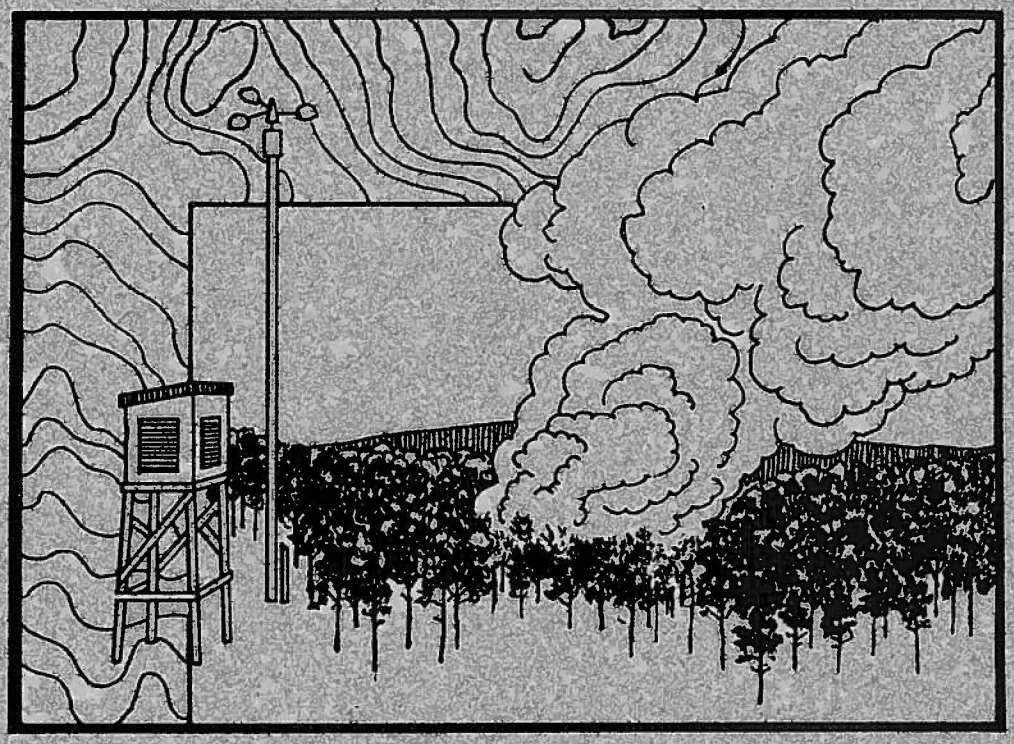
TEXAS FOREST SERVICE

Smoke Management System



Forest Resource Development Department
College Station
March 1995

Texas Forest Service
Smoke Management System

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Introduction

The importance of prescribed fire as a forest management tool is well recognized in the South. Prescribed burning is important not only for economic reasons in cases where it is used to control competing vegetation or to prepare a site for planting, but also for ecologic reasons. The southern pine ecosystem has evolved with periodic fire; indeed, longleaf pine requires fire to perpetuate itself.

Although prescribed fire provides many benefits, both economic and ecologic, it does produce a necessary evil—SMOKE. Smoke from prescribed burning has sometimes been partially or wholly responsible for highway accidents. In addition, besides being a nuisance to people who may not appreciate the importance of this forestry practice, smoke can be hazardous to people with health problems aggravated by poor air quality.

Texas is now the second most populous state in the nation. As land development radiates out from urban areas, the potential for more complaints by the public on smoke from prescribed burning increases. This is especially true in the commercial forest region north of Houston and Conroe.

Most southern states have initiated some form of smoke management for forestry prescribed burning. Most all states have voluntary guidelines although several states issue permits for burning. In Texas, several significant incidents of smoke from forestry burns in 1988 resulted in major public complaints. It became apparent that the forestry community in Texas needed a more formal approach to help prevent future air quality problems. The most important need was a screening system for use by persons responsible for managing forestry burns. This system would help predict problem situations and better manage burning workloads and burn opportunities while minimizing air quality problems.

In developing a system to use, smoke management guidelines from other southern states were reviewed. South Carolina's guidelines were deemed most appropriate for Texas and were subsequently implemented on a trial basis. These have since been modified for use in Texas.

The Texas Forest Service Smoke Management System is a voluntary approach with the Texas Forest Service serving as coordinator for the forestry community. It is not expected to be a perfect tool for solving all smoke-related problems. It simply provides fire managers an opportunity to better manage their own operations. It does not relieve the person or company conducting the burn from liability for fines or damages that might occur, or transfer any liability to the state.

It is envisioned that this management system will be modified and improved as we all gain experience and as better information becomes available. However, this commitment to a coordinated management system provides a basis from which we can refine and improve this important forestry initiative.

This coordinated effort also provides the forestry community the opportunity to control its own future in prescribed burning, and hopefully, avoid intervention by those not trained in the use of fire to manage the ecosystem.

TNRCC Regulations

The Office of Air Quality within the Texas Natural Resource Conservation Commission (TNRCC) has state regulatory responsibility for safeguarding air quality. The TNRCC regulations on outdoor burning (31 TAC §§ 111.101-111.107, and § 101.4) are given in full in Appendix B. Three TNRCC Regional Offices cover East Texas: Tyler—Region 5, Beaumont—Region 10, and Houston—Region 12.

Outdoor burning in Texas is prohibited under Rule 111.101 except when authorized as stated in Rule 111.103. Outdoor burning that is authorized under this rule must still meet the requirements of Rules 111.105 and 101.4. Furthermore, Rule 111.107 states that authority to conduct outdoor burning does not exempt anyone from liability should damage or injury occur as a result of the burning. It also does not exempt anyone from complying with all other applicable laws and ordinances.

Under state air statutes, a person may be assessed an administrative or civil penalty. An administrative penalty, not to exceed $10,000 for each violation, may be assessed by the TNRCC. For civil penalties, $25,000 may be assessed and is recovered through the court system. Each day that a continuing violation occurs may be considered a separate violation.

TNRCC regulations pertaining to forestry prescribed burning are summarized as follows:

Outdoor burning for forest management purposes is allowed if their are no other practical alternatives and if the following conditions are met.

- Prior to forestry prescribed burning, the Texas Forest Service shall be notified.
- Burning must be outside the corporate limits of a city or town except when necessary to eliminate a naturally occurring fire hazard.
- Burning shall begin only when wind direction is such as to carry smoke away from any city, town, residential, recreational, commercial or industrial area, public road, or landing strip which may be affected by the smoke.
- Burning shall not create nuisance conditions or impair traffic.
- If burning causes smoke to blow onto a road or highway, it is the responsibility of the person initiating the burn to post flag persons in accordance with the requirements of the Department of Public Safety.
- Burning shall not begin before 9:00 a.m. and should be completed by 5:00 p.m.
- Burning shall not begin when surface windspeed is predicted to be less than 6 mph or greater than 23 mph.

Summary of System

The Smoke Management System used by the Texas Forest Service (TFS) is a modification of the South Carolina Smoke Management Guidelines. The System makes recommendations on whether or not specific prescribed burns should be conducted using three criteria: (1) smoke dispersal conditions, (2) proximity of downwind smoke sensitive areas, and (3) interaction with other prescribed burns being conducted in the vicinity.

Smoke dispersal conditions are quantified using dispersion index, a measure developed specifically as a smoke management tool by Lee Lavdas with the Southeastern Forest Experiment Station of the USDA Forest Service . Dispersion index is calculated from mixing height, transport windspeed, and stability class. When dispersion index is not available, ventilation rate can be used instead. Ventilation rate is used by South Carolina and is determined by multiplying mixing height by transport windspeed.

Recommendations are also dependent upon the proximity of downwind smoke sensitive areas. Recommended maximums are determined for fires that are likely to produce smoke at smoke sensitive areas located within a projected smoke impact area, or smokeshed. This projected smoke impact area is defined as a 60-degree sector extending 20 miles from the fire and centered in the direction to which the transport wind blows.

