Report: Environmental Effects of Forest Biomass Removal

Office of the State Forester
Oregon Department of Forestry

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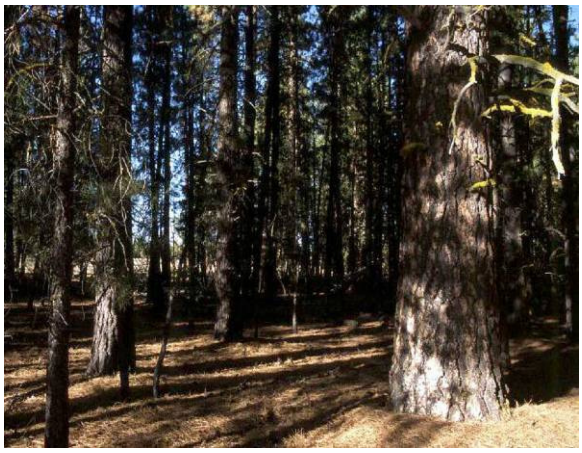

Typical overcrowded stand conditions

Restoration thinnings utilizing woody biomass

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Report on Environmental Effects of Forest Biomass Removal

Concerned about the health of Oregon's forestlands, increasingly large and frequent wildfires, and associated expenditures and impacts, the 2005 Oregon Legislature passed Senate Bill 1072 (Chapter 772, Oregon Laws 2005) as part of broader efforts to reduce wildfire fuels, and to promote the health of forests and rural economies via active forest management. Key elements of SB 1072 direct the State Forester to:

- Become more involved in federal forestland policy development to improve forest conditions on federal lands; (Addressed through the Oregon Board of Forestry -Federal Forestland Advisory Committee)
- Identify areas of interface between urban lands and forestlands that possess the highest potential to threaten lives & private property; (Addressed through Community Wildfire Protection Planning)
- Support efforts to build, and place in service, biomass fueled energy production facilities while promoting public understanding that woody biomass utilization may be an effective tool for restoration of forest health and for economic development in rural communities; (Addressed through the Oregon Forest Biomass Work Group) and
- Prepare a report every three years utilizing, to the greatest extent practicable, data collected from state and federal sources that specify the effect of woody biomass collection and conversion on the plant and wildlife resources and on the air and water quality of this state. The report shall identify any changes that the State Forester determines are necessary to encourage woody biomass collection and conversion and to avoid negative effects on the environment from woody biomass collection and conversion. The State Forester shall submit the report to the Governor and to an appropriate legislative interim committee with jurisdiction over forestry issues (Addressed through this and future reports).

In this report, woody biomass is defined as material from trees and woody plants, including limbs, tops, needles, leaves and other woody parts that are by-products of forest management, ecosystem restoration or hazardous fuel reduction treatments.

Primary components of the report include:

- An introductory section of the report summarizes forest health and biomass conditions that led to passage of SB 1072,
- Literature review synthesis regarding the effects of removing woody biomass from forest ecosystems on plant, wildlife, soil, water and air resources,
- Current resource protections for biomass removal operations on various forestland ownerships in Oregon,
- Woody biomass utilization trends for energy production in Oregon, and
- State Forester conclusions and recommendations to encourage woody biomass collection and conversion while avoiding negative effects on the environment.

The potential environmental outcomes of woody biomass removal are complex and inter-related. Effects may be positive, negative or a mix of both. The **Literature Review Synthesis** that follows has sections on plant, wildlife, soil, water and air quality effects. Very few studies identified in this review address the effects of forest biomass removal specifically. Most information came from research on the effects of thinning and fuel reduction treatments. Refer to Appendix A for a more detailed review of available research information.

Plants: In general, opening up dense stands over time increases understory plant biomass and biodiversity, and habitat diversity for wildlife. Conifers may re-establish but newly open habitats may also be colonized by other native plants, or by invasive exotics. Thinning densely stocked ponderosa pine and Douglas-fir stands generally improves the vigor of remaining trees by reducing competition for water and soil nutrients. Increased tree vigor can reduce susceptibility to insect attack. Thinning creates new germination sites and canopy openings that may increase light, water, nutrient availability and soil temperatures. However removing a portion of standing trees can also increase the susceptibility of residual trees to windthrow and alter fire behavior by facilitating increased wind speeds through the forest. Additionally, residual trees may be damaged during biomass removal.

Conifer root diseases can cause significant tree mortality but are also natural and necessary decomposers in forest ecosystems. Root disease effects may be considered beneficial or detrimental depending on social values, landowner goals and management objectives for the stand. Fuel treatments can influence root disease in complex ways that should be considered at the stand level. It is beneficial to know where root diseases occur in a stand before removing biomass, and to avoid wounding trees during harvesting.

Wildfire is a key ecological process, but effects of uncharacteristically severe fires may be negative and substantial. Topography and weather may play greater roles than fuels in governing fire behavior, but woody biomass fuel is the only aspect of the fire environment- fuels, topography, weather- that resource managers can alter. While thinning can reduce crown fire potential and mitigate crown fire severity, it can also increase surface wind speeds. Thinning allows for more precise and controlled fuel treatments than prescribed fire, but should not be considered the ecological equivalent of fire. Thinning ladder fuels without prescribed burning or removal of this biomass can increase surface fuels, crown scorch and tree mortality in subsequent wildfires. Coarse woody debris (large down logs and standing snags) is essential for many wildlife species, but also contributes to fuel loadings and is often consumed during wildfires.

Wildlife: Active management of stands of small diameter trees established as a result of past human actions can address wildlife habitat fragmentation and promote habitat maintenance and restoration. However, there are tremendous knowledge gaps in how different animal species will respond. Fire-dependent species, species preferring open habitats, and species associated with early successional vegetation or that consume seeds and fruit usually benefit from fuel treatments. On the contrary, species that prefer closed-canopy forests or dense understories, and species that are closely associated with large snags or down logs that may be removed by fuel treatments, will likely be negatively affected from both fuel treatments and fire. Some habitat loss, such as understory vegetation, may persist for only a few months or years, but lost large

snags and down wood may take decades to recover and are thus important to conserve. Biomass removal prescriptions that retain untreated refugia stands and create a mosaic of different forest structures across the landscape will likely support greater wildlife species diversity than large, homogeneous stands given the same treatment.

Individual species responses may also vary over time. A small mammal species that needs shrub cover to avoid predators may decline following treatment, but then later exceed pretreatment levels when shrubs recover, and food resources increase from greater light, plant growth and seed production that result from opening up the forest canopy.

While relatively rare, most forest carnivores have fairly large ranges so few species will be significantly affected by stand-level fuels projects. However, some could be affected by any loss of denning habitat and changes in prey populations due to cumulative effects of past management, past disturbances and larger scale projects. Both marten and fisher are sensitive to loss in canopy cover and are strongly associated with coarse woody debris cover.

Ungulates such as deer and elk use dense thickets of shrubs and trees as thermal cover, to hide from predators, for daybeds and for fawning, while also utilizing open areas for foraging. Thinning generally increases forage quantity and quality for ungulates, but retaining patches of dense cover is important. A mosaic of thinned and unthinned areas probably benefits deer and elk more than thinning uniformly across broad areas. Elk may be more likely than mule deer to benefit from thinning treatments.

Small mammal species vary in habitat preference and thus in response to biomass removal. Shrubs and coarse woody debris provide important cover from predators. Loss of these habitat elements may negatively impact some small mammal species. Species that prefer open habitats can benefit from food provided by fruit-producing shrubs, grasses and forbs that may establish after fuel treatments. Small mammals seem to recolonize disturbed areas quickly, although diversity and species dominance differ as succession progresses. Thinning can reduce truffle production and in turn populations of small mammals such as chipmunks and flying squirrels that feed on these fungi.

Little data exists on the direct effects of fuel treatments on bats, but several species roost under the bark of tall, large-diameter trees or in cavities of large snags. As long as large snags and trees are protected, thinning may have minimal or even positive effects on bat populations depending on initial site conditions and land use history. Loss of these habitat features may be detrimental to bat populations.

In western dry conifer forests, bird community composition depends largely on the diversity of habitats available. Reported effects of fuel treatments on birds are somewhat inconsistent. Stand scale effects may differ from those at the landscape or regional scale. Fuel treatments are likely to reduce nesting habitat for some species. Treatments during the nesting season may result in high mortality of nestlings. Bird species that prefer early successional and open forests are likely to increase in abundance after fuel reduction. Opening densely stocked, second growth stands has been shown to increase bird species diversity, especially in western Oregon.

Thinning forest understories may benefit hawks, owls, and eagles that prey on small mammals. But treatments that reduce density of pole-sized to mature trees are likely to negatively impact accipiter hawks, which are closely associated with very dense stands. Removal of trees with dwarf mistletoe brooms will likely impact raptors that nest in the brooms including the great gray owl, long-eared owl, great horned owl, northern spotted owl, northern goshawk, Cooper's hawk, and red-tailed hawk. Spotted owl management guidelines specify little active management in defined habitat areas. To the degree that they reduce the risk of stand-replacing fires in these areas, restoration treatments outside of them should benefit spotted owls over time. Variable-density thinning in mixed conifer forests may accelerate development of northern spotted owl habitat and dense prey populations especially when snags, cavity trees and large downed wood are conserved. Thinning may reduce northern spotted owl habitat quality locally, but this should be weighed against the risk of stand replacing fires and loss of habitat over large areas.

If fuel treatments remove snags, loss of nesting habitat for primary cavity nesting birds (e.g. woodpeckers) and secondary cavity-nesters (e.g. western bluebirds) might be expected for many years. Several studies showed that thinning or thinning and burning treatments result in reduced populations of cavity nesters due to loss of dead trees used for nesting and roosting. Other studies showed that thinning densely stocked conifers in landscapes dominated by younger stands enhances habitat for several species of songbirds. A variety of thinning intensities and patterns, from no thinning to very widely spaced residual trees, can maximize bird diversity at the landscape scale. Thinning that results in vigorous understory shrub growth may also promote greater bird abundance and diversity.

Few lizard and snake species occupy western closed canopy coniferous forests, although reptiles do inhabit specific forest patches, such as wetlands, meadows, and rock outcroppings that provide shelter, microclimates, and prey. Leaving snags and down wood on site should benefit the many lizard species that prefer these habitat elements to live trees. Little is known about the effects of thinning on reptiles, but most species would probably benefit from reduction in shrubs, ground vegetation, and litter cover as long as snags and down wood are left on site.

Amphibians' response to reduced canopy cover from either fuel treatments or fire will likely be negative due to warmer, drier conditions created in understory vegetation, down wood, litter and soil. Most salamanders need moist soils or decomposing wood to maintain water balance, so dry conditions usually result in suppressed populations. Frogs and toads may be less affected by fuel treatments because they tend to travel at night and during rain events, they are more mobile than salamanders, and they are closely associated with wetlands. Treatments that increase surface runoff and contribute fine sediment to streams may reduce egg and tadpole survivorship of some stream-breeding amphibians that lay eggs and rear tadpoles under rocks or in spaces in stream cobbles.

Fuel treatment effects on terrestrial invertebrates in western dry coniferous forests (insects, spiders, mites, scorpions, centipedes, millipedes, isopods, worms, snails and slugs) are probably as diverse as the group itself. Invertebrates comprise over half of the animal diversity in forests, occupy all forested habitats and have varied ecological roles including decomposers, predators, herbivores and pollinators. Some invertebrates can explode in population but many are scarce and of conservation concern. Thinning may have significant negative effects, at least in the

short-term, on invertebrates of soils and organic layers through soil compaction and disruption or loss of organic layers. Compaction will depend on soil type and thinning treatment. Soil organisms may be more protected than those in litter layers. Refugia (untreated areas from which populations can recolonize) are widely recommended to minimize effects of mortality and accelerate recovery of terrestrial invertebrates.

Species such as root and bark beetles and wood borers that benefit from stress or weakened defenses of living host trees usually increase in the short-term to disturbance created by thinning and prescribed fire, but treatment timing affects responses. Several studies have shown that some bark beetles and wood borers increase less with thinning treatments than with prescribed fire, or with combinations of thinning and fire, probably due to fewer trees being injured with thinning. However, during periods of high infestation, injured and uninjured trees are equally likely to be attacked.

Soil: Removing woody biomass from a stand rather than letting it decompose onsite can affect soil chemistry, soil fertility and growth of residual plants. Decomposing wood helps replenish soil nutrients. But leaving excess forest biomass on the forest floor affects wildfire risk, and uncharacteristically severe wildfire can have a significantly negative impact on soil chemistry. Decisions of whether or not to remove woody biomass should be informed by the overall soil nutrient budget in a particular stand, including which nutrients are limiting.

A 14-year study found that coarse woody debris does not appear to make a significant contribution to nitrogen and phosphorus levels in soils of three conifer forest types. Wood decay organisms may actually compete with vegetation for these limiting nutrients. This suggests that guidelines for coarse woody debris management in these forests should be based on objectives for other potential values (e.g. wildlife habitat) rather than its role in soil nutrient cycling.

Undisturbed watersheds have little erosion but natural forests have natural disturbances, including wildfire and large floods, with return periods that range from decades to centuries. Long-term natural background sediment yields from watersheds are a combination of low levels of erosion from undisturbed forests plus added erosion from occasional disturbances. Although undisturbed watersheds have little erosion, wildfire or flood can lead to significant upland erosion, and sediment deposition and movement in forest streams. Thinning activities are considered to be a disturbance. However, erosion rates associated with thinning are generally lower than from wildfire or flooding but may occur more frequently.

Thinning and removal of small diameter wood and slash generally requires lighter equipment than traditional logging, but still entails some soil impacts. These impacts must be weighed against potential impacts from uncharacteristically severe wildfires, and the potential benefits of thinning. Soil compaction can take decades to recover, reduces plant growth and inhibits water infiltration, which increases erosion, sedimentation and spring run-off. In some areas, compaction can be largely mitigated by conducting thinning operations on frozen and snow-covered soil. Proper use of low-impact harvesting equipment and measures to utilize pre-existing skid trails and avoid creating new ones can help maintain ecologically important soil properties in managed forest stands.

Water Quality: Erosion rates associated with woody biomass harvests are in general much lower than effects from wildfire or roads, but result in higher erosion levels than in undisturbed landscapes. Wildfire risk reduction if done appropriately can have long term positive effect on water quality, especially in areas of high fire risk.

Air Quality: The effects of forest biomass removal and use on air quality is a very complex topic, ranging from local smoke management concerns to national issues of carbon budgets, climate change and energy policy. Economically removing many small, non-merchantable trees from forests is the central dilemma in implementing fuel treatments. Leaving cut trees on the ground often increases fire hazard and the severity of pest insect outbreaks. This material is generally either burned in prescribed fires or in uncharacteristically severe wildfires that occur post thinning. Open burning of forest biomass in wildfires, prescribed fires, or slash burning can also impact forest ecosystems and produces large amounts of smoke, particulates, and significant quantities of nitrogen oxides, carbon monoxide and hydrocarbons that contribute to atmospheric ozone. Open burning also emit substantial amounts of carbon dioxide as well as methane and can impact human health. Quantifying emissions is difficult due to wide variation in fuels, burning practices and environmental conditions.

Use of woody biomass as an energy feedstock vastly reduces the smoke and particulate emissions associated with its disposal, and significantly reduces the amounts of carbon monoxide, nitrogen oxides and hydrocarbons released to the atmosphere. By one estimate, if nonmerchantable forest thinnings were consumed in biomass power boilers instead of open burning, nitrogen oxides emissions could be reduced by 64% and particulate matter could be reduced by 97%. The U.S. Environmental Protection Agency estimates that emissions from biomass power plants are approximately 9 to 20% of emissions from open burning.

Woody biomass biomass power plants still emit large amounts of carbon dioxide, sometimes even in excess of fossil fuel plants because of lower combustion efficiencies for biomass. However, carbon dioxide released by combustion of forest biomass was recently removed from the atmosphere through photosynthesis, and new plant growth will continue to remove carbon dioxide from the atmosphere after biomass is harvested. For this reason it is often argued that biomass is "carbon dioxide neutral." However, power production from woody biomass involves other carbon flows, including fossil fuel burned during biomass harvesting, processing and transportation. Net carbon dioxide emissions from a biomass power plant are clearly lower than those from a fossil fuel plant, but the assumption that woody biomass power is currently a "carbon dioxide neutral" process should be tempered.

Current Resource Protections

Resource protection requirements during biomass removal operations vary for private, state, and federal land ownerships in Oregon.

- On federal lands managed by the US Forest Service or the Bureau of Land Management agencies must comply with applicable federal laws, land management plan standards and guidelines, and meet National Environmental Policy Act (NEPA) review standards.
- On private forest lands regulations under the Oregon Forest Practices Act serve to protect forest resources during biomass removal operations.

- On state owned, and Department of Forestry managed, forestland resources are protected during biomass removal. This is accomplished through implementation of rules for Board of Forestry forestlands, including the forest management plans, and implementation of the Common School Forest Lands agreement; incorporating appropriate contact provisions into timber sale contracts; and utilizing logging practices and equipment that minimize adverse impacts to the site.

While all three ownerships have different mechanisms in play they share the common goal of providing adequate forest land resource protection. All three ownerships have opportunities in place for public input where concerns over adequacy of resource protection measures can be voiced, examined, and acted on as warranted. As scientific understanding increases in this arena these processes will serve as pathways for any needed changes to existing protection requirements.

For more information on resource protection requirements, refer to Appendix B.

Woody Biomass Utilization Trends in Oregon

Oregon Department of Energy conducted a survey of 78 woody biomass energy users in October 2008. Data reported is for biomass collection and utilization in 2007. A similar survey was conducted in 2005. Calendar year 2007 woody biomass collection and use was down from 2005 by 1 million bone dry tons principally due to mill residue reductions resulting from the current business cycle (downturn in housing and the economy generally).

In 2007, throughout Oregon, 6.3 million bone dry tons of woody biomass was collected and used. Approximately 1.2 million bone dry tons of biomass and spent pulping liquor were used as thermal or electric generation fuel. Approximately 320,000 bone dry tons were used in production of prepared fuels (pellets, extrusion logs, briquettes). Just over 1 million bone dry tons was used for soil amendments and landscaping. The remaining 3.8 million bone dry tons were used as fiber for paper pulp, reconstituted pressed board or other forest products. Fewer than 50,000 bone dry tons were reported as sent to landfills and most of that was short fiber sander dust.

In 2007, the largest percentage of woody biomass collected (over 5 million bone dry tons) was from saw, paper and veneer mill residues. In 2007, fewer than 100,000 bone dry tons were reported recovered from federal forest stewardship contracts or other forest site slash. Under 700,000 bone dry tons of construction and demolition debris were recovered. Less than 700,000 bone dry tons of post consumer woody biomass was collected.

In comparison, 2005 saw approximately 7.3 million bone dry tons of woody biomass collected and used. Over 800,000 bone dry tons (half being spent pulping liquor equivalent) was used for energy generation. No distinction in the sources was made in that survey.

Federal utilization figures shown below for Bureau of Land Management (BLM) and U.S. Forest Service (USFS) show mixed results. Biomass utilization on BLM land has decreased slightly in the last two years while activity on lands managed by the USFS has an increasing trend. The

overall downturn in the economy, and resulting job loss for the logging industry could be resulting in added interest in restoration work on USFS federal lands.

Tons of Biomass Volume Offered in OR/WA BLM*

Fiscal Year	Green Tons
2008	30,412
2007	34,279
2006	42,250
2005	12,060
2004	6,660
2003	200

*Official Biomass reporting started in 2004.

