Forest Floor Consumption and Smoke Characterization in Boreal Forested Fuelbed Types of Alaska

a proposal for the USDI/USDA Forest Service Joint Fire Science Program Announcement for Proposals, 2003-2 Task #1 Obtain, document and evaluate critical time-sensitive information or data during wildfire incidents. This proposal also closely links with AFP 2003-1, task 3.

Principal Investigators:
Roger D. Ottmar, Research Forester; Sue Ferguson; and Robert Vihnanek, Forester; USDA Forest Service, Pacific Northwest Search Station, 400 North 34th Street, Suite 201, Seattle, Washington, 98103. General Phone (206) 732-7800; Desk Phone: (206-732-7826); Fax (206) 732-7801
e-mail: rottmar@fs.fed.us; sferguson@fs.fed.us; bvihnanek@fs.fed.us
Ron Babbitt, Research Chemist, USDA Forest Service, Rocky Mountain Research Station, Fire science Laboratory, P.O. Box 8089, Missoula, MT 59807; Desk phone: (406) 329-4817; e-mail: rbabbitt@fs.fed.us

Other Collaborators
Kent Slaughter, BLM Alaska Fire Service; Randi Jandt, BLM Alaska Fire Service, Jennifer Allen National Park Service; Karen Murphy, U.S. Fish and Wildlife Service; Brad Cella, National Park Service; Larry Vanderlinden, U.S. Fish and Wildlife Service; Scott Billings, Alaska Fire Service; Dave Dash, Alaska Fire Service

Abstract: Many areas of the boreal forest of Alaska contain deep layers of moss, duff, and peat, resulting in a large pool of biomass that potentially can burn and smolder for long periods of time creating hazardous smoke episodes for local residents and communities and causing detrimental landscape impacts. Research to quantify fuel consumption, flammability thresholds, and smoke production in boreal forest types is critical for effective modeling of fire effects (e.g. smoke emissions, regional haze, permafrost melting, erosion, plant succession, etc) and landscape management if prescribed burning is to become an important land management technique in the future. Preliminary research has generated a hypothesis of the controlling variables that govern the fuel consumption in the moss and duff layers, but this hypothesis needs to be verified and tested through field-based experimentation. Very limited smoke emissions characterization has been completed. **The purpose of this study is to collect fuel consumption data and characterize smoke emissions on active wildfires and prescribed fires. The data will be used to develop new and modify existing forest floor fuel consumption models and develop emission rate equations for the boreal forest fuelbed type.** The fuel consumption and emission factors and rate equations will be implemented into the software program Consume 3.0 to better predict moss/peat/duff fuel consumption and smoke production during wildland fires in Alaska. This research will make Consume 3.0 and other fuel consumption, fire effects, and smoke production models more robust and aid managers, planners, and researchers in developing environmentally, socially, and legally responsible land management plans. This research will also allow for a more effective and informed use of emission production and wildfire/prescribed fire trade-off models providing improved wildland fire emissions accounting and planning at the local, regional, and global scales. The fuel consumption and smoke characterization module will be a scientifically based support tool that can be used to improve fire management decision processes (AFP-2003-2, task #1 and linkages with AFP-2003-1, task 3).

Introduction

Background and Justification

Fire is recognized as an essential natural process in Alaska and managers are increasingly expected to use fire as a landscape-level fuel treatment mechanism to improve ecosystem health, improve wildlife habitat, and reduce the likelihood of catastrophic fires. In order to complete this task, the public has required managers to improve their decision-making processes and use science-based models to meet various regulatory requirements. One of the most critical regulatory requirements is smoke management. Since fuel consumption is the key to all fire effects including smoke generation, it is imperative scientists develop a forest floor consumption model and refine smoke production estimates for use in fuel consumption, fire effects, fire severity, emission production, and dispersion models that are more applicable to the boreal forest types.

On the average, more than 2.5 million acres are burned annually (in 2002 alone, over 5 million acres burned) during wildland fires in Alaska generating thousands of tons of pollutants including CO, CO_2, and particulate matter. These pollutants can have widespread impacts on human health, visibility, and regional haze. The pollutants are a direct result of the inefficient combustion of forest fuels including tree crowns, shrub stem, and leaves, dead woody debris, litter, and deep forest floor layers composed of lichen, moss, peat, and duff. Although the consumption of the tree crowns, shrub layer, downed woody material, and litter can be a significant source of pollutants, they often represent less than 20 percent of the total fuel available for consumption in the boreal forest ecosystem (Ottmar and Vihnanek 1998). The forest floor has the greatest potential for emitting large masses of pollutants because it may reach depths in excess of 12 inches, resulting in over 200 tons per acre of potentially consumable biomass. In addition, most of the forest floor is consumed during the smoldering phase when the combustion efficiency is low and smoke generation is high. Using smoldering emission factors for Douglas-fir and hemlock fuels of 26 pounds per ton for $PM_{2.5}$, 436 pounds per ton for CO, and 2804 pounds per ton for CO_2 (Hardy and other 2001), forest floor consumption during a wildland fire could generate nearly 2.8 tons per acre of $PM_{2.5}$, 47 tons per acre of CO, and 302 tons per acre of CO_2.

Although smoke emitted from burning moss and duff is a major concern, there are other problems associated with the consumption of organic forest floor. The combustion and heat produced during the smoldering period can result in substantial effects on other resources within the region. The removal of the forest floor may melt permafrost, damage soil, increase erosion, and change plant successional patterns.

There has been a considerable amount of forest floor consumption research completed for understory and clearcut burns in the lower 48 states. However, the unique lichen, moss, and duff forest floors typical of the boreal forests of Alaska have received little attention. Viereck and Dyrness (1979) burned four small units at a site near Fairbanks. They observed that the forest floor reduction from the fire was not dependent on consumption of the woody materials. Dyrness and Norum (1983) burned seven 2-hectare units between July 19 and August 8, 1978, over a range of conditions typical of most fire seasons in Alaska. Preburn forest floor depth, lower moss (dead moss), fuel moisture, and lower duff moisture were the variables used in regressions to predict forest floor reduction. Lawson et al. (1997) developed a probability curve relating probability of sustained smoldering ignition of the forest floor as a function of duff moisture content. Miyanish and Johnson (2002) found a positive relationship between duff consumption and moisture content and depth in mixed wood forests of Canada.