The TFS Smoke Management System uses the following equation for determining recommended maximum fuel weights for dispersion indices of greater than 30 and distances from nearest downwind smoke sensitive area greater then ¼ mile:

$$FW_{max} = 0.072928 \times [144 + (91.2 \times D) - (1.92 \times D^2)] \times (DI - 30)$$

where FW_{max} is recommended maximum fuel weight
D is distance in miles to the nearest downwind smoke sensitive area
DI is dispersion index

When dispersion index is 30 or less, or when distance to nearest downwind smoke sensitive area is less than ¼ mile, then no burning is recommended ($FW_{max} = 0$).

Under "special" understory burning conditions, the recommended maximums can be increased over the normal recommended maximums when dispersion index is greater than 33 and the nearest downwind smoke sensitive area is at least 4 miles away.

The system also accounts for multiple prescribed burns that may have overlapping projected smoke impact areas. In cases where two or more fires may simultaneously produce smoke on the same smoke sensitive area, recommended maximum fuel weights may be reduced for the lower priority fires. Prescribed burns are prioritized according to the order in which they are reported.

Recommended maximums can be determined from (1) the FW_{max} equation using a calculator, (2) table look-up values, or (3) the TFS Smoke Management System computer program.

The menu-driven computer program runs on PC-based systems and is operated at each TFS Area Office in East Texas. It requires information on the weather, planned prescribed burns, and any pertinent smoke sensitive areas.

Dispersion index, transport windspeed, and transport wind direction are entered into the system. If dispersion index is not available, then mixing height and stability class (or the variables needed for calculating stability class) are entered and dispersion index is calculated and used. If neither stability class nor the variables that go into its calculation are known, the system calculates and uses ventilation rate.

Minimum information that must be entered for each prescribed burn includes name and phone number of burner, location of burn (TFS Block and Grid coordinates), acres, start and end times, type of burn, and total available fuel weight (acres × available fuel loading). If total available fuel weight is not provided, the computer program determines it from default available fuel loading values.

Primary responsibility for identifying the nearest smoke sensitive area lies with the burn manager. If information on the location is not provided by the burn manager, TFS staff will identify the appropriate area on TFS quadrangle maps. In addition, TFS staff will locate pertinent smoke sensitive areas occurring within overlapping smokesheds.

Using start and end times and transport windspeed, the computer program "moves" the smoke through the projected smoke impact areas. Therefore, in order for one fire to limit another fire, they must have overlapping projected smoke impact areas in terms of both time and space.

On the morning of a planned prescribed burn, the person conducting the burn (or representative) should call the local TFS Area Office and provide the necessary information on the planned burn along with locations of any smoke sensitive areas that may not be on TFS maps. TFS staff will enter the fire into the computer program and place an overlay of the projected smoke impact area on the wall map. After determining the recommendations for that particular fire, the TFS will contact the caller and recommend that (1) the prescribed burn proceed as planned, or (2) either postpone the burn or reduce the size of the burn to within recommended maximums. A response from the TFS on the recommendation will occur within 10 minutes in most cases.

The Texas Forest Service Smoke Management System does not provide guidelines for predicting smoke settling in areas down-drainage from prescribed burns. This responsibility is left to the burn manager on site. However, down-drainage smoke settling is one of the major, if not the major, causes of detrimental impact of smoke produced from prescribed fires. Therefore, the possibility of smoke settling in low areas should be thoroughly analyzed by the burn manager on each burn site before fires are ignited.

Description of System

The Texas Forest Service Smoke Management System is an enhancement of one proposed by Lee Lavdas with the Southeastern Forest Experiment Station of the USDA Forest Service. Lavdas' proposed system is actually a modification of South Carolina's Smoke Management Screening System. The detailed description of the TFS System that follows begins with an overview of the South Carolina System. This overview is followed by a description of the change proposed by Lee Lavdas. Modifications made by the TFS for use in Texas are then presented in detail including the mathematics involved.

South Carolina Smoke Management System

The Smoke Management System used by South Carolina (in 1990) determines a recommended maximum fuel weight (fuel allocation) that can be burned in a 16,000-acre airshed on a particular day. The 16,000-acre airshed is a moving circle having a diameter of 5.64 miles. The amount of fuel burned within these airsheds, whether from one or several fires, should not exceed the recommended maximums. These maximums are determined by two parameters—(1) distance to the nearest downwind smoke sensitive area and (2) weather conditions indicative of smoke dispersal. Downwind is defined as a line radiating from the fire in the direction to which the wind is blowing.

South Carolina uses ventilation rate to characterize the atmosphere's ability to disperse smoke. Ventilation rate is calculated by multiplying mixing height by transport windspeed.

Mixing height represents the top of the atmospheric volume available for dispersion and acts as a lid to trap smoke beneath it. At this height, airmass stability is strong enough and deep enough to inhibit further upward transport of smoke. With higher mixing heights, smoke concentrations will be less—especially at long distances from the fire. Mixing height is usually given in meters (m), and heights of less than 500 meters are often associated with air pollution episodes.

Transport windspeed is the arithmetic average of all windspeeds within the mixing layer, including surface windspeed. Windspeeds usually increase with height, and smoke concentrations usually decrease as transport windspeed increases. Transport windspeed is given in meters per second (m/s), and windspeeds less than 4 m/s indicate stagnant conditions which often result in air pollution episodes.

South Carolina groups ventilation rate into five classes, termed category days, that partially determine the recommended maximum amount of fuel that should be burned at a given distance that the nearest downwind smoke sensitive area is from a fire. The recommended maximum weight is determined according to the scheme given in the following table.

South Carolina Fuel Allocation Scheme

Ventilation Rate (m^2/s)	Category Day	Recommended Maximum Fuel Weight (tons)
0 to 4,499	1	none
4,500 to 5,999	2	1.00 × fuel-by-distance factor
6,000 to 7,999	3	1.25 × fuel-by-distance factor
8,000 to 14,999	4	2.00 × fuel-by-distance factor
15,000 and greater	5	2.50 × fuel-by-distance factor

In the above scheme, the fuel-by-distance factor increases with distance that a downwind smoke sensitive area is from a fire. If the burn is an understory burn and "special" conditions apply to it, the fuel-by-distance factor can be doubled when nearest downwind smoke sensitive area is at least 5 miles away and the ventilation rate is at least 6,000 m^2/s (Category Day 3, 4, or 5). These "special" understory burning conditions are met if any of the following techniques are used:

- Backing fires
- Heading fires in 3-year rough or less
- Mass ignition where all lines are fired by 3:00 pm and burned out by 5:00 pm (4:00 pm if forecasted night time dispersion is poor).

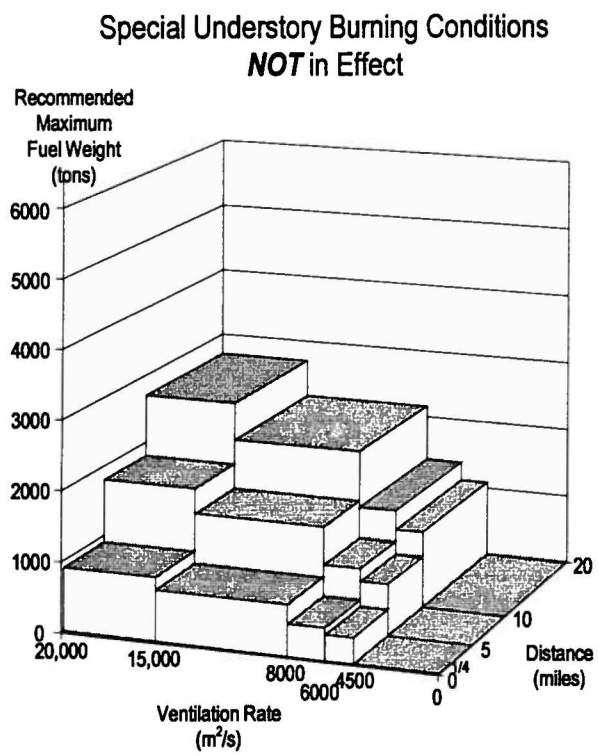
The fuel-by-distance factor increases with distance a fire is from the nearest downwind smoke sensitive area according to the following table.