Tons of Biomass Volume Offered in OR/WA USFS

Fiscal Year	Green Tons Bioenergy	Green Tons Bio-products	Total Green Tons
2008	478,165	317,547	795,712
2007	369,334	389,233	758,567

*2007 first year of reporting

Conclusion and State Forester Recommendations

This report is the first in a series of three-year reports responding to the legislative charge in SB 1072 (2005 session)

The literature review, while not exhaustive, is a beginning point given the time, budget, and resources available within the Department of Forestry and other state and federal agencies asked to contribute to its development. With the attention this topic is getting across the country, no doubt future reports will build significantly on our current understanding of the effects of biomass removal across the different forest cover types in Oregon.

The literature review looks across the resource effects of removing woody biomass as seen through mainly fuel reduction and thinning studies. The literature synthesis shows there are potential positive and negative effects with woody biomass removal. The same can be said for taking no action to reduce fuel build-ups and tree overstocking on forestlands.

However, the literature gives us insight into responsible actions landowners can take when harvesting woody biomass. Care should be taken to:

- Select silviculture treatments that provide a diversity of forest structure so a wider range of habitats for wildlife and understory plants can provide for overall biodiversity.
- Leave adequate snags and downed wood during these operations to provide habitat for species that require use of them.
- Employ a skilled workforce utilizing the appropriate equipment to protect forest soils and hence the resource values dependent on them.

The State Forester has determined that protection measures in place in Oregon across ownerships are currently adequate to protect forest resources during biomass removal, but as interest and

advances in bioenergy occur we will need to continue to evaluate the forest landscapes and forest cover types to ensure ongoing resource protection. In particular we can look to insure that adequate downed wood and snags are left on site during these operations to protect resources dependent on these habitat elements. Scientific input is needed to help establish appropriate remove/residual policies for forest slash in thinnings and fuel reduction treatments by forest cover type. Also key is continuing to encourage logger certification programs, such as Associated Oregon Loggers' Professional Logger certification program, to include woody biomass harvesting techniques training.

Biomass utilization trends in Oregon show a modest decrease in utilization of available supply. While the 2007 Oregon Legislature did pass a number of legislative elements to further biomass utilization, the housing industry downturn and the global financial crisis have served to decreased biomass utilization. However, on lands managed by the US Forest Service removal of biomass as a part of forest restoration and fuels reduction work has increased.

With respect to air quality and Oregon's carbon "footprint," utilization of woody biomass for renewable energy production should be viewed as clearly a better choice of feedstock than the current use of fossil fuels.

A number of actions recommended by Oregon Board of Forestry (through the *Forestry Program for Oregon*), the Oregon Forest Biomass Work Group, Oregon Federal Forestlands Advisory Committee, Oregon Forest Cluster Economic Development Strategy core team, and others need to be considered and actions taken to further biomass utilization in Oregon. Although recently the Federal Production Tax credit was extended, several key recommendations still require action:

- Addressing the inadequate USFS and BLM budgets for land management activities needed to expand restoration and monitoring work. This could be accomplished through a combination of increased appropriations, efficiencies, and revenue generation. This is needed on federal lands to reduce the number of uncharacteristic wildfire habitat losses, improve forest and rangeland health, provide needed economic activity, and serve to help meet state and national energy goals. Instead federal agencies find their management funds being utilized for fire suppression efforts, putting them in a reactive mode rather than addressing the issues.
- Language in the Energy Independence and Security Act of 2007 (Public Law 110–140; 121 Stat. 1492) that defines biomass for applicability to the Renewable Fuels Standard does not include woody biomass from federal lands. A change in the law is needed to allow rural communities surrounded by federal land the opportunity to develop appropriately-scaled renewable energy facilities to help address national energy goals.
- Foster increased demand for woody biomass by promoting it as a fuel for heating large buildings with efficient boilers. This could include schools, colleges and universities, hospitals, prisons and process heat applications of industrial users.

Appendix A

Literature Review

This literature review includes information regarding the environmental effects of removing nonmerchantable woody biomass – material from trees and woody plants, including limbs, tops, needles, leaves and other woody parts that are by-products of forest management, ecosystem restoration or hazardous fuel reduction treatments.

1.0 Introduction

In dry interior western U.S. forests, biomass accumulates faster than it decomposes. Prior to Euro-American settlement, wildfire was the ecological process that kept these accumulations in check (Graham and others 2004). But policies of wildfire exclusion in place for most of the past century, combined with factors such as selective harvest of larger, fire resistant trees, livestock grazing, tree species composition shifts, tree die-offs from insects and disease in overcrowded stands, and stress factors from climate change have resulted in buildups of uncharacteristically high levels of wildfire fuels in western dry forests. Across millions of acres of these forests where low-severity fires were historically the norm, mixed or high-severity fires typically occur today. Higher severity fires are more likely to detrimentally affect soils, watersheds and wildlife habitat, and also humans who settle in and around these forests. (Brown and others 2004.) Fuel accumulations are a primary cause of the increasingly frequent, costly and uncharacteristically severe wildfires that have occurred in recent decades.

Consequently, forest and fire management agencies, legislators and communities are intensely focused on the near-term priority of mechanically reducing wildfire fuels. This action is a critical first step in longer-term efforts to manage fire-prone forests in safer, more sustainable ways. The extent to which mechanical fuel treatments should be implemented in backcountry wildlands continues to be debated (U.S. General Accounting Office 2004), but treatments in forests closer to communities are less controversial, and there is widespread agreement about the need to reduce fuels in wildland-urban interface areas where wildfires can threaten human lives and property. Rummer and others (2003) estimate that at least 28 million acres of forestlands in 15 western states could benefit from fuel reduction efforts, while Aplet and Wilmer (2003) estimate that 11 million acres need to be treated to protect communities from wildfire.

Natural wildfire regimes and Fire Regime Condition Classes

A natural *fire regime* describes the type of wildfires that typically occurred in a forest prior to modern human mechanical intervention. Natural (historical) fire regimes have been described for different forest types based on a combination of fire *frequency* and fire *severity*, i.e. the percentage of overstory trees killed. Coastal Oregon forests historically had very infrequent (about every 100-400 years), but very severe wildfires, in contrast to central and eastern Oregon forests which historically had quite frequent (as often as every 4-20 years), low severity fires.

Fire Regime Condition Classes are coarse-scale descriptions of current fire conditions in terms of degree of departure from historical fire regimes. These departures from historical fire frequency or severity can result in alterations of key ecosystem components, e.g. species composition, forest structural stage, forest stand age, forest canopy closure, and fuel loadings. One or more of the following activities may cause fire frequency and severity to be different than they were historically: fire suppression, timber harvesting, livestock grazing, establishment of exotic plants, insects or disease, or other management activities.

If a forest stand is in Fire Regime Condition Class 1, the fire regime is within its historical range and the risk of losing key ecosystem components is low. If a stand is in Fire Regime Condition Class 2, the regime has been moderately altered from its historical range, and the risk of losing key ecosystem components is moderate. If a stand is in Fire Regime Condition Class 3, the fire regime has been significantly altered and the risk of losing key ecosystem components is high, due to dramatic changes in fire size, intensity, severity, or pattern across the landscape (Schmidt and others 2003).

Potential supplies of forest biomass and prioritizing areas for treatment
A 2003 United States Forest Service (USFS) study illustrates the amount and configuration of tree biomass that hazardous fuel treatments in Oregon could potentially generate. The study provided a broad-scale, conservative estimate of the number, size classes and volumes of trees that could be removed to address National Fire Plan hazardous fuel reduction and ecosystem restoration objectives (USDA Forest Service 2003). The analysis covered several regional forest types on both public and private forest land in 15 western states and described all standing tree volume including stems, limbs, and tops. Reserved forests and low productivity areas were not considered. Across the 15-state study area, 72% of the *volume* identified for removal would come from trees larger than 8 inches in diameter, but 86% of the total *number* of trees identified for removal were 8 inches or less- over 2 billion trees in the 2-inch diameter class, and another 1.5 billion trees in the 4-inch diameter class.

Even after excluding 40% of the study area that was high elevation, steep slopes or not within 15 miles of major transportation infrastructure, the 2003 USFS study identified 55 million bone-dry tons (BDT) of biomass in Oregon that would need to be removed from Fire Regime Condition Class 3 areas alone, second only to California among the 15 western states. It is generally considered unsafe to use prescribed fire in such areas until fuel loadings have been reduced by mechanical treatments.

All else being equal, Fire Regime Condition Class 3 areas are the highest priority for treatment. But the immense scale of restoration needs far exceeds resources available for such work and coarse-scale analysis is insufficient for developing regional and local restoration priorities. Thus strategies are needed for prioritizing which areas to treat and finer-scale factors must be considered. Brown and others (2004) submit that forests with historically low-severity fire regimes- e.g. ponderosa pine, dry Douglas-fir, and dry grand-fir forests- should have the highest priority for active fuels reduction and biomass removal. Wet Douglas-fir, grand-fir and red-fir forests would have intermediate priority, while low priority would be assigned to sitka spruce, western hemlock, Pacific silver fir, mountain-fir and subalpine fir forests unless unusual situations require local treatment.

Within low-severity fire regime forests, higher priority might be assigned to more productive dry mixed-conifer forests where ecological changes in the form of abnormally high fuel loadings have been the most significant. Brown and others (2004) also argue that areas containing old-growth ponderosa pine stands, which are rare across the landscape compared to conditions that existed prior to Euro-American settlement, should be a high priority for treatment. Brown (2008a) additionally notes that some Fire Regime Condition Class 3 areas have little remnant old-growth pine, whereas a Fire Regime Condition Class 2 area may have more old-growth and therefore be a higher priority for protection. Areas where understory trees are sufficiently large or dense that use of prescribed fire runs a high risk of killing overstory trees are also high priority for thinning.

A report on the potential for biomass energy and biofuels in Oregon (Oregon Forest Resources Institute [OFRI] 2006) notes that estimates of forest biomass supplies from forest health thinnings in Oregon vary widely, from 0.8 – 7.3 million BDT annually depending on assumptions of area needing treatment, volume removed per acre, proportion of volume that is biomass versus commercial timber, and the number of years over which treatments are conducted.

The OFRI report authors analyzed potential biomass supply from fuel treatments across 20 eastern and southern Oregon counties in the dry, inland forests where stand conditions and fuel loadings are the farthest outside their natural range. Areas deemed eligible for treatment were defined as public and private forestlands with high fire risk outside of designated roadless areas, wilderness areas, parks and other forestlands where timber harvesting is excluded. Results suggested that a biomass supply of approximately 20 million BDT would result from treatment of 4.25 million acres of eligible forestland, or approximately 27% of total forestland in the 20 counties. About 71% of this forestland is publicly owned, mostly federal, with private lands accounting for 29%. Under this scenario, if treated over 20 years, approximately 1 million BDT of noncommercial forest biomass would be produced annually assuming no allowance for growth.

Fuel treatments include a suite of mechanical methods and the use of fire to reduce overall fuel loading and change the spatial arrangement of fuel in stands and landscapes (Fitzgerald 2002). Mechanical fuel treatment methods include thinning, mowing, and pruning of lower tree branches. Thinning typically removes small diameter trees that may or may not have commercial value. A tractor and mowing carriage can be utilized to mow large shrubs and small trees, reducing surface and ladder fuels. Pruning lower tree branches increases tree crown height and makes it more difficult for surface fire to move up into the canopy. Prescribed fire can also be used to reduce surface fuels, usually after the site has been mechanically treated.

Most biomass targeted for removal during hazardous fuels and forest health restoration treatments is in the form of ladder fuel trees that range from one to 40 feet tall and two to five inches in diameter. These trees have zero or low value for timber products, and are thus usually considered to be waste material. Recently, there has been an increasingly specific focus on ways to dispose of this material. Non-commercial trees and slash are typically either chipped and spread over the site or piled and then later burned. Other options include simply letting felled trees and slash decompose on the forest floor (which often increases fuel loadings in the short to

medium term), broadcast burning, or removing it from the site for utilization into products or as fuel for energy production.

Potential consequences that could result from utilizing woody biomass for energy needs in Oregon include:

- Impacts to soil, air, water quality, plants and wildlife if forest health needs are not adequately assessed and measures taken to provide adequate levels of protection to these forest resources in determining the amount and method of biomass to be removed.
- Not addressing the existing fire threat in Oregon has implications for the continued loss of forest values experienced over the last decade, firefighting costs and lost revenues to local communities.

1.1 Oregon Senate Bill 1072

Extreme fire seasons are occurring more often in Oregon such as 2002 when the Biscuit Fire alone burned 500,000 acres and cost $150 million to suppress, and then again in 2003 which included the very visible 90,000 acre B & B Fire. Local and state government costs to support evacuation, traffic control, security, and public information during events such as these are significant. There are also over 240,000 homes worth an estimated $6.5 billion in Oregon wildland-urban interface communities. Costs of property damage from wildfires can be high in these communities, as can resource losses from fires in forests managed for timber. These events and the likelihood of severe wildfires in the future have set the stage for active discussions on fuels management, especially on federal lands, to mitigate wildfire intensity, severity and size and increase the chance of rapidly suppressing fires once they start. At the same time, rising energy costs and policies to promote greater national, regional, and state energy independence have spurred interest in cost-effective ways to simultaneously reduce wildfire risk, increase forest health, and produce sustainable energy from excess forest biomass.

In 2005, the Oregon Legislature passed SB 1072, in an effort to promote forest health and facilitate "…the development of biomass markets, including energy markets, that use forest biomass unsuitable for lumber, pulp and paper products as a primary source of raw material [to] assist in the creation of a sustainable, market-based model for restoring complexity and structure to Oregon's forests." Language in SB 1072 stated that "the policy of [Oregon] is to support efforts to build, and place in service, biomass fueled energy production facilities that utilize biomass collected from forests", that "a biomass-based industry may provide a renewable source of energy, reduce net greenhouse gas emissions, reduce air pollution from wildfires, improve fish and wildlife habitat…", and that "through the collection and conversion of forest biomass, ancillary benefits may be realized through the improvement in forest health…and the stabilization of soils within critical watersheds."

SB 1072 further noted that "the collection and conversion of forest biomass diminishes fuel loads…where the reintroduction of fire is not appropriate" and that in addition to forest products and recreation, forest values such as water and wildlife should be considered. SB 1072 suggested that the use of woody biomass for energy should maintain or enhance "…the biological productivity of the land, taking into consideration…existing forest conditions,

management objectives, vegetation growth rates and the need to sustain water quality and fish and wildlife habitat."

Points of discussion during drafting and passage of SB 1072 included uncertainty regarding environmental effects of biomass harvesting, removal and utilization, tension between prescriptions for fuels reduction, forest health improvement and pressures to make projects cost-effective, and concerns that future biomass energy infrastructure and demand might eventually outstrip biomass supplies from fuels treatment and ecosystem restoration projects. Thus, in addition to its other provisions, SB 1072 requires the Oregon State forester to submit a report every three years to the Oregon Governor and Legislature:

". . .utilizing, to the greatest extent practicable, data collected from state and federal sources that specify the effect of woody biomass collection and conversion on the plant and wildlife resources and on the air and water quality of this state. The report shall identify any changes that the State Forester determines are necessary to encourage woody biomass collection and conversion and to avoid negative effects on the environment from woody biomass collection and conversion."

By statute, the first edition of this report was due to the Governor and the "appropriate interim legislative committee" no later than October 1, 2008. The ODF Forest Resources Planning Program initiated work on this report for the past year but were limited in the amount of progress that could be made due to existing work assignments, and pending delivery of new information essential for the report. A two month extension was provided by the Governor's office and appropriate legislative committees. The department worked with an outside contractor to help with the scientific literature review needed for the report.

The full text of SB 1072 is shown in Appendix C.

1.2. Scope of literature review

This section reviews literature that includes information regarding the environmental effects of removing non-merchantable woody biomass – material from trees and woody plants, including limbs, tops, needles, leaves and other woody parts that are by-products of forest management, ecosystem restoration or hazardous fuel reduction treatments.

Potential environmental effects of biomass removal are diverse, complex and inter-related, depending on forest type, pre-existing stand conditions, the timeframe being considered and the particular silvicultural prescription used. These changes can be either positive or negative in nature and can vary greatly in scale from site and stand-level to much larger spatial scales. Local to watershed-level effects include altered understory plant communities and wildlife habitat, changes in soil physical properties and chemistry, impacts on water quality and runoff patterns, changes in biodiversity and populations of individual species, and modified wildfire regimes. At larger spatial scales, woody biomass removal and conversion into products or energy can also affect carbon sequestration, atmospheric carbon emissions and climate patterns.

The range of sources from which to draw information on the effects of woody biomass removal and conversion is similarly diverse and extensive. Rather than a comprehensive review, this

report covers a sample of available, relevant literature, focusing primarily on local to watershed-level environmental effects of biomass removal activities on forest ecosystems.

From an ecological viewpoint, it may be hard to distinguish between "woody biomass removal" associated with fuels reduction projects, and thinning treatments associated with traditional forest management focused on promoting vigorous tree growth. Literature on the effects of silvicultural thinning treatments is much more voluminous than literature targeted specifically towards fuel treatments and non-commercial biomass removal. However, over the past ten years, the volume of research focused directly on the effects of fuel treatments has grown, paralleling greater concern about uncharacteristically severe wildfires, expansion of wildland-urban interface areas and values at risk.

This report draws on all of these sources of literature, with an emphasis on studies and synthesis documents that examine the effects of non-fire fuels treatment techniques. The report is laid out in sections that discuss effects on particular aspects of forest ecosystems- e.g. soil properties, water quality, wildlife, etc. Most of the available literature does not specifically examine the effects of removing biomass from the site, but focuses instead on the effects of opening up the forest canopy and impacts associated with mechanical fuel treatments. Many studies examine both thinning and prescribed fire and some combination of the two, but may not specify how thinned biomass is treated, specifically whether or not it is piled, burned, masticated, left onsite or removed. If such information is available, it is often mentioned in passing because it was not a primary focus of the study. Systematic review techniques (Institute for Natural Resources 2006, 2008) require time and resources well beyond what was available for this review, but could potentially be used to develop a more thorough and in-depth analysis by applying systematic techniques to define, locate and stratify "relevant" literature and by examining full studies rather than just abstracts as was often done here. Finally, it should be noted that most biomass removal projects do not include rigorous ecological monitoring, and that existing studies address a small range of the potential effects of biomass removals. Much more research is needed to assess effects under the vast range of local forest types, conditions and land use histories (Forest Guild 2008).

When interpreting the information presented, care should be taken to note – where the information is available - the particular forest type being discussed, the ecological context and stand conditions prior to treatment, the silvicultural treatment that was applied and methods used to assess environmental outcomes. To some degree, findings can be extrapolated to similar forest types elsewhere in the region, but it is important to remember that pre-existing stand conditions, silvicultural treatments, study designs and analyses are rarely the same across different information sources and locales.

2.0. Effects of woody biomass collection and conversion on plant resources

2.1 Effects on residual trees

A large body of research has demonstrated that, in general, thinning of densely stocked stands of conifers such as ponderosa pine and Douglas-fir improves the vigor of trees that are left in the stand by reducing competition for water and soil nutrients. Trees that are more vigorous are also less susceptible to insect attack. Indeed, improved tree health and growth, and resistance to

insect attack are often key aspects of the rationale for thinning treatments. But thinning prescriptions involve more complex harvesting procedures than clearcutting, and can result in damage to residual trees. Opening up the stand can also make residual trees more susceptible to windthrow, and increase wind speeds, which in turn can affect fire behavior. This section summarizes some selected studies that investigated the effects of thinning on residual trees.

