Paul, MN. http://www.frc.state.mn.us/FMgdline/MFRC%20Approved%20Biomass%20scoping%20document%205-17-06.pdf

Minnesota Forest Resources Council (MFRC). 2005. *Sustaining Minnesota forest resources: Voluntary site-level forest management guidelines for landowners, loggers and resource managers*. St. Paul, MN: Minnesota Forest Resources Council.

Minnesota Forest Resources Council (MFRC). 2007. *Biomass Harvesting on Forest Management Sites*. Minnesota Forest Resources Council, St. Paul, MN.

Minnesota Logger Education Program (MLEP). 2008. *Membership Directory*. Duluth, MN.

Minnesota Statutes. 2004. Office of the Revisor of Statues. State of Minnesota. Chapter 89A. St. Paul, MN.

Niemala, J. 1997. Invertebrates and boreal forest management. *Conservation Biology* 11:601-610.

RE Consulting and Innovative Natural Resource Solutions LLC. 2007. *Forest Harvest Systems for Biomass Production: Renewable Biomass from the Forests of Massachusetts*. Prepared for the Massachusetts Division of Energy Resources and Massachusetts Department of Conservation and Recreation. Orono, ME.

Rummer, B. 2004. Managing water quality in wetlands with forestry BMPs. *Water, Air and Soil Pollution*: Focus 4:55-66.

Semlitsch, R.D., and J.R. Bodie. 2003. Biological criteria for buffer zones around wetlands and riparian habitats for amphibians and reptiles. *Conservation Biology* 17(5):1219-1228.

Sorensen, L. 2006. *Minnesota Logged Area Residue Analysis*. St. Paul, MN: Minnesota Department of Natural Resources, Forestry Division Utilization and Marketing Program.

Sorensen, L. 2007. *Woody Biomass Energy Facilities in Minnesota*. St. Paul, MN: Minnesota Department of Natural Resources, Forestry Division Utilization and Marketing Staff.

Sturtevant, B., R. Bissonette, J. Long, and D.W. Roberts. Coarse woody debris as a function of age, stand structure and disturbance in boreal Newfoundland. *Applied Ecology* 7:702-712.

Tikkannen, O-P, P. Marttikainen, E. Hyvarinen, K. Junninen, and J. Kouki. 2006. Red listed boreal forest species of Finland: associations with forest structure, tree species, and decaying wood. *Animal Zoology* 43:373-383. Fennici.

USDA Forest Services. 2006. Query from FIA database for Minnesota. Website: http://www.fia.fed.us.

IX. Glossary

Biological Legacy: "Anything handed down or carried over from a predisturbance forest ecosystem, including green trees, patches of undisturbed vegetation, surviving propagules and organisms (e.g., buried seeds, seeds stored in serotinous cones, surviving roots, basal buds, mycorrhizal fungi, and other soil microbes, invertebrates and mammals), dead wood, and certain aspects of soil chemistry and structure" (Minnesota Forest Resources Council, 2007).

BHGs: Biomass Harvesting Guidelines, as developed by the MFRC (2007)

CWD: Coarse Woody Debris

dbh: **Tree** Diameter at Breast Height (1.3 m, 4.5 ft)

ETS: Endangered, Threatened and Special Concern Species

FSC: Forest Stewardship Council

FWD: Fine Woody Debris

GEIS: Generic Environmental Impact Study

GIS: Geographic Information Systems

MCBS: Minnesota County Biological Survey

MFRC: Minnesota Forest Resources Council

MLEP: Minnesota Logger Education Program

MNDNR: Department of Natural Resources

NIPF: Non-industrial Private Forest

RMZ: Riparian Management Zones

SFI: Sustainable Forestry Initiative

SFP: Special Forest Products

SFRA: Sustainable Forest Resources Act

SRWC: Short Rotation Woody Crops

TH/FM: Timber Harvest/Forest Management

TSI: Timber Stand Improvement

USDA: United States Department of Agriculture

IX. Survey Questions

I. Harvest Information

1. How many years have you been operating a chipper or grinder?
2. On what percent of your chipping or grinding sites do you also harvest roundwood (either pulp, bolts or sawtimber)?
3. What are the most desirable tree species to chip or grind? Why?
4. What are the least desirable tree species to chip or grind? Why?
5. What parts of the tree do you chip or grind?
   - -Stems (Always Sometimes Seldom)
   - -Tops (Always Sometimes Seldom
   - -Limbs and Branches (Always Sometimes Seldom)
6. What percent of your chips go to:
   - -Utilities (for example, Laurentian energy)
   - -Wood product manufacturing (for example, GP)
   - -Hogfuel at a wood processing facility (for example, SAPPI)
   - -Other (specify)
7. On average, how much chip material do you remove from the harvest site from each acre harvested (tons per acre harvested)?
8. How large is your chip van (tons capacity)?
9. On average, how long does it take you to fill a chip van?

II. Logging Site Configuration

10. When does the chipping or grinding take place?
11. Indicate the equipment (and quantity) you usually have on site when you chip or grind:
    - -chipper
    - -grinder
    - -feller buncher
    - -skidder
    - -harvester
    - -forwarder
    - -delimber (brand, model)
    - -slasher (brand, model)
    - -loader
    - -other
12. Do you delimb next to where your chipper or grinder is located (or will be located if you chip after the roundwood harvest is complete)? If no, explain why not.
13. Do you lay out your plan for harvesting a site differently if you are going to chip or grind as part of a roundwood harvest? If yes, explain how the layout differs.
14. If you do not chip the limbs and branches, what is done with them?
    - -Limbs and branches are piled at various locations across the site
    - -Limbs and branches are left piled at the landing
    - -Limbs and branches are left on the ground across the harvest site
15. If the limbs and branches are piled, are they burned?

16. What percent of the time to you wait until the roundwood harvest is completed before beginning your chipping/grinding operation?

III. Biomass Guideline Interpretation

17. Are you familiar with Minnesota's Biomass Harvesting Guidelines?

18. Have you attended a training session for using Minnesota's Biomass Harvesting Guidelines?

19. How do you attain the biomass guideline recommendation of leaving approximately 33% of material on site?

- -leave limbs and branches
- -leave tops
- -leave trees unharvested
- -other (specify)

20. Do you have any suggestions for improving Minnesota's Biomass Harvesting Guidelines? If yes, please explain.

IV. Environmental Considerations

21. Are there certain types of sites or areas within sites where you would no chip or grind? If yes, please explain.

V. Constraints and Opportunities

22. Looking into the future, what do you see as the greatest opportunity regarding biomass harvesting?

23. What do you see as the greatest constraint regarding biomass harvesting?

24. Are there any additional comments you would like to make?