A small study was carried out in Alaska over the past 10 years by the Fire and Environmental Research Applications Team (FERA) and results indicate a strong relationship between forest floor consumption, moisture content, and fuelbed depth which shows promise for building predictive models for consumption (Ottmar in press). However, a small number of samples were collected for this study and did not cover an adequate range of moisture conditions (figure 1).

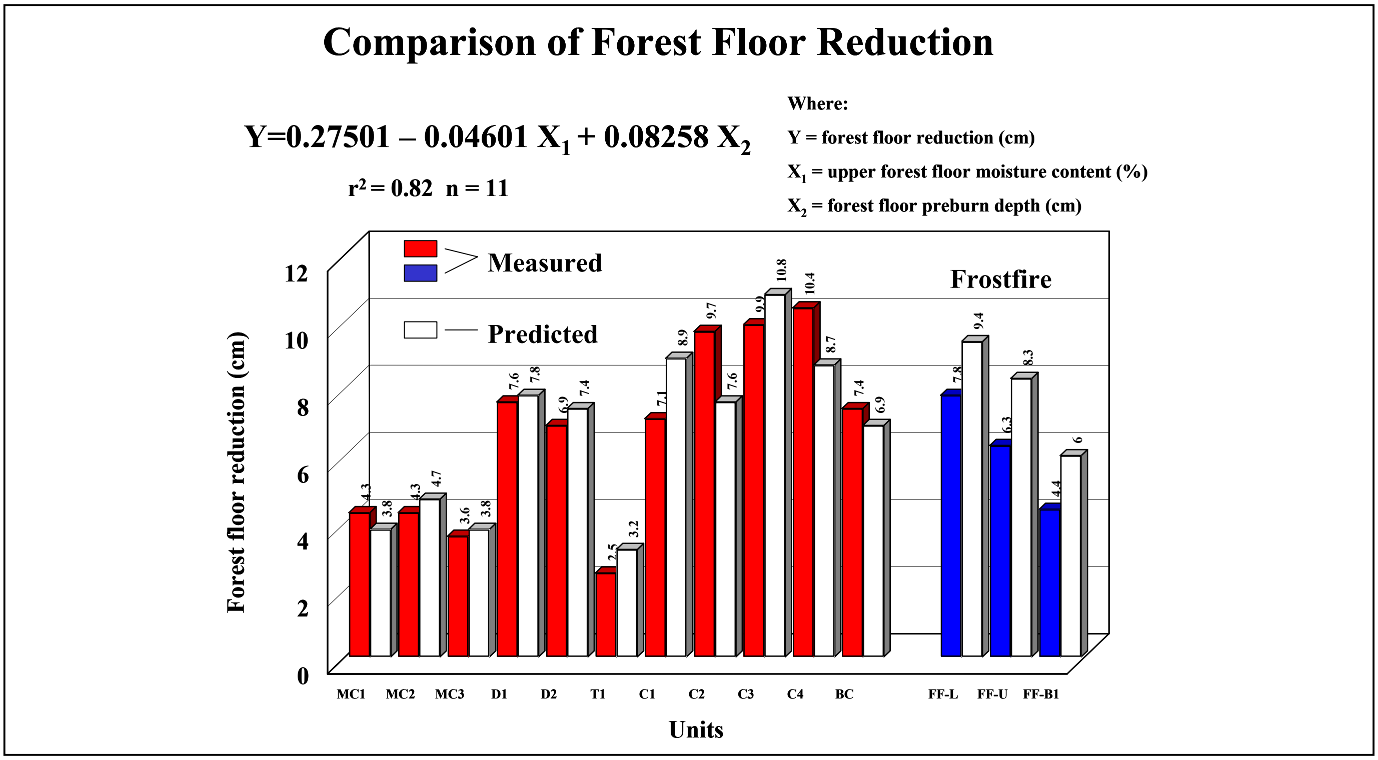

Figure 1. Forest floor consumption prediction (Ottmar, in press)

The limited success achieved with this earlier study was due in part to concurrent wildland fire activity and shortage of personnel and aircraft to conduct prescribed burns. Consequently, we are considering a different approach for this proposal. Rather than relying solely on the unpredictable prescribed burning program in Alaska to obtain fuel consumption data, we will rapidly deploy and sample on wildfires in Alaska. Opportunities for sampling in conjunction with prescribed fire in Alaska have been few, and tend to represent the higher end of the moisture spectrum, when burning conditions are less extreme. Wilfires—large ones in particular—burn over a wider range of conditions, and a larger area (over 2 million acres consumed in Alaska in 2002) and land managers desire a higher level of monitoring on some of these fires. Rapid deployment of the FERA team, along with other fire monitors, will increase the value of fire data being collected by land managers. It is proposed that red carded FERA personal, be dispatched on wildfires when opportunities exist. Evaluation and dispatch will be coordinated by a liaison from the Alaska Fire Service with support from the National Park Service, U.S. Fish and Wildlife Service, and the State of Alaska.

Objective

The primary objectives of this wildfire rapid response proposal for Alaska are to:

1. ***Develop a model that predicts fuel consumption of the moss, duff, and peat layers during wildland fires in the boreal forest types of Alaska and provide a fuel consumption module for implementation into fuel consumption and fire effects software tools such as Consume 3.0, EPM, and FOFEM 5.0.***

2. *Characterize the smoke emissions from smoldering residual combustion in boreal ecosystems.*

There are 4 primary goals of these objectives that include: (1) improved operation of fuel consumption and emission production models to feed systems that estimate fire effects and smoke impacts, (2) improve wildland fire emission tracking ability; (3) provide the basic fuel consumption algorithms for large landscape and global assessments for the northern latitudes; (4) improve the ability to model and track moss and duff moisture conditions.