Since Euro-American settlement, forests in many inland western ponderosa pine-dominated forests have changed from open, low-density stands to closed, high-density stands, which has been detrimental to the vigor of old-growth trees. Stone and others (1999) examined whether the vigor of old-growth, presettlement trees could be improved by restoring the original stand structure through thinning of smaller trees that established after settlement. This treatment resulted in the following changes in presettlement trees and their environment in the first year following thinning: an increase in volumetric soil water content between May and August, an increase in predawn xylem water potential in July and August, a decrease in midday xylem water potential in June and August, an increase in net photosynthetic rate in August, an increase in foliar nitrogen concentration in July and August, and an increase in bud and needle size. These results show that the thinning restoration treatment improved the condition of presettlement ponderosa pines by increasing canopy growth and the uptake of water, nitrogen, and carbon.

Kolb and others (1998) compared foliar physiology and several measures of tree resistance to insect attack among ponderosa pine trees growing in thinned stands. The study area was a second-growth forest in northern Arizona, where four different density treatments (6.9, 18.4, 27.6, 78.2 m2 ha-1) have been experimentally maintained by frequent thinnings for 32 years before measurements began in 1994. Most of the physiological characteristics measured were affected by the basal area treatments. As stand basal area increased from 6.9 to 78.2 m2 ha-1, predawn water potential, midday water potential, net photosynthetic rate, resin production, phloem thickness, and foliar toughness decreased. Foliar nitrogen concentration was greatest in trees in the intermediate basal area treatments. Results indicated that the physiological condition of second-growth ponderosa pine can be improved by reducing stocking levels, and that dense stocking levels increase tree stress and decrease tree resistance to insect attack.

Sala and others (2005) measured soil water and nitrogen availability, physiological performance and wood radial increment of second growth ponderosa pine trees in the Bitterroot National Forest, Montana, 8 and 9 years after four treatments: thinning only; thinning followed by prescribed fire in spring; thinning followed by prescribed fire in fall; and untreated controls. Trees of similar size and canopy condition in the three thinned treatments (with and without fire) displayed higher leaf-area-based photosynthetic rate, stomatal conductance and mid-morning leaf water potential in June and July, and higher wood radial increment relative to trees in control units. Results suggest that, despite minimal differences in soil resource availability, trees in managed units where basal area was reduced had improved gas exchange and growth compared with trees in unmanaged units. Interestingly, prescribed fire (spring or fall) in addition to thinning had no measurable effect on the mid-term physiological performance and wood growth of second growth ponderosa pine.

Mitchell and others (1983) evaluated thinned and unthinned stands of lodgepole pine in eastern Oregon to determine their vigor and susceptibility to mountain pine beetle attack. Comparisons

of stem growth per square meter of crown leaf area showed that thinning from below improved the vigor of residual trees and reduced beetle attack. Beetle mortality was significant in unthinned and lightly thinned stands where annual stemwood growth of residual trees averaged less than 80 g/m2 of foliage. Stands where stemwood growth in residual trees was around 100g/m2 were beginning to suffer beetle attack. There was no mortality in heavily thinned stands where stemwood growth in residual trees exceeded 120 g/m2. These findings suggest that lodgepole pine can be managed through stocking control to avoid mountain pine beetle attack.

Bailey and Tappeiner (1998) studied understory composition and structure in thinned and unthinned Douglas-fir/western hemlock stands on 32 western Oregon sites. These stands had regenerated naturally after timber was harvested between 1880 and 1940 and were thinned between 1969 and 1984. Commercially thinned stands had 8–60% of their volume removed 10-24 years before the study. Undisturbed old-growth Douglas-fir stands were compared on 20 paired sites. Conifer regeneration density and frequency were consistently greater in thinned than unthinned stands. Seedling density and frequency were strongly related to the volume removed and to stand density index (and other measures of overstory density) just after thinning. In thinned stands, the density of small trees (intermediate crown class overstory trees and advanced regeneration) was 159/ha, significantly greater than in unthinned stands (90/ha), but not significantly different from that of old-growth (204/ha). The live crown ratio of these trees in thinned stands (66%) was greater than in unthinned (44%) and old-growth (48%) stands. Bailey and Tappeiner (1998) concluded that thinning young Douglas-fir stands will hasten development of multistory stands by recruitment of conifer regeneration in the understory and by enabling the survival of small overstory trees and growth of advanced understory regeneration.

McIver and others (2003) examined fuel reduction by mechanical thinning and removal in mixed-conifer stands in northeastern Oregon. The experiment compared a single-grip harvester coupled with either a forwarder or a skyline yarding system, and unharvested control sites. Both extraction systems achieved nearly equivalent (~46%) mass fuel reduction. Of seedlings and trees examined, 32% had noticeable damage after harvest, including bole wounding (38.9% of damaged stems), bark scraping (35.0%), wrenched stems (28.9%), broken branches (26.5%), broken terminal leaders (15.4%), and crushed foliage (4.1%). More damage occurred to residual large trees than to seedlings.

2.2 Effects on non-tree plant understory species

This section addresses effects of thinning and removal of forest biomass on plant communities in the forest understory. In general, opening up densely stocked stands increases understory plant biomass and biodiversity, which in turn increases habitat heterogeneity for wildlife. But newly available niches may also be colonized by invasive exotics.

Kerns and others (2003) reviewed literature regarding the effects of forest management practices, including thinning and selection harvesting, on common Pacific Northwest understory non-tree species (i.e. shrubs, fungi, native mosses, lichens, ferns and herbs) with commercial, social or cultural value. In addition to the social values of these species, the authors note that many of them play important ecological roles in forest communities by contributing to biodiversity and

long-term ecosystem productivity, and underpinning populations of mammals and birds. Understory species are also an important aesthetic component of forests.

Kerns and others (2003) note that from the end of World War II until fairly recently, clearcut logging and even-age management dominated forest practices in forests west of the Cascade Range, with the primary objectives of timber production and maintaining vigorous crop trees. With this management legacy, the understory in managed stands is generally an unintentional byproduct of timber management. Since the early 1990's there has been an increasing focus on alternative silvicultural systems and forest practices that embrace a broader range of values, including biodiversity and forest structural complexity.

Kerns and others' 2003 review focused on peer-reviewed empirical studies and widely available literature that address understory species response from a range of scales and viewpoints, with a geographic focus on western Oregon and Washington. Some studies use general measures such as species composition, abundance, and diversity while others focus on a single species, species-specific responses, or species reproduction. The following discussion is paraphrased and condensed from Kerns and others (2003).

At fine spatial scales, overstory stand structure strongly influences understory plant communities by controlling the amount of light that penetrates the canopy. Other factors that influence the composition of forest understories include the disturbance that originated the stand, the degree of biotic legacies (e.g. downed logs and surviving vegetation) retained following the disturbance, and the rapidity with which trees established on the site and formed a dense canopy.

Active management prescriptions that remove woody biomass can directly or indirectly alter rates and patterns of succession among understory species. If small conifer biomass is removed from the understory, the newly available habitat may be re-colonized by conifer seedlings, but is often colonized by other species – native and exotic. Removing biomass from the overstory influences understory species distribution and abundance by increasing light availability- a major limiting resource for most photosynthetic understory species in coniferous forests.

Most thinning operations are low to medium intensity disturbances compared to high intensity disturbances such as clearcut logging and stand-replacing fires. Thinning can increase microhabitats, creating new germination sites and small openings in the canopy. Light, water, nutrient availability and soil temperatures may increase. Therefore, thinning favors species that can rapidly colonize or expand into newly available resources, either by seeds or by vegetative propagation.

Thinning intensity, frequency, stand age when thinned, uniformity of thinning and operational disturbance all influence understory species response. Uniform thinning leaves evenly spaced trees and usually a compositionally simple understory. Irregular or variable density thinning that creates openings and tree patches of different sizes can increase understory biodiversity. Understory response to thinning, especially by shrubs, is typically correlated with the amount of canopy removed. With very light thinning, impacts of the initial disturbance may outweigh the benefits of making more resources available to understory plants. But heavy thinning with even spacing can reduce moisture availability due to increased wind and sunlight.

A major concern with thinning or woody biomass removal is the potential for such activities to introduce and/or spread invasive exotic species. Greater frequency and abundance of exotics in thinned compared to unthinned stands has been reported in several studies; effects that can last for decades and lead to significant management costs in their own right. The degree to which thinning favors desirable native or invasive exotic species depends to a large extent on the seed species present in the soil, and on how the seed bed is treated after thinning.

Kerns and others (2003) conclude that variable density thinning prescriptions show promise for increasing the biodiversity of understory plants, fungi, native mosses, lichens, ferns and herbs.

Metlen and others (2004) evaluated understory response to fuel treatments in northeastern Oregon ponderosa pine-Douglas-fir forests. Treatments included: no management (control), prescribed fall burning (burn), low thinning (thin), and low thinning followed by prescribed fall burning (thin/burn), replicated four times in a completely randomized design. Treatment effects were observed three seasons after thinning. Species richness of understory vegetation was significantly lower in the thin than in the control, but Shannon-Weaver's index of diversity (a commonly used index for measuring diversity at the ecosystem level) was not affected by fuel reduction treatments. Graminoid (grasses and grasslike plants- e.g. sedges, rushes) cover was not influenced by treatment, forb (herbaceous flowering plants that are not graminoids) cover was reduced in treatments that included thinning, and shrub and total cover were reduced in treatments that included burning. Individual species responded to treatment in a manner consistent with their life history characteristics. Prairie Junegrass cover increased in those treatments that included burning, while cover of other graminoid species was not significantly influenced. Thin treatment significantly lowered elk sedge and total cover, but did not strongly influence the cover of other species. Resilience of plant community diversity to fire and the consistent effect of burning on individual species demonstrate their adaptation to frequent low-intensity fire, and the subsequent moderate impact of low thinning and fall prescribed burning on understory vegetation.

In discussing the relatively modest (and in some cases negative) treatment effects, especially those in response to thinning treatments, Metlen and others (2004) suggest that the modest treatments (probably tied to the disturbance history of the sites) would likely elicit only moderate responses from the understory vegetation. They also cite several studies suggesting that peak species richness may not be observed for several growing seasons after thinning treatments.

Metlen and Fiedler (2006) evaluated the effects of 1) no action, 2) thin-only, 3) spring burning, and 4) thinning followed by spring burning on the understory plant community in a second-growth western Montana ponderosa pine/Douglas-fir forest that initiated after harvest in the early 1900s and has not burned since. Treatments were implemented at an operational scale (~22 acres). Data were collected before and in each of three years after treatment, at two spatial scales: plot (1000 sq meters) and quadrat (1 sq meter). Treatments differentially impacted the understory plant community, most dramatically in the thin-burn. The burn-only treatment initially reduced understory richness and cover but by year three all active treatments increased plot-scale understory richness relative to pre-treatment and the control. Forbs, both native and exotic, were the most responsive lifeform and increased in richness and cover after thinning, with

the greatest response in the thin-bum. Increased native species richness was not detected at the quadrat-scale in any treatment, but was significant at the plot-scale in numerous combinations of treatments and years. Short-term reduction in shrub richness and abundance after burning was detected at the quadrat-scale. Sapling density was reduced in all active treatments. Active treatments create more open overstories and increase understory diversity at the stand level, but a mix of treated and untreated areas will likely maximize heterogeneity and diversity at the landscape scale.

Dodson and others (2008) assessed prescribed fire and thinning treatment effects on understory vegetation species richness, cover, and species composition in dry coniferous forests of central Washington. They applied thinning and prescribed fire treatments to 12 large (10 ha) management units, and surveyed understory vegetation before treatment, and during the second growing season after treatment. Many understory vegetation traits changed significantly, regardless of treatment. Changes were often proportional to pre-treatment condition. In general, cover declined and species richness increased. Thinning followed by prescribed fire increased species richness, particularly where species richness was initially low. Thinning alone had a similar, but lesser effect. Forb richness was increased by thinning, and shrub richness was increased by the combined thin/burn treatment, but graminoid (grass) richness was unaffected. Exotic species cover and richness also increased in the thin/burn treatment, but constituted only a very small portion of the total understory.

Understory plant cover was not affected by treatments, but did decline from pre- to post-treatment sampling, with cover losses highest in areas where cover was high prior to treatment. Forb cover increased in the thin/burn treatment where forb cover was low initially. Burning reduced graminoid cover with or without thinning. Species composition varied within and among treatment units, but was not strongly or consistently affected by treatments. Thinning and burning treatments had mostly neutral to beneficial effects on understory vegetation, with only minor increases in exotic species. However, the pre-treatment condition had strong effects on understory dynamics, and also modified some responses to treatments. Dodson and others (2008) found that the maximum benefit of restoration treatments appears to be where understory richness is low prior to treatment, and suggest that restoration efforts should focus on these areas.

Korb and others (2001) investigated the inoculum potential for arbuscular mycorrhizal (AM) and ectomycorrhizal (EM) fungi in thinned and uncut control stands in a northern Arizona ponderosa pine forest. Three stands of each treatment were sampled by collecting soil cores along 10 randomly chosen transects within each stand. The relative amount of infective propagules of AM fungi was significantly higher in samples collected from thinned stands than controls. Conversely, the relative amount of infective propagules of EM fungi in samples collected from thinned stands decreased slightly compared to controls but this difference was not significant. These preliminary results indicate that population densities of AM fungi can rapidly increase following restoration thinning in northern Arizona ponderosa pine forests, which may have important implications for restoring the herbaceous understory of these forests because most understory plants depend upon AM associations for normal growth.

Bailey and Tappeiner (1998) studied understory composition and structure in thinned and unthinned Douglas-fir/western hemlock stands on 32 western Oregon sites. These stands had

regenerated naturally after timber was harvested between 1880 and 1940 and were thinned between 1969 and 1984. Commercially thinned stands had 8–60% of their volume removed 10-24 years before the study. Undisturbed old-growth Douglas-fir stands were compared on 20 paired sites. There was significantly less tall shrub cover in unthinned stands than in either thinned or old-growth stands, which did not differ. Thinned stands had the most low shrub cover. Salal and bracken fern cover was greater in thinned stands than in the other stand types, but there was no difference in sword fern and Oregongrape cover. Leaf area index in thinned stands (6.6) was not significantly different from that in unthinned (6.8) and old-growth stands (7.1); however, there was more leaf area in shrubs in the thinned stands. Bailey and Tappeiner (1998) concluded that thinning young Douglas-fir stands will help develop the shrub layer by increasing tall shrub stem density and cover of some low shrubs.

2.3 Effects on conifer root diseases

This section addresses the effects of thinning on conifer root diseases, and some of the processes by which these effects can occur.

Rippy and others (2005) summarize knowledge regarding the influence of fuel treatments, including thinning, on conifer root diseases in the Inland West. They note that interactions between trees, root pathogens, and environment are complex and vary by forest structure, stand and land use history, habitat type, species composition, soil characteristics, bark beetle populations, and activity of other forest insects and pathogens.

The following discussion is paraphrased and condensed from Rippy and others (2005).

Conifer root diseases are a natural and necessary part of forest ecosystems that play important, beneficial roles in ecological processes of succession, decomposition, and fire in forests with moderate- to high-intensity fire regimes. Native root diseases usually do not cause permanent loss of large stands or threaten the existence of host tree species. However, shifts in stand composition and other natural and human-caused disturbances often increase the prevalence of root diseases. Mid-seral tree species such as white pine, western larch, and ponderosa pine tend to be root disease tolerant but have declined over much of the Inland West. For example, in northern Idaho, the combined effects of blister rust, selective harvesting, planting practices, and fire exclusion have reduced the stand representation of these species, but increased that of root disease-susceptible Douglas-fir and true firs. In some situations, changes in root rot dynamics may influence forest growth and succession for centuries.

Fuel treatments can influence root disease in complex ways that should be considered at the ecosystem level. Successful use of thinning and biomass removal to lower the risk of severe wildfire depends, in part, on the impacts of such treatments on levels of root disease that contribute to subsequent fuels accumulation. Tree mortality may result directly from root disease or from indirect consequences of infection, such as susceptibility to bark beetle attack. Killed trees can persist as standing snags or windthrown logs, so treatments that cause increases in root disease mortality will likely increase the accumulation of woody debris. A single type of fuels treatment is not appropriate for all forest conditions and root diseases- choices of silvicultural prescription should be made on a site-by-site basis, with knowledge of diseases that

are present and where they are located in the stand. Some fuel treatments may increase root disease incidence, so managers should consider what levels of mortality and growth loss will be acceptable. The type of treatment can often be selected to match the overall objectives for a stand, while addressing root rot dynamics and possible detrimental effects on a site.

Tree thinning can generate stumps and residual root systems that are susceptible to colonization by root-rot pathogens. Stumps, roots, and slash can serve as nutrient substrates that increase growth rates and distribution of root rot fungi. Thinning-associated wounds on retained trees can provide vectors for new root disease infections. When mid-seral stage tree species—e.g., pine and larch—are removed in thinning operations, the resulting stand may have a higher proportion of late-seral stage tree species that are more susceptible to root rots, such as grand fir or Douglas-fir. Thinning may increase damage from some root diseases, such as *Armillaria* root rot, laminated root rot, and *annosus* root disease. Incidence of black stain root disease and *Schweinitzii* root and butt rot may be less affected by thinning if specific guidelines are followed. Soil compaction may predispose tree roots to damage by some root diseases. For all root diseases, steps should be taken to avoid wounding trees during harvesting and removal to reduce future impacts on stand health. Thinning treatments should also favor the species most tolerant to root disease and be timed to avoid problems with bark beetles.

Root disease effects may be considered beneficial or detrimental depending on social values, landowner goals and management objectives for the stand. Impacts generally viewed as negative include increases in fuels, reduced timber volume, damage to buildings from wind-thrown trees and potential personal injury. Conversely, root disease-induced changes in forest structure such as canopy openings, reduced stand density and increases in snags and downed large wood may produce benefits such as forage for large game animals, habitat for small animals and cavity-nesting birds, greater plant biodiversity, sources for specialty forest products, and reduced likelihood of severe wildfire.

Despite the importance and complexity of these issues, the knowledge base regarding interactions of fuel treatments with root diseases is limited. More precise information for specific sites, diseases, and host trees would be desirable to optimize fuel treatments with stand conditions and locations. (Rippy and others 2005.)

2.4 Effects on wildfire behavior and severity

The primary rationale for treatments that reduce wildfire fuel loadings is that doing so will reduce the intensity and severity of the effects of wildfires when they do occur. This section summarizes some of the research that has been conducted to investigate relationships between fuel treatments and the effects of subsequent wildfires.

Raymond and Peterson (2005) quantified the relationship between fuels and fire severity using prefire surface and canopy fuel data and fire severity data after a wildfire in a mixed-evergreen forest of southwestern Oregon with a mixed-severity fire regime (the Biscuit Fire). Modeled fire behavior showed that thinning reduced canopy fuels, thereby decreasing the potential for crown fire spread. Potential for crown fire initiation remained fairly constant despite reductions in ladder fuels, because thinning increased surface fuels, which contributed to greater surface fire

intensity. Thinning followed by underburning reduced canopy, ladder, and surface fuels, thereby decreasing surface fire intensity and crown fire potential. However, crown fire is not a prerequisite for high fire severity; damage to and mortality of overstory trees in the wildfire were extensive despite the absence of crown fire. Mortality was most severe in thinned treatments (80%-l00%), moderate in untreated stands (53%-54%), and least severe in the thinned and underburned treatment (5%). Thinned treatments had higher fine-fuel loading and more extensive crown scorch, suggesting that greater consumption of fine fuels contributed to higher tree mortality. Raymond and Peterson (2005) conclude that fuel treatments intended to minimize tree mortality will be most effective if both ladder and surface fuels are treated.

