FEWG – A WORKING GROUP FOR NCDFR MTM

NC SMP Technote 10 – December 13th, 2008

A Simple Smoke Vector Screening Tool

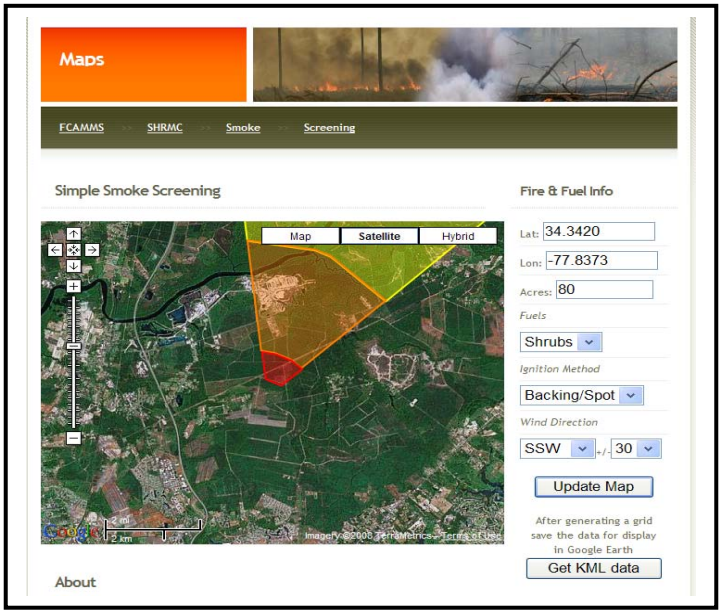
NC Smoke Management Program

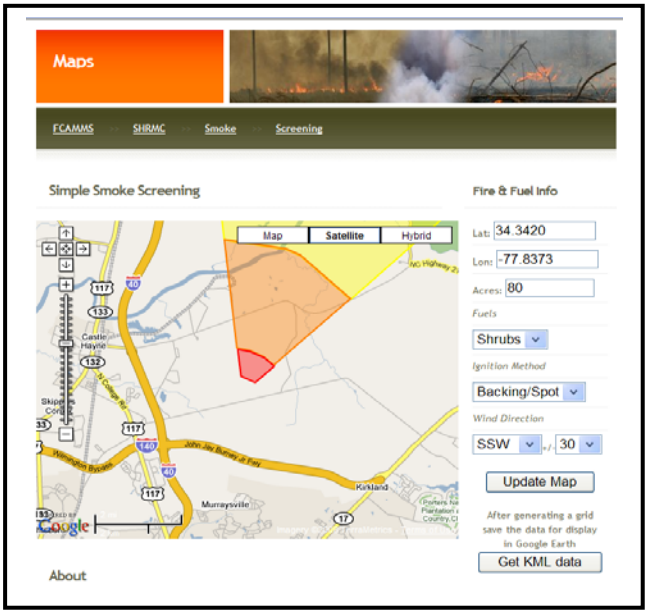
Managing Your Smoke version 02 – "A Simple Screening Tool for use with NC Smoke Management Program"

This document was prepared from the publication United States Department of Agriculture, Forest Service Southern Region, February 1989; Technical Publication R8-TP 11, the Southern High Resolution Modeling Consortium website and editing provided by the NCDFR Fire Environment.

Your comments are welcomed. With the issues that smoke can generate for the North Carolina (NC), this document serves as a review and guidance for the NC Smoke Management Program and a basic vectoring tool for prescribed fire.

For A Basic Tool to Vector Smoke go to: http://shrmc.ggy.uga.edu/maps/screen.html as it is linked to Google Earth with Maps or Photographs.





The Southern Smoke Management Guide made use of a simple graphical smoke screening system. This system relied upon a simple protractor to use with paper maps in marking out a smoke impact zone. SHRMC has created a digital version of this tool. This is a simple screening tool designed to help identify smoke sensitive targets not to predict smoke concentrations. It follows the graphical screening method outlined above in this paper. The acreage value is used to set the width of the screening grid and also increases the screening distance for larger burns. *Latitude and Longitude should be entered in decimal degrees*. This tool is weak in topography and when winds are "not "persistent in their direction and speed.