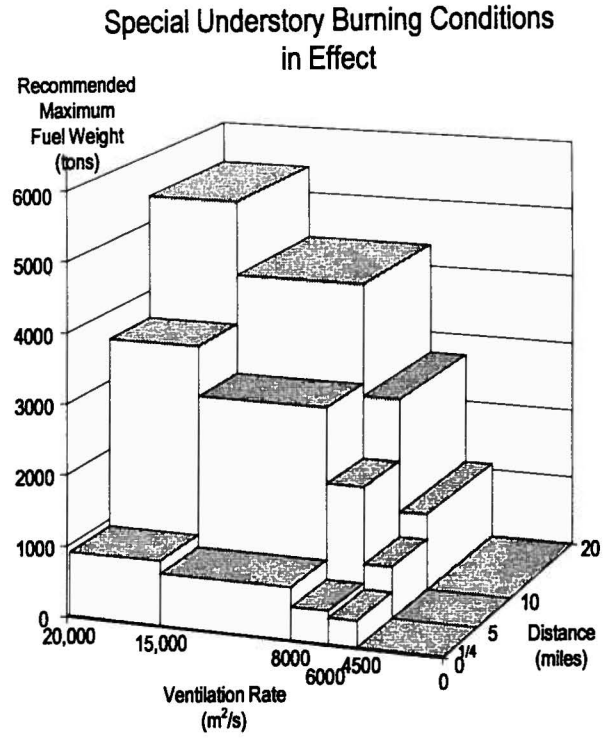
South Carolina Fuel-by-Distance Factors

Miles from downwind smoke sensitive area	Fuel-by-distance factor	Fuel-by-distance factor for "special" conditions
< ¼	0	0
¼ to 5	360	360
5 to 10	720	1440
10 to 20	1080	2160

The South Carolina System can be summarized by the stair-step 3-dimensional graphs on the following page.

SOUTH CAROLINA SYSTEM





Incorporation of Dispersion Index

Lee Lavdas modified the South Carolina System by replacing the use of ventilation rate with dispersion index. Dispersion index is a better indicator of the atmosphere's ability to disperse smoke. As in ventilation rate, mixing height and transport windspeed go into calculations of the index; however, dispersion index goes one step further by incorporating stability class.

The rate of pollutant dispersion within the atmosphere is largely dependent upon stability. Atmospheric stability is determined by the rate of temperature change with respect to height within the atmosphere. A dry atmosphere that cools at a rate greater than 5.5 °F per 1000 ft is unstable. One that cools at a lesser rate or becomes warmer with height is stable. Stability class is used to characterize the atmosphere's stability. Stability class is determined from solar elevation angle, surface windspeed, opaque cloud cover, and cloud ceiling height. Seven classes ranging from extremely unstable through neutral to extremely stable are used where class 1 (or class A) is the most unstable. The atmosphere tends to be unstable or neutral during the day and stable or neutral at night. Neutral conditions are most likely during cloudy or windy conditions. Details for estimating stability class are given in Appendix C.

Dispersion index is directly proportional to transport windspeed. For example, with unchanged mixing height and stability class, doubling transport windspeed doubles the dispersion index. Doubling the mixing height will also increase dispersion index, but due to incomplete mixing within the mixing layer, the index may not double. Dispersion index also is increased when stability class indicates a more unstable atmosphere (i.e., a lower class letter or number).

Dispersion index is formulated such that if the dispersion process were instantaneous within the mixing layer, the dispersion index would be 1 percent of the ventilation rate. For example if ventilation rate = 8000 m^2/s, the maximum potential value of dispersion index would be 80. Because "instantaneous" mixing never occurs for non-zero mixing height, the index is always somewhat less than 1 percent of the ventilation rate whenever a substantial mixing height exists. However, dispersion index can exceed 1 percent of the ventilation rate when the mixing height is small, because ventilation rate omits stable dispersion processes.

Lavdas maintains that using the precise value of dispersion index is a more mathematically consistent method for maintaining acceptable air quality than by simply plugging dispersion index into a coarse categorical system as done with ventilation rate in the South Carolina System. Lavdas derived an equation where recommended maximum fuel weight is a function of dispersion index and fuel-by-distance factor. By comparing the frequencies of daily values for ventilation rate and dispersion index over a 3-year period in Florida, the equation maintains the same level of prescribed fire activity as would occur using ventilation rate. According to Lavdas' modification, the recommended maximum fuel weights for a given airshed is

$$FW_{max} = 0.072928 \times FD \times (DI - 30)$$

where FW_{max} is recommended maximum fuel weight,
FD is fuel-by-distance factor,
DI is dispersion index,
0.072928 is a coefficient, and
30 is the minimum dispersion index for which burning is recommended

Relationship of Dispersion Index to On-the-Ground Burning Conditions[1]

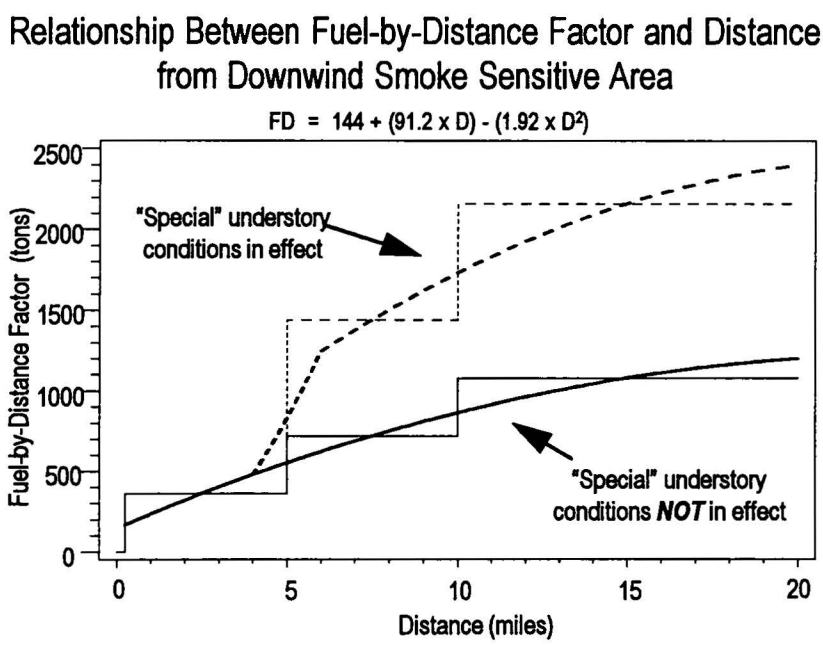
Dispersion Index	Burning Conditions
> 100	Very good — Burning conditions may be so good that fires may be hazardous and present fire control problems. Reassess decision to burn.
61 — 100	Good — Preferred range for prescription burns.
41 — 60	Generally OK — Climatological afternoon values in most inland forested areas in this range.
21 — 40	Fair — Stagnation may be indicated if accompanied by low windspeeds.
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.

[1] This table is taken from USDA Forest Service Technical Publication R8-TP 11 (February 1989) *A Guide for Prescibed Fire in Southern Forests.*

Texas Forest Service System

The Texas Forest Service modified the South Carolina System several ways. The first modification was changing the geometry of the airshed for which recommended maximums were computed. While the South Carolina System determines maximums for 5.64-mile diameter airsheds, the TFS System determines maximums that can be burned in an area unique to each fire. This area is called the projected smoke impact area. It is defined as a 60-degree sector extending 20 miles from the fire and centered in the direction to which the transport wind is blowing. Recommended maximums are then determined accounting for the closest smoke sensitive area within that projected smoke impact area. Observations on actual smoke plumes show that they generally do not expand downwind more than about 30 degrees (15 degrees either side of the center-line). However, due to uncertainty in the forecast of transport wind direction, or shifts that might occur, a more conservative 60 degrees is used.