Raymond and Peterson (2005) also note that "comparing fire severity at the scale of a few hectares is informative for evaluating the relative effects of three management options (no action, thinning, and thinning followed by burning) on fuels and fire severity at small scales. However, further inference is limited by the small spatial scale of this study relative to the spatial scale of the disturbance being studied. The Biscuit Fire burned a large area, creating a mosaic of low, moderate, and high fire severity patches, and when the study area is evaluated in the context of the larger fire, then each treatment is simply one patch within this mosaic. At this scale, factors in addition to forest structure, such as topography, weather, and climate may control the size and relative abundance of patches within the burn mosaic." (P. 2992.)

It should be noted that the southern Oregon forest type studied by Raymond and Peterson (2005) is not typical of eastside forests in Oregon that are usually considered for fuel treatments. Much of the understory in the Biscuit Fire was evergreen hardwoods that typically don't function as fuel ladders. (Brown 2008a.)

Agee and Lolley (2006) applied prescribed fire and low thinning treatments (4 control, 4 thin, 2 burn and 2 thin/burn units) to dry forests dominated by ponderosa pine and Douglas-fir in the eastern Washington Cascades, and modeled wildfire behavior. Low thinning focused on smaller, commercial-sized trees and was designed to reduce basal area to 10-14 m2 ha-1 in a non-uniform pattern to mimic natural stand patterns and increase resistance to bark beetle attack. Yarding was done by helicopter; branches and tops were left onsite. Nonmerchantable small trees were felled by hand on thinned units. Burning was a low intensity spring burn, but coverage was spotty, ranging from 23-51%, and considered ineffective in reducing fuels at the time of application by management and research personnel. Both thinning and burning affected vegetation and fuels variables. Thinning reduced canopy closure, canopy bulk density, and basal area, and increased canopy base height. Burning had no influence on these canopy variables. Thinning increased 10-hr timelag (0.62-2.54 cm) fuels. Burning decreased 1-hr (0-0.62 cm) and 10-hr timelag fuels, forest floor depth and mass, and increased fuelbed depth. Differences in fuel properties did not translate into differences in simulated wildfire behavior and tree mortality. Thinning did increase potential surface fire flame length under 97 percentile weather, and active crown fire potential decreased on thinned units, but basal area survival did not significantly differ between treatments under 80 and 97 percentile weather. The scale at which data are presented has a large influence on interpretation of results. For example, torching fire behavior, expressed as an average at the unit level, was low, but 17% of individual plots (about 30 plots total per unit) across all treatments did exhibit potential torching behavior. Agee and Lolley (2006) state that "thinning increased crowning index and therefore reduced crown fire hazard. But whatever the

crowning index, it must be compared to expected windspeeds in the area in order to identify real risk. Arbitrary thresholds that define low, moderate, and high crowning potential across a state or region need to have a more site-specific interpretation based on local wind data." (P. 155-156.)

Pollet and Omi (2002) quantitatively examined fire effects in treated and untreated stands in four ponderosa pine sites in Montana, Washington, California and Arizona. Fuel treatments included prescribed fire only, whole-tree thinning, and thinning followed by prescribed fire. On-the-ground fire effects were measured in adjacent treated and untreated forests. The researchers developed post facto fire severity and stand structure measurement techniques to complete field data collection. They found that crown fire severity was mitigated in stands that had some type of fuel treatment compared to stands without any treatment. At all four of the sites, the fire severity and crown scorch was significantly lower at the treated sites. Results from this research indicate that fuel treatments removing small diameter trees may be beneficial for reducing crown fire hazard in ponderosa pine sites.

Pollet and Omi (2002) found that differences in fire severity and crown scorch were less extreme at the site treated with prescribed fire than the sites treated with thinning. Apparently, mechanical fuel treatments allow for more precise and controlled results compared to prescribed fire. Mechanical fuel treatments may specify the exact number of post-treatment residual trees per hectare. By contrast, prescribed fire fuel treatment often varies across a stand and results in less precise stand structure changes.

Pollet and Omi (2002) note that while topography and weather may play a greater role than fuels in governing fire behavior, fuels are the only leg of the fire environment triangle (fuels, topography, weather) that land managers are able to manipulate. But they caution that, in extreme weather conditions (e.g. drought and high winds) fuel treatments may do little to mitigate fire spread or severity. Pollet and Omi (2002) suggest focusing programs, funding and management attention where the wildfire risk is greatest: wildland-urban interface areas, tree plantations, critical watersheds and habitat for threatened and endangered species. Finally, Pollet and Omi (2002) argue that in order to lower the probability of a severe wildfire over a landscape, the entire landscape should be analyzed for determining the most appropriate scales and locations for fuel treatments. Intensively treating most of the landscape may not be necessary (or feasible) but treating strategically located stands for fuel treatment or treating strips of fuels may be beneficial for reducing severe wildfire potential across a large area.

2.5 Effects on snags and coarse woody debris

Stephens and Moghaddas (2005) report on impacts of several replicated fuel treatments on snag and coarse woody debris (CWD) quantity and structure in a Sierra Nevada mixed conifer forest. These treatments included prescribed fire, commercial thinning (crown thinning and thinning from below) followed by rotary mastication of understory trees, mechanical followed by prescribed fire, and control, on snag and coarse woody debris (CWD) quantity and structure in a Sierra Nevada mixed conifer forest. Density of snags greater than 15 cm DBH in decay class 1 significantly increased in fire only and mechanical plus fire treatments compared with mechanical only and control treatments. Snag volumes (m3 ha-1) were not significantly

different between treatments for all decay classes. CWD (density, percent cover, volume) in decay classes 1 and 2 was not significantly altered by any treatment when aggregated across all diameter classes. Volume of CWD in decay class 3 was significantly reduced in the fire only treatment when compared to controls. Density and volume of CWD in class 4 was significantly reduced in mechanical plus fire and fire only treatments when compared with controls and mechanical only treatments. Stephens and Moghaddas (2005) argue that retaining large CWD levels may benefit some wildlife species short-term but increases in fire hazards and increased difficulties in fire control are negative consequences. High overall fuel loads also increase the probability of snag and CWD consumption when an area inevitably burns. Influences of altering snag and CWD characteristics should be analyzed in the context of long-term forest management goals, including reintroduction of fire as an ecosystem process and creation of forest structures that can incorporate wildfire without tree mortality outside a desired range.

3.0 Effects of woody biomass collection and conversion on Wildlife

This section addresses potential effects - positive and negative- of forest biomass removal on wildlife. Depending on local conditions and the specific prescriptions used, thinning and removal of biomass from dense, overstocked stands can often improve wildlife habitat, but not all species benefit and some may be negatively impacted. General issues that land managers might wish to consider are discussed first, followed by summaries of what is known about effects on individual species and wildlife groups.

3.1 Effects on wildlife: general comments

The following general comments and discussions of specific wildlife groups consist primarily of information and references paraphrased from a recent synthesis on wildlife effects by Pilliod and others (2006), augmented with additional study summaries and citations. Pilliod and others (2006) refer to numerous studies on effects of prescribed fire, many of which assessed both fire and thinning effects simultaneously, and in ways that make it difficult to clearly differentiate between the two types of treatments. For this report, the focus is primarily on studies that address thinning effects, under the assumption that forest biomass utilization usually starts with thinning operations, but the biomass will be removed from the site rather than burned.

Pilliod (2004) notes that managers face a difficult task in predicting the effects of fuel treatments on wildlife due to the paucity of information for most species and wide variability in habitat needs and responses, but suggests that predictions may be possible after considering an animal's ecology and then using available information in a conceptual framework that includes 1) species distribution and abundance, 2) migratory and dispersal characteristics, 3) habitat requirements and preferences, and 4) potential responses to changes in habitat.

Brown (2000) discusses opportunities for using thinning to jointly improve wildlife habitat and reduce wildfire risk. (The original text quoted includes references, which have been omitted here for brevity.) "*Low elevation, dry forests appear to offer the clearest opportunities for thinning — in conjunction with prescribed fire — to contribute to restoration of wildlife habitat while making forests more resistant to uncharacteristically severe fire. For reducing fire risk, priorities are to reduce surface and ladder fuels and raise the bottom of the live canopy.*

Thinning is most apt to be appropriate where understory trees are sufficiently large or dense that attempts to kill them with fire would run a high risk of also killing overstory trees. Using prescribed fire alone can be desirable in that it provides the full range of ecological effects of fire. However, fire is an imprecise tool and a chainsaw or harvester can provide much more control over which trees are actually killed. The larger understory trees that are less likely to be safely thinned with fire are more apt to be large enough to have economic value if they are logged. This presents opportunities to defray expenses while providing employment and wood products, as well as risks that economic pressures will bias decisions about which trees to cut and thus undermine the credibility of restoration.

Even where understory trees can safely be thinned with fire, consideration will need to be given to potential smoke production and soil heating during subsequent burns that will be necessary to consume the dead understory trees once they fall to the ground. Although anecdotal evidence, computer modeling and common sense provide considerable support for the premise that thinning can reduce fire risk and restore habitat, there is precious little empirical scientific research on the subject and humility and caution should be the order of the day." (Brown 2000, p. 25.)

Lehmkuhl and others (2002) explain how active management of stands with small diameter trees can improve wildlife habitat. They note that species extirpations caused by habitat fragmentation are a primary concern for wildlife managers, typically addressed by designated reserve areas that are not actively managed. But in landscapes significantly influenced by human activities (e.g. fire suppression; timber harvesting) active management to maintain or restore habitat for individual species and promote greater biodiversity is equally important. Active management of small diameter stands can directly address both habitat fragmentation and habitat maintenance/restoration issues. Forested landscapes in the interior Pacific Northwest are dominated by small diameter forests as a result of previous management and wildfire in the early 20th century. Old forest habitats have declined and become fragmented, and some wildlife species associated with them have become threatened or endangered. Lehmkuhl and others (2002) maintain that, in general, fewer wildlife species use middle-age, pole-sapling, or young forests, where dense canopy structure results in relatively low understory vegetation diversity, than older forests. Active management (thinning) in these middle-aged, small diameter stands can diversify understory habitat and accelerate development of old forest characteristics, such as large diameter trees and patchy understories, that are currently lacking.

Pilliod and others (2006) synthesized information regarding the effects of hazardous fuel treatments on terrestrial wildlife and invertebrates in western dry coniferous forests. The following discussion is paraphrased from their synthesis, which included thinning (and/or prescribed burn) studies in ponderosa pine, dry-type Douglas-fir, lodgepole pine and mixed conifer forests. Pilliod and others (2006) found tremendous gaps in information needed to evaluate the effects of fuel treatments on the majority of species found in these forests. Differences in study location, fuel treatment type and size, and pre- and post-treatment habitat conditions resulted in considerable variability in species responses. A species may respond positively to fuel reduction in one situation and negatively in another. There is a great need for long-term observational and experimental studies on the effects of a range of fuel reduction treatments at multiple spatial scales (stand or larger). Until more complete information on many species becomes available,

management activities that allow retention of critical habitat elements are warranted, particularly for slow to recover elements such as large-diameter down wood and snags.

Despite these major information gaps, Pilliod and others (2006) identified a few consistent patterns. Fire-dependent species, species preferring open habitats, and species associated with early successional vegetation or that consume seeds and fruit usually benefit from fuel treatments. Conversely, species that prefer closed-canopy forests or dense understories, and species that are closely associated with large snags or down logs that may be removed by fuel treatments, will likely be negatively affected. Some habitat loss may persist for only a few months or years, such as understory vegetation and litter that recover quickly. But lost large snags and down wood- important habitat elements for many wildlife and invertebrate species- may take decades to recover and thus represent some of the most important habitat elements to conserve. Pilliod and others (2006) suggest that managers should retain refugia of untreated stands and critical habitat elements, particularly slow to recover features such as large-diameter down wood and snags, to increase habitat heterogeneity and benefit the greatest number of species over time.

In most cases, conserving habitat heterogeneity also conserves biodiversity. Therefore, fuels treatment planners may want to coordinate with biologists to plan treatments that, over time, create a mosaic of forest structures and conditions that approximate natural disturbance patterns, which could be expected to support greater species diversity than large, homogeneous stands given the same treatment. Treating fuels in habitat patches adjacent to untreated patches that are occupied by a given wildlife species may increase the rate of colonization and recovery compared to restoring areas at random. (Pilliod and others 2006.)

A species' response to habitat changes from fuels treatment depends on habitat elements that species needs to survive and reproduce, and how the treatment affects these habitat elements. Potential effects of a fuels treatment on a particular species should be considered within the context of that species' distribution and abundance, migratory and dispersal characteristics, habitat associations, and potential responses to habitat changes. If a species is widely distributed, localized fuels projects may have relatively minor effects on population viability, depending on the species' ability to recolonize from surrounding areas. But for species with a limited distribution, especially in cases where an entire subpopulation of a rare species lies within the treatment area, it may be necessary to protect specific habitat components or leave untreated refugia within project boundaries. (Pilliod and others 2006.)

Species responses may also vary over time. For example, the population of a small mammal species that requires shrub cover to avoid predators may decline following treatment, but then later exceed pretreatment levels when shrubs recover and food resources increase from greater light, herbaceous growth and seed production that result from opening up the forest canopy. (Pilliod and others 2006.)

3.2 Effects on forest Carnivores

Forest carnivores native to western dry coniferous forests include mountain lion, bobcat, wolf, coyote, black bear, grizzly bear, fisher and American marten. Wolverine and lynx generally

prefer cooler, higher elevation forests. American marten primarily inhabit older forests of Engelmann spruce and subalpine fir in northeastern Oregon but occasionally occur in drier stands of grand fir and lodgepole pine with high densities of down wood and snags (Bull and others 2005a). Most forest carnivores are relatively rare, and there are substantial information gaps on their responses to tree harvest. Because most have relatively large ranges, few forest carnivore species will be affected by stand-level fuels projects. But some could be affected by loss of denning habitat and changes in prey populations due to cumulative effects of past management, past disturbances and larger scale projects (Pilliod 2006). Both marten and fisher are sensitive to loss in canopy cover and are strongly associated with downed wood cover. These are both indicator species, which can complement ecosystem-level conservation planning by revealing thresholds in habitat area and landscape connectivity (Carroll and others 2001).

Black bears are more common than most other forest carnivores and their diet and habitat may be influenced by fuels projects. Black bears use areas with abundant down wood and dense thickets of shrubs and smaller trees adjacent to or within mature forests. About 25% of black bear diet can consist of insects (mainly ants and yellowjackets) obtained primarily from down logs (Bull and others 2001), so decreases in down wood can make less of this food available to black bears. Black bears also strip bark from smaller trees and feed on sapwood. In a western larch, lodgepole pine and Engelmann spruce forest in northwestern Montana, black bear feeding on sapwood was 5 times higher in thinned stands where bears mostly selected 5”-10” larch trees compared with adjacent unthinned stands (Mason and Adams 1989). The health and condition of residual trees may have attracted the bears. Treated stands may also provide dependable food sources for bears when fruit, mast, grass, and herbaceous plant production increase after prescribed fire. But fuel treatments may reduce the amount of escape cover, perhaps the most critical component of black bear habitat (Hamilton 1981). Sites used by black bears for traveling and resting typically have high stem density and dense canopies, presumably for security. Bears use large-diameter hollow logs for denning (Bull and others 2000) that may be lost in thinning operations.

3.3 Effects on ungulates

North American ungulate species, including deer, elk, moose, mountain goats and bighorn sheep generally utilize open areas for foraging and forested areas for cover. Ungulates such as deer and elk use dense thickets of shrubs and trees as thermal cover, to hide from predators, for daybeds and for fawning. All ungulates require areas of abundant forage, such as grasses, forbs and shrubs. Both of these habitat types, and their proximity to each other, are important. In Douglas-fir and mixed conifer forests in western Montana, elk generally remain within 200 meters of foraging areas during summer. Thinning alone or combined with prescribed fire generally increases forage quantity and quality for elk and other ungulates (Demarais and Krausman 2000, Huffman and Moore 2004). However, retaining patches of dense cover (greater than 40% closure of midstory canopies) is beneficial for providing security and escape cover for mule deer (Chambers and Germaine 2003).

Henjum (2006) notes that thinning large areas of forest cover may force wintering ungulates to lower elevations resulting in increased conflict and damage losses for neighbors. Subsequent green-up of thinned areas may attract ungulates for longer periods during spring-summer,

increasing the potential for damage to adjacent property or crops. Henjum (2006) suggests that integrating wildlife needs with fuels reduction can be achieved through intensive planning and close cooperation between resource disciplines. Reigel (2006) states that in central Oregon, thinning dense second-growth trees and mowing or burning of understories dominated by fire sensitive bitterbrush has successfully reduced fire risk, but the treatments often stimulate fire dependent species such as rabbitbrush, snowbrush, and greenleaf manzanita. This shift in species composition reduces bitterbrush cover and abundance- the primary browse for mule deer.

Long and others (2008a) investigated the effects of fuels reduction on quantity and quality of forage available to elk in Starkey Experimental Forest and Range in northeastern Oregon. From 2001 to 2003, 26 stands of true fir and Douglas-fir were thinned and burned, with 27 similar stands left untreated as experimental controls. (The effects of thinning only, or thinning and removal of thinned biomass, were not tested separately.) Percentage of cover, percentage of dry-matter digestibility, and percent of nitrogen (%N) of 16 important forage species and genera were estimated in treatment and control stands during spring (May–June) and summer (July–August) of 2005 and 2006. Quantity and quality of forage were lower in summer than spring in both stand types. Total cover of forage was higher in treatment stands during spring and higher in control stands during summer. For grasses, %N was higher in control than in treatment stands whereas digestibility did not differ between stand types. For forbs, neither index of forage quality differed between stand types. When treated stands were separated out by years since burning, %N and digestibility of forbs and %N of graminoids increased from 2 to 5 yr following treatment, and by the fifth year after burning had exceeded maximum values observed in control stands in both seasons. Due to interacting effects of fuels reduction and season on forage characteristics, treated stands provided better spring foraging for elk, whereas control stands provided better summer foraging. Long and others (2008a) suggest that maintaining a mosaic of burned and unburned (late successional) habitat may be of greater benefit to elk than burning a large proportion of a landscape. In another paper on the same experiment, Long and others (2008b) suggest that in ecosystems similar to their study area, combination "thin-burn" fuel treatments may benefit elk more than mule deer where the two species co-exist.

3.4 Effects on small mammals

Small mammals require cover and food resources. Shrubs, down wood, and snags provide important cover from predators, so loss of these habitat elements may negatively impact some small mammal species (Chambers 2002). But species that prefer open habitats can benefit from food resources provided by fruit-producing shrubs, grasses and forbs that may establish after fuel treatments. Small mammals seem to recolonize disturbed areas soon after disturbance, although diversity and species dominance differ as succession progresses. Generalist species typically dominate in early successional stages, while specialist species dominate later (Fisher and Wilkinson 2005).

Small mammal species vary in habitat preference and thus in response to different types of fuel treatments. In a lodgepole pine/mixed conifer forest in northeastern Oregon, a commercial thinning designed as a fuels treatment resulted in an increase in chipmunks and a decrease in red-backed voles, red squirrels and snowshoe hares one year after thinning (Bull and Blumton 1999). Hares continued to use small patch-cut stands (10-m-wide circular cuts interspersed in unthinned stands comprising 30 to 40 % of the stand), but avoided stands thinned to a uniform

4.2-m spacing, which suggests that retaining unthinned patches may help maintain hare populations in fuel treatment areas until understory vegetation recovers (Ausband and Baty 2005, Shick 2003, Sullivan and Sullivan 1988).

