Air Quality and Prescribed Fire Management – Moving Toward a Solution Space

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Smoke issues have come to the forefront as National Forests increase prescribed fire management treatments to implement the Healthy Forests Initiative and the Healthy Forests Restoration Act. Increases in the population living within the wildland-urban interface have resulted in a larger population exposed to prescribed fire smoke. The combination of increased burning and public smoke exposure has created a need for detailed public involvement plans; planning and prioritization of areas for treatment; interagency coordination between regulatory agencies, smoke managers, and public health officials; better predictive tools for weather forecasting, smoke production and dispersion; real-time air quality monitoring; creative methods of responding to legitimate health conditions; and derivation of realistic, quantifiable air quality objectives. The Okanogan-Wenatchee National Forests (OWNFs) in north-central Washington are a focal point for implementing a prescribed fire program of landscape-scale burns. Local objective levels of air quality particulate have been defined, and are monitored using an air quality instrumentation network. An extensive program of public information has been developed. Collaborative forest health treatments have been initiated with private property landowners and homeowner associations. The forests and the Washington State Department of Ecology (DOE) have entered an agreement whereby the Forest Service operates a network of nephelometers that are incorporated into a DOE air quality website. The desired outcome is the successful completion of an accelerated prescribed fire program with minimal exposure of the public to unhealthy levels of smoke concentration. This paper focuses on OWNFs' efforts since the wildfires of 1994 to develop quantifiable air quality objectives and incorporate them into an interagency prescribed fire management regulatory framework for an expanding burn program.

Keywords: *air pollution, air quality, smoke, prescribed fire, fire management*

Introduction

On 28 July 1994, dry-lightning storms started multiple wildfires across the Eastern Cascades of central Washington State. Conditions were extremely dry in the national forests. The 1994 water year was the third in a row in which annual streamflow had been well below average at various long-term gaging stations (USGS 2004; Robison 2004). Water years 1993 and 1994 were more than one standard deviation below period of record average values for the Wenatchee, Stehekin and Methow Rivers. The largest of the fires burned 185,000 acres (74,867 ha) on the Wenatchee National Forest. At that time, it was the largest wildfire complex within a single national forest in the history of the Forest Service (FS). The fires caused many weeks of impaired air quality in all five cities of Chelan County. This paper discusses the evolution of two resource management programs, the Healthy Forests Initiative, relying heavily on prescribed fire, and the Air Quality Management Program, both of which have evolved since the fires of 1994. The subject area is the Okanogan-Wenatchee National Forests (Forests) of central Washington State (Figure 1).

Following the 1994 wildfires, emergency fire restoration efforts began immediately with a detailed assessment of the burn area. Burn intensity mapping showed that sixth-field subwatersheds had as much as 50-75% of total drainage area in a condition of moderate to high burn severity. This fact as well as the large area burned increased the emphasis on quickly accomplishing emergency fire restoration. Various efforts to seed, fertilize, contour-fell burned snags across steep slopes, remove road culverts and improve road drainage were completed in what became the largest and most expensive emergency fire restoration effort in agency history.

In addition to the emergency restoration efforts, the forest supervisor chartered a science team to review the fires and make specific recommendations as to actions that could be taken to reduce the risk of recurrence of such large and intense wildfires. The team was charged with finding answers to three specific questions: Why were the