Methods

This boreal forest consumption project will be accomplished in three major phases, each closely linked and occurring, in many cases, simultaneously. During the **coordination phase**, a literature review, needs assessment, and consultation with managers and consumption experts, will provide new procedures and methodologies for measuring the moss and forest floor consumption and characterizing the smoke, with a detailed study plan as the major project resulting from this phase. The **research phase** will collect, reduce, and analyze the field data, develop models, and characterize emission factors and emission rates. The **implementation phase** provides the consumption model and emission factors and emission rate equations in a modular format that will be implemented into Consume 3.0 and posted on a website for downloading by other software packages such as The First Order Fire Effects Model (FOFEM 5.0), Emissions Production Model (EPM), and Fire Effects Tradeoff Model (FETM).

Coordination Phase

This project has been discussed with several land managers and scientists in Alaska and with the Alaska Wildfire Coordinating Group and their science team. The Alaska Fire Service, National Park Service, and U.S. Fish and Wildlife Service have given full support to the project and have offered Kent Slaughter as our liaison, with additional support of several fire ecologists including Randi Jandt (BLM-AF), Jennifer Allen (NPS), and Karen Murphy (USF&WS). During the coordinating phase the project discussion will continue with the Alaska Fire Service, National Park Service, U.S. Fish and Wildlife Service, and the State of Alaska to finalize logistical planning which will include: 1) in-kind helicopter support; 2) housing, meals, and fire dispatch; 3) logistical support, and 4) FERA training requirements.

Although a sophisticated sampling technique for measuring fuel consumption and collecting independent variables has been refined over the years from earlier efforts by FERA, improvements can be made. An extensive synthesis of the literature and consultations with experts and land managers will be used to design and prepare a detailed study plan that will include the protocols for monitoring fire behavior and weather conditions, forest floor consumption, smoke, and several independent variables. This phase also reviews all available fuel consumption and emissions literature, assesses needs from managers, and develops a study plan with monitoring protocols and analysis techniques by consulting with scientists such as Brad Hawkes, Marty Alexander, Ron Susott, Wei Min Hao, and land manager representatives such as Randi Jandt and Kent Slaughter (AFS), Brad Cella (NPS), and Larry Vanderlinden (USFWS).

Research Phase

Roger Ottmar and Bob Vihnanek will lead an aggressive field effort to gather fuel consumption data during wildfires in Alaska. The FERA team will have a minimum of 2 scientists, 2 foresters, and 3 forestry technicians that will be red carded at the arduous level and on call for dispatch starting on May 1, 2003. The Air Chemistry Group from the Missoula Fire Lab will also have a minimum of two red-carded personnel that will be on call. All participates will receive bear training and other pertinent fire and safety training before being dispatched.

Upon notification of an active wildland fire meeting suitable criteria, the two teams would dispatch immediately to Alaska and be transported to a safe area in proximity to the fire (either outside the current perimeter in an area expected to burn or in an unburned inclusion or island within the fire perimeter). The team will complete a preburn fuels inventory, monitor for fuel moisture conditions, establish a weather station and Fire Atmosphere Sampling

System (FASS) towers for smoke measurements, aerially monitor fire behavior, and return to the site for a post burn inventory following the fire front passage or ignition of the unburned island by a helicopter or hand torches. A minimum of 8 wildfires will be monitored for fuel consumption.

In addition to wildfire data collection, 6 five-acre plots will be established near Fairbanks or on the Kenai Peninsula and burned under prescriptions ranging from very moist to very dry. This will help ensure an appropriate range of flammability conditions is sampled to supplement the wildfire data. A weather station will be positioned at each site to supply weather and fuel moisture data to assess forest floor moisture regime (Ferguson and others [in press]). The FASS system will be positioned in each site to collect smoke emissions.

Site Selection and Inventory

Wildfire

The wildfire portion of this study will concentrate on black and white spruce forested sites. Criteria used to locate sites within a fire perimeter will include access, safety, moss and duff layer thickness, fuel uniformity, drying potential, projected weather, and helicopter availability.

There are two major wildfire scenarios that the team will be assessing for fuel consumption monitoring. First, if an island of several hundred acres of unburned fuel has occurred within the perimeter of a larger fire, forest floor consumption monitoring plots and a FASS emissions sampling tower will be positioned at the site. A portable weather station that measures relative humidity, temperature, precipitation, wind speed and direction, and moss moisture will be positioned at the site. The area will then be ignited by a helicopter or by a hand drip torch.

The second option will be to establish inventory plots several miles in front of an active fire front. This will require the helicopter to remain at the site while fuels inventory and a simpler emission sampling equipment is set up and will assume the fire will eventually burn through the plots. This option is more expensive and has a larger level of uncertainty.

When a wildfire opportunity exists, a scientist, liaison, and a two to four person crew from FERA and the Air Chemistry Group will be briefed by the fire management office, travel to the site, assess the area, locate plots, begin to collect pre-fire data, and set up a weather station and smoke sampling packages. Ten fuel consumption plots will be positioned in a grid pattern to cover a 5-acre area. Forest floor consumption will be measured as depth reduction following the fire using light weight welding rod (up to 30 inches long) inserted around each plot and clipped flush with the lichen, moss, or duff surface prior to the burn. Approximately 80 points will be measured for the forest floor reduction on each site. Several possible independent variables will be measured including live and dead moss moisture, upper and lower duff moisture, bulk density, live shrub and lichen moisture, down woody fuel loading, ice depth, rate of spread, flame length, relative humidity, temperature, wind speed and direction, and precipitation. In addition, 80 independent measurements of the forest floor depth by layers in the vicinity of the plots will be collected and a photo taken along each fuels transect and at each plot point pre- and post burn figure 2).

The data will be used to (1) generate coefficients for theoretical and empirical fuel consumption model design for implementation into a national consumption software product Consume 3.0 (Ottmar 2002); (2) validate current fuel consumption models such as Consume 2.1 (Ottmar and others in press), FOFEM (Reinhardt and others 1997), and Burnout (Albini and Reinhardt 1997); (3) determine emission factors for primary carbon containing gases and $PM_{2.5}$; (4) develop smoldering combustion rate models for the forest floor consumption; and (5) estimate total fuel consumption from carbon released and compare with measured consumption. Data synthesis, field sampling, and product development will be coordinated with other related studies to make efficient use of time, dollars and resources.