Small mammals that prefer high canopy closure may be adversely affected by thinning. Thinning will likely have a drying effect on high-canopy, high-density stands of grand fir, potentially having a negative effect on northern flying squirrel populations. Northern flying squirrel abundance in dry Douglas-fir-ponderosa pine-western larch forests in northeastern Oregon decreased 1-2 years after a thinning treatment (Bull and others 2004), possibly due to habitat changes and decreases in truffles, the primary food of northern flying squirrels and other small mammals (Lehmkuhl and others 2004). Lehmkuhl and others (2006) concluded that thinned and burned stands would likely be poor bushy-tailed woodrat habitat in eastern Washington dry forests due to woodrats' association with abundant large snags, mistletoe brooms and soft log cover.

Forest floor litter is important to some small mammals, especially westside Oregon forests. Fuels reduction treatments, primarily fire, are likely to reduce presence and/or depth of litter.

Meyer and others (2005) examined short-term impacts of prescribed burning (no burn and burn), mechanical thinning (no thin, light thin, and heavy thin), and combinations of these treatments on production of truffles and their consumption by lodgepole chipmunks in a mixed-conifer forest of the southern Sierra Nevada of California. Truffle frequency, biomass, and species richness were lower in thinned or burned plots than controls, as was frequency and richness of truffles in the diet of lodgepole chipmunks. These impacts also were lower in heavily thinned and thinned and burned plots than in those that were only burned. These results suggest that either thinning or burning can reduce short-term truffle production and consumption, and potentially the dispersal of ectomycorrhizal spores by small mammals. Moreover, truffles decreased with treatment intensity, suggesting heavy thinning and higher burn intensity, particularly when applied together, can significantly affect short-term truffle abundance and small mammal consumption. Impacts to truffles will also impact northern flying squirrels.

Converse and others (2006) examined short-term patterns in small-mammal responses to mechanical thinning, prescribed-fire, and mechanical thinning/prescribed-fire combination treatments at eight different study areas across the United States by modeling taxa-specific densities and total small-mammal biomass as functions of treatment types and study area effects. Small-mammal taxa examined included deer mice, yellow-pine chipmunks, golden-mantled ground squirrels, as well as all Peromyscus (deer mouse) and Tamias (chipmunk) species. The top-ranked model of total small-mammal biomass was one with biomass varying only with treatment (i.e., treated vs. untreated), not by treatment type or study area. Individual species and taxa appear to have variable responses to fuels treatment types in different areas; however, total small-mammal biomass appears generally to increase after any type of fuel reduction. Converse and others (2006) found that predicting responses of a particular small-mammal species to a treatment is difficult given present information, but indicate that it is reasonable to expect total small-mammal biomass to increase with thinning, prescribed-fire, or the combination of thinning and prescribed-fire treatments. Adaptive management policies may be necessary to help reduce

uncertainty as to which treatments are locally optimal for meeting management objectives for small-mammal populations.

Edge and Manning (2002) report preliminary results for a study that examined the effects of three types of treatments for managing fuel loading- 1) piling, 2) piling and burning, and 3) lopping and scattering, on small mammals. Small mammals were sampled before (1999) and after (2000) treatments. Fifteen small mammal species were captured during 2000 sampling. The deer mouse and western red-backed vole were most abundant, and so were used for analysis. Edge and Manning (2002) found no evidence that mean survival of either species was affected by fuel treatments, but suspect that intense solar radiation reaching the forest floor following thinning resulted in severe environmental conditions that masked treatment effects on small mammal survival. Effects of thinning on the small mammal community are indicated by the approximately 10% decline in mean total number of small mammals captured across all treatments. Results are preliminary, but suggest interactions among fuel treatments, regional climate and opening of the forest canopy following thinning. Authors suggest that elsewhere in the PNW where solar radiation is less extreme, slash management may affect small mammals differently.

Conservation of small mammals requires knowledge of ecologically meaningful spatial scales (e.g., individuals or populations) at which species respond to habitat heterogeneity. Between July and October of 1998, Manning and Edge (2004) sampled small mammals, understory vegetation, and downed wood at multiple scales (trap sites, 1-hectare forest patches, and stands) in 2 managed Douglas-fir forests in western Oregon. Objectives were to determine if downed wood or understory vegetation varied among or within forest patches or among forest stands and whether variation in survival of small mammals coincided with the scale in which these varied. Understory vegetation explained most variation within patches, but did not vary among patches or stands. Survival of the 2 most abundant species, the deer mouse and creeping vole also varied within patches by differing among individual home ranges, and was most related to downed wood volume (cubic meters per 0.01 hectare) and herb and grass cover (%). Survival of deer mice was explained by a function of downed wood within individual home ranges. Survival of creeping voles was dependent on a function of downed wood within home ranges, and was highest in home ranges lacking downed wood. Results demonstrate that these species may not be generalists, as previously suspected, but rather specialists tied to specific amounts of particular habitat components within home ranges.

Because of fires and intensive logging practices, young forests dominate much of the Pacific Northwest landscape. Most young stands were reforested with Douglas-fir at high densities. Researchers have proposed thinning these stands as a means to improve habitats for vertebrates. But effects of thinning intensity on forest-floor small mammals are not well understood. During 1994-1996, Suzuki and Hayes (2003) conducted experimental and retrospective studies using pitfall trapping to assess effects of thinning intensity on abundance and reproduction of small mammals in Oregon Coast Range Douglas-fir forests. They investigated short-term effects of thinning stands to moderate and low tree densities on small mammals during the first 2 years following thinning, and potential long-term effects of thinning by comparing relative abundance and reproductive performance of small mammals in previously thinned (7-24 years prior to the study) and unthinned stands. Among 12 small mammal species examined in the experimental

study, number of captures increased for 4 and decreased for 1 within 2 years of thinning. Responses were similar between moderately and heavily thinned stands. Among 9 species examined in the retrospective study, number of captures was greater for 5 and lower for none in previously thinned than in unthinned stands. Furthermore, total number of small mammals captured was higher in previously thinned than in unthinned stands. Effects of thinning on 2 species- creeping voles and Pacific jumping mice- were consistent in the short and long term. Captures for both species increased in the first 2 years following thinning and were greater in stands thinned 7-24 years previously than unthinned stands. Western red-backed vole captures decreased within 2 years of thinning but were similar in stands thinned 7-24 years previously and in unthinned stands. Reproductive performances of deer mice and creeping voles improved following thinning in the short term. In the retrospective study, reproductive performance of western red-backed voles was higher in thinned than in unthinned stands. Overall, thinning did not have substantial detrimental effects on any species investigated and had positive effects on several. Suzuki and Hayes (2003) suggest that thinning is a viable option to enhance habitat quality for several species of forest-floor small mammals in densely stocked, young Douglas-fir stands.

3.5 Effects on bats

Bats inhabit stands with adequate roosting habitat (large trees and snags) and plentiful food (flying insects). Little data exists on direct effects of fuel treatments on bats, but some inferences can be made based on their known habitats. Long-legged myotis, silver-haired bats and other bat species roost under the bark of tall, large-diameter trees or in cavities of large snags (Betts 1998, Ormsbee and McComb 1998, Rabe and others 1998, Vonhof and Barclay 1996). In South Dakota, silver-haired bats roosted primarily under loose bark, in tree crevices, and in woodpecker cavities in ponderosa pine snags averaging about 39 cm dbh (Mattson and others 1996). These stands averaged 21 snags per hectare. As long as large snags and trees are protected, thinning may have minimal or even positive effects on bat populations depending on initial site conditions and land use history (Boyles and Aubrey 2006, Patriquin and Barclay 2003, Schmidt 2003) whereas loss of these habitat features may be detrimental (Chambers and others 2002).

In the Oregon Coast Range, bat activity in Douglas-fir stands was highest in old-growth, lowest in unthinned second growth (50-100 years old), and intermediate in thinned second growth stands (Humes and others 1999). Elsewhere in Oregon, old-growth Douglas-fir-western hemlock, ponderosa pine-sugar pine, and true firs stands were also preferred by hoary and silver-haired bats compared to younger stands (Perkins and Cross 1988). Bat activity was higher in old-growth stands of Douglas-fir than in mature and young stands in the southern Washington Cascades and Oregon Coast Range (Thomas 1988). Preference for old growth might be explained by the high density of large-diameter snags used as roosts, open spaces among trees, which allows bats to gain flight when leaving their roosts, or other factors. Whether or not bats also prefer old-growth stands in the interior dry coniferous forests of the West remains unknown.

Loeb and Waldrop (2008) tested the effects of thinning and burning on bat foraging and commuting activity in pine stands in South Carolina's Clemson Experimental Forest. They also tested whether vertical use of stands varied with treatment and whether activity of three common

species varied among treatments. Twelve stands dominated by loblolly and shortleaf pine at least 14 ha in size were selected. Three replicates of four treatments were installed: 1) prescribed burn, 2) thin only, 3) thinning and burning, and 4) no treatment (control). Bat activity was sampled in 2001 and 2002. Big brown bats, eastern red bats, and eastern pipistrelles were the most frequently recorded species. In 2001, overall activity was significantly greater in thin only stands than in control stands; activity in thinned and burn and burned stands was intermediate. Activity was also greater in treated stands than in control stands in 2002, but the difference was not statistically significant. None of the treatments affected vertical use of the stands. Activity of big brown bats and red bats was significantly higher in thinned stands than in control or burned stands, but activity of the genus of pipistrelles bats did not vary among treatments. Results suggest that treatments that reduce clutter, particularly thinning, increase the suitability of pine stands for bats' foraging and commuting activity in managed pine forests in the South.

3.6 Effects on birds: general comments

Factors that influence bird species richness and diversity in a stand include the structure and composition of living and dead vegetation. In western dry coniferous forests, bird community composition depends on the diversity of habitats available, proximity to water, fire history, and silvicultural legacy (Brawn and Balda 1988, Finch and others 1997, Hejl and others 2002). As with other wildlife, species most likely to be affected by fuel treatments are those whose nesting and foraging habitats are associated with the fuels being removed or created, and species that either prefer or avoid disturbed areas. Because of their great mobility as adults, population-level responses of birds to fuel treatments are strongly influenced by their distribution and abundance in the surrounding landscape, but pre-treatment conditions will also influence responses.

Reported effects of fuel treatments on birds are somewhat inconsistent. Stand scale effects may differ from those at the landscape or regional scale (Kotliar and others 2002). But it is possible to make some general predictions. Thinning conducted during the nesting season is more likely to result in high mortality of nestlings, especially for species that nest on the ground or in shrubs and small trees (Smith 2000). Bird species that prefer early successional and open habitats are likely to increase in abundance after fuel reduction (DeGraaf and others 1991, Hagar and others 1996, Provencher and others 2002, Simon and others 2000, Wilson and others 1995). If conducted prior to nesting season, fuel treatments are likely to reduce nesting habitat for ground- and shrub-nesting species, but shrubs and ground cover lost during treatment will likely recover within a few years (Pilliod and others 2006).

3.7 Effects on raptors

The more open understories created by fuel treatments may benefit hawks, owls, and eagles that prey on small mammals and birds in open forests and small clearings because prey species that have less cover are more easily captured. (Pilliod and others 2006.) However, some raptor species and some small mammal and avian prey prefer closed canopy forests and thus may avoid stands that have been treated to reduce fuels. Any fuels reduction treatments that reduce density of pole-sized to mature trees is likely to negatively impact accipter hawks. All three species, especially sharp-shinned and Cooper's hawks, are closely associated with very dense stands (Reynolds and Wight 1978, Reynolds and others 1982, Moore and Henny 1983).

Removal of trees with dwarf mistletoe brooms during thinning will likely be detrimental to raptor species that nest in the brooms including the great gray owl, long-eared owl, great horned owl, northern spotted owl, northern goshawk, Cooper's hawk, and red-tailed hawk (Bull and others 1997). Northern goshawks prefer closed canopy forests of large-diameter trees with relatively open understories (Reich and others 2004). Management recommendations for sustaining northern goshawk habitat and prey include thinning from below to achieve non-uniform spacing of large trees, a maximum of 30 to 50% canopy opening, and various slash treatments (Reynolds and others 1992, Squires and Reynolds 1997).

The endangered Mexican spotted owl and northern spotted owl both occur in dry forest environments. Management guidelines for both species specify little active management in defined areas. By reducing the risk of stand-replacing fires in these defined areas, restoration treatments outside of these areas should benefit spotted owls over time (Beier and Maschinski 2003). Variable-density thinning may accelerate development of northern spotted owl habitat and dense prey populations (Carey 2001, 2003, Carey and others 1999a, b; Carey and Wilson 2001; Muir and others 2002), especially when snags, cavity trees and large downed wood are conserved (Bunnell and others 1999; Carey 2002; Carey and others 1999a, b) though this treatment may be more appropriate in mixed conifer stands with mixed-severity fire regimes than in drier pine, low-intensity fire regimes (Lehmkuhl and others 2006). Fuel treatments may reduce northern spotted owl habitat quality, but this should be weighed against the risk of stand replacing fires and complete loss of habitat over large areas (Everett and others 1997).

3.8 Effects on cavity nesting birds

Primary cavity nesters excavate nest cavities in large trees and large snags. These cavities also provide nesting, roosting, and shelter habitat for secondary cavity-nesting birds and some mammals. Preference for large snags for nesting has been well documented for the pileated woodpecker, hairy woodpecker, northern flicker, and Williamson's sapsucker in dry forests in northeastern Oregon (Bull 1986), woodpeckers in ponderosa pine forests in central Oregon (Bate 1995, Dixon 1995), and cavity nesters in ponderosa pine forests after wildfires in southwestern Idaho (Saab and Dudley 1998, Saab and others 2002) and northern Arizona (Chambers and Mast 2005).

If fuel treatments remove snags, a loss of nesting habitat for primary and secondary cavity-nesting birds might be expected for many years. Most studies report that thinning or thinning and burning fuel treatments result in reduced populations of cavity nesters due to loss of dead trees used for nesting and roosting. Preliminary results of research in southeastern British Columbia show that thinning in dry Douglas-fir and ponderosa pine forests resulted in lower snag densities, cavity-nesting bird densities, and species richness of cavity nesters in the first two breeding seasons after thinning (Machmer 2002).

Treatments that do not remove large snags may improve ponderosa pine habitat for breeding Lewis's woodpeckers by decreasing canopy cover- open canopies are preferred habitat for this species (Saab and Vierling 2001).

Maintaining a minimum number of snags per unit area in a ponderosa pine or Douglas-fir stand may be insufficient given the ephemeral nature of snags, which continually change in height, decay state, and presence of sapwood decay organisms (Parks and others 1999, Zack and others 2002). Research in dry forests in Idaho suggests that most cavities are only used once by seven of the eight woodpecker species that were considered (Saab and others 2004), so a continual supply of snags is needed to maintain new nesting sites over time. Responses of secondary cavity nesters to fuel treatments in ponderosa pine and Douglas-fir forests will likely follow a pattern similar to primary cavity nesters, i.e. some positive, some negative, and some neutral (Medin and Booth 1989). Clutch size and number of nestlings of the western bluebird, a secondary cavity nester, did not differ between control stands and stands thinned and burned in ponderosa pine forests in Arizona (Germaine and Germaine 2002). Bluebirds had a higher probability of successfully fledging young in treated stands but with greater risk of parasitic infestations.

In northeastern Oregon, 65% of pileated woodpecker foraging occurs in down wood and snags. Bull and others (2005b) compared abundance of logs, snags, stumps, and of woodpecker foraging in mixed-conifer (ponderosa pine-Douglas-fir-grand fir) stands that had undergone 1) prescribed burning after mechanical fuels treatment, 2) mechanical fuels treatment without prescribed burning, or 3) no treatment. Pileated woodpecker foraging was significantly higher in untreated or mechanically treated stands. Ants, the primary prey of pileated woodpeckers, were also significantly more abundant in these stands. Pileated woodpecker foraging in mechanical removal treatments was less common than in control treatments but significantly higher than in prescribed burn treatments. Prescribed burning did not allow the same degree of control in retaining coarse woody debris as mechanical fuels treatment.

Lyons and others (2008) examined short-term responses of cavity-nesting birds in dry conifer forests of Washington to fuel treatments in 2004 and 2005 to determine if mechanical thinning or prescribed burning or a combination of the two would alter foraging tree selection. Results suggested that fuel treatments had a positive impact. Chickadees selected for large diameter, live, Douglas-fir trees in treated stands, nuthatches selected for large diameter, ponderosa pine in treated stands, and woodpeckers selected for large diameter, ponderosa pine snags, in thinned and thinned–burned stands. Birds were more likely to forage in treated stands, an outcome that was strongest in stands that received both thinning and burning. Bird groups selected trees at least 1.6 times as large in diameter in treated stands compared to control stands. Thinning and burning may enhance foraging habitat for bark gleaning species as a whole. Results support treatment design considerations including small tree removal, canopy opening to increase herbaceous and bare ground cover resulting in improved invertebrate assemblages and thus improved forage abundance, and retention of large trees and snags (>40 cm dbh) that provide important foraging substrate and nesting habitat.

McIver and others (2003) examined fuel reduction by mechanical thinning and removal in mixed-conifer stands in northeastern Oregon in an experiment that compared a single-grip harvester coupled with either a forwarder or a skyline yarding system, and unharvested control sites. Both extraction systems achieved nearly equivalent (~46%) mass fuel reduction. Mean log length was lower in harvested units compared to unharvested controls, but this did not decrease occupation of logs by ants or the activities of woodpeckers feeding on them.

3.9 Other bird studies

Hayes and others (2003) experimentally manipulated stands to evaluate influences of two thinning intensities on populations of diurnal breeding birds in western Oregon. They conducted point counts of birds seven times each year in 1994 (prior to treatment) and from 1995-2000 (subsequent to treatment). Of 22 species for which there was adequate data, nine species decreased and eight species increased in thinned stands relative to controls. There was no strong evidence that thinning influenced numbers of five species. Of the 17 species that responded to thinning, the magnitude of response of eight species varied with thinning intensity. For each of these species, response was greatest in more heavily thinned stands. No species was extirpated from stands following thinning, but detections of Hutton's vireos, golden-crowned kinglets, brown creepers, black-throated gray warblers, and varied thrushes, decreased to less than half of detections in controls in one or more treatment types. This evidence suggests that thinning may significantly reduce the numbers of detections for the species that were studied.

In contrast, American robins, Townsend's solitaires and Hammond's flycatchers were rare or absent in controls but regularly present in thinned stands, and detections of western tanagers, evening grosbeaks, and hairy woodpeckers increased by threefold or more in thinned stands relative to controls. Only Pacific-slope flycatchers, warbling vireos, and western tanagers showed strong evidence of temporal trends in response. For these species, differences between numbers in controls and treated stands became more extreme through time. Findings suggest that thinning densely stocked conifers in landscapes dominated by younger stands enhances habitat suitability for several species of birds, but that some unthinned patches and stands should be retained to provide refugia for species that are impacted by thinning.

Hagar and others (2004) studied forest songbird response to three different intensities and patterns of thinning in 40-year-old stands dominated by Douglas-fir in the Oregon Cascades. They compared changes in songbird density 2 years before and 4 years after experimental thinning, between each thinning treatment and the control. Species richness and the density of 10 species increased following thinning. Four additional species were detected with higher frequency in thinned stands. The density of five species decreased following thinning but no species disappeared. Hagar and others (2004) conclude that commercial thinning rapidly promotes diversity of breeding songbirds in young, conifer-dominated stands, but suggest using a variety of thinning intensities and patterns, from no thinning to very widely spaced residual trees, to maximize avian diversity at the landscape scale and structural diversity both within and among stands.