Prescribed burning helps achieve many desired resource objectives, but it nevertheless it does disperse pollutants into the atmosphere. Therefore, we have an obligation to minimize smoke's adverse environmental effects. If this obligation is disregarded, prescribed burners can be held liable for damages from accidents or associated problems resulting from their actions. Our obligation to minimize adverse environmental effects for wildfires needs to be no different but it is more difficult as these are unplanned ignitions. Loss of visibility on a highway can be severe safety hazard for motorists. Use of the following guidelines presented here will assist in the management of smoke from wildfires or prescribed fires under the NC Smoke Management program which is presently based on a Ventilation Index System.

A. **Define objectives. -** Be sure you have clear resource objectives and have considered both on-site and offsite environmental impacts.

B. **Obtain and use weather and smoke management forecasts -** Weather information and fire-weather and smoke management forecasts are available to all resource managers and private woodland owners by various websites in particular by the National Weather Service (NWS). Such information is needed to project smoke generation and movement as well as fire behavior. If the forestry weather outlook does not agree reasonably well with the radio/TV forecast, find out why.

C. **Don't burn during pollution alerts, stagnant conditions or when the Burning Category is a 1 (Ventilation Rate is less than 33,499). There is an exception to burning on a BC 1. It is when the NCDFR BC 1 to BC 2 Flow Chart can be successfully used.** If the flow chart cannot be successfully applied then environmental conditions are such that smoke will tend to stay near the ground and will not disperse readily. This information is presented in the NWS Fire Weather and Smoke Management Forecasts. During wildfires burn out operations if at all possible should be conducted when dispersion is favorable and control is likely.

D. **Comply with air pollution control regulations during prescribed fires and when possible during wildfires. –** Know NC Division of Air Quality regulations and the Air Quality Index. Both apply to the proposed burn. Consider these when making the prescription. Be thoroughly familiar with D 1900 Open Burning Rule as it is stated that prescribed fire can take place on code Orange Days.

Air Quality Index (AQI) Values When the AQI is in this range:	Levels of Health Concern air quality conditions are:	Colors ...as symbolized by this color:	Meaning
0 to 50	Good	Green	Air quality is considered satisfactory, and air pollution poses little or no risk.
51 to 100	Moderate	Yellow	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.
101 to 150	Unhealthy for	Orange	Members of sensitive groups may experience health effects. The general public is not likely to be affected.
151 to 200	Sensitive Groups	Red	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.
201 to 300	Unhealthy	Purple	Health alert: everyone may experience more serious health effects.
301 to 500	Very Unhealthy	Maroon	Health warnings of emergency conditions. The entire population is more likely to be affected.

E. **Burn when conditions are good for rapid dispersion. -** Ideally, the atmosphere should be thermally neutral to slightly unstable so smoke will rise and dissipate, but not so unstable as to

The Atmospheric Dispersion Index (DI) is a better picture of what is taking place in the mix layer. It is a better indicator of the atmosphere's ability to disperse smoke. DI is calculated by SHRMC. See table 1. This can be used as additional supportive information. It is not a replacement for the NWS Fire Weather (FWF) and Smoke Management Forecasts (SMF). Reassess your decision to burn when the daytime Atmospheric Dispersion Index (DI) value is below 41. Successful burns have been conducted at 27. At these values running Dispersion Models would be an excellent support tool to in making a GO Decision to burn. NCDFR is currently working with the NWS to provide DI as a new product. The DI can be viewed at the following website: **http://shrmc.ggy.uga.edu/state_maps.php?field=dispf&state=northcarolina&time=18&submit=view**

Table 1. - Relationship of Atmospheric Dispersion Index to On-the-Ground Burning Conditions

Atmospheric Dispersion Index	Burning Conditions
>100	Very good - Burning conditions may be so good that fires may be hazardous and present fire control problems. Reassess decision to burn.
61 - 100	Good - preferred range for prescription burns.
41 - 60	Generally OK - climatologically afternoon values in most inland forested areas fail in this range.
21 - 40	Fair - stagnation may be indicated if accompanied by low wind speeds. Reassess decision to burn.
13 - 20	Generally poor - do not burn. Stagnant if persistent, although better than average for a night value.
7 - 12	Poor - do not burn. Stagnant during the day, but near or above average at night.
1 - 6	Very poor - represents the majority of nights at many locations.