Prescribed Fires

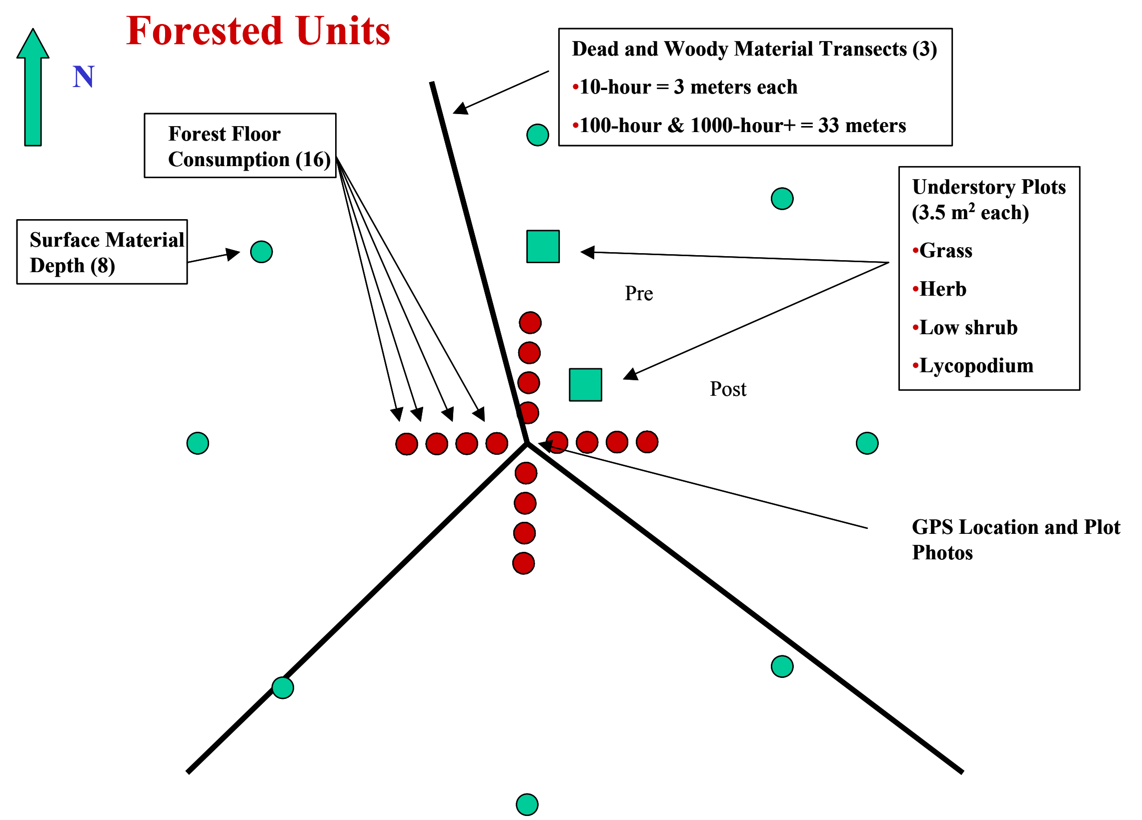

Figure 2. Inventory plot layout.

Since there is always the chance that our wildfire effort may fall short of expectations and that consumption monitoring during wildfires will generally represent the drier end of the moisture regime scale, a series of prescribed fires are planned to represent a range of forest floor moisture conditions. We plan to establish two study sites in an easily accessable area that are planned for prescribed burning. Each site will be split into three 5-acre areas. Eighteen fuel consumption plots will be located in a grid pattern to represent the site with 8 forest floor pins positioned around each plot (figure 2). Brown (1974) planar intercept transects will be established to characterize the woody fuel biomass. In addition, eight forest floor depth measurements for the live and dead moss and upper and lower duff layers will be collected prior to the burn. Fifteen bulk density samples will be collected to represent the forest floor density for the site.

The Fire Atmosphere Sampling System (FASS) towers will be positioned within each burn to characterize smoke emissions from Residual Smoldering Combustion (RSC). The tower system will collect measurements of CO_2, CO, CH_4 and primary non-methane hydrocarbons, and particulate matter less than 2.5 microns in diameter (PM2.5), using specialized instruments that have been developed at the Missoula Fire Sciences Laboratory. This will be used to determine emission factors for the primary carbon containing gases and PM2.5, develop smoldering combustion rates for these fuels, and make an estimate of total fuel consumption from the carbon released. We will compare the estimates of fuel consumption with actual field measurements. We will calculate total emissions in boreal ecosystems from these data.

A weather station will be established at each site to continually measure relative humidity, temperature, wind speed, wind direction, precipitation, and a moisture signal from the forest floor at various depths (Ferguson and others [in press]). If cell phone coverage is available, the station will be linked via cell phone and daily output transmitted to the FERA website for display and use by managers and scientists. If cell phone coverage is not available, a satellite linkage will be implemented or data stored and collected monthly.

Weekly moisture samples of the live and dead moss, and upper and lower duff will be collected at each site and used to calibrate the moisture meters located at the weather station (Wilmore and others [in press]). Both the periodic duff moisture samples and moisture signals from the weather station will be used to determine the wet, moist, and dry regime for burning. Following the burn, forest floor reduction will be measured at each forest floor pin. Forest floor bulk density determined prior to the burn will be used to convert the forest floor reduction to biomass consumption in tons/acre. These prescribed burns will provide the range of fuel moisture conditions and other independent data, in conjunction with fuel consumption data collected on wildfires to develop the robust forest floor consumption model.

Data Reduction and Analysis

The data collected from the wildland fire and prescribed fire research plots will be entered and reduced by the FERA team. Based on a thorough review of the fuel consumption and combustion, a physically-based moss and duff consumption model will be derived with coefficients adjusted using the wildland fire and prescribed fire data collected from this study and earlier studies (Ottmar [in press]).