The second modification expanded on what Lavdas had proposed and eliminated the stair-step characteristic of the fuel-by-distance factor. A quadratic least squares equation was derived for fuel-by-distance factor as a continuous function of distance to downwind smoke sensitive area. This equation and relationship are shown in the following figure.



Therefore, the TFS Smoke Management System uses the following equation for determining recommended maximum fuel weights for dispersion indices of greater than 30 and distances from nearest downwind smoke sensitive area greater than ¼ mile:

$$FW_{max} = 0.072928 \times [144 + (91.2 \times D) - (1.92 \times D^2)] \times (DI - 30)$$

When Dispersion Index is 30 or less, or when distance to nearest downwind smoke sensitive area is less than ¼ mile, then ***no*** burning is recommended ($FW_{max} = 0$).

In addition, the "step" effect was eliminated for doubling fuel weights when special understory burning conditions are in effect. As described earlier, under these special conditions, fuel weights can be doubled if the nearest downwind smoke sensitive area is at least 5 miles away and when ventilation rate is at least 6000 m^2/s, which corresponds roughly to a dispersion index of 38. Instead of jumping from a factor of 1 to a factor of 2 when these distance and dispersion conditions are met, this multiplication factor increases linearly from 1 to 2 as distance increases from 4 to 6 miles and as dispersion index increases from 33 to 43. This results in a curvilinear (increasing rate of change) increase in fuel weights as distance and dispersion index increase from 4 to 6 and 33 to 43, respectively. When distance is 6 or more miles and dispersion index is 43 or greater, a full doubling occurs. The following box shows how the values determined from the basic equation for recommended maximum fuel weights are adjusted for special understory burning conditions.

FW_{max} for Special Understory Burning Conditions

$$FW_{max} = 0.072928 \times [144 + (91.2 \times D) - (1.92 \times D^2)] \times (DI - 30) \times U$$

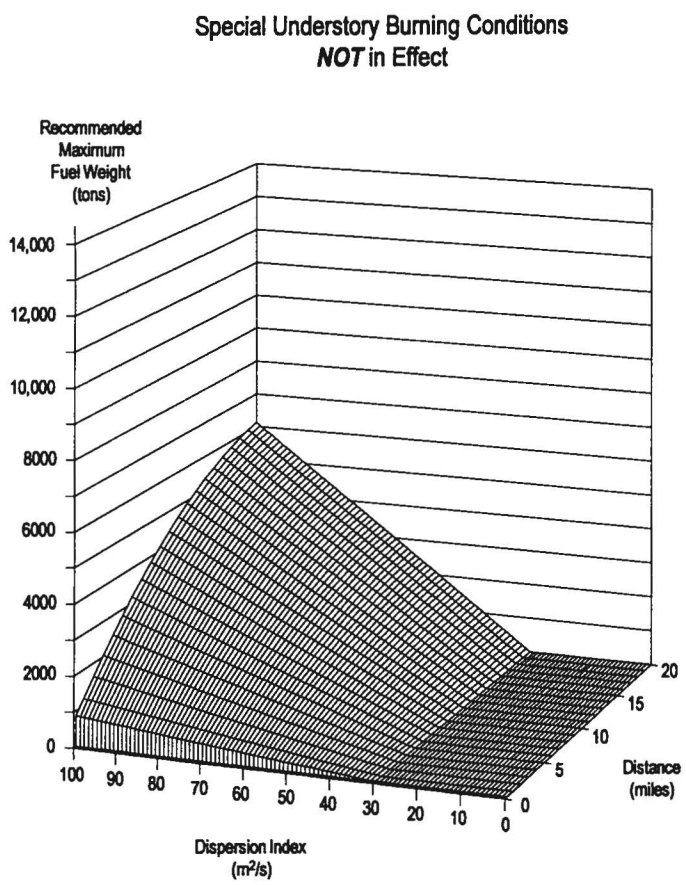
where FW_{max} = Recommended maximum fuel weight
DI = Dispersion index
D = Miles from downwind smoke sensitive area
U = Multiplication factor for special understory story burning conditions (given in following table)

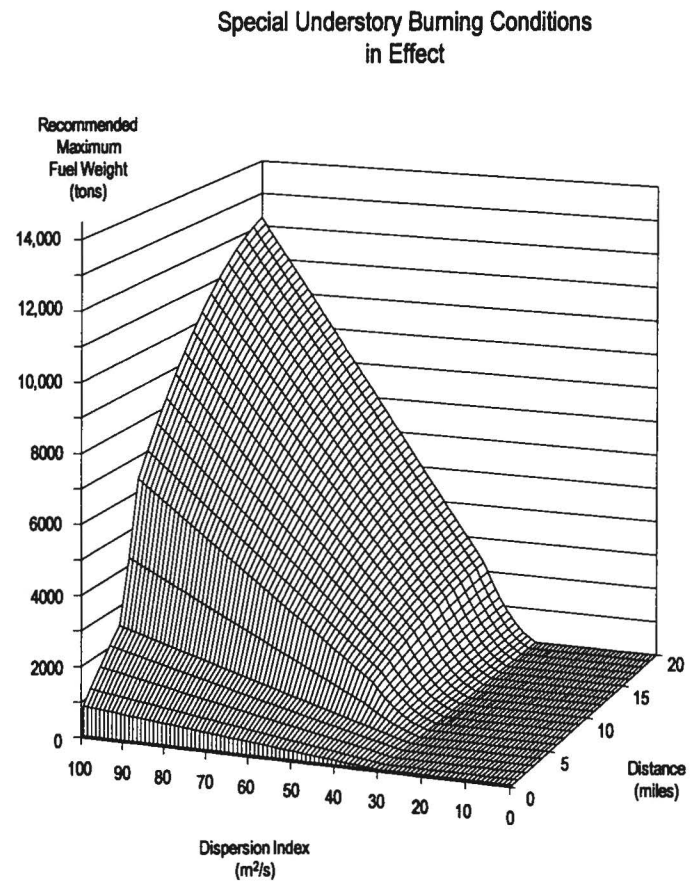
Multiplication Factors (U) for Special Understory Burning Conditions

Dispersion index	Miles from nearest downwind smoke sensitive area			
	< ¼	¼ to 4	4 to 6	> 6
0 to 30	0	0	0	0
30 to 33	0	1	1	1
33 to 43	0	1	1 + [(0.1×DI) - 3.3] × [(0.5×D) - 2]	1 + [(0.1×DI) - 3.3]
> 43	0	1	1 + [(0.5×D) - 2]	2

The following figure graphically shows the relationship that recommended maximum fuel weight has to dispersion index and distance to nearest downwind smoke sensitive area when special understory burning conditions are and are not applicable.

Texas Forest Service System





The TFS System also deals with situations where a smoke sensitive area may lie within overlapping smokesheds of two or more simultaneous fires. When this occurs, burns are prioritized according to the order in which they are reported. When a prescribed burn is reported and the estimated fuel weight that will be burned is less than the recommended maximum fuel weight, a proportion of that maximum is still available for use. For instance, if a burn manager reports he will be burning 600 tons of fuel, and the recommended maximum fuel weight is 1000 tons, (1000-600)/1000 = 0.40, or 40 percent, is available for other fires in the area. However, the adjusted recommended maximum fuel weight for a second fire will not be 40 percent of 1000 tons unless the second fire is the same distance from the smoke sensitive area as the first fire. Instead, the adjusted maximum will be 40 percent of the recommended maximum found for the distance that the smoke sensitive area is from the second fire.

Example calculations for adjusting FW_{max} for multiple fires producing smoke at a common smoke sensitive area.