Caution: Check For Down Drainage Smoke Flow at Night!

F. **Use caution when near or upwind of smoke-sensitive areas. -** Burning should be done when wind will carry smoke away from public roads, airports, and populated areas. Do not burn if a smoke-sensitive area is within 1/2 mile downwind of the proposed burn unless a mitigation action plan (MAP) for the smoke sensitive area is in place.

G. **Use caution when smoke-sensitive areas are down drainage.** - Minimize the production of residual smoke. Use aggressive mop up as necessary.

H. **Estimate the amount and concentration of smoke you expect to generate. -** This guideline is especially important near highways and populated areas (see table 2 below) and the write-up on "MAV" as shown in table 3. NC's Smoke Management Program assists burners in making this estimate. NC's SMP links allowable dispersion of pollutants to Burning Category Day. See table 4.

Table 2 - Effect of Smoke Concentration on Visibility

Smoke concentration (micrograms/m^3)	Visibility (miles)[1]
125	2.0 - 8
250	1.0 - 4
500	0.5 - 2
1,000	0.25 - 1

[1] These numbers are only valid when relative humidity is below 70 percent.

Table 3 – MAV – Minimum Acceptable Visibility On Highways Due To Smoke.

Posted Speed Limit	(EB + FB) x (AF)	Daytime MAV (ft.)	Simple Divided Hwy or Nighttime MAV (ft.)
10	(10.5 + 6.6) x 1.75	28	56
15	(16.0 + 12.5) x 1.75	50	100
20	(21.5 + 22.2) x 1.75	76	152
25	(27.0 + 34.7) x 1.75	108	216
30	(32.5 + 50.0) x 1.75	144	288
35	(38.0 + 68.0) x 1.75	185	370
40	(43.5 + 88.9) x 1.75	232	454
45	(49.0 + 112.5) x 1.75	283	566
50	(54.5 + 138.9) x 1.75	338	676
55	(60.0 + 168.0) x 1.75	399	798
60	(65.5 + 200.0) x 1.75	465	930
65	(71.0 + 234.7) x 1.75	535	1070

The MAV should be doubled if smoke is present along the road at night. The MAV should also be doubled when the road is a simple divided highway, because there is an increased chance of head-on collisions. The visibility adjustment factor does not take into account a head-on encounter of two vehicles traveling in opposite directions

Table 4 - Burning Category Days.

NC Burn Category Day	Ventilation Rate (mixing height x transport wind)
1	**0 to 33499**
2	**33500 to 44999**
3	**45000 to 59999**
4	**60000 to 111999**
5	**≥ 112,000**

I. **Notify your local VFD (911), nearby residents, and adjacent landowners. -** Notification is common courtesy and is required in NC to notify adjacent landowners. People need to know that your burn is not a wildfire or is a wildfire. In addition, the burner will get advance notice of any adverse public reaction and be made aware of special problems, such as respiratory ailments, washday, etc.

J. **Use test fires to confirm smoke behavior. -** Set these in or adjacent to the area proposed for burning, away from roads or other edge effects.

K. **Use backing fires when possible. -** Backing fires consume dead fuels more completely and produce less smoke. Even though slower and more expensive, they produce fewer pollutants and restrict visibility less.

L. **Burn during middle of the day when possible. -** Atmospheric conditions for dispersion of smoke will be most favorable. The burning window is determined by burn off temperature if there is one in the morning and the Nighttime Smoke Dispersion.

M. **Consider burning in small blocks if Atmospheric Dispersion Index (DI) is below 61. -** The larger the area being burned, the higher the concentration of particulates put into the air, and the longer the duration of the visibility reduction downwind. However, if weather conditions are good for rapid smoke dispersion, e.g., the DI is above 60, it is often better to burn the whole area at one time from a smoke management standpoint. However at this DI level control may be difficult.