Implementation Phase

During this phase, a progress report will be prepared annually and submitted to the Joint Fire Science Program Committee, Alaska Wildfire Coordinating Group, and other cooperators. Progress reports will be posted on FERA's website: www.fs.fed.us/pnw/fera. After the active field research is completed and the forest floor consumption and emission characterization modules have been developed, we will release a new version of Consume 3.0. In addition, a forest floor moisture algorithm will be completed with guidelines on how to deploy moisture meters for monitoring moss and duff moisture content. The modules will become available on the FERA website for distribution to other software applications. A research paper or journal article will be drafted for publication. A training session will be produced for implementation into fire effects and smoke management national courses (Rx 310, Rx 410).

Location of Proposed Work

This research will be led and conducted by the Fire and Environmental Research Applications (FERA) team headquartered in Seattle, Washington. FERA is an extremely mobile, field-oriented, fire and fuels research team. The Missoula Fire lab Air Chemistry Project will characterize the smoke. All employees for this study will be red-carded at the arduous level and be provided with the appropriate safety training. Our field jurisdiction will be defined by our Alaska Fire Service, National Park Service, USF&WS, and Alaska State collaborators and will provide the broadest possible range of environmental conditions and issue relevance within the boreal forest regime of Alaska. We will perform field studies throughout Alaska, concentrating in the white and black spruce regions of the interior of Alaska, Anchorage, and Kenai Pennisula.

Linkages

This boreal forest fuel consumption project will be closely linked with the fuel moisture and fire danger rating study being conducted in Alaska by the Alaska Fire Service, National Park Service, and U.S Fish and Wildlife Service. The project will glean information from the earlier fuel consumption study funded by the JFSP (Ottmar 1999) and from a wealth of fuel consumption information collected during the Frostfire project (Ottmar in press). Opportunities to link this study with other efforts and to acquire matching dollars from other agencies such as the Bureau of Land Management, Department of Defense or NASA is very good and will be pursued. Also, in-kind cooperation from Alaska Fire Service, National Park Service, and US Fish and Wildlife Service through helicopter time and employee liaison assistance will be approximately $116,000 over the 3.5 years.

Project Team

Personnel	**Responsibility**
Roger Ottmar, Research Forester (USDA Forest, PNW—FERA)	Project management, study design, communication, publication
Robert Vihnanek, Forester (USDA Forest Service, PNW-FERA)	Study design, data collection, data reduction
Ron Babbitt, Engineer (USDA Forest Service, RMRS)	Smoke sampling, data reduction, communication, publication
Kent Slaughter, Assistant Fire Management Officer (BLM-Alaska Fire service)	AFS logistics liaison with FERA, wildfire assessment, data collection, consultation
Dr. David Peterson, Research Biologist (USDA Forest Service, PNW—FERA)	Analysis, software module development, web design
Larry Vanderlinden, (US Fish and Wildlife Service)	Consultation, liaison with AWCG
Randi Jandt, Fire Ecologist (BLM-Alaska Fire Service)	AFS logistics, consultation, data collection
Jennifer Allen, Fire Ecologist (National Park Service)	NPS logistics, consultation, data collection
Karen Murphy, Fire Ecologist (US Fish and Wildlife Service)	USFWS logistics, consultation, data collection

Literature Cited

Albini, F. A. and Reinhardt, E. D. 1997. Improved calibration of a large fuel burnout model. International Journal of Wildland Fire. 7: 21-28.

Brown, J.K. 1974. Handbook for inventorying downed woody material. General Technical Report INT-16. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT. 24 p.

Dyrness, C. T. and Norum, R.A. 1983. The effects of experimental fire on black spruce forest floors in interior Alaska (*Picea mariana*). Canadian Journal of Forestry Research 13: 879-893.

Ferguson, S.A.; Rorig, M.L.; Bluhm, A.; and Sandberg, D.V. [In press] Measuring moss moisture dynamics to predict fire severity. In: Brennan, L.A. et al. (eds.) National Congress on Fire Ecology, Prevention, and Management Proceedings, No 1., Tall Timbers Research Station, Tallahassee, FL.

Hardy, C. C.; Ottmar, R. D.; Peterson, J. L. [and others] 2001. Smoke management guide for prescribed and wildland fire: 2001 edition. Boise, ID: National Wildfire Coordinating Group. 226 p.

Lawson, B.D.; Frandsen; W.H.; Hawkes; B.C.; and Dalrymple, G.N. 1997. Probability of sustained smoldering ignition for some boreal forest duff types. Forestry Management Note 63. Natural Resources Canada, Canadian Forest Service, Northern Forestry Center, Edmonton, Alberta, Canada.

Miyanishi, K.; Johnson, E. 2002. A. Process and patterns of duff consumption in the mixedwood boreal forest. Can, J. For. Res. 32: 1285-1295.

Ottmar, Roger D.; Vihnanek, Robert E. 1998. Stereo photo series for quantifying natural fuels, Volume II: black spruce and white spruce types in Alaska. PMS 831. Boise, ID. National Wildfire Coordinating Group. National Interagency Fire Center. 65 p.

Ottmar, Roger D. [in press]. Predicting forest floor consumption from wildland fire in boreal forests of Alaska. Manuscript submitted for publication Dec, 2000 to Fire 2000 Cconference; Dec, 2000, San Diego, CA.

Ottmar, R.D. 2002. Modification and validation of fuel consumption models. Progress report on file: http//:www.nifc.gov/joint_fire_sci/jointfiresci.html

Reinhardt, Elizabeth D.; Keane, Robert E.; Brown, James K. 1997. First Order Fire Effects Model: FOFEM 4.0, user's guide. Gen. Tech, Report INT-GTR-344. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 65 p.

Viereck , L. A.; and Dyrness, C.T. (eds.). 1979. Ecological effects of the Wickersham Dome fire near Fairbanks, Alaska. General Technical Report PNW-90. U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station, OR. 71 p.

Wilmore, B.; Fox, J.D. Jr; Sandberg, D.V.; and Alexander, M.E. [In press]. Duff moisture dynamics in black spruce feather moss stands and their relation to the Canadian Forest Fire Danger Rating System. *in*

LA Brennan, et al. (eds.) National Congress on Fire Ecology, Prevention, and Management Proceedings, No. 1. Tall Timbers Research Station, Tallahassee, FL.