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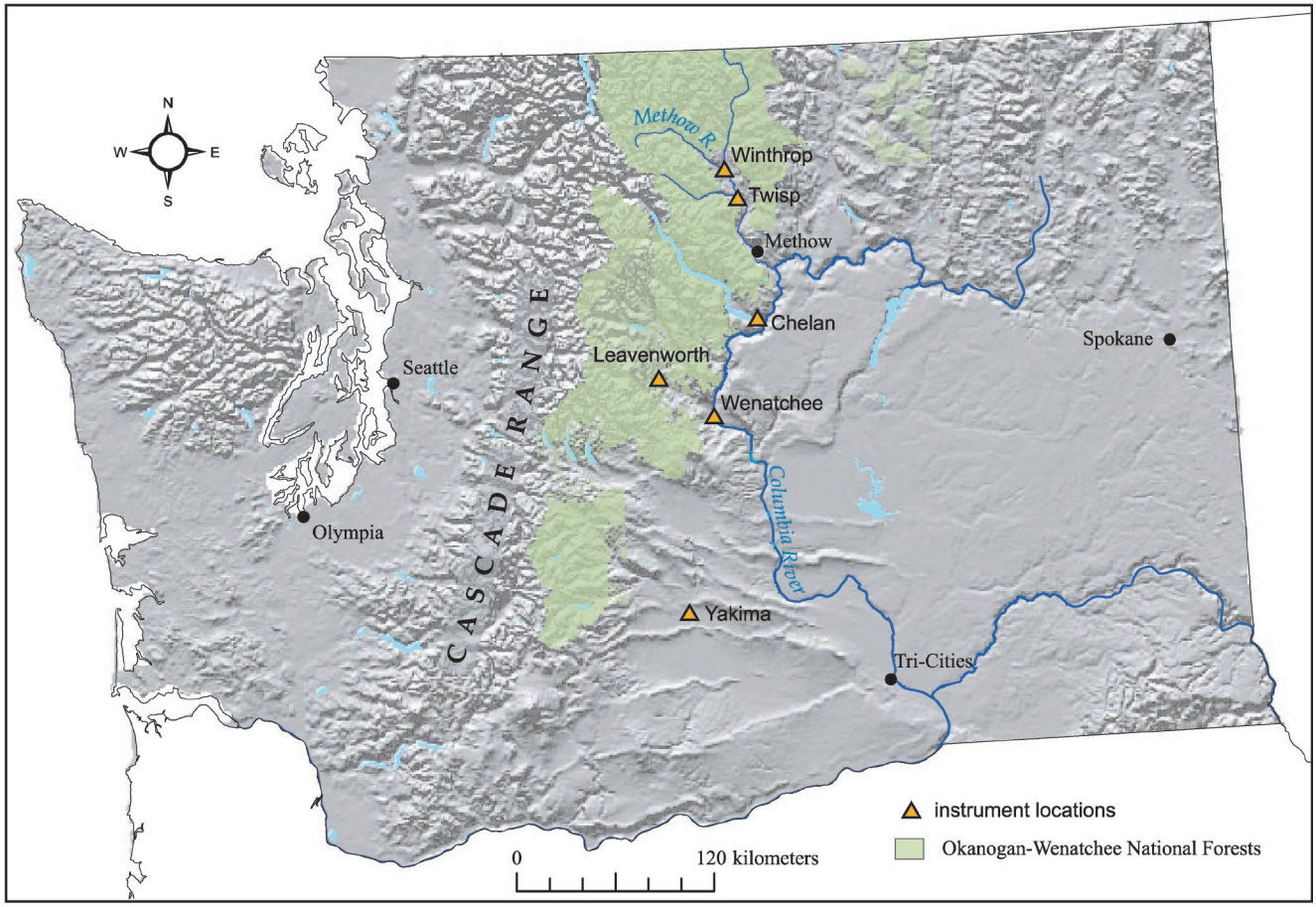
Figure 1. Location of air quality instruments within the Okanogan-Wenatchee National Forests of central Washington state.



fires so large? Why did they burn with such intensity? Were they within an expected range of natural variability?

Scientific Review Findings

The science team effort produced a number of key findings regarding changes in fire ecology, and the composition and structure of vegetative stands across the Eastern Cascades, especially on sites in the lower elevational range of coniferous vegetation. This broad area was labeled "dry site forest". It parallels but is east of the crest of the Cascades. These observations were packaged into a "Dry Site Initiative" which became one of a number of resource discussions that have led to the "Healthy Forests Initiative" (HFI) on a national scale (Office of the President 2002; Townsley 2004). The initiative focuses on identifying areas of "dry site forest", reducing fuel loadings, removing understory vegetation, reducing potential for insect and disease infestation across large landscapes, and creating a vegetative mosaic less prone to catastrophic fires on the scale of the 1994 fires. The amount of silvicultural burning, and especially the use of large-scale prescribed fire, has increased as a result of the initiative.