N. **Do not ignite organic soils. -** It is virtually impossible to put out an organic soil fire without submerging it in water. It will smoke for weeks despite control efforts, creating severe smoke problems for miles around. Such fires can also reignite surface fuels, resulting in a wildfire.

O. **Be very cautious of nighttime burning. -** Smoke drift and visibility are very difficult to predict at night. The wind may lessen or stop completely keeping smoke concentrations high in the vicinity of the burn. Burn at night only when you have a definite forecast of optimum conditions. A nighttime smoke patrol is often necessary (see table 5 for NC Nighttime Smoke Dispersion).

Table 5 - Nighttime Smoke Dispersion.

Nighttime Dispersion	Forecast Surface Wind	Interpretation
Stagnant	Near Calm	Day burning concludes 3 hrs. prior to sunset
Very Poor	2 – 4 MPH	Day burning concludes 2 hrs. prior to sunset
Poor	5 -8 MPH	Day burning concludes prior to sunset
Fair	9-12 MPH	Nighttime burning permissible
Good	>12 MPH	Nighttime burning permissible
Excellent	>14 MPH	Nighttime burning permissible but dangerous

P. **Anticipate down-drainage smoke flow. -** Atmospheric conditions tend to become stable at night. Stable conditions tend to keep smoke near the ground. In addition, down slope or down drainage winds generally prevail at night. Thus, smoke will flow down drainage and concentrate in low areas. When relative humidity rises above 80 percent and smoke is present, the formation of fog becomes increasingly likely as moisture condenses on the smoke particles. There seldom are satisfactory solutions to these problems, so they should be avoided entirely whenever possible.

Q. **Mop up along roads. -** Start mop up along roads as soon as possible to reduce impact on visibility. Extinguish all stumps, snags and logs. Mop up should be particularly aggressive whenever roads are in areas where smoke could travel down slope or up or down drainage.

R. **Have an emergency plan. -** Be prepared to extinguish a prescribed burn if it is not burning according to plan or if weather conditions change. Have warning signs available. If wind direction changes, be prepared to quickly contact the local law enforcement agency and to direct traffic on affected roads until traffic control personnel arrive. Have smoke signs ready for deployment.

Screening System for Managing Smoke

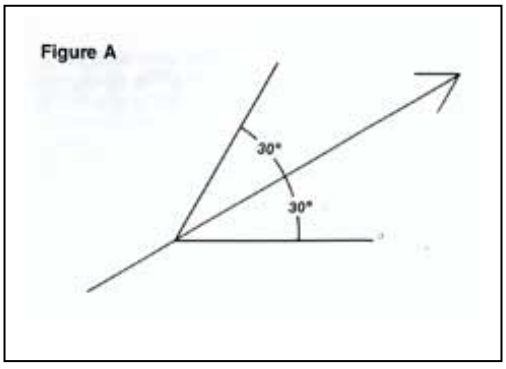
North Carolina presently has a voluntary smoke management program that embraces basic smoke management practices. This program is presently under consideration to be revised to a mandatory program. The program's guidelines need to be followed when planning a prescribed burn. Your local NCDFR office can advise you of sound, recommended procedures and practices. The program's guidelines use a term called the ventilation rate or ventilation factor which estimates the atmosphere's capacity to disperse smoke. As mentioned previously another way to estimate this capacity is to review the Atmospheric Dispersion Index (see table 1) developed at the Southern Forest Fire Laboratory. This calculated index incorporates diurnal changes in the lower atmosphere and is presently available for review at the Southern High Resolution Model Consortium website. It is also presently being worked on to be included in the NWS Fire Weather and Smoke Management Forecasts.