CURRICULUM VITAE
Roger D. Ottmar

December 15, 2002

USDA Forest Service Pacific Northwest Research Station
Seattle Forestry Science Laboratory
400 North 34th Street, Suite 201
Seattle, Washington 98103
Desk (206) 732-7826; general (206) 732-7800; Fax (206) 732-7801
Cell: (206) 849-3172
e-mail: rottmar@fs.fed.us
website: www.fs.fed.us/pnw/fera

SUMMARY

Roger Ottmar is a Research Forester with the Fire and Environmental Research Applications Team, Pacific Northwest Research Station at the Seattle Forestry Sciences Laboratory. He received his M.S. degree in Forest Management, B.S. degree in Atmospheric Sciences, both from the University of Washington. He also obtained a B.A. degree in secondary education from Eastern Washington University. He has been involved with fuels, fire, and smoke related research for over 23 years and is currently leading efforts to 1) develop a natural fuels photos; 2) develop fuel consumption models by combustion phase and fuelbed layer for forested and non-forested fuel types; and 3) develop a fuel characterization system for the United States. Roger has recently completed research efforts to assess fuel loading, fire behavior, and emissions from different management scenarios for the Interior Columbia River Basin, upgrade and modify the fuel consumption software called Consume 2_1, produce 7 natural fuel photo series for 22 fuel types of the United States, complete a fuels photo series for the savanna region of Brazil, and assess wildland firefighter exposure to smoke and the associated health risk. Roger has authored over 60 research publications and final reports and has served as principal investigator on more than 60 grants, agreements, and coops between other USDA Forest Service Research Stations, governmental agencies, private corporations, and Universities. Roger also teaches over 30 lessons at land management Rx training sessions including Smoke management, Fire effects, and Burn Boss, and recently completed the rewrite of 6 lessons for RX 410, Smoke Management.
Roger is a member of the Society of American Foresters, American Meteorological Society, Ecological Restoration Society, International Association of Wildland Fire, and Tall Timbers Society. Roger has received four USDA Forest Service Certificates of Merits, the PNW Station Technology Transfer Award, National Fire Management Award, and Pacific Northwest Region Excellence in Prescribed Fire Award.

Selected Publications.

Ottmar, Roger D.; Sandberg, David V. 1985. Calculating moisture content of 1000-hour timelag fuels in western Washington and western Oregon. Res. Pap. PNW-336. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 16 p.

Ottmar, Roger D.; Hardy, Colin C. 1989. Stereo photo series for quantifying forest residues in coastal Oregon forests: second-growth Douglas-fir--western hemlock type, western hemlock--sitka spruce type, and red alder type. Gen. Tech. Rep. PNW-152. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 67 p.

Ottmar, Roger D.; Hardy, Colin C; Vihnanek, Robert E. 1990. Stereo photo series for quantifying forest residues in the Douglas-fir--hemlock type of the Willamette National Forest. Gen. Tech. Rep. PNW-258. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 63 p.

Ottmar, Roger D., Burns, Mary F., Hall, Janet N., Hanson, Aaron D. 1993. CONSUME users guide. Gen. Tech. Rep. PNW-GTR-304. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 118 p.

Huff, Mark H.; Ottmar, Roger D.; Alvarado, Ernesto [and others]. 1995. Historical and current forest landscapes in eastern Oregon and Washington. Part II: Linking vegetation characteristics to potential fire behavior and related smoke production. Gen. Tech. Rep. PNW-GTR-355. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 43 p.

Ottmar, Roger D.; Vihnanek, Robert E.; Wright, Clinton S. 1998. Stereo photo series for quantifying natural fuels, Volume I: mixed-conifer with mortality, western juniper, sagebrush and grassland types in the interior Pacific Northwest. PMS 830. Boise, Idaho: National wildfire Coordinating Group, National Inetragency Fire Center. 73 p.

Ottmar, Roger D.; Vihnanek, Robert E. 1998. Stereo photo series for quantifying natural fuels, volume II: black spruce and white spruce types in Alaska. PMS 831. Boise, ID. National Wildfire Coordinating Group. National Interagency Fire Center. 65 p.

Ottmar, Roger D.; Vihnanek, Robert E. 1999. Stereo photo series for quantifying natural fuels, volume V: red and white pine, northern tall grass prairie, and oak/hickory in the Midwest. PMS 834. Boise, ID: National Wildfire Coordinating Group, National Interagency Fire Center. 99 p.

Reinhardt, Timothy E.; Ottmar, Roger D.; Halett, Michael J. 1999. Guide to monitoring smoke exposure of wildland firefighters. Gen. Tech. Rep. PNW-GTR-448. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 17 p.

Ottmar, Roger D.; Vihnanek, Robert E. 2000 (a). Stereo photo series for quantifying natural fuels, Volume III: lodgepole pine, quaking aspen, and gambel oak types in the Rocky Mountains. PMS 832. Boise, ID. National Wildfire Coordinating Group. National Interagency Fire Center. 85 p.

Ottmar, Roger D.; Vihnanek, Robert E. 2000 (b). Stereo photo series for quantifying natural fuels, Volume VI: longleaf pine, pocosin, and marshgrass types in the Southeast United States. PMS 831. Boise, ID. National Wildfire Coordinating Group. National Interagency Fire Center. 56 p.

Ottmar, Roger D.; Vihnanek, Robert E; Regelbrugge, Jon C. 2000. Stereo photo series for quantifying natural fuels, Volume IV: pinyon-juniper, sagebrush, and chaparral types in the Southwestern United Sates. PMS 833. Boise, ID. National Wildfire Coordinating Group. National Interagency Fire Center. 97 p.

Reinhardt, Timothy E.; Ottmar, Roger D. 2000. Smoke exposure at western wildfires. Smoke exposure at western wildfires. Research Paper PNW-RP-525. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 72 p.

Reinhardt Timothy E.; Ottmar, Roger D. 2000. Smoke exposure among firefighters at prescribed burns in the Pacific Northwest. Research Paper PNW-RP-526. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 45 p.