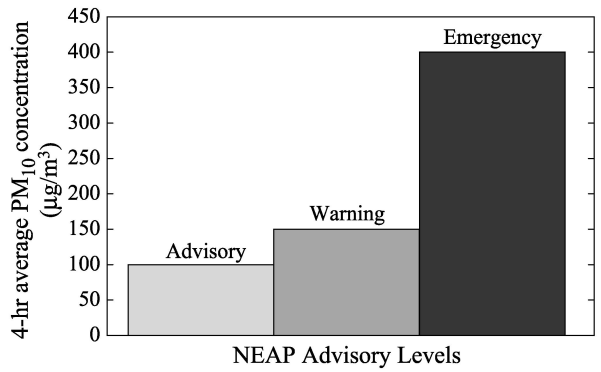
Chelan County Natural Events Action Plan

A second outcome of the fires of 1994 was the preparation of a Natural Events Action Plan (NEAP) for Chelan County. The Washington State Department of Ecology (DOE) led an interagency effort to prepare this contingency plan for wildfire. The NEAP was published in June 1997 and contained three goals: educate the public about wildfire, mitigate health impacts, and institute best available control measures (Greef 1997).

The NEAP defined three threshold levels of air particulate concentration: advisory, warning and emergency, and prepared a public health news release for each. The levels were based on a 4-hour average concentration of fine particulate less than 10 microns in diameter (PM_{10}) as measured in micrograms per cubic meter ($\mu g/m^3$) (Figure 2). This was the first NEAP in the country prepared as a contingency plan for wildfire and a subsequent adverse air quality situation.

Agency roles and responsibilities were defined. The Forests' role is to provide information about weather and wildfire conditions, and alert state and local agencies whenever a wildfire could potentially grow to such size

Figure 2. Natural Event Action Plan (NEAP) advisory levels of particulate.



as to generate a smoke incident. The DOE will review nephelometer data both from permanent DOE operated instrument sites and from any temporary sites established for the fire emergency, release public health information, and provide advice and counsel to the local public health agencies. Local public health officials issue public service news releases as needed. The NEAP has been implemented in Chelan County for wildfire situations almost every year since publication in 1997.

Air Quality Management During Prescribed Fire Operations

The emphasis on prescribed burning as a result of the local "Dry Site Initiative" and the national-scale HFI has increased attention on refining working relationships, roles and responsibilities of all agencies involved in fire management. The Washington State Department of Natural Resources (DNR) administers the Smoke Management Plan for the State of Washington via statute. DNR reviews each silvicultural burn request and makes daily approval decisions based on meteorological forecasts and projections of smoke production and dispersion (Washington Department of Natural Resources 1993). DOE operates air quality monitoring instrumentation, posts air quality information, and issues approvals for agricultural burning for the State. The FS is the prescribed fire manager for fires occurring on the national forests.

Prior to 1994, DOE's air quality focus was monitoring air quality in major population centers; it operated only two air samplers in the Eastern Cascades. In 2002 the Forest Service and DOE signed an agreement for the operation of five additional instruments, to provide better definition of background air quality, define impacts from all particulate sources including prescribed burning, and identify acceptable windows for burning. The Forest Service purchased and operates Radiance Research Nephelometers, but pays DOE for quality control oversight and posting of data on a state-wide DOE website. Figure 1 shows the location of instruments in the Eastern Cascades.

The collective knowledge and experience of the agencies involved in wildland fire management and public health since the 1994 fires has led to some consensus as to how to successfully operate these programs. It has become clear that wildfires occur on an almost annual basis, causing negative air quality impacts across a broad geographic area of the Eastern Cascades. Smoke becomes an air quality issue when trapped in local valley bottoms. Upper Columbia River valley communities, and often other states and Canada, are affected by adverse air quality conditions when major wildfire events occur. The causative events of air quality incidents can be a considerable distance away, but still may result in impacts on valley communities. Fires as far away as western Washington, Canada, and Alaska, and at least on one occasion, a dust storm in China, have resulted in noticeable air quality impacts. Agencies have concluded that the public should be given as much advance notice as possible when adverse air quality conditions are anticipated.

Forest fire management specialists have concluded, based on local experience and observation, that fuel reduction treatments have made a difference in control of wildfires (Harrod 2004). Wildfires have different burn behavior in stands where site treatments have reduced stocking of standing trees, minimized fuel ladder structure, and reduced volume of fuels. Agencies further concluded that strategic placement of these treatments has been effective in protecting areas of urban interface from fast-moving wildfires. Although these treatments have shown to be effective, they are limited in number. It will take many more treatments across a broader landscape to accomplish HFI objectives.