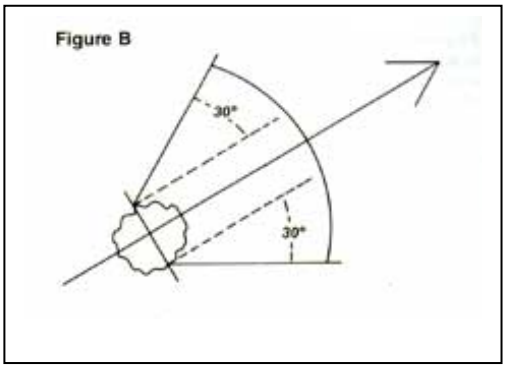
The *Southern Forestry Smoke Management Guidebook is recommended reading*. This guidebook tells you how to predict smoke concentrations at any distance downwind. An improved and computerized version, called ***PRESMOK,*** simplifies use of this prediction system. A similar tool is presently available on the Southern High Resolution web site. Use of this smoke screening tool does **not** take precedence over the NC's program guidelines, but it can be used in conjunction with the NC's guidelines. The full tool is not discussed here, but its application is discussed below. It is very similar to what is already being practiced under the NC's SMP. When conducting a prescribed burn there are six steps: (1) Plot an acceptable direction for the smoke plume, (2) Identify smoke-sensitive areas, (3) Identify critical smoke-sensitive areas, (4) Determine fuel type, (5) Determine permissible tonnage to be dispersed and (6) Minimize risk

Step 1. Plot Direction of the Smoke Plume and Determine Daytime Smoke Impact Zone (DSIZ)

A. Use maps on which the locations of smoke-sensitive areas can be identified. Plot the anticipated downwind smoke movement a distance of: 5 miles for grass fuels regardless of fire type; 10 miles for brush fuels when using line-backing fires or spot fires; 20 miles for brush fuels using line-heading fires; 30 miles for all logging debris fires; 5 miles for line backing fires in all other fuel types; and 10 miles for line-heading fires in all other fuel types, or burns of 250 acres or more. First locate the planned burn area on a map and draw a line representing the centerline of the path of the smoke plume (direction of transport wind) for the distance indicated. If the burn will last 3 or more hours, draw another line showing predicted wind direction at completion of the burn.

B. To allow for horizontal dispersion of smoke as well as shifts in wind direction, draw two other lines from the fire at an angle of 30 degrees from the centerline(s) of observed wind direction (45 degrees if forecast wind direction used). If fire is represented as a spot, draw as in figure A.
If larger, draw as in figure B. The result is your probable DSIZ.





C. Now go down-drainage for one-half the distance determined above, but do not spread out except to cover any valleys or bottoms. The result is your probable nighttime smoke impact zone (NSIZ), providing the burn will be completed at least 3 hours before sunset, and providing the forecast night winds are light and variable.

Step 2. Identify Smoke-Sensitive Areas (SSA)

Identify and mark any smoke-sensitive areas (such as airports, highways, communities, recreation areas, schools, hospitals, and factories) within the DSIZ plotted in step 1. These areas are potential SSA for smoke from your burn.

A. If ***no*** potential SSA are found within the DSIZ, burn as prescribed.
B. If the unit to be burned contains organic soils, extensive duff or root mat and they are assessed as not likely to ignite and sustain ignition, burn as prescribed.
C. If any SSA is found within the DSIZ, continue this screening process.

Step 3. Identify "Critical" Smoke-Sensitive Areas

A. Critical smoke-sensitive areas are:
    1. Those that already have an air pollution-or visibility problem (What is the AQI for PM and Ozone?)
    2. Those within the probable DSIZ as determined below. If the distance determined in step 1 was:
        a. 5 miles, any smoke-sensitive area within 1/2 mile is critical, both downwind and down-drainage.
        b. 10 miles, any smoke-sensitive area within 1 mile is critical.
        c. 20 miles, any smoke-sensitive area within 2 miles is critical.
        d. 30 miles, any smoke-sensitive area within 3 miles is critical.

B. If any "critical" smoke-sensitive areas are located, consider the following:

    1. Prescribe a new wind direction that will avoid such targets and return to the beginning of this screening system, or
    2. If the critical smoke-sensitive areas are in the last half of distance of the respective mile distance, consider reducing the size of the area to be burned by approximately ½, or
    3. Complete all phases of the burn (ignition, spread, and smoldering) as determined by the NTSD, and aggressively mop-up and monitor, or
    4. If critical smoke sensitive areas within the DSIZ are mitigated then proceed with the burn prescription, or
    5. Use an alternative other than burning.