1 ID number and priority of fire	2 Miles upwind from smoke sensitive area	3 Reported fuel weight estimate (tons)	4 Unadjusted FW_{max}[1] (tons)	5 Adjusted FW_{max}[2] (tons)	6 Unadjusted proportion "unreserved"[3]	7 Adjusted proportion "unreserved"[4]
1	6	500	1361	1361	(1361-500)/1361 = 0.63	0.63
2	4	600	1046	0.63 × 1046 = 659	(659-600)/659 = 0.09	0.63 × 0.09 = 0.06
3	10	113	1890	0.06 × 1890 = 113	(113-113)/113 = 0	0.63 × 0.09 × 0 = 0
4	3	200	876	0 × 876 = 0		

[1] Table look-up value or calculated using fuel loading equation.
[2] Calculated by multiplying column 4 by column 7 of next higher priority fire (except for fire 1 which does not change from unadjusted value).
[3] Calculated by dividing the difference of columns 5 and 3 by column 5.
[4] Calculated by multiplying column 6 by all values of column 6 for any higher priority fires (except for fire 1 which does not change from unadjusted value).

Using start and end times for each fire, the TFS System "moves" smoke through the projected smoke impact areas at the rate given by the transport windspeed. Therefore, in order for one fire to limit another fire, they must have overlapping projected smoke impact areas in terms of both time and space. If two prescribed fires produce smoke at the same smoke sensitive area but at different times of day, then the higher priority fire does not limit the lower priority one.

As an example, say the nearest smoke sensitive area is 10 miles downwind from a particular fire, the reported start and end times for this fire are 11:00 and 13:00, respectively, and that the transport windspeed is 10 mph (4.5 m/s). Using these values, smoke is estimated to be present at the smoke sensitive area from 12:00 to 14:00. Let's say a second fire is reported that is 5 miles upwind of the same smoke sensitive area, and the start and end times are 9:00 and 11:00. The System determines that smoke will be present from this second fire on the smoke sensitive area in question from 9:30 to 11:30. Although this sensitive area will be receiving smoke from both fires, the first will not limit the second fire since their smoke is not simultaneously present.

The end time for a particular fire should be the time estimated when the area will be "burned over". To increase the effectiveness of this accounting, burn managers are encouraged to call in upon completion and provide the "true" end time if it is different from the estimated end time.

The following scenarios illustrate how the System is applied under various circumstances.

Scenario 1

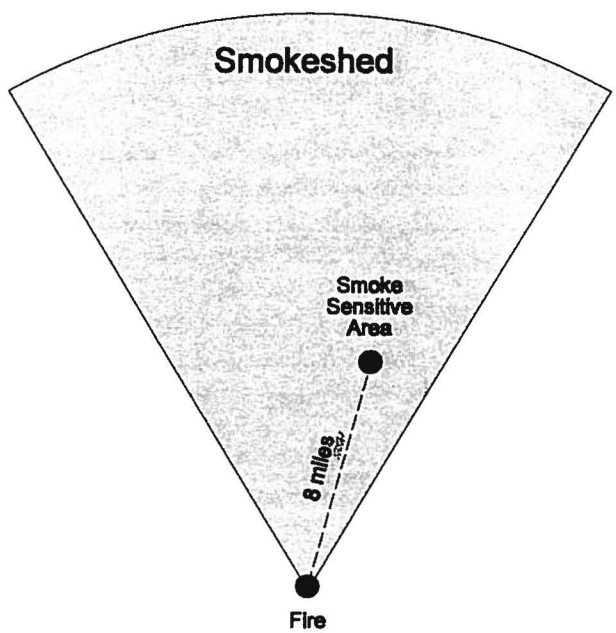
A prescribed burn is planned on a day when the dispersion index is predicted to be 60. The 100-acre burn is estimated to begin at 10:00 and last for two hours. The burn manager estimates that 60 percent of the estimated total fuel loading of 15 tons/acre will be consumed. This gives an estimated available fuel loading of 9 tons/acre and a total available fuel weight for the burn of 900 tons (9 tons/acre × 100 acres). The nearest smoke sensitive area within the projected smoke impact area is 8 miles away. Since the burn is estimated to last two hours and the transport windspeed is 3.0 m/s (6.71 mph), smoke may be present at the smoke sensitive area from 11:12 to 13:12 (start and end times plus 8 miles/6.71 mph × 60 minutes). The recommended maximum fuel weight is calculated as

$$\begin{aligned} FW_{max} &= 0.072928 \times [144 + (91.2 \times D) - (1.92 \times D^2)] \times (DI - 30) \\ &= 0.072928 \times [144 + (91.2 \times 8) - (1.92 \times 8^2)] \times (60 - 30) \\ &= 1642 \text{ tons} \end{aligned}$$

This burn is well within the recommended maximum since it uses only 900 tons of the 1642 recommended maximum tons. The recommendation for this burn is PROCEED AS PLANNED.

Weather Conditions	
Transport wind direction:	S (180°)
Transport wind speed:	3.0 m/s
Mixing height:	3700 m
Opaque cloud cover:	4 tenths
Cloud ceiling height:	8000 ft
Surface wind speed:	7 mph
Dispersion Index:	60

Prescribed Burn Information	
Acres:	100
Total fuel loading:	15 tons/ac
Available fuel loading:	9 tons/ac
Total available fuel weight:	900 tons
Start time:	10:00
End time:	12:00



1 ID number and priority of fire	2 Miles upwind from smoke sensistive area	3 Reported fuel weight estimate (tons)	4 Unadjusted FW_{max}[1] (tons)	5 Adjusted FW_{max}[2] (tons)	6 Unadjusted proportion "unreserved"[3]	7 Adjusted proportion "unreserved"[4]
1	8	900	1642	1642	(1642-900)/1642 = 0.45	0.45

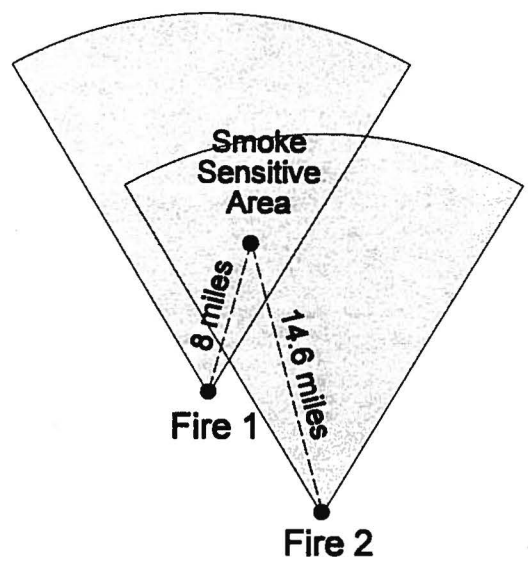
[1] Table look-up value or calculated using fuel loading equation.
[2] Calculated by multiplying column 4 by column 7 of next higher prioity fire (except for fire 1 which does not change from unadjusted value).
[3] Calculated by dividing the difference of columns 5 and 3 by column 5.
[4] Calculated by multiplying column 6 by all values of column 6 for any higher priority fires (except for fire 1 which does not change from unadjusted value).

Scenario 2

A prescribed burn (fire 1) is planned as in Scenario 1. Shortly after receiving a call-in for fire 1, a second planned burn (fire 2) is called in which is 50 acres. It so happens that the nearest downwind smoke sensitive area for fire 2 is the same one for fire 1. The distance to it from fire 2 is 14.6 miles. The burn manager on fire 2 estimates that 10 tons/acre of the total 14 tons/acre of fuel will be consumed giving a total available fuel weight of 500 tons (10 tons/acre × 50 acres). Fire 2 is estimated to begin at 10:30 and be essentially burned-out by 12:00. From the start and end times and transport wind speed, it is determined that smoke from fire 2 will be present at the smoke sensitive area from 12:40 to 14:10 which overlaps with the time smoke from fire 1 will be present. Therefore, the recommended maximum fuel weight for fire 2 must be adjusted downward to account for smoke from fire 1. The unadjusted FW_{max} for fire 2 of 2333 tons is multiplied by 0.45 to give the adjusted maximum recommended fuel weight of 1050 tons. The reported fuel weight estimate for fire 2 of 500 tons is within the recommended maximum. The recommendation would be to PROCEED AS PLANNED.