2003 Issuance of a Notice of Violation

The 2003 burning program in the Methow Valley began on 15 May and continued until 10 June. The Methow Valley Ranger District (MVRD) burned over 2,000 acres (809 ha) of prescribed fires. On 18 June, as a result of air quality conditions in the Methow Valley, DOE issued a Notice of Violation (NOV) to the Regional Forester, Pacific Northwest Region, "for causing and/or allowing air pollution from prescribed silvicultural burning in violation of the Washington Clean Air Act…that caused a nuisance, obscured visibility on roads, and presented a risk to the health of people who were residing in the area of the fires". The peak hourly $PM_{2.5}$ particulate value was 129 µg/cm^3 at the Twisp nephelometer on 5 June. Figure 3 shows daily maximum hourly nephelometer readings converted to $PM_{2.5}$ particulate in units of micrograms per cubic

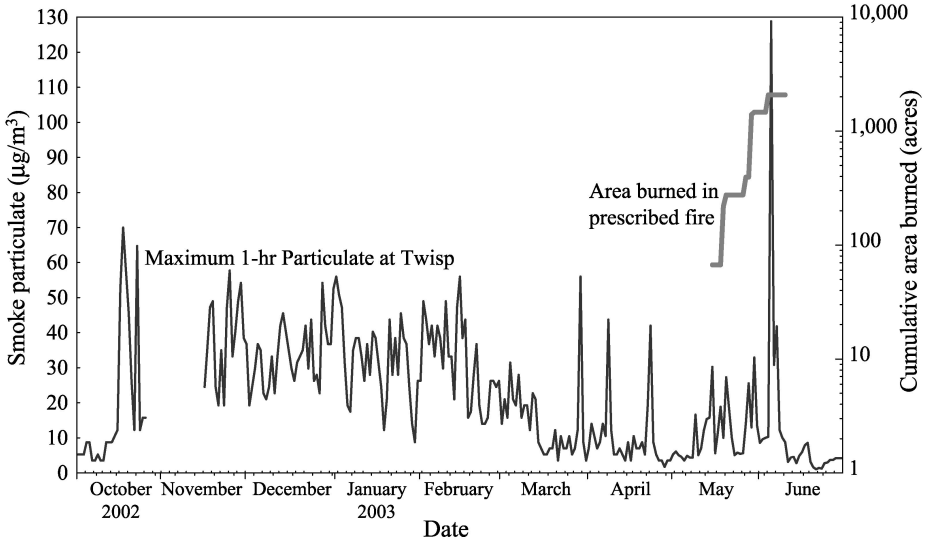


Figure 3. Twisp nephelometer daily 1-hour maximum $PM_{2.5}$ values for October 2002 to June 2003, with burn acreage.

meter (µg/m³). The monitor at Twisp was the only air quality instrument in the Methow Valley at the time. Observations of local conditions at Winthrop, eight miles further up valley and closer to the burns, were reported to be considerably worse.

The legal basis for this NOV is still debatable given that the burns had been ignited following daily dialogue between the Forests and DNR, and approval had been given by DNR. However the incident did highlight the fact that further dialogue was needed between the three agencies involved, especially given the increase in the prescribed fire program and the use of landscape scale burns. Because of the magnitude of air quality impacts, the forest conducted an internal review and initiated a number of corrective actions. These actions were incorporated into a settlement agreement between the three agencies and became the basis for further refinement of working relationships.

Settlement Agreement Action Items. A number of action items were implemented immediately as part of the settlement agreement.

- A Forest Service nephelometer was moved to Winthrop in the Methow Valley and added to the DOE state network, supplementing the existing DOE instrument at located at Twisp.
- A camera was installed at the Forest Service IMPROVE monitoring site overlooking the lower Methow Valley to provide live images of air quality conditions in the lower valley on the FS website. The live camera image can be viewed at *http://www.fsvisimages.com/pasa1/pasa1.html*.
- The MVRD started routinely requesting an on-site meteorologist for landscape-scale fires when conditions warranted.
- The forests began identifying landscape burns when requesting burn approval from DNR.
- This allowed DNR to issue three-day, instead of one-day, approval windows when warranted for these multiple day burns.
- DOE was given a daily listing of approved burns.