C. If no critical smoke-sensitive areas are found, or criteria B1, B2, B3, or B4 is met, continue the screening system.

Step 4. Determine Fuel Type and Total Tons to be dispersed.

A. The smoke produced may vary greatly by type, amount, and condition of fuel consumed. From the list below determine which broad type best fits your fuel.

1. Grass
2. Litter
3. Brush
4. Slash (Scattered logging debris)
5. (KG & Pile)

B. Review fuel categories or combinations.

1. If the fuel type is described by one of the above categories, continue. Review the document NC Smoke Management Program: Burning Category.

2. If your fuel type is not comparable to any of the above, pick the fuel type for which fire behavior and smoke production most nearly compare with yours and proceed with EXTREME CAUTION on the first few burns.

C. If the burn unit fuel type is windrowed logging debris is more than 5 acres and is in a High Hazard County, **Do Not Burn** under present prescription. You need to obtain a special permit from your local NCDFR County Ranger who will determine how many windrows can be ignited each day. Smoke production is great and can last into the night when smoke dispersion is not adequate. If you are in a non-High Hazard County you will need to determine that your fuel tonnage to be dispersed is acceptable for the downwind distance of the smoke sensitive areas and that the major smoke production will be concluded timely as determined by the Night Time Smoke Dispersion. Prescribe burning piles or windrows are not advocated by NCDFR but do recognize its use as a management practice. Select a wind direction that avoids smoke-sensitive areas or one that minimizes the smoke impact.

D. If the fuel type is scattered logging debris or natural understory vegetation, the following conditions offer sound guidance:

1. Size of area to burn is less than 100 acres or the burn unit if it is larger can be burned when the burn window adequately disperses the smoke during both the spreading fire phase and smoldering fire phase smoke. Also, the amount of tonnage to be released has been determined to be acceptable.
2. No major highways are within 5 miles down drainage or the smoke drift is adequately dispersed by the time it reaches the highway. Visibility needs to remain acceptable for the posted speed limit as determined by Minimum Acceptable Visibility.
3. No other smoke-sensitive areas within 3 miles down drainage, or the smoke drift is adequately dispersed by the time it reaches the smoke sensitive areas.
4. If relative humidity is predicted to stay below 80 percent and surface winds above 6 M.P.H. all night, the downwind distances in 2 and 3 above can be cut in half.

E. If your comparable fuel type is one listed in 4A, determine your total per-acre fuel loading by use of the table.

Forest Fuel Types loading Table			
Fuel Type	**Available Tons per Acre**		
	Low	Medium	High
Pine litter	3	6	12
Hardwood litter	3	5	7
Mixed litter	4	6	8
Brush < 2 ft.	4	7	10
Brush 2 – 4 ft.	6	8	15
Brush > 4 ft.	10	20	30
Light slash (thinning)	5	10	20
Medium slash (Chopping)	10	20	40
Heavy slash (KG & Pile)	30	40	60
Short grass / Wire grass	2	5	7
Tall grass / Broom sedge, Marsh grass	3	6	8

Step 5. Determine Total Tons to be dispersed within a 25 sq. mi area or 16,000 acres.

1. With the total per-acre fuel loading determined from the table above multiply this value by the acreage to be burned. This is the total planned tons to be released (TPT).
2. With the Burning Category Day forecasted by the NWS, Distance to Smoke Sensitive Areas identified and Burn Type selected, determine for the day, the total allowable tonnage (TAT) within a 25 sq. mi. area.
3. TAT minus TPT can be equal to 0 or greater than 0, but never less than 0.
4. If TAT minus TPT = < 0, then the burn needs to be rescheduled for a more acceptable burning day with better dispersion or the acreage needs to be reduced.