Ottmar, R. D.; Sandberg, D. V. 2001. Wildland fire in eastern Oregon and Washington. Northwest Science. 75(Special Issue): 46-54.

Hardy, C. C.; Ottmar, R. D.; Peterson, J. L. [and others] 2001. Smoke management guide for prescribed and wildland fire: 2001 edition. Boise, ID: National Wildfire Coordinating Group. 226 p.

Sandberg, David V.; Ottmar, Roger D.; Cushon, Geoffrey H. 2001. Characterizing fuels in the 21st Century. International Journal of Wildland Fire, 2001, 10, 381-387.

Wright, Clinton S., Ottmar, Roger D.; Vihnanek, Robert E.; Weise, David R. 2002. Stereo photo series for quantifying natural fuels: grassland, shrubland, woodland, and forest types in Hawaii. Gen. Tech. Rep. PNW-GTR-545. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 91 p.

Ottmar, Roger D., Alvarado, Ernesto, Hessburg, Paul F. (in press). Historical and current forest and range landscapes in the Interior Columbia River basin and portions of the Klamath and Great Basins. Part II: Linking vegetation patterns to potential smoke production and fire behavior. Gen. Tech. Rep. PNW-GTR-XXX. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 310 p.

Ottmar, Roger D.; Anderson, Gary K.; DeHerrera, Paul J., Reinhardt, Timothy E. (in press). Consume user's guide. Gen. Tech. Rep. PNW-GTR-XXX. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

SUE A. FERGUSON
USDA-Forest Service, Pacific Northwest Research Station
400 North 34th Street, Suite 201, Seattle, WA 98103
Tel. 206-732-7828 **Fax.** 206-732-7801 **Email.** SFerguson@fs.fed.us

Education
1984 Ph.D., Geophysics/Atmospheric Science, University of Washington, Seattle
1976 B.S., Physics, University of Massachusetts, Amherst

Professional Affiliations
American Association of Avalanche Professionals, American Geophysical Union, American Meteorological Society, International Association of Wildland Fire, International Glaciological Society

Selected Publications

S.A. Ferguson, S.J. McKay, D.E. Nagel, T. Piepho, M.L. Rorig, C. Anderson, and L. Kellogg. In Press. Assessing values of air quality and visibility at risk from wildland fires. Res. Pap. PNW-RP-xxx. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

S.A. Ferguson, J. Ruthford, M. Rorig, and D.V. Sandberg. In press. Measuring moss moisture dynamics to predict fire severity. [Summary presented at the 2000 Fire Congress, Long Beach, California]. Tall Timbers.

M.L. Rorig, S.A. Ferguson, and D.V. Sandberg. In press. Fire weather indexes and fuel condition in Alaska. [Summary presented at the 2000 Fire Congress, Long Beach, California]. Tall Timbers.

M.L. Rorig, S.A. Ferguson, and D.V. Sandberg. In press. The use of historical fire weather indexes in planning a prescribed fire. [Summary presented at the 2000 Fire Congress, Long Beach, California]. Tall Timbers.

S. A. Ferguson, J. E. Ruthford, S. J. McKay, D. Wright, C. Wright, and R. Ottmar. 2002. Measuring moisture dynamics to predict fire severity in longleaf pine forests. International Journal of Wildland Fire. 11:267-279.

M.L. Rorig and S.A. Ferguson. 2002. The 2000 fire season: lightning-caused fires. Journal of Applied Meteorology. 41:786-791.

S.A. Ferguson. 2001. Smoke Management Meteorology. In 2001 Smoke Management Guide. C.C. Hardy, R.D. Ottmar, J.L. Peterson, J.E. Core, and P. Seamon, editors. National Wildfire Coordinating Group, Fire Use Working Team. National Interagency Fire Center, ATTN: Great Basin Cache Supply Office, 3833 S. Development Avenue, Boise, Idaho 83705. NFES 1279. 121-128.

S.A. Ferguson. 2001. Smoke Dispersion Prediction Systems. In 2001 Smoke Management Guide. C.C. Hardy, R.D. Ottmar, J.L. Peterson, J.E. Core, and P. Seamon, editors. National Wildfire Coordinating Group, Fire Use Working Team. National Interagency Fire Center, ATTN: Great Basin Cache Supply Office, 3833 S. Development Avenue, Boise, Idaho 83705. NFES 1279. 163-178.

S.A. Ferguson, J. Peterson, and A. Acheson. 2001. Automated, real-time predictions of cumulative smoke impacts from prescribed forest and agricultural fires. Fourth Symposium on Fire and Forest Meteorology, 13-15 November 2001, Reno, Nevada, American Meteorological Society. 168-175.

S.A. Ferguson, 2001. Real-time mesoscale model forecasts for fire and smoke management: 2001. Fourth Symposium on Fire and Forest Meteorology, 13-15 November 2001, Reno, NV. American Meteorological Society. 162-167.

S.A. Ferguson. 2001. Climatic Variability in Eastern Oregon and Washington. Northwest Science. 75:62-69.

S. A. Ferguson, D. V. Sandberg, and R. D. Ottmar. 2000. Modeling the effect of land-use changes on global biomass emissions. In: Biomass Burning and its Inter-Relationships with the Climate System, edited by J. L. Innes, M. Beniston, and M. M. Verstraete, Boston:Kluwer Academic Publishers. 33-50.

S. A. Ferguson. 1998. Air quality climate in the Columbia River basin. Portland, Oregon:U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. PNW-GTR-434.

S. A. Ferguson. 1998. Real-time mesoscale model forecasts for fire and smoke management. 2nd Symposium on Fire and Forest Meteorology. 11-16 January 1998, Phoenix, AZ, American Meteorological Society. 161-164.

Breyfogle, S. and S.A. Ferguson. 1996. A User Assessment of Smoke Dispersion Models. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. PNW-GTR-379.

Ferguson S. A. and C. C. Hardy. 1994. Modeling smoldering emissions from prescribed boradcast burns in the Pacific Northwest. Int. J. Wildland Fire. 4(2):135-42.