Longer-term improvements were also implemented. The MVRD improved and expanded the district public involvement plan (USDA FS 2004). A Forest Service complaint tracking system was developed and implemented so the District could document every inquiry from the public about burn activity and record agency responses. Coordination meetings and field reviews were scheduled for the three agencies. Attention was focused on coordinating public information messages issued through the news media regarding burning. Collaborative work continued with the Pacific Northwest Research Station and University of Washington research scientists to refine smoke dispersion computer models (Ferguson 2004). A resolution to settle the NOV was signed by DOE, DNR, and the Forest Service Pacific Northwest Region in September 2003.

2004 Refinements to the Air Quality Management Program

Action items were implemented in 2004 with good results. Between 29 March and 1 June over 7,600 acres (3,075 ha) were burned on the Forests. The MVRD burned 3,200 acres (1,295 ha), including several multiple-day landscape burns. Ranger district personnel implemented an expanded public involvement plan, while recording and responding to all public contacts (USDA FS 2004). DOE monitored complaints, coordinated responses with the MVRD, and monitored air quality data. The Forests continued to submit landscape burn requests as a special category, and DNR reviewed these for multiple day burn approval. DNR agreed that in the event a three-day approval was given for a landscape burn, approval would

not be rescinded, even if conditions deteriorated on day 2 or 3. In that case the prescribed fire manager and forest staff would make the decision whether to proceed on each subsequent day.

The forests began tracking data from the network of nephelometers to show daily conditions, seasonal variability and trends, downloading data each morning from the DOE website. Data were converted to $PM_{2.5}$ particulate concentration in units of micrograms per cubic meter using relationships established by Trent et al. (2001). Daily concentrations were graphed as daily 24-hour average, daily maximum hourly average, and daily maximum 4-hour average values. The daily trend lines for these three indices were compared graphically to the U.S. Environmental Protection Agency (EPA) 24 hour Air Quality Index (AQI), the EPA 1-hour AQI, and the Chelan County NEAP advisory levels, respectively. These graphical presentations were reviewed daily to view background conditions prior to ignition of a new prescribed burn, and to monitor conditions during and following a burn, in an attempt to better define the contribution of each prescribed burn to local particulate air quality levels. The forests selected the daily maximum hourly average value of particulate as the key indicator of background air particulate because experience showed considerable variation in daily conditions during a burning event that was not registered with either the 24-hour average or 4-hour-average values. The Forest defined an air quality objective of maintaining particulate levels resulting from prescribed burning between 41 and 80 $\mu g/m^3$, within the "Moderate" level EPA 1-hour AQI category (Hardy 2001). EPA defines six condition categories: Good, Moderate, Unhealthy for Sensitive Groups, Unhealthy, Very Unhealthy and Hazardous. The Forests' procedure was to monitor air quality particulate levels and avoid new prescribed fire ignitions when particulate measurements approached the lower end of the Moderate range.

On 28 March, early in the 2004 prescribed burning season, an approved multiple-day landscape-scale fire was burning in the Methow Valley. The maximum hourly reading for the Twisp nephelometer the previous day was 39 $\mu g/m^3$. The forest elected not to ignite a second portion of the prescribed burn area scheduled for 28 March because of potential adverse smoke impacts in Methow Valley. The same situation occurred on 26 April when the prior day maximum particulate reading was 37 $\mu g/m^3$. In both cases, though approval had been given for ignition of an adjacent unit within the project perimeter, ignition was postponed, and within one day, air quality conditions improved enough so that burning could be resumed.

By defining an air quality objective, the Forests attempted to incorporate ambient air quality conditions into the daily prescribed burning decision-making process, in order to avoid new ignitions when background air quality conditions are poor, to postpone additional ignitions for ongoing multiple-day burns when conditions are marginal, and to better monitor the contribution of particulate from a burn to local air quality conditions. A number of factors were considered in selecting the 41 to 80 $\mu g/m^3$ particulate level as the numeric objective. This particulate level is comparable to local air quality conditions during winter months, based on a two-year period of air quality data collection. The "Moderate" level EPA 1-hour AQI category is an established index. Particulate concentration is monitored by local real-time instruments. Data can be accessed essentially real-time via web sites and are available for daily prescribed fire decision-making. And finally, experience has taught us that when local conditions