Weather Conditions	
Transport wind direction:	S (180°)
Transport wind speed:	3.0 m/s
Mixing height:	3700 m
Opaque cloud cover:	4 tenths
Cloud ceiling height:	8000 ft
Surface wind speed:	7 mph
Dispersion Index:	60

Prescribed Burn Information		
Fire ID:	Fire 1	Fire 2
Acres:	100	50
Total fuel loading:	15 tons/ac	14 tons/ac
Available fuel loading:	9 tons/ac	10 tons/ac
Total available fuel weight:	900 tons	500 tons
Start time:	10:00	10:30
End time:	12:00	12:00



1 ID number and priority of fire	2 Miles upwind from smoke sensistive area	3 Reported fuel weight estimate (tons)	4 Unadjusted FW_{max}[1] (tons)	5 Adjusted FW_{max}[2] (tons)	6 Unadjusted proportion "unreserved"[3]	7 Adjusted proportion "unreserved"[4]
1	8	900	1642	1642	(1642-900)/1642 = 0.45	0.45
2	14.6	500	2333	2333 × 0.45 = 1050	(1050-500)/1050 = 0.52	0.45 × 0.52 = 0.23

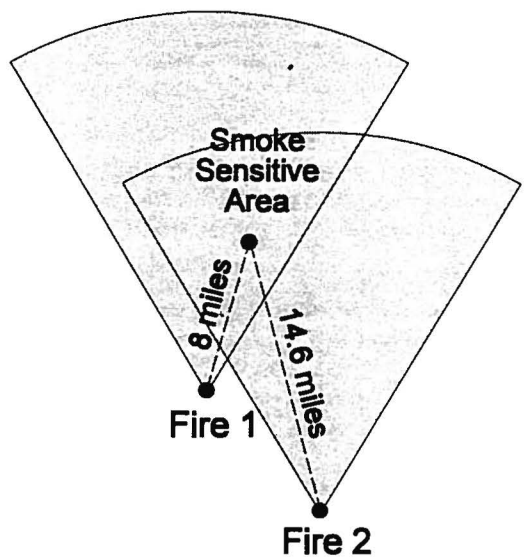
[1] Table look-up value or calculated using fuel loading equation.
[2] Calculated by multiplying column 4 by column 7 of next higher prioity fire (except for fire 1 which does not change from unadjusted value).
[3] Calculated by dividing the difference of columns 5 and 3 by column 5.
[4] Calculated by multiplying column 6 by all values of column 6 for any higher priority fires (except for fire 1 which does not change from unadjusted value).

Scenario 3

Two prescribed burns are planned as in Scenario 2 with the exception that fire 2 is 200 acres instead of 50 acres and will last about 3 hours instead of 1½ hours. Total available fuel weight for fire 2 is 2000 tons (10 tons/acre × 200 acres). The unadjusted FW_{max} for fire 2 is 2333 tons. Smoke from fire 1 will be present at the smoke sensitive area from 11:12 to 13:12 while smoke from fire 2 will present from 12:40 to 15:40. Since the times that smoke from fire 1 and fire 2 will be present at the smoke sensitive area overlap, the adjusted FW_{max} for fire 2 is 1050 tons (0.45 × 2333 tons). The recommended maximum fuel weight is less than the total available fuel weight for fire 2. Therefore, the recommendation for fire 2 would be to either POSTPONE THE BURN or REDUCE THE ACRES. Fire 2 could be postponed until another day or it could be postponed at least 32 minutes on the same day since this would allow smoke from fire 1 to have cleared out by when smoke from fire 2 blows over the smoke sensitive area (see Scenario 4). The second burn would also be within recommended maximums if the area burned was reduced to 105 acres (1050 tons/2000 tons × 200 acres).

Weather Conditions	
Transport wind direction:	S (180°)
Transport wind speed:	3.0 m/s
Mixing height:	3700 m
Opaque cloud cover:	4 tenths
Cloud ceiling height:	8000 ft
Surface wind speed:	7 mph
Dispersion Index:	60

Prescribed Burn Information		
Fire ID:	Fire 1	Fire 2
Acres:	100	200
Total fuel loading:	15 tons/ac	14 tons/ac
Available fuel loading:	9 tons/ac	10 tons/ac
Total available fuel weight:	900 tons	2000 tons
Start time:	10:00	10:30
End time:	12:00	13:30



1 ID number and priority of fire	2 Miles upwind from smoke sensistive area	3 Reported fuel weight estimate (tons)	4 Unadjusted FW_{max}[1] (tons)	5 Adjusted FW_{max}[2] (tons)	6 Unadjusted proportion "unreserved"[3]	7 Adjusted proportion "unreserved"[4]
1	8	900	1642	1642	(1642-900)/1642 = 0.45	0.45
2	14.6	2000	2333	2333 × 0.45 = 1050		

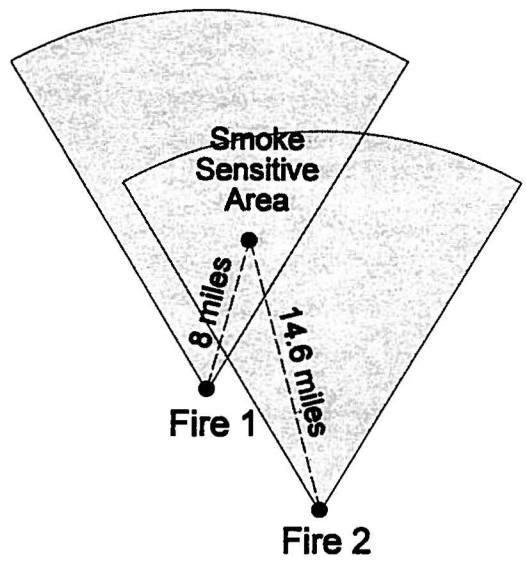
[1] Table look-up value or calculated using fuel loading equation.
[2] Calculated by multiplying column 4 by column 7 of next higher prioity fire (except for fire 1 which does not change from unadjusted value).
[3] Calculated by dividing the difference of columns 5 and 3 by column 5.
[4] Calculated by multiplying column 6 by all values of column 6 for any higher priority fires (except for fire 1 which does not change from unadjusted value).

Scenario 4

Two prescribed burns are planned as described in Scenario 3 with the exception that fire 2 will begin at 11:30 instead of 10:30. Smoke from fire 1 will be present at the smoke sensitive area from 11:12 to 13:12. Smoke from fire 2 will be present at the smoke sensitive area from 13:40 to 16:40. Since smoke from both prescribed fires will *not* be present at the smoke sensitive area at the same time, no adjustment need be made to the recommended maximum for fire 2. The reported total available fuel weight for fire 2 of 2000 tons is within the recommended maximum of 2333 tons. Therefore, the recommendation for fire 2 would be PROCEED AS PLANNED.

Weather Conditions	
Transport wind direction:	S (180°)
Transport wind speed:	3.0 m/s
Mixing height:	3700 m
Opaque cloud cover:	4 tenths
Cloud ceiling height:	8000 ft
Surface wind speed:	7 mph
Dispersion Index:	60

Prescribed Burn Information		
Fire ID:	Fire 1	Fire 2
Acres:	100	200
Total fuel loading:	15 tons/ac	14 tons/ac
Available fuel loading:	9 tons/ac	10 tons/ac
Total available fuel weight:	900 tons	2000 tons
Start time:	10:00	11:30
End time:	12:00	14:30



1 ID number and priority of fire	2 Miles upwind from smoke sensistive area	3 Reported fuel weight estimate (tons)	4 Unadjusted FW_{max}[1] (tons)	5 Adjusted FW_{max}[2] (tons)	6 Unadjusted proportion "unreserved"[3]	7 Adjusted proportion "unreserved"[4]
1	8	900	1642	1642	(1642-900)/1642 = 0.45	0.45
2	14.6	2000	2333	2333	(2333-2000)/2333 = 0.14	0.14

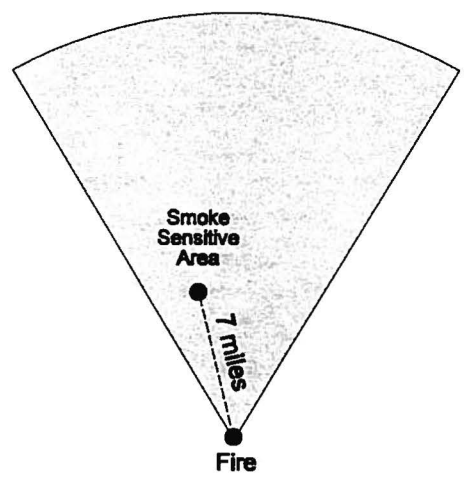
[1] Table look-up value or calculated using fuel loading equation.
[2] Calculated by multiplying column 4 by column 7 of next higher prioity fire (except for fire 1 which does not change from unadjusted value).
[3] Calculated by dividing the difference of columns 5 and 3 by column 5.
[4] Calculated by multiplying column 6 by all values of column 6 for any higher priority fires (except for fire 1 which does not change from unadjusted value).