Hagar and others (1996) compared abundance and diversity of breeding and winter birds between commercially thinned and unthinned 40- to 55-year-old Douglas-fir stands in the Oregon Coast Ranges. Breeding bird abundance was greater in thinned stands. Bird species richness was correlated with habitat patchiness and densities of hardwoods, snags, and conifers. During the breeding season, Hammond's flycatchers, hairy woodpeckers, red-breasted nuthatches, dark-eyed juncos, warbling vireos, and evening grosbeaks were more abundant in thinned than unthinned stands. Pacific-slope flycatchers were more abundant in unthinned stands. Golden-crowned kinglets, gray jays and black-throated gray warblers were more

abundant in unthinned than thinned stands, but these patterns were inconsistent between seasons, regions, or years. Stand-scale habitat features were associated with the abundance of 18 bird species.

Siegel and DeSante (2003) compared avian community composition and nesting success in thinned and unthinned stands of commercially managed Sierran mixed conifer forest. They conducted point counts and monitored 537 active nests of 37 species on 10 study plots during three consecutive breeding seasons in the northern Sierra Nevada. All 10 study plots had a similar long-term management history that included fire suppression and single-tree selection logging, but five plots also underwent combined commercial and biomass thinning 5-8 years prior to the study. Pooling species by nest substrate, Siegel and DeSante (2003) found that detections of ground-nesting bird species were similar on thinned and unthinned plots, but detected canopy-, cavity-, and especially shrub-nesting species much more frequently on the thinned plots. Nest success rates were not statistically different between thinned and unthinned plots for ground-, shrub-, canopy-, or cavity-nesting species. Thinned stands were characterized by significantly less canopy cover, significantly lower density of small and medium conifers, and significantly greater understory cover and deer brush cover than the unthinned stands. Siegel and DeSante (2003) surmise that thinning stimulated vigorous shrub growth, and conclude that forest conditions associated with a relatively open canopy and a well-developed shrub understory are highly beneficial to numerous breeding bird species in the Sierran mixed conifer community, including many species that may not nest or forage in the understory. Forest thinning that promotes vigorous shrub growth may correlate with increased abundance of nesting birds, at least in stands affected by historical fire suppression and single-tree selection logging.

3.10 Effects on reptiles

Reptile diversity is generally lower in forests than in deserts, grasslands, and chaparral. Few lizard and snake species occupy western closed canopy coniferous forests except for perhaps the rubber boa. But reptile species do inhabit specific forest patches, such as wetlands, meadows, and rock outcroppings that provide shelter, microclimates, and prey (Heatwole 1977, Lillywhite 1977) including the western fence lizard, eastern fence lizard, sagebrush lizard, ornate tree lizard, western skink, northern alligator lizard, garter snakes, mountain king snake, racer, gopher snake and western rattlesnake. Very little is known about the effects of thinning on reptiles, and Pilliod and others (2006) found no studies specific to dry coniferous forests. Reptile species that prefer forest floor cover might decrease when such habitat is lost, but most reptile species would probably benefit from reduction in shrubs, ground vegetation, and litter cover and depth (Germaine and Germaine 2002; Knox and others 2001; Mushinsky 1985; Singh and others 2002). Many lizard species prefer snags and down wood over live trees (James and M'Closkey 2003), so fuel treatments that leave snags and down wood on site may improve habitat for these species.

3.11 Effects on amphibians

Most forest amphibians use upland habitats at various times during the year, depending primarily on the availability of moist duff and litter and rotting down wood. Unlike reptiles, amphibians' response to reduced canopy cover will likely be negative due to warmer, drier conditions created

in the understory vegetation, down wood, litter and soil (McGraw 1997, Meyer and others 2001, Pough and others 1987). Most terrestrial salamanders require moist soils or decomposing wood to maintain water balance, therefore dry conditions usually result in suppressed populations (Bury and Corn 1988, deMaynadier and Hunter 1995). Frogs and toads may be less affected by environmental changes associated with fuel treatments because they tend to travel at night and during rain events, their greater mobility compared to salamanders, and their close association with wetlands (Constible and others 2001, Pilliod and others 2003). Still, species that frequently occupy terrestrial habitats, including many salamanders, boreal toads, and tree frogs may be killed during fuel treatments or find post-treatment conditions unsuitable (Pilliod and others 2003).

Pilliod and others (2006) found only one study that addressed effects of thinning on amphibians in dry coniferous forests. In a western Montana lodgepole pine forest, 70% fewer long-toed salamanders were captured in selectively harvested stands compared to unharvested stands, a difference that was attributed to reduction in overstory canopy and subsequent temperature increases (Naughton and others 2000). The importance of overstory canopy has been demonstrated for other amphibian species in the central Oregon Coast Range (Martin and McComb 2003).

Concerns have been expressed that fuel treatments may contribute fine sediment to streams because of increased surface runoff (Elliott and others 1999, Robichaud 2000, Robichaud and Waldrop 1994). Sedimentation reduces egg and tadpole survivorship of some stream-breeding amphibians that lay eggs and rear tadpoles under rocks or in spaces in stream cobbles (Corn and Bury 1989, Gillespie 2002).

3.12 Effects on invertebrates: general comments

Fuels treatment effects on terrestrial invertebrates in western dry coniferous forests- insects, spiders, mites, scorpions, centipedes, millipedes, isopods, worms, snails and slugs- are probably as diverse as the group itself. Invertebrates comprise over half of the animal diversity in forests (Niwa and others 2001), occupy all forested habitats and have varied functional roles including detritovores, predators, herbivores and pollinators. Many invertebrates are specifically associated with habitat elements targeted in fuel treatments, e.g. shrubs, snags, litter, and duff. Most invertebrates occupy distinctly different habitats during their life cycles. For example, some species live below ground when young and above ground as adults or feed on vegetation as immatures and then on flower nectar as adults. Forest invertebrates are short lived and either have small dispersal ranges or are sedentary in one or more life stages, so fuel treatments can potentially affect local populations through direct mortality depending on the season, type, and size of treatment. Some invertebrate species can potentially explode in population but many are scarce and recognized as threatened, endangered or of conservation concern. Across invertebrate groups and for diverse ecosystems, the provision of refugia (leaving untreated areas from which populations can recolonize) is widely recommended to minimize the effects of direct mortality and accelerate recovery. (Pilliod and others 2006.)

Relatively few studies have examined fuels treatment effects on invertebrates in dry coniferous forests; a significant limitation in understanding and predicting responses of species in this

group- native and nonnative- to such treatments. Threats to forest health posed by outbreaks, particularly of some bark beetles and defoliators, are somewhat unique to invertebrates. Silvicultural practices such as precommercial thinning that improve stand health have long been assumed to reduce the risk and impact of these disturbance agents (Gast and others 1991). But the use of fuel treatments to achieve combined goals of fuel and insect management has not been widely applied or studied, with the exception of thinning residue treatments aimed at reducing surface fuels and population build-ups of some bark and woodboring insects. (Pilliod and others 2006.)

McIver and others (2003) examined fuel reduction by mechanical thinning and removal in mixed-conifer stands in northeastern Oregon in an experiment that compared a single-grip harvester coupled with either a forwarder or a skyline yarding system, and unharvested control sites. Both extraction systems achieved nearly equivalent (~46%) mass fuel reduction. Light displacement of soil resulted in a short-term increase in the abundance of soil microarthropods. Effects of compaction on litter microarthropods was more persistent, with lower numbers in compacted litter a year after harvest.

Pilliod and others (2006) organize available information regarding thinning effects on invertebrates around functional groups- detritivores, predators, forest herbivores, and pollinators- paraphrased and condensed below.

3.13 Effects on invertebrate detritivores

Invertebrates of the forest soil and floor are crucial to decomposition and nutrient cycling and include detritivores (e.g. earthworms, land snails and slugs, and arthropods including millipedes, isopods, mites and springtails) and species active in decomposition of dead down wood and snags (e.g. termites, beetles and ants). Few studies have specifically examined the effects of fuel treatments on detritivores and decomposers in western dry coniferous forests. Researchers (e.g. Niwa and others 2001) hypothesize that thinning is likely to have significant negative effects, at least in the short-term, on invertebrates of the soils and organic layers through soil compaction and disruption or loss of organic layers. Compaction will depend on soil type and thinning treatment.

Soil organisms may be more protected from treatments effects than those in litter layers. For example, long-term effects of thinning (16-41 years post-treatment) on densities of microinvertebrates (including oribatid, mesotigmid, and prostigmatid mites) were found in the litter of late-successional white fir and Douglas-fir forests in the southwestern Oregon Cascades, but no differences were found in mite or Collembola densities in the upper 5 cm of soil between thinned and unthinned stands (Peck and Niwa 2004). Tenebrionid beetles- forest floor scavengers- were found at higher richness and diversity in ponderosa pine stands of northern Arizona 13-14 years after fuel treatments (thinning alone and thinning with prescribed burning) compared to untreated stands (Chen and others 2006). Studies in other ecosystems have shown that fuel treatments can negatively affect soil and litter invertebrates directly through mortality and loss of food and cover, and many have prolonged recovery periods (Hanula and Wade 2003). Better information is needed on effects of changes in soil and litter invertebrates on ecosystem functions (e.g. nutrient cycling). (Pilliod and others 2006.)

3.14 Effects on predatory invertebrates

Predatory invertebrates are found in all forest habitats. Forest floor predators are frequently studied, especially spiders and carabid beetles. These invertebrates usually recover from fuel treatments more quickly than those in the soil, particularly those with greater mobility and ability to disperse. They may also benefit from greater habitat diversity created by fuel treatments. One study on response to thinning (>16 years post-treatment), focused on spiders and carabid beetles in late-successional white fir and Douglas-fir forests in the Cascade Mountains of Oregon (Peck and Niwa 2004). No difference was found in overall abundance or species richness of carabids between thinned and unthinned stands, but some individual species were more or less abundant in thinned stands. Spider abundance and species richness were significantly higher in thinned stands. Generally, hunting spiders were more numerous in thinned stands, whereas sheet web-building spiders were more numerous in unthinned stands. Site management history and size of treatment area were important factors in moderating changes in diversity and abundance of leaf litter arthropods in mixed-conifer stands in the Sierra Nevada Mountains of California one year after fire and fire surrogate treatments (prescribed burning, overstory thinning with understory mastication, and combined thinning and burning) (Apigian and others 2006.)

In a longer-term study in northern Arizona ponderosa pine stands, the ground beetle species assemblage did not vary between thinned (4-10 years post-treatment) and untreated stands, was richer in thinned stands that were subsequently (3-4 years) treated with prescribed fire, and was highest in stands two years following wildfire (Villa-Castillo and Wagner 2002). High diversity in burned stands was attributed to temporary colonization by open-area species, pyrophilous species, and recolonization from refugia. Another study in northern Arizona ponderosa pine stands found consistently higher richness and diversity of carabids more than 13 years following fuel treatments (Chen and others 2006). Carabids may provide a useful indicator of ponderosa pine stand conditions following fuel treatments or wildfire.

3.15 Effects on invertebrate herbivores and pollinators

Depending on the timing of fuel treatments, invertebrate herbivores and pollinators such as moths and butterflies that inhabit and feed on live vegetation during some life stage can be immediately affected through direct mortality or loss of food or cover. Longer-term, these invertebrates may benefit from changes in structural diversity resulting from fuel treatments that increase the amount of light reaching foliage and the forest floor. Two years after thinning that removed 50 % of basal area in young ponderosa pine in central Oregon, abundance of pandora moths (which feed as larvae on pine foliage) was not affected but adult emergence and egg hatch occurred seven to 10 days earlier in thinned stands, presumably due to increased solar radiation and temperature (Ross 1995).

In a northern Arizona ponderosa pine/oak forest, adult butterfly abundance and species richness were greater with a combination of thinning and prescribed fire than in paired control sites. Elevated responses up to two years post-treatment corresponded with significantly greater light intensity in the treated site, although larval host and nectar plant richness did not change (Waltz and Covington 2004). Huntzinger (2003) reported similar results after prescribed fire (1 to >15

years) in late-successional reserve Douglas-fir and hardwoods in the Siskiyou Mountains of Oregon and mid- to late-seral pines and firs in western Sierra Nevadas of California. Huntzinger (2003) pointed out that nonnative plant species invasion following prescribed fire and other disturbances could have secondary negative impacts on invertebrate herbivores and pollinators through loss of host plants.

3.16 Effects on bark and wood boring insects

Species such as root and bark beetles and wood borers that benefit from stress or weakened defenses of living host trees usually respond positively in the short-term to disturbance created by thinning and prescribed fire, but treatment timing affects responses. Some bark beetles and wood borers increased significantly in abundance and diversity after prescribed fire only (170% increase), partial harvest and prescribed fire (54% increase), and partial harvest only (45% increase) compared to untreated controls (up to one year post-treatment) in interior Douglas-fir and ponderosa pine stands in British Columbia (Machmer 2002). Several other studies (e.g. Apigian and others 2006, Hanula and others 2002) have produced similar results, but thinning and prescribed fire treatments are not always examined separately. In prescribed fire studies, attack success is often higher in injured trees when beetle populations were low (e.g. Elkin and Reid 2004). At high population levels, injured and uninjured trees are usually equally likely to be successfully attacked.

Over a three-year period in northern Arizona ponderosa pine, there was no evidence of an outbreak of endemic bark beetles regardless of treatment history including untreated, thinned (4-11 years prior), thinned followed by prescribed fire (3-4 year after), or stand replacement by wildfire (two years prior). (Sanchez-Martinez and Wagner 2002.) These results are counter to the hypothesis that dense stands should be more susceptible to beetle infestation.

4.0 Effects of woody biomass collection and conversion on soil resources: Compaction, soil nutrient changes, erosion

This section addresses the effects of thinning and forest biomass removal on forest soils- one of the primary concerns cited by conservation groups regarding biomass removal activities. Thinning and removal of small diameter wood and slash generally requires lighter equipment than traditional logging projects, but active harvesting of any kind generally entails some degree of soil impact. A key consideration is weighing the physical soil impacts of management activities to remove small diameter wood against impacts that can result from uncharacteristically severe wildfires that may occur if stands are left untreated.

Removing thinnings and slash from a stand rather than leaving it onsite to decompose can also affect soil chemistry. Decomposing wood helps replenish soil nutrients. But managers must also consider how leaving excess forest biomass on the forest floor affects fuel loadings and wildfire risk- uncharacteristically severe wildfire can also negatively impact soil qualities. Whether or not removing biomass negatively effects soil fertility and growth of residual plants depends on the overall soil nutrient budget in the stand, and which nutrients are limiting.

Some studies that investigated the effects of forest biomass removal on forest soil physical properties and soil chemistry are summarized below.

Brown (2000) discusses a primary challenge with understory thinning- the low value of the wood that is usually targeted for removal encourages use of low-cost harvesting methods. This typically means ground-based equipment, which can seriously degrade forest soils. Soil is not only the fundamental source of productivity in forest ecosystems, but also strongly influences hydrologic function and water quality. Soil compaction, which can take decades to recover, reduces plant growth and also inhibits infiltration of water, which increases erosion, sedimentation and spring run-off. Fire can also adversely affect forest soils, but Brown (2000) maintains that these effects are relatively short-lived. To maintain ecological integrity during thinning operations, it is essential to employ low impact equipment and use it properly. Brown (2000) argues that establishing standards to keep soil compaction, disturbance, and puddling to less than 10% of a project area, and monitoring to ensure that these standards are met would be a significant, and feasible improvement over past practices.

Gundale and others (2005) examined the responses of physical, chemical and biological properties of soil to forest restoration treatments of 1) thinning, 2) controlled burning and 3) thinning combined with controlled burning 1 and 3 years post-treatment, using a replicated field experiment in Montana. Individual restoration treatments were implemented in 9 ha units. Treatments had a pronounced effect on the depth of the soil organic (O) horizons. Both the burn and thin/burn treatments had thinner O horizons, while the thin only treatment had a thicker O horizon compared to the control. By year 3, the O horizons remained diminished in both burn treatments, but the thin only treatment did not differ from the control, suggesting that significant settling and decomposition had occurred. During year 1, both burn treatments had significantly more exposed mineral soil compared to the thin only and control, but these differences were no longer detectable by year 3.

No differences in soil bulk density were detected among the treatments. Gundale and others (2005) surmised that higher soil bulk densities resulting from harvest operations were likely avoided in the burn and thin/burn treatment areas because harvests were conducted on frozen and snow-covered soil using harvesting techniques designed to minimize soil compaction. A high C:N substrate decomposed more rapidly in both burn treatments relative to the unburned treatments. Treatments had no immediate effect on the soil microbial community.

Moghaddas and Stephens (2008) evaluated mechanical fuel treatment effects on soil compaction in a managed Sierra Nevada mixed-conifer forest using three treatments: Thin, Thin + Burn, and an untreated Control. To examine impacts of mastication equipment traveling through a stand to reduce fuels, soil sampling was stratified to examine effects at treatment unit, skid trail network, and non-skid trail area scales. At all scales, Thin and Thin + Burn did not increase soil bulk density compared to Control. At the treatment unit level, soil strength was increased in Thin + Burn relative to Control, but this was attributed to increased strength in skid trails rather than in the non-skid portion of the stand. Compacting forces of the masticator were buffered by the debris bed it created. No significant compaction due to mastication was observed away from skid trails. Soil strength appeared to be a more sensitive measure of compaction, although a very weak relationship was observed between soil bulk density and soil strength. Despite frequent

stand entries prior to these fuel treatments, the cumulative extent of detrimental compaction was not increased as a result of Thin and Thin + Burn treatments. Mean soil strength in skid trails was consistently greater than in non-skid trail areas to a depth of nearly 60 cm. Measures to avoid creation of new skid trails will help curtail increased soil compaction in managed forest stands, particularly in areas that may require repeated fuel treatments to remain effective.

McIver and others (2003) examined fuel reduction by mechanical thinning and removal in mixed-conifer stands in northeastern Oregon in an experiment that compared a single-grip harvester coupled with either a forwarder or a skyline yarding system, and unharvested control sites. Both extraction systems achieved nearly equivalent (~46%) mass fuel reduction. Of 37 logged hectares, 1.4% (0.5 ha) of the soil area was compacted, mostly within forwarder units, log landings, and trails close to landings. Displaced soil varied from 5 to 43% area among units and was located within trails or in intertrail areas between the trails.

Elliot and Miller (2002) used the Water Erosion Prediction Project (WEPP) model to compare erosion rates from fuel management operations, including roads, to erosion following wildfire for climates across the western U.S. Forest sediment yields were estimated with the Disturbed WEPP online forest erosion prediction interface, an adjunct to the WEPP model that allows users to easily describe numerous disturbed forest and rangeland erosion conditions. The interface presents the probability of a given level of erosion occurring the year following a disturbance.

All scenarios assumed that if no harvesting occurred, the area would progress to the point of a high severity fire. No scenarios were examined for undisturbed conditions (neither harvesting nor fire occurrences). All thinning and prescribed fire simulations retained 85% surface cover as recommended by most Forest Service regional soil quality guidelines. The wildfire scenario assumed a 45% cover. Results indicated that erosion from fuels treatment operations, including thinning and prescribed fire, are less than from wildfire, even when road erosion rates are included. Forest erosion rates from the wildfire scenario were predicted to be about 40 times the erosion rates from prescribed fire with buffers. Erosion due to thinning was predicted to be about 70% that of prescribed fire, or 1% that of wildfire.