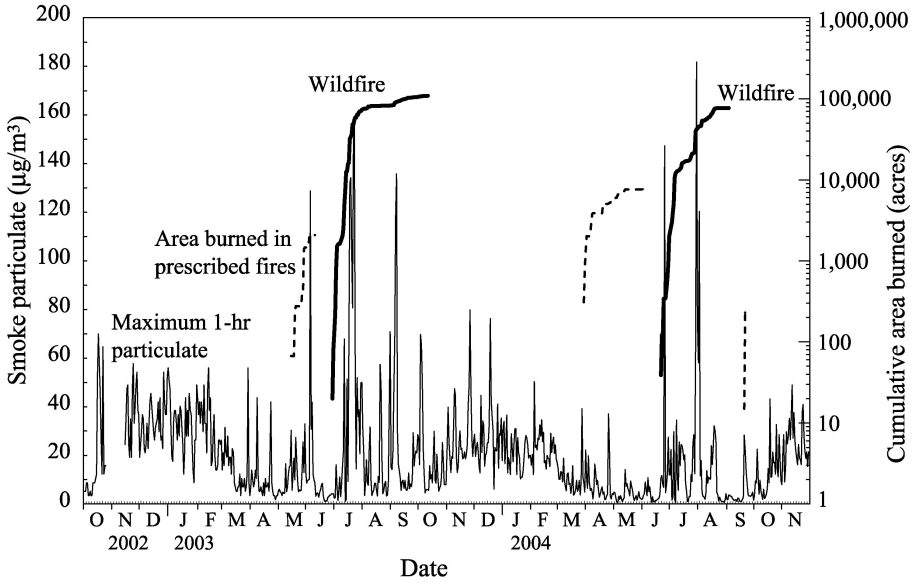


Figure 4. Twisp nephelometer daily 1-hour maximum $PM_{2.5}$ values for October 2002 to November 2004 with burn acreage.

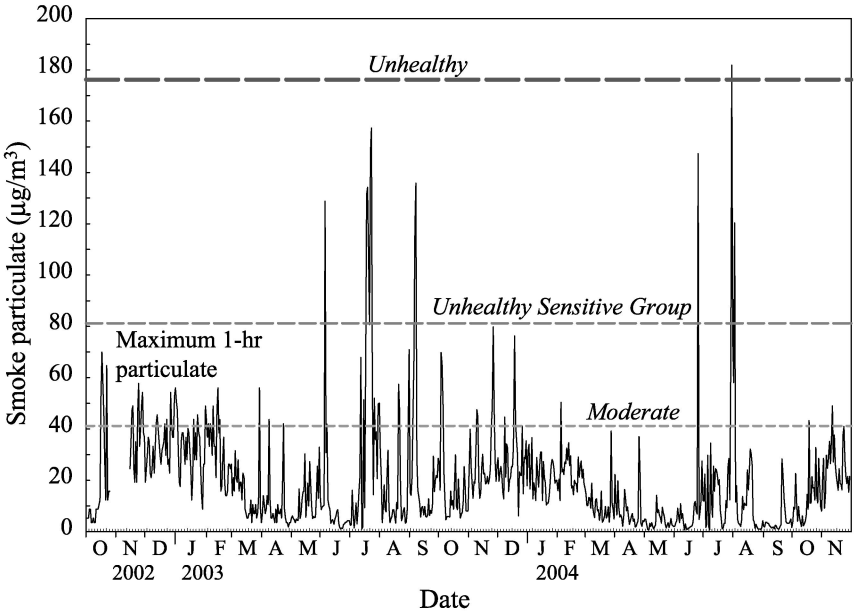


Figure 5. Twisp nephelometer daily 1-Hour maximum $PM_{2.5}$ values, EPA 1-Hour AQI for October 2002 to November 2004.

reach the objective level the general public starts to express concern. With the guidelines in place, particulate values did not exceed 41 µg/m^3 for the 2004 prescribed burn season at any nephelometer site. However hourly values reached 182 µg/m^3 later in the year, during the 2004 wildfire season (Figure 4).

Summary

Experience gained from increased use of prescribed fire in an area where wildfire is an annual occurrence, urban interface issues are escalating, and air quality can suffer significant impacts, has led to a better understanding of how to protect air quality while implementing the HFI.