Smoke Management Daily Total Allowable Tonnage Table for a 25 sq. mi. area or 16,000 acres													
Burn Cat.	**1**	**2**		**3**		**4**				**5**			
Burn Type	None	Open	Under story	Open	Under story	Open	Under story	Open	Under story	Open	Under story	Open	Under story
Smoke Disp.	Any	Any	Any	Any	Any	VP to P	VP to P	Fair to Good	Fair to Good	VP to P	VP to P	Fair to Good	Fair to Good
Time of burn	Day Only	Day Only	Day Only	Day Only	Day Only	Day Only	Day Only	Day Only	Day Only	Day Only	Day Only	Day Only	Day Only
0 < ½ mi	0	0	0	0	0	0	0	0	1030	0	0	0	1350
½ < 5	0	360	720	450	900	720	1440	1440	2160	900	1800	1800	2700
5 < 10	0	720	1440	900	1800	1400	2880	2880	4320	1800	3600	3600	5400
10 < 20	0	1080	2160	1350	2700	2160	4320	4320	6480	2700	5400	5400	8100
20 < 30	0	1200	2400	1600	3200	2500	5000	5000	7500	3000	6000	6000	9000
30+	0	1440	2880	1800	3600	2880	5760	5760	8640	3600	7200	7200	10800

The following is additional guidance in determining a burn unit's tonnage:

1. Generally, the **total** fuel loading will be less than 10 tons in the fuel types listed below when age of rough is:

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a. Grass (with pine overstory), any age. Also wheat fields and other agricultural burns.
b. Light brush, 7 years old or less (10 years if basal area is less than 100 square feet per acre).
c. Loblolly pine with
    a. gallberry understory, 7 years or less if basal area is less than 150 square feet per acre.
    b. little or no understory, 15 years or less if basal area is less than 150 square feet per acre.
    c. little or no understory, 8 years or less if basal area is less than 150 square feet per acre.

2. When the tonnage is greater than 10 tons per acre, doubling the distance of DSIZ needs to be considered as determined in step 1A. and if is at 10 tons per acre, 1½ times the DSIZ listed in Step 1.

Step 6. Minimize Risk

To meet your smoke management obligations when any smoke-sensitive area may be affected by your burn, the following criteria to minimize any possible adverse effects need to be implemented.

- **Height of mixing layer** (mixing height) is **1,650** feet (500 meters) or greater.
- **Transport wind speed is 9 mph** (4 meters per second) or greater unless using dispersion models.
- Background visibility is at least 5 miles within the plotted area.
- If rough is older than 2 years, use a backing fire or spot fire. If burn can be completed 3 hours before sunset, or if no smoke-sensitive areas are located in the first half of the DSIZ, other firing techniques can be used.
- Promptly mop-up and monitor to minimize smoke hazards.
- If a smoke-sensitive area is in the overlapping trajectory of two smoke plumes, it should be 1 mile from either source (2 miles if one is from logging debris).
- For night burns, backing fires or spot firing with surface wind speed equal to or greater than 9 mph and relative humidity under 80 percent should be prescribed.
- If it appears that stumps, snags, or logs may cause a residual smoke problem, take steps to keep them from burning. If they do ignite, extinguish them.
- Daytime value of the Atmospheric Dispersion Index between 41 and 60 is adequate for prescribed fires. Atmospheric Dispersion Index of less than 27, daytime burns need to be considered for another day. As either size of individual fires or level of burning activity increases, the Atmospheric Dispersion Index value should also increase.

Many variables affect the behavior and resulting smoke from a prescribed burn. The above system works best in flat terrain and was not designed for use in mountainous country. It does not attempt to consider all the variables: it can only offer broad guidelines. If your prescribed fire complies with all conditions in these six steps, you should be able to safely burn without causing a smoke problem. If you have any marginal weather conditions for smoke dispersion, areas that are especially sensitive to smoke, heavy fuel loadings or wet fuels, use a dispersion modeling system such as VSMOKE to support a GO Decision. You must make the final judgment and it needs to be supported with documented information. **Caution: Be Sure Atmospheric Conditions Are Assessed and Are Conducive For Acceptable Dispersion of Smoke!**