Curriculum Vitae
Robert E. Vihnanek
December 15, 2002
USDA Forest Service, PNW Research Station
Seattle Forestry Sciences Lab.

Educational Background

BS. Forestry. Southern Illinois University, Carbondale, Il. 1979

MS. Forestry. University of British Columbia, Vancouver, BC, Canada. 1985

Professional Experience

1999 – Present: Supervisory Forester, Pacific Northwest Research Station, USDA Forest Service, Seattle, Wa.

1988 - 1999; Forester, Pacific Northwest Research Station, USDA Forest Service, Seattle, Wa.

April 1987 - Nov. 1987; Lead Forestry Technician, USDA Forest Service, Mt. Baker - Snoq. NF, Skykomish RD.

June 1984 - Feb. 1985; Academic Assistant, Faculty of Forestry, University of British Columbia.

Sept. - May 1981 - 1984; Graduate Teaching Assistant, Faculty of Forestry, Univ. of British Columbia

June 1983 - Sept. 1983; Aerial Observer, State of Washington, Dept. of Natural Resources.

May - Aug. 1981, 1982; Forest Scientist, MacMillan - Bloedel Ltd. Woodland Services Division.

April 1980 - Nov. 1980; Forestry Technician, USDA Forest Service, Willamette NF, Detroit RD.

May - Sept. 1977 -1979; Forestry Technician, USDA Forest Service, Helena NF, SO.

Honors and Awards

PNW Research Station 2002 Group Award for Lab-wide collaboration

USDA Certificate of Merit 2000 for superior accomplishments

USDA Certificate of Merit 1989 for sustained superior performance.

USDA Certificate of Merit 1988 for sustained superior performance.

G.S. Allen Scholarship, UBC 1982,1983

Meyer Fellowship, UBC 1981

Southern Illinois University Scholarship 1976,1977

Illinois State Scholarship 1977,1978

Deans List SIU 6 semesters, 1975 - 1979

Publications

Wright, Clinton S., Ottmar, Roger D.; Vihnanek, Robert E.; Weise, David R. 2002. Stereo photo series for quantifying natural fuels: grassland, shrubland, woodland, and forest types in Hawaii. Gen. Tech. Rep. PNW-GTR-545. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 91 p.

Ottmar, Roger D.; Vihnanek, Robert E. 2000 (a). Stereo photo series for quantifying natural fuels, Volume III: lodgepole pine, quaking aspen, and gambel oak types in the Rocky Mountains. PMS 832. Boise, ID: National Wildfire Coordinating Group. National Interagency Fire Center. 85 p.

Ottmar, Roger D.; Vihnanek, Robert E. 2000 (b). Stereo photo series for quantifying natural fuels, Volume VI: longleaf pine, pocosin, and marshgrass types in the Southeast United States. PMS 831. Boise, ID: National Wildfire Coordinating Group. National Interagency Fire Center. 56 p.

Ottmar, Roger D.; Vihnanek, Robert E; Regelbrugge, Jon C. 2000. Stereo photo series for quantifying natural fuels, Volume IV: pinyon-juniper, sagebrush, and chaparral types in the Southwestern United Sates. PMS 833. Boise, ID: National Wildfire Coordinating Group. National Interagency Fire Center. 97 p.

Ottmar, Roger D.; Vihnanek, Robert E. 1999. Stereo photo series for quantifying natural fuels, volume V: red and white pine, northern tall grass prairie, and oak/hickory in the Midwest. PMS 834. Boise, ID: National Wildfire Coordinating Group, National Interagency Fire Center. 99 p.

Ottmar, Roger D.; Vihnanek, Robert E. 1998. Stereo photo series for quantifying natural fuels, volume II: black spruce and white spruce types in Alaska. PMS 831. Boise, ID: National Wildfire Coordinating Group. National Interagency Fire Center. 65 p.

Ottmar, Roger D.; Vihnanek, Robert E.; Wright, Clinton S. 1998. Stereo photo series for quantifying natural fuels, Volume I: mixed-conifer with mortality, western juniper, sagebrush and grassland types in the interior Pacific Northwest. PMS 830. Boise, ID: National wildfire Coordinating Group, National Interagency Fire Center. 73 p.

Huff, Mark H.; Ottmar, Roger D.; Alvarado, Ernesto , Vihnanek, Robert E. (and others) 1995. Historical and Current Forest Landscapes In Eastern Oregon and Washington. Part II: Linking Vegetation Characteristics to Potential Fire Behavior and Related Smoke Production. Gen. Tech. Rep. PNW-GTR-355. Portland. Or: U.S.D.A. Forest Service, Pacific Northwest Research Station. 43p.

Ottmar, Roger D.; Vihnanek, Robert E.; Alvarado, Ernesto 1994. Forest Health Assessment: air quality tradeoffs. In: Proceedings of the 12th international conference on fire and forest meteorology; 1993 October 26-28; Jekyll Island, Ga. Bethesda, Md: Society of American Foresters: 47-61.

Vihnanek, Robert E.; Ottmar, Roger D. 1994. When logged units burn in a wildfire, does slash treatment mitigate effects ? In: Proceedings of the 12th international conference on fire and forest meteorology; 1993 October 26-28; Jekyll Island, Ga. Bethesda, Md: Society of American Foresters: 709-714.

Swift, Lloyd W.; Elliot, K.J.; Ottmar, Roger D. ; Vihnanek, Robert E. 1993. Site preparation burning to improve southern Appalachian pine-hardwood stands: fire characteristics and soil erosion, moisture, and temperature. Canadian Journal of Forestry. 23:2242-2254.

Ottmar, Roger D.; Hardy, Colin C.; Vihnanek, Robert E. 1990. Stereo photo series for quantifying forest residues in the Douglas-fir--hemlock type of the Willamette National Forest. Gen. Tech. Rep. PNW-258. Portland, Or.: U.S.D.A. Forest Service, Pacific Northwest Research Station. 63p.

Vihnanek, R.E.; Ballard, T.M. 1988. Slashburning effects on stocking, growth, and nutrition of young Douglas-fir plantations in salal-dominated ecosystems of eastern Vancouver Island. Can. J. For. Res. 18: 718-722.