Nitrogen (N) is a critical limiting nutrient that regulates plant productivity and the cycling of other essential elements in forests. Johnson and Curtis (2001) performed a meta-analysis of forest management effects on soil carbon (C) and nitrogen (N). Results indicated that that forest harvesting, on average, had little or no effect on soil C and N. But significant effects of harvest type and species were noted. Leaving residues on site (i.e., sawlog harvest) caused an 18% increase in soil C and N whereas residue removal (i.e. whole tree harvesting) caused a 6% decrease compared to controls. The positive effect of sawlog harvesting appeared to be restricted to coniferous species, although reasons for this were not clear. Conversely, several studies from widely varied conditions clearly showed that residues had little or no effect on soil C or N in hardwood or mixed forests.

Johnson and Curtis (2001) include a discussion regarding harvesting residues: "Several studies found that soil C and N temporarily increase after sawlog harvesting, apparently a result of residues becoming incorporated into the soil. The general trends found in a number of these studies, however, are consistent with the concept of high C/N ratio residues becoming

incorporated into soils over the short-term with soil C re-equilibrating to lower levels and to C/N ratios more similar to background as time passes. This raises other questions regarding C balances. Specifically, what is the long-term fate of the residues? They remain part of the O [organic] horizon for long periods in some cool coniferous forests but in warmer hardwood forests, they rapidly decompose. If leaving residues on site has no long-term positive effect on mineral soil C, removing residues for biomass burning may be more C efficient (by offsetting fossil fuel combustion) than leaving them on site. Conversely, nutrients left behind in residues may result in long-term carbon gains in aboveground vegetation and cause residue removal to be less C efficient. If the latter is true, how do the C and economic costs of fertilization compare with the costs of leaving residues on site? Our analysis in this study can only provide partial answers to these questions. Indeed, the answers to these questions while very important to both intensive forestry and the global C issue surely vary substantially by site and probably defy generalization." (P. 235.)

Prescott and Laiho (2002) assessed the nutritional significance of coarse woody debris (CWD) in lodgepole pine, white spruce-lodgepole pine, and subalpine fir-Engelmann spruce forests in the Rocky Mountains of southern Alberta, Canada. Mass loss and changes in carbon (C), nitrogen (N), and phosphorus (P) concentrations in decomposing log segments were measured over a 14-year period. Organic matter input was measured during 10 years for CWD, 1 year for ground vegetation, and 5 years for other aboveground litter types. Carbon, N, and P release from decomposing litter were simulated for a period of 40 years to determine the relative contributions of each aboveground litter type, including CWD.

After 14 years, pine log segments had lost 71% of their dry mass; spruce and fir lost 38% and 40%, respectively. Nitrogen (N) content of the logs increased in pine, changed little in spruce, and decreased by almost 30% in fir logs. Phosphorus (P) accumulated in decaying log segments of all three species, especially fir logs in which P content was nearly five times the initial content after 14 years. Tree species with the lowest initial concentration had the greatest relative accumulation. Thus, wood decay organisms may compete with vegetation for limiting nutrients in these forests. The proportion of CWD in aboveground litter input was 19% at the pine site, 3% at the spruce site, and 24% at the fir site. Contribution of CWD to N and P release was 2% or less, except at the fir site where CWD released 5% of the N.

Prescott and Laiho (2002) state that their estimates are only valid for the forests they studied and at the time of measurements, but the sites represent a variety of common forest types and stand development stages: a dense self-thinning lodgepole pine stand, a mature post-thinning spruce stand, and an old-growth spruce-fir stand. Their findings indicate that CWD does not appear to make a significant contribution to N and P cycling in these forests and may actually compete with vegetation for limiting nutrients. Prescott and Laiho (2002) argue that guidelines for management of CWD should be based on management objectives related to other potential values (e.g. wildlife habitat) rather than its role in N and P cycling.

A brief literature review conducted by the Forest Guild (2008) found that soil compaction impacts of forest biomass removal projects can generally be minimized by using good harvest layouts and appropriate harvesting equipment. The Forest Guild (2008) study also noted the paucity of studies on soil nutrient level effects of forest biomass removals, but cite studies (Kelty

and others 2008, Grigal 2004) indicating that soil nutrient levels are replenished within 50-70 years.

5.0. Effects of woody biomass collection and conversion on water quality

Elliot and Robichaud (2005) describe sources of sediment in upland forest watersheds in the context of fuel management activities. They note that undisturbed watersheds have little erosion but that natural forests have natural disturbances, including wildfire and large floods, with return periods that range from decades to centuries. When either event occurs there will be significant upland erosion, and sediment deposition and movement in forest streams. Thus, long-term natural background sediment yields from watersheds are a combination of low levels of erosion from undisturbed forests plus added erosion from occasional disturbances. Activities such as thinning generally cause some level of disturbance. Erosion rates associated with these activities are generally much lower than rates from a wildfire, landslide, or flooding but may occur more frequently.

Elliot and Robichaud (2005) provide estimates of long-term average annual sediment delivery for different types of disturbance in northern Rocky Mountain forest ecosystems:

Wildfire:	0.15	Mg/ha	=	0.0669 tons/acre
Prescribed Fire:	0.001	Mg/ha	=	0.0005 tons/acre
Thinning or Logging:	0.005	Mg/ha	=	0.0022 tons/acre
Roads (assume 2.5% of watershed:	0.125	Mg/ha	=	0.0558 tons/acre

6.0 Effects of woody biomass collection and conversion on air quality

The effects of noncommercial forest biomass removal and utilization on air quality is a complex topic that ranges from local-level smoke management concerns to national and international scale issues of carbon budgets, climate change and energy policy. This section addresses some of the issues and tradeoffs that policymakers and planners are faced with as they consider how to move forward, and summarizes some of the analyses and discussions of these topics that are underway in Oregon.

Finding economically viable ways remove huge numbers of small, non-merchantable trees from the landscape is the central dilemma facing managers as they try to implement hazardous fuel treatments. One option is to simply cut these trees and leave them on the forest floor. However, doing so often increases fire hazard and the severity of pest insect outbreaks. Historically this material was either burned in prescribed fires or in uncharacteristically severe wildfires. But high fuel loadings, air quality restrictions, short windows of appropriate weather, and risk of escaped fire are some factors that limit application of prescribed fire (USDA Forest Service 2003).

Within its natural range, wildfire has a number of beneficial effects on forest ecosystems, and both prescribed fire and wildland fire use are viable and useful tools for managers. On the other hand, open burning of forest biomass – whether in wildfires, prescribed fires, or slash burning – can have detrimental impacts on forest ecosystems and produces large amounts of visible smoke, particulates, and significant quantities of nitrogen oxides, carbon monoxide and hydrocarbons that

contribute to the formation of atmospheric ozone. Wildfires also emit substantial quantities of carbon dioxide (CO2) as well as methane, and other trace gases (Morris 1999; McNeil Technologies 2003) and can impact human health. Quantification of emissions is difficult because of extreme variability in fuels, burning practices and environmental conditions (Morris 1999).

Converting biomass waste into energy is one promising way to sustainably address some of these problems. Use of biomass waste as power plant fuel vastly reduces the smoke and particulate emissions associated with its disposal, and significantly reduces the amounts of carbon monoxide, nitrogen oxides, and hydrocarbons released to the atmosphere. By one estimate, if non-merchantable forest thinnings were consumed in biomass power boilers instead of open burning, nitrogen oxide emissions could be reduced by 64% and particulate matter could be reduced by 97% (Antares Group, Inc. 2003).

Particulate matter emissions from open burning depend on the amount of fuel and type of fire, generally ranging from 25 to 40 pounds per ton of fuel burned. Estimates of fuel burned per acre range from 11.0 tons for a prescribed fire in a low-density stand to 79.5 tons during a high intensity wildfire in a high-density stand (Sampson and others 2001). Resulting emissions therefore could range from 275 to over 3,000 lbs. per acre burned.

Estimates of emissions from biomass power plants by the EPA include 0.22 – 0.3 lbs. per MMBTU of fuel input (United States Environmental Protection Agency 1995). This equates to 3.7 – 5.1 lbs. per ton of fuel, or 9 to 20% of the emissions from open burning. Emission levels for ethanol plants are expected to be similar or less than biomass power facilities (McNeil Technologies 2003).

A 2003 report commissioned by the Oregon Department of Energy assessed the potential for forest biomass utilization in three eastern Oregon counties (McNeil Technologies 2003). The report discussed forest biomass in comparison with coal because both are solid fuels that employ similar technologies. Use of biomass fuels produces lower emissions than coal-fired plants, so to the extent that biomass replaces coal use, air quality will benefit. Biomass is lower in sulfur than is most U.S. coal. Typical biomass contains 0.05 wt % to 0.20 wt % sulfur on a dry basis. In comparison, coal has 2 wt % to 3 wt % sulfur on a dry basis. Biomass sulfur content translates to about 0.12 to 0.50 lb of sulfur dioxide per million BTUs. Using biomass to generate power typically produces lower sulfur dioxide emissions than using coal. Nitrogen oxide emissions should also generally be lower for biomass, due to lower fuel nitrogen content and the higher volatile fraction of biomass versus coal.

The McNeil Technologies (2003) report also addressed the complex issue of the "carbon footprint" of forest biomass energy in comparison to fossil fuels. Biomass power plants can produce large emissions of carbon dioxide (CO2), sometimes even in excess of fossil fuel plants because of lower combustion efficiencies for biomass. However, the CO2 released by combustion of forest biomass was removed from the atmosphere in the recent past through photosynthesis and new plant growth will continue to remove CO2 from the atmosphere after biomass is harvested. For this reason it is often argued that biomass is "CO2 neutral." In practice, the picture is somewhat more complex. Other carbon flows are involved with biomass power production, including CO2 emissions from fossil fuel burned during harvesting,

processing and transportation operations. Net CO2 emissions from a biomass power plant are clearly lower than those from a fossil fuel plant, but under current production practices, biomass power is not a net zero CO2 process.

Along these lines, Brown (2008b) notes that it is commonly assumed, including by many scientists, that fuel treatments also reduce carbon emissions and that while this seems intuitively obvious, thinning also releases carbon to the atmosphere from disturbance of soil and forest floor during, transport and processing of thinned trees, and burning of biomass, even if this occurs in a biomass plant. Brown suggests two types of analysis that could help determine how these releases compare to emissions avoided due to reduced fire behavior:

• A complete accounting of carbon emissions associated with thinning (from both the forest and fossil fuels) and prescribed burning, as well as carbon gains—if any—from increased sequestration in treated forests, and emissions avoided due to reduced severity of subsequent fire.

• Quantifying the probabilities that treated and untreated forests will burn during conditions likely to lead to a crown fire (a wildfire spreading in the treetops). That is, even if treatments would successfully reduce fire behavior, what is the likelihood that treated acres would burn in a high-severity wildfire during the time that the treatment would be effective?

Brown (2008b) concludes that in general, treatments strategically located to influence fire behavior and spread, or that protect the greatest biomass (i.e., old growth), may have the greatest probability of providing net carbon benefits and that while further research is needed, the carbon implications of fuel treatments will probably be small, one way or the other, and won't be the dominant consideration in deciding whether and how to proceed with such treatments.

Appendix B

Resource Protection Requirements for Different Ownerships in Oregon

Resource protection requirements during biomass removal operations vary for private, state, and federal land ownerships in Oregon.

- On federal lands managed by the US Forest Service or the Bureau of Land Management agencies must comply with applicable federal laws, land management plan standards and guidelines, and meet National Environmental Policy Act (NEPA) review standards.
- On private forest lands regulations under the Oregon Forest Practices Act serve to protect forest resources during biomass removal operations.
- On state owned and managed forestland resources are protected during biomass removal through implementation of rules for Board of Forestry forestlands, including the forest management plans, and implementation of the Common School Forest Lands agreement; incorporating appropriate contact provisions into timber sale contracts; and utilizing logging practices and equipment that minimize adverse impacts to the site.

What follows is an expanded discussion of the protection measures at work under each of the different major ownership types.

7.0 Federal Forestlands

Specific resource protection requirements are not prescribed at the national level on federal land due to the diversity of ecosystems to which they would apply. Federal actions must meet national standards such as the Clean Air and Water Acts, the National Historic Preservation Act, and the Endangered Species Act. Federal lands are also subject to protection requirements established by the states in which they reside, such as Oregon's water quality standards. BLM and USFS management units also must comply with their applicable land management plans. BLM Districts and Field Offices operate under Resource Management Plans and the USFS National Forests must comply with their Forest Resource Management Plans. The plans contain different protection requirements for specific ecosystems and sites within the applicable land use planning area. Specifically in the Pacific Northwest, the BLM and USFS must also comply with the standards and guidelines set forth for in the Northwest Forest Plan and Interior Columbia Basin Management Plan Environmental Impact Statements.

Any federal action, including those related to biomass removal operations, falls under the NEPA umbrella and is analyzed on a case-by-case basis. A site specific, project-level analysis reveals resource protection necessary for special status species, water quality, soils, and air. If an action has potentially adverse consequences, such as soil erosion, measures may be added to the proposed action to mitigate negative side effects. If mitigation measures are not sufficient to protect a resource, the proposed action may be altered or not implemented. For example, once a proposed action is developed, specialists review habitat in the project area to determine the

likelihood of sensitive or threatened or endangered species occurring there. If potential sensitive species habitat is detected, specific species will be surveyed for and avoided in operations. If the affected area is in critical habitat, the specialist consults with the Fish and Wildlife Service.

NATIONAL ENVIRONMENTAL POLICY ACT SPECIFIC:

In additions to their management plans, the National Environmental Policy Act (NEPA) requires federal agencies to incorporate environmental considerations in their planning and decision-making through a systematic interdisciplinary approach. Specifically, all federal agencies are to prepare detailed statements assessing the environmental impact of and alternatives to major federal actions significantly affecting the environment. The NEPA process consists of an evaluation of the environmental effects of a federal undertaking including its alternatives. There are three levels of analysis depending on whether or not an undertaking could significantly affect the environment. These three levels include: 1) categorical exclusion determination; 2) preparation of an Environmental Assessment/Finding Of No Significant Impact; and 3) preparation of an Environmental Impact Statement (EIS).

At the first level, an undertaking may be categorically excluded from a detailed environmental analysis if it meets certain criteria which a federal agency has previously determined as having no significant environmental impact. A number of agencies have developed lists of actions which are normally categorically excluded from environmental evaluation under their NEPA regulations.

At the second level of analysis, a federal agency prepares a written Environmental Assessment to determine whether or not a federal undertaking would significantly affect the environment. If the answer is no, the agency issues a Finding Of No Significant Impact. The Finding Of No Significant Impact may address measures which an agency will take to reduce (mitigate) potentially significant impacts.

If the Environmental Assessment determines that the environmental consequences of a proposed federal undertaking may be significant, an EIS is prepared. An EIS is a more detailed evaluation of the proposed action and alternatives. The public, other federal agencies and outside parties may provide input into the preparation of an EIS and then comment on the draft EIS when it is completed.

If a federal agency anticipates that an undertaking may significantly impact the environment, or if a project is environmentally controversial, a federal agency may choose to prepare an EIS without having to first prepare an Environmental Assessment.

After a final EIS is prepared and at the time of its decision, a federal agency will prepare a public record of its decision addressing how the findings of the EIS, including consideration of alternatives, were incorporated into the agency's decision-making process.

How biomass is merchandized in the US Forest Service, the Central Oregon experience

Following are the business methods under which biomass is utilized.

1) SERVICE CONTRACTS - This method involves the USFS paying for a service, for example, thinning small trees in plantations where the operator who is paid to do the work, an option can be added to the contract for first right of refusal of the woody biomass. That is, he/she can be sold the biomass at minimum rates without competition. The contract length can vary from 1 year or under multi year contracting up to ten years.

2) STEWARDSHIP CONTRACTS - The USFS can retain receipts or use appropriated funds to pay the operator to forward and remove biomass material in any stewardship contract areas. The operator pays low rates for the biomass material. The length of contract can be from one to ten years.

3) STEWARDSHIP AGREEMENTS - A partner, often a not for profit group, as the Rocky Mtn Elk Foundation or the National Turkey Federation, manages the work in a treatment area to achieve USFS/partner defined desired outcomes. The USFS does the timber accountability work, but the partner is responsible for accomplishing all the rest of the work. The partners can use stewardship contracts/agreements or service contracts to accomplish the work. The length of agreement is variable and can be for up to ten years.

4) TIMBER SALES - Timber: sawtimber, non-saw, and biomass are offered up for bid, minimum value is $10,000. Often biomass removal is optional, but forwarding biomass material to landings is often required. Biomass is sold at low rates. Length of contract period is five years.

5) SMALL SALES - Small volume timber/firewood sales are offered up for bid for up to $10,000 in value. Length of contract period is one year.

6) COMMERCIAL FIREWOOD AND /OR POST AND POLE PERMITS - the upper limit for each permit is $300 in value. Length of permit period is one year.

7) FORCE ACCOUNT WORK - Using USFS' own labor force and often combining it with workforces from partners as the Oregon Department of Forestry or the Dept. of Corrections under formal agreements, small tree material is decked to be sold for personal use firewood and/or post and poles.

The least cost and most frequently used method is to remove the biomass under a timber sale or a stewardship contract, where the logger removes small tree boles to markets as animal bedding and then subcontracts to a hogg operator for grinding tops, needles and branches. The hogg operator then has input on the design, size, access, and layout of the slash piles and shares the road maintenance costs. The use of logging machinery to forward biomass, enables efficient accumulation of large amounts for grinding operations. The Forest Service has not sold any stand alone biomass piles for hogging after the timber sale has closed. Since this work is done as part of the timber sale or stewardship contract, all the same operating restrictions exist as for example, using designated skid trails, abiding to seasonal restrictions, restricted riparian area operations, etc. The Forest Service expects the impacts from forwarding small trees, tree tops, limbs and needles is bulky and not compact on machines, so that minimum additional soil

impacts occur. The agency estimates that it harvested around 69,000 green tons last year using these methods.

The remaining 20% of Central Oregon USFS thinning work is done with small sales, service contracts, permits, force account labor, or agreements where small machines and/or manual labor, are used for harvest operations. Firewood and/or post and poles are the forest products produced. Utilization is less efficient, as some biomass is left to be hand piled and burned. Central Oregon National forests produced 18,000 cords of firewood last year.

8.0 Private Forestlands

Forest Practices Act requirements related to biomass removal operations
Notification requirements include reporting removal of any commercial forest product, including biomass, from forestland. These requirements are for both resource protection and tax collection purposes. (OAR 629-605-0150; ORS 527.670(6))

Interest in removing biomass, small diameter material that is often seen as the waste stream after timber harvest or restoration harvests, for energy or other forest products, calls into question what protections the Oregon Forest Practices Act are in play as these activities occur across the landscape. The following is a short outline of the protection measures and aspects of the Forest Practices Act that would likely come into play with these activities. In general they are the same requirements that apply to commercial timber harvests under the Act.

Treatment of Slash
Removing biomass from operation sites reduces the need for use of measures identified under the Act or associated administrative rules to offset the additional fire hazard created from operations and minimize opportunities for insect and disease infestation. (OAR Chapter 629, Division 615) Mitigation measures like onsite piling, burning, or crushing to treat residual slash can be replaced by biomass removal operations. Special provisions are included to protect soil productivity, riparian areas and waters of the state during mechanized site preparation or prescribed burning.