Scenario 5

An understory prescribed burn that meets the "special" understory burning requirements is planned on a day when weather conditions are given as in the previous scenarios. The planned burn is 1000 acres in size. The burn manager estimates that 4 of the 7 tons/acre of fuel will burn. The total available fuel weight for the burn is thus 4000 tons (4 tons/acre × 1000 acres). Under these conditions, FW_{max} is equal to 3012 tons. Because the reported total available fuel weight is greater than the recommended maximum, the recommendation for this burn is to either POSTPONE THE BURN or REDUCE THE ACREAGE.

Weather Conditions	
Transport wind direction:	S (180°)
Transport wind speed:	3.0 m/s
Mixing height:	3700 m
Opaque cloud cover:	4 tenths
Cloud ceiling height:	8000 ft
Surface wind speed:	7 mph
Dispersion Index:	60

Prescribed Burn Information	
Acres:	1000
Total fuel loading:	7 tons/ac
Available fuel loading:	4 tons/ac
Total available fuel weight:	4000 tons
Start time:	09:00
End time:	14:00



1 ID number and priority of fire	2 Miles upwind from smoke sensistive area	3 Reported fuel weight estimate (tons)	4 Unadjusted FW_{max}[1] (tons)	5 Adjusted FW_{max}[2] (tons)	6 Unadjusted proportion "unreserved"[3]	7 Adjusted proportion "unreserved"[4]
1	7	4000	3012	3012		

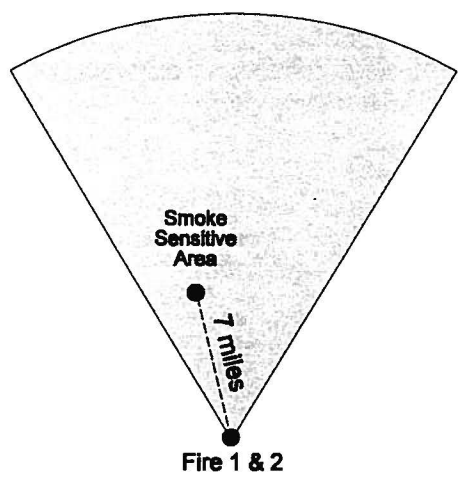
[1] Table look-up value or calculated using fuel loading equation.
[2] Calculated by multiplying column 4 by column 7 of next higher prioity fire (except for fire 1 which does not change from unadjusted value).
[3] Calculated by dividing the difference of columns 5 and 3 by column 5.
[4] Calculated by multiplying column 6 by all values of column 6 for any higher priority fires (except for fire 1 which does not change from unadjusted value).

Scenario 6

A large 1000-acre understory prescribed burn is planned as described in Scenario 5. After it is determined that the recommended maximum fuel weight has been exceeded, the burn manager decides to break the fire up into two smaller fires. In reality, only a portion of the 1000 acres will be burning at any one time. Therefore, the manager decides that the burn can easily be split into two burns—one 600-acre block and one 400-acre block—along logical delineations in the field. It is estimated that if ignition begins on the 600-acre block at 09:00, the block will be essentially burned out by 13:00. The 400-acre block will then be ignited beginning at 13:00 and should be essentially complete at 15:00. The two sub-blocks of the same planned major burn can be treated as two separate burns in the smoke management system. The 2400 tons of total available fuel on fire 1 is within the recommended maximum fuel weight of 3012 tons. Since smoke from the second burn (block 2) would not impact the smoke sensitive area at the same time as smoke from the initial burn (block 1), the FW_{max} for fire would not need to be adjusted. The 1600 tons of total available fuel for the second burn would be within the recommended maximum. Therefore, recommendations for both burns would be PROCEED AS PLANNED.

Weather Conditions	
Transport wind direction:	S (180°)
Transport wind speed:	3.0 m/s
Mixing height:	3700 m
Opaque cloud cover:	4 tenths
Cloud ceiling height:	8000 ft
Surface wind speed:	7 mph
Dispersion Index:	60

Prescribed Burn Information		
Fire ID:	Fire 1	Fire 2
Acres:	600	400
Total fuel loading:	7 tons/ac	7 tons/ac
Available fuel loading:	4 tons/ac	4 tons/ac
Total available fuel weight:	2400 tons	1600 tons
Start time:	09:00	13:00
End time:	13:00	15:00



1 ID number and priority of fire	2 Miles upwind from smoke sensistive area	3 Reported fuel weight estimate (tons)	4 Unadjusted FW_{max}[1] (tons)	5 Adjusted FW_{max}[2] (tons)	6 Unadjusted proportion "unreserved"[3]	7 Adjusted proportion "unreserved"[4]
1	7	2400	3012	3012	(3012-2400)/3012 = 0.20	0.20
2	7	1600	3012	3012	(3012-1600)/3012 = 0.47	0.47

[1] Table look-up value or calculated using fuel loading equation.
[2] Calculated by multiplying column 4 by column 7 of next higher prioity fire (except for fire 1 which does not change from unadjusted value).
[3] Calculated by dividing the difference of columns 5 and 3 by column 5.
[4] Calculated by multiplying column 6 by all values of column 6 for any higher priority fires (except for fire 1 which does not change from unadjusted value).

Scenario 7

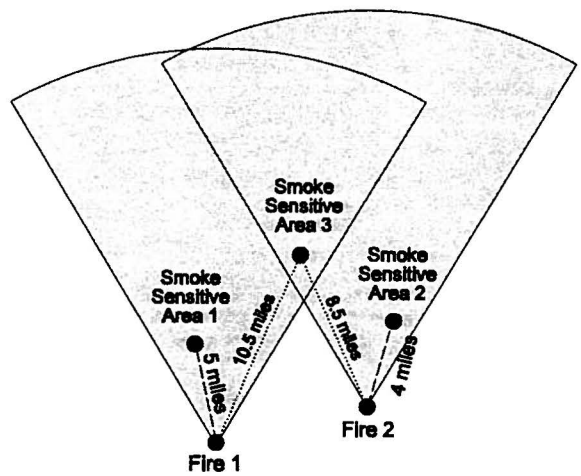
A prescribed burn is planned on a day when weather conditions are as given for the previous scenarios. The nearest downwind smoke sensitive area is 5 miles away. Total available fuel weight, estimated to be 1170 tons, is within the recommended maximum of 1208 tons. Therefore, the recommendation for this fire (fire 1) is PROCEED AS PLANNED.

Another prescribed burn is planned for the same time within a few miles of the first one. The reported total available fuel weight for the second prescribed burn is 900 tons. The closest smoke sensitive area within the projected smoke impact area is 4 miles away. FW_{max} for fire 2 is 1046 tons. Total available fuel weight is within the recommended maximum based on the closest smoke sensitive area.

However, when there are overlapping projected smoke impact areas, impact on the closest smoke sensitive area within the overlapping portion of the projected smoke impact areas must also be taken into account. To do this, FW_{max} for fire 2 in relation to the smoke sensitive area in common must be adjusted by multiplying by the adjusted proportion "unreserved" for fire 1 in relation to the same smoke sensitive area. This results in a recommended maximum fuel weight for fire 2 of 683 tons which is less than the reported total available fuel weight. Although the smoke sensitive area within the overlapping smokesheds is not the closest one to fire 2, it is the most limiting. The recommendation for fire 2 is either POSTPONE THE BURN or REDUCE THE ACREAGE.