A local public involvement plan is an essential component of a HFI strategy. Reliable sources of information and opportunities for public involvement and comment are needed at both the program and project planning stages. There should be multiple opportunities for agency contact with local residents. The general public has a wide range of opinions about HFI prescribed fire treatments. Most of the public is supportive where treatments have been applied, reviewed on the ground, and obviously been effective in wildfire control and protection of urban interface developments. But there are those who feel that prescribed fire should not be used as a treatment because smoke intrusions are invasive, harmful, and unnecessary. We have found that public misinformation abounds regarding the relevant pollutants in smoke, possible health effects, and how to interpret monitoring values. The public feels that the FS has an obligation to study health impacts of smoke and inform them of both negative impacts and benefits of burning; to provide air quality and public health information; and to find, explore, analyze and fund alternative treatments. Individuals who wish to burn agricultural residues on private land off-forest continue to express confusion and frustration because of the two state regulatory agencies involved and duplicate processes for approval of agricultural versus silvicultural burn requests.

Smoke can be life threatening to those predisposed to respiratory ailments. Smoke impacts are real, and include a range of health conditions ranging from eye and respiratory tract irritation to asthma, bronchitis, and reduced lung function, to significant respiratory and cardiovascular-related effects (USEPA 2003; Hardy 2001; Therriault et al. 2001). Even with limited period-of-record data, annual patterns are becoming apparent. Average daily particulate concentrations are higher during winter months, and lower in spring and fall (Figure 5). One-hour and 4-hour maximum spikes can occur from prescribed fire but are of short duration. The maximum hourly values over the period of record are the result of wildfire events. These latter air quality incidents last for a considerably longer period of time.

Air quality objectives need to be developed for prescribed burns. It is apparent that 24-hour $PM_{2.5}$ air particulate standards are not an appropriate measure for determining accomplishment of air quality objectives, given that significant peak values can occur for much shorter periods of time. A 1-hour daily maximum value provides a better identifier of significant particulate events on a local scale. It is important to have local real-time monitoring data to assess ambient conditions and to monitor attainment of air quality objectives. This allows management decisions regarding a day's burn activities to be based on the prior day's values, and even the current day's early morning conditions.

Opportunities

There are a number of opportunities for refinement of air quality objectives for use in prescribed fire management. There should be further discussion of the use of a specific air quality numeric value of 41 $\mu g/m^3$ as a project scale objective. It should be understood that this air quality objective is not proposed as a regulatory standard, requirement, or threshold, but as an objective that incorporates a quantitative air quality measurement into a decision making process that includes many factors including legal requirements, regulatory procedures, public and fire fighter safety, costs, resource management objectives and local public health.

The ability to project the impact of a particular landscape burn relative to an air quality objective needs improvement. Spatial models that project particulate production and dispersion, given site-specific fuel loading, topographic features, and meteorological forecasts, do not currently have the resolution to accurately project particulate dispersion at a local scale. Research scientists are refining the BlueSkyRAINS computer model to incorporate a finer resolution of detail for project-scale landscape burns in Eastern Cascade valleys (Ferguson 2004). This predictive tool would allow fire managers to design prescribed burn projects, and select areas to be burned that optimize natural smoke dispersion and minimize local public exposure to adverse smoke conditions.

Conclusion

The Healthy Forests Initiative is a forest management priority on a national scale because of the extensive wildfires that occurred in the Eastern Cascades in 1994, and those that occurred on an even larger scale elsewhere. The forests are implementing this initiative with a variety of treatments including more frequent use of landscape-scale prescribed fire. Landscape burns will be conducted by the forests within a State Smoke Management Plan regulatory framework administered by DNR. The forests will respond to air quality issues by implementing a comprehensive local public involvement plan and by establishing local site-specific air quality objectives that will be used as one criterion in reviewing daily burn approvals and in making a final decision to burn. Following two years of air quality monitoring, we conclude that these air quality objectives have value on the OWNFs because they allow immediate assessment of local conditions and input to a daily go, no-go decision-making process. Data now available allow an immediate read on whether objectives have been attained for the previous day. The forests will collaborate with DOE in monitoring air quality conditions, reviewing air quality data and in responding to public comments.

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