Reforestation
Reforestation following operations that reduce tree stocking below the productivity-based standards in the rules is essential to continued forest productivity and forest resource protection. (OAR Chapter 629, Division 625)

Road Construction and Maintenance
Access to biomass harvesting operation areas is subject to the road construction and maintenance rules. These rules establish standards for locating, designing, constructing and maintaining efficient and useful forest roads while maintaining forest productivity, water quality, and fish and wildlife habitat. (OAR Chapter 629, Division 625)

Harvesting, Riparian, and Wetland Protection Rules
Felling and yarding requirements under the Act apply to removing forest biomass from operations sites. These requirements are variously designed to prevent adverse disturbance to the

beds and banks of streams, water quality, retained vegetation, wetland hydrology, soil productivity, and soils' natural rainfall infiltration. (OAR Chapter 629, Divisions 630-660)

Green Tree, Snag, and Down Wood Retention
These regulations intend to provide nutrient cycling, wildlife maintenance, and moisture retention and other resource benefits of retained wood. These regulations are only triggered when harvest units are of a size (>25 acres) and stocking density is reduced below certain criteria (Type 2 & 3 harvests; ORS 527.676). When applicable, two standing trees (dead or live of certain height and diameter) and two downed pieces of wood are required per acre. Thinning operations that maintain higher stocking densities of standing trees (Type 1 harvest) will not trigger regulations requiring retention of downed wood in a harvest unit. Standing and downed wood retention standards are also found within the riparian, wetland, and specified resource site protection rules.

Specified Resource Site Protection
Special resource sites used by sensitive, threatened, or endangered species such as spotted owls are protected by rules in OAR Chapter 629, Division 665.

Shallow, Rapidly Moving Landslides and Public Safety
OAR Chapter 629, Division 623 describes protection measures for forest operations that occur on steep slopes vulnerable to shallow, rapidly moving landslides. Harvest and road building activities associated with biomass removal would be designed to minimize risk to public safety where vulnerable landforms occur.

9.0 State Forests Forestlands

Forest resources are protected on Oregon Department of Forestry managed state forests during biomass removal through three main factors:

1. In order to contribute to the overall maintenance of wildlife, nutrient cycling, moisture retention and other resource benefits of retained wood, forest management plans for forestlands managed by the Oregon Department of Forestry meet the Forest Practices Act requirements, or exceed these if deemed appropriate to meet management goals. Under current forest management plans, standards for live tree retention and downed wood exceed those of the Forest Practices Act.

2. In State of Oregon timber sale contracts and forest management plans, there are usually instances where standards or practices required by the timber sale contract exceed those of the Forest Practices Act. State of Oregon timber sale contracts have specific sections of the contract that address and enforce protection requirement issues, including:
   - Protection to Reforested Areas
   - Protection of Watershed
   - Protection of Utility Lines
   - Protection of Recreation Trails
   - Protection of Markings and Monuments

- Protection of Cultural Resources
- Protection against Fire

There are other instances where the forest practice rules are the applicable standard that determines contract compliance. Thus, it is possible to be in non-compliance with the contract and not be in violation of a forest practice rule (i.e., riparian leave areas). It is not possible to violate the Forest Practices Act without also being in violation of the timber sale contact.

3. Harvesting technology and economics have favored more whole-tree yarding on timber sales. So slash creation on State Forest land has shifted from widespread slash on harvest units to more concentrated slash piles on landings and roads. Thus biomass is usually made available (piled) as a byproduct of a regular commercial tree removal process. Biomass removal operations usually operate on the landings and roads and don't have to impact the harvest units by reentering them.

Appendix C

Enrolled SB 1072 (2005 Session) see section 4.9

73rd OREGON LEGISLATIVE ASSEMBLY--2005 Regular Session

Enrolled

Senate Bill 1072

Sponsored by Senator NELSON

CHAPTER

AN ACT

Relating to forestry policy.

Whereas forested lands comprise some of the most important environmental, economic and recreational resources in the State of Oregon; and

Whereas some of Oregon's forested lands are increasingly jeopardized by vulnerability to drought stress, the risk of severe insect and disease outbreaks and catastrophic wildfires fed by overstocking and unprecedented accumulation of forest fuels; and

Whereas reducing vulnerability to drought stress and the risk of severe insect and disease outbreaks and catastrophic wildfires is of interest to all Oregon residents; and

Whereas such active forest management may restore structural diversity of forest stands, enhance wildlife habitat and create other ecological, economic and social benefits; and

Whereas federal and state funds are not sufficient to carry out the management activities necessary to restore forest resilience and reduce the risk of severe insect and disease outbreaks and catastrophic wildfires; and

Whereas suppressing catastrophic wildfires affects federal, state and county treasuries; and

Whereas increased participation by the residents of this state and by state agencies in the development of federal forestland policies and management plans may improve the management of those lands; and

Whereas the development of a means to utilize biomass harvested from federal lands in an ecologically beneficial manner may assist in reducing the wildfire risk while reducing costs to the state; and

Whereas changes in the management of federal forests may produce a range of benefits to all Oregonians; and Whereas the State Board of Forestry is charged by ORS chapter 526 with the supervision of all matters of forest policy and management under the jurisdiction of the state; now, therefore,

Be It Enacted by the People of the State of Oregon:

SECTION 1. The Legislative Assembly finds and declares that:

(1) The State Forestry Department is well-positioned, due to experience in managing Oregon forests and its understanding of science-based, active forest management, to facilitate state government participation in forest management on federal lands located within the state.

(2) The State Department of Fish and Wildlife has expertise with fish and wildlife habitat and the Department of Environmental Quality has expertise with water quality. Both departments have an important role to play in the management of federal forests located within the state.

(3) A collaborative relationship between the State Forestry Department, the federal government, other agencies of the executive department, as defined in ORS 174.112, interested persons and nongovernmental organizations may restore the health, diversity and resilience of federal forests by increasing the information shared and by providing a variety of perspectives on site-specific and landscape-level determinations.

(4) In cooperation with the State Forestry Department and the federal government, many communities in wildfire-prone areas have completed a community wildfire protection plan that identifies priority areas for hazardous fuel removal from federal lands.

(5) The federal government has provided opportunities for agencies of the executive department, as defined in ORS 174.112, to become involved, to a greater extent, in the management of federal lands.

SECTION 2. In furtherance of the policy established in section 1 of this 2005 Act, the State Board of Forestry, in consultation with the Governor, may:

(1) In conformance with federal law, including Public Law 108-7, direct the State Forester to facilitate the development of stewardship contracts utilizing private contractors and, when appropriate, to seek and enter into a stewardship contract agreement with federal agencies to carry out forest management activities on federal lands. The State Forester may, under the stewardship contract agreements:

(a) Perform road and trail maintenance;

(b) Set prescribed fires to improve forest health, composition, structure and condition;

(c) Manage vegetation;

(d) Perform watershed restoration and maintenance;

(e) Restore wildlife habitat;

(f) Control exotic weeds and species; and

(g) Perform other activities related to stewardship.

(2) Create a forum for interagency cooperation and collaborative public involvement regarding federal forest management issues that may include, at the discretion of the board, the appointment of advisory committees, the use of existing advisory committees and procedures for holding public hearings.

(3) Provide guidelines for the State Forestry Department and State Forester to follow that contain directions regarding the management of federal lands and that specify the goals and objectives of the board regarding the management of federal lands.

(4) Participate, to the extent allowed by federal law, in the development of federal forest policies and the forest management planning processes of federal agencies.

(5) Provide guidelines for the department to follow in implementing this section.

(6) Coordinate with Oregon State University, the State Department of Fish and Wildlife, the Oregon Forest Resources Institute, the Department of Environmental Quality, the Economic and Community Development Department, the State Department of Energy and other agencies of the executive department, as defined in ORS 174.112, to assist the State Forestry Department in carrying out the provisions of this section.

SECTION 3. The Legislative Assembly finds and declares that:

(1) Forestlands in federal, state and private ownership comprise some of the most important environmental, economic and recreational resources in the State of Oregon. However, federal lands, and to a lesser extent state and private lands, are increasingly jeopardized by the risk of drought-induced mortality, severe insect and disease outbreaks and catastrophic wildfires.

(2) Enhancing forest health, wildlife habitat and other ecological values and reducing the risk of severe insect and disease outbreaks and catastrophic wildfires through forest management are of interest to the residents of this state. Federal and state funds have not proved sufficient to carry out the management activities necessary to achieve these goals on federal lands, and it is unlikely that the funds will be available on a continuous basis.

(3) The development of new market-based solutions to reduce the risk of severe insect and disease outbreaks and catastrophic wildfires may reduce the requirement for public funding. The development of biomass markets, including energy markets, that use forest biomass unsuitable for lumber, pulp and paper products as a primary source of raw material may assist in the creation of a sustainable, market-based model for restoring complexity and structure to Oregon's forests.

(4) A biomass-based industry may provide a renewable source of energy, reduce net greenhouse gas emissions, reduce air pollution from wildfires, improve fish and wildlife habitat, create jobs and provide economic benefits to rural communities. Through the collection and conversion of forest biomass, ancillary benefits may be realized through the improvement in forest health, the protection of infrastructure and the stabilization of soils within critical watersheds.

(5) The collection and conversion of forest biomass diminishes fuel loads and is an ecologically and economically sustainable practice where the reintroduction of fire is not appropriate.

(6) The policy of this state is to support efforts to build, and place in service, biomassfueled energy production facilities that utilize biomass collected from forests or derived from other sources such as agricultural crop residue when:

(a) The facilities utilize sustainable supplies of biomass from cost-effective sources;

(b) The use of woody biomass for energy maintains or enhances the biological productivity of the land, taking into consideration transportation costs, existing forest conditions, management objectives, vegetation growth rates and the need to sustain water quality and fish and wildlife habitat; and

(c) The set of forest values to be sustained, in addition to wood and biomass for energy, is considered. Forest values include forest products, water, wildlife and recreation.

(7) As used in this section and section 4 of this 2005 Act:

(a) "Biomass" means any organic matter, including woody biomass, agricultural crops, wood wastes and residues, plants, aquatic plants, grasses, residues, fibers, animal wastes, municipal wastes and other waste materials.

(b) "Woody biomass" means material from trees and woody plants, including limbs, tops, needles, leaves and other woody parts, grown in a forest, woodland, farm, rangeland or wildland-urban interface environment that is the by-product of forest management, ecosystem restoration or hazardous fuel reduction treatment.

SECTION 4. In furtherance of the policy established in section 3 of this 2005 Act, the State Forester shall:

(1) Establish a policy of active and inclusive communication with the federal government, public bodies as defined in ORS 174.109, residents of Oregon and interested parties regarding the utilization of woody biomass produced through forest health restoration. The State Forester shall actively utilize the statutory provisions of the National Forest Management Act of 1976, the Forest and Rangeland Renewable Resources Planning Act of 1974, the National Environmental Policy Act of 1969, the Federal Land Policy and Management Act of 1976 and the Healthy Forests Restoration Act of 2003 that allow the state to participate in federal policy development in a manner that expresses the policy established in section 3 of this 2005 Act.

(2) Promote public involvement in the identification of the areas of interface between urban lands and forestlands that pose the highest potential to threaten lives and private property.

(3) Solicit public comment on the location of biomass-based energy projects and conversion facilities.

(4) Promote public understanding, through education and outreach, of forest conditions, forest management options, the potential benefits and potential consequences of woody biomass utilization, the quality and quantity of woody biomass on federal lands and the potential for woody biomass utilization to assist in reducing wildfire risk and in enhancing forest health, diversity and resilience. The State Forestry Department may coordinate with the State Department of Energy, the Economic and Community Development Department, Oregon State University, the State Department of Fish and Wildlife, the Department of Environmental Quality and other entities in any education and outreach performed pursuant

to this subsection.

(5) Allow the State Forestry Department to conduct inventories of the types of woody biomass available and to serve as an information resource for persons seeking to utilize woody biomass for energy development. Notwithstanding ORS 192.501, reports on any inventories of biomass conducted by the department shall be made available for public inspection.

(6) Promote public understanding that woody biomass utilization may be an effective tool for restoration of forest health and for economic development in rural communities.

(7) Develop and apply, with advice from the forestry program at Oregon State University, the State Department of Fish and Wildlife, the Department of Environmental Quality and other sources, the best available scientific knowledge and technologies pertaining to forest and wildlife habitat restoration and woody biomass utilization when developing rules under ORS 527.630.

(8) Seek opportunities to provide a source of woody biomass from federal, tribal, state and private forests.

(9) Prepare a report every three years utilizing, to the greatest extent practicable, data collected from state and federal sources that specify the effect of woody biomass collection and conversion on the plant and wildlife resources and on the air and water quality of this state. The report shall identify any changes that the State Forester determines are necessary to encourage woody biomass collection and conversion and to avoid negative effects on

the environment from woody biomass collection and conversion. The State Forester shall submit the report to the Governor and to an appropriate legislative interim committee with jurisdiction over forestry issues.

SECTION 5. The State Forester shall prepare a report referred to in section 4 (9) of this 2005 Act no later than October 1, 2008.

Passed by Senate July 26, 2005

Repassed by Senate August 4, 2005

Enrolled Senate Bill 1072 (SB 1072-BCCA) Page 4

Appendix D

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Appendix E

Report Methodology

1. Initial work following passage of Oregon SB 1072 (2005 session) was to establish the Forest Biomass Work Group and the Federal Forestland Advisory Group to infuse public process into furthering the discussion around increasing biomass utilization in Oregon.

2. April 2008 the Oregon Department of Forestry sought input from a select group of folks both inside and outside of Oregon to contribute to the literature search (see attachment 1).

3. July 2008 the Oregon Department of Forestry again sought input from a broader group within Oregon to contribute to the literature search (see attachment 2).

4. Hired consultant and began work on synthesis of literature (August – Mid October 2008).

5. Internal review of rough draft for input (mid to late October).

6. External review sent to Forest Biomass Work Group members (early to mid November).

7. Report cleaned up and delivered by December 1, 2008.

Attachment 1

From: MISEK Joe F
Sent: Tuesday, April 15, 2008 3:46 PM
To: 'Ron Saranich'; Lindsey Goetz (goetz@blm.gov); KENDALL Mark W; CLOUGHESY; KRAHMER Rod W; (jbarbour01@fs.fed.us); (richard@westernforestry.org); DAUGHERTY Peter; FINNERAN Brian; Debbie Page-Dumroese (ddumroese@fs.fed.us); Carl Skinner (cskinner@fs.fed.us); Russ Hoeflich; 'GREG MILLER'; Chad Davis(cdavis@sustainablenorthwest.org)
Cc: MORMAN David A; MAHR Darren
Subject: Report on effect of woody biomass collection

I'm contacting each of you to begin a dialogue as a way to help shape a report that the Oregon State Forester is to make to the Governor and to an appropriate legislative interim committee every three years, with the first report due by October 2008. The report is a requirement passed in the 2005 Legislative session in enrolled SB 1072 (attached). In the report the State Forester with input from other state and federal agencies is directed to :

- Utilize data collected from state and federal sources that specify the effect of woody biomass collection and conversion on the plant and wildlife resources and the air and water quality of the state (I would add the word soil to this mix).
- Identify any changes that the State Forester determines are necessary to encourage woody biomass collection and conversion and to avoid negative effects on the environment from woody biomass collection and conversion.

The impetus for SB1072 passing was the recognition of the fuel build-up, especially on federal lands, the number of acres of condition class 2 and 3 lands which are outside the realm of natural variation and more prone to catastrophic wildfire. The legislature sought to address this threat in part by expanding woody biomass utilization for a variety of products (including energy) while insuring good stewardship of the natural systems.

In this email I am reaching out to our neighbors in California (Carl Skinner - Pacific SW Research Station at the suggestion of Tad Mason) as well as to the east (Debbie Page-Dumrfoese - Rocky Mountain Research Station), and I am including Jamie Barbour from the Pacific NW Research Station. You folks will know better than I who else may need to be included. In addition there are a number of folks I work with that are a part of the Forest Biomass Work Group (FBWG) from state and federal agencies in Oregon. Two things have led me to reach to the south and the east. First California has been involved in biomass utilization, especially for energy, in a bigger way than most states in the nation and I'm sure there are lessons learned. Secondly I am signed up to travel to Spokane for a conference that is looking at "Forest Biomass Utilization: The impact on Forest Resources" (program attached) in which the Rocky Mountain Research Station is carrying most of the presentation load. I hope to create a dialogue on what all has been learned from our neighbors, and become more aware of any work completed out of the PNW station or from other sources that additionally informs us about the benefits and consequences of biomass utilization. Perhaps down the road this would lead to information about the impacts of biomass utilization that could be shared at a conference for the PNW region.

For now I'm hoping this effort will aid a group of us here in Oregon to become better informed about what is known about the impacts of biomass utilization for the report. I imagine that in preparation for the Spokane presentations and other similar events in California, that the essence of what has been learned to date, related to impacts of biomass utilization on various resources, is available and has been distilled. There is also likely information from my own back yard that I am unaware of. If it is possible to share this information electronically that would be most appreciated. Ideally this information would also identify gaps or limits of the information, or perspectives related to limits might be shared in an email.

In Oregon, from my own perspective, we have developed some policy tools in the 2007 session (incentives) that will work to stimulate the building of renewable energy infrastructure. Of course the current economic times we are experiencing as a nation are working to some degree to slow down that investment (banks etc). While there has not been a huge increase in woody biomass utilization occur to date, some energy and other forest products infrastructure development is occurring so utilization will increase. Taking these steps now to understand what is known will help us build on this information into the future.

I'd like to thank you all for any help you can give me in this endeavor. Please feel free to call or email me with suggestions on how to modify this effort to be more effective in getting at what is known. I'll try and do updates to what knowledge has been shared so we are all on the same page.

Joe

Joe Misek
Oregon Department of Forestry
Forest Policy Analyst
2600 State Street, Bldg D
Salem, Or. 97310
503-945-7414

Attachment 2

From: MORMAN David A
Sent: Monday, July 21, 2008 9:39 AM
Subject: Information Requested for Oregon Biomass Report

Good morning,

This email is being sent to key people in the following agencies and organizations:

USDA Forest Service Pacific Northwest Research Station, USDA Forest Service Rocky Mountains Research Station, USDA Forest Service Region 6, USDI Bureau of Land Management Oregon/Washington Office, Oregon Department of Environmental Quality, Oregon Department of Fish and Wildlife, Oregon State University College of Forestry, Oregon Forest Biomass Work Group, Oregon Department of Forestry

For some of you this will be a repeat request and for others a first contact. I am writing to solicit your help in preparing a report for Governor Kulongoski and the 2009 Oregon Legislature on the environmental effects of forest biomass use. Specifically, 2005 Senate Bill 1072 requires the State Forester, among other things, to report using ". . . data collected from state and federal sources that specify the effect of woody biomass collection and conversion on the plant and wildlife resources and the air and water quality of the state."

In this context, "woody biomass" means material from trees and wood plants, including, limbs, tops, needles, leaves and other woody parts grown in a forest, woodland, farm, rangeland or wildland-urban interface environment that is the by-product of forest management, ecosystem restoration, or hazardous fuel reduction treatment.

The Department of Forestry views the report as a great opportunity to further the public dialogue about forest biomass unitization in Oregon's public and private forests. If your organization has data or other information on the known positive or negative effects of woody biomass collection and conversion on other forest resources, the Department of Forestry would like to receive references to that information as soon as possible. It is also appropriate to highlight data gaps where they exist so those can also be mentioned in the report.

Please send these references to either me or ODF Policy Analyst Joe Misek (jmisek@odf.state.or.us) before August 22, 2008 to be considered in development of the report.

Please forward this email to the appropriate folks in your organization.

Let me know if you have any questions. Thanks for your help!

David Morman, Director
Forest Resources Planning Program
Oregon Dept. of Forestry
2600 State Street
Salem, Oregon 97310
503-945-7413 (fax 503-945-7490)