Weather Conditions	
Transport wind direction:	S (180°)
Transport wind speed:	3.0 m/s
Mixing height:	3700 m
Opaque cloud cover:	4 tenths
Cloud ceiling height:	8000 ft
Surface wind speed:	7 mph
Dispersion Index:	60

Prescribed Burn Information		
Fire ID:	Fire 1	Fire 2
Acres:	130	90
Total fuel loading:	15 tons/ac	14 tons/ac
Available fuel loading:	9 tons/ac	10 tons/ac
Total available fuel weight:	1170 tons	900 tons
Start time:	10:00	10:00
End time:	13:00	12:00



1 ID number and priority of fire	2 Miles upwind from smoke sensistive area	3 Reported fuel weight estimate (tons)	4 Unadjusted FW_{max}[1] (tons)	5 Adjusted FW_{max}[2] (tons)	6 Unadjusted proportion "unreserved"[3]	7 Adjusted proportion "unreserved"[4]
Smoke Sensitive Area 1						
1	5	1170	1208	1208	(1208-1170)/1208 = 0.03	0.03
Smoke Sensitive Area 2						
2	4	900	1046	1046	(1046-900)/1046 = 0.14	0.14
Smoke Sensitive Area 3						
1	10.5	1170	1947	1947	(1947-1170)/1947 = 0.40	0.40
2	8.5	900	1708	1708 × 0.40 = 683		

[1] Table look-up value or calculated using fuel loading equation.
[2] Calculated by multiplying column 4 by column 7 of next higher prioity fire (except for fire 1 which does not change from unadjusted value).
[3] Calculated by dividing the difference of columns 5 and 3 by column 5.
[4] Calculated by multiplying column 6 by all values of column 6 for any higher priority fires (except for fire 1 which does not change from unadjusted value).

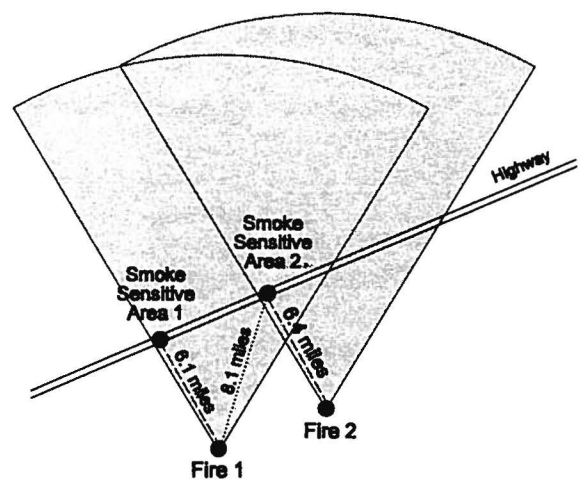
Scenario 8

The preceeding scenarios deal with smoke sensitive areas as points. This scenario deals with smoke sensitive areas that may be long strips such as would occur with a highway. In this scenario, a major highway crosses through the overlapping smoke impact acres, or smokesheds, of two planned prescribed burns. The first burn reported is 6.1 miles from the closest point where the highway passes through its smoke impact area and has an estimated total available fuel weight of 720 tons. This is within the recommended maximum of 1375 tons.

The second burn is 6.4 miles from the highway, which is the closest smoke sensitive area for this fire. Since this smoke sensitive area is within overlapping smoke impact areas, FW_{max} for fire 2 must be adjusted for fire 1. The unadjusted FW_{max} for fire 2 is 1420 tons. Since fire 1 is also producing smoke on this smoke sensitive area, FW_{max} is determined by multiplying the unadjusted value by the adjusted proportion "unreserved" for fire 1. This results in an adjusted FW_{max} of 809 tons (1420 × 0.57). The reported total available fuel weight is still within the recommended maximum. Therefore, the recommendation for both prescribed burns is PROCEED AS PLANNED.

Weather Conditions	
Transport wind direction:	S (180°)
Transport wind speed:	3.0 m/s
Mixing height:	3700 m
Opaque cloud cover:	4 tenths
Cloud ceiling height:	8000 ft
Surface wind speed:	7 mph
Dispersion Index:	60

Prescribed Burn Information		
Fire ID:	Fire 1	Fire 2
Acres:	60	90
Total fuel loading:	20 tons/ac	3 tons/ac
Available fuel loading:	12 tons/ac	2 tons/ac
Total available fuel weight:	720 tons	180 tons
Start time:	10:00	10:00
End time:	12:00	11:00



1 ID number and priority of fire	2 Miles upwind from smoke sensistive area	3 Reported fuel weight estimate (tons)	4 Unadjusted FW_{max}[1] (tons)	5 Adjusted FW_{max}[2] (tons)	6 Unadjusted proportion "unreserved"[3]	7 Adjusted proportion "unreserved"[4]
Smoke Sensitive Area 1						
1	6.1	720	1375	1375	(1375-720)/1375 = 0.48	0.48
Smoke Sensitive Area 2						
1	8.1	720	1656	1656	(1656-720)/1656 = 0.57	0.57
2	6.4	180	1420	1420 × 0.57 = 809	(809-180)/809 = 0.78	0.57 × 0.78 = 0.44

[1] Table look-up value or calculated using fuel loading equation.
[2] Calculated by multiplying column 4 by column 7 of next higher prioity fire (except for fire 1 which does not change from unadjusted value).
[3] Calculated by dividing the difference of columns 5 and 3 by column 5.
[4] Calculated by multiplying column 6 by all values of column 6 for any higher priority fires (except for fire 1 which does not change from unadjusted value).

Smoke Sensitive Areas

Areas that may be sensitive to smoke from prescribed burning are termed smoke sensitive areas. These areas may be considered sensitive for either health or traffic hazard reasons. Smoke sensitive areas are essentially areas where people are concentrated or roads that receive a significant amount of traffic.

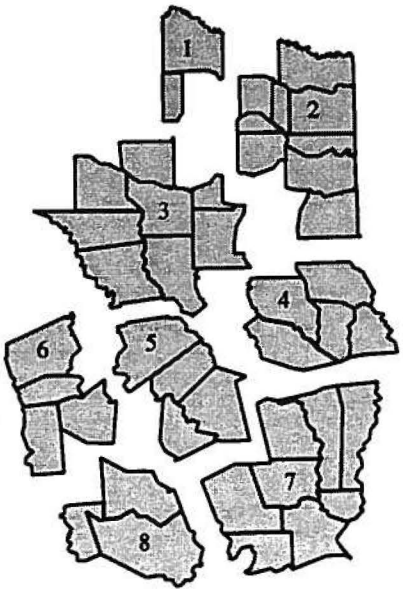
Recommended maximum fuel weights are dependent upon how close the nearest smoke sensitive area is to a burn. Therefore, the nearest smoke sensitive area within the projected smoke impact area should be identified and located on a map for each burn. In addition, the closest smoke sensitive area within overlapping portions of projected smoke impact areas needs to be identified.

Smoke sensitive areas include

- Airports, highways, communities, recreational areas, schools, hospitals, nursing homes, and other known health-related sites

- Farm-to-market road segments with average daily traffic counts of 500 or more. However, the burn manager should treat segments with less than 500 per day with caution and place warning signs and flagmen if these roads are covered in smoke. Burns involving these excluded road segments should be completed by 4:00 p.m. to better ensure against smoke visibility problems during high traffic flow.

The Texas Department of Transportation (TexDOT) produces Traffic Maps by TexDOT district that show average daily traffic counts for each public road. These 18- by 25-inch maps are updated annually and can be obtained from local TexDOT district offices or from the state office in Austin. Appendix E contains reduced versions of these maps.



TexDOT Districts

1 Paris
2 Atlanta
3 Tyler
4 Lufkin E
5 Lufkin W
6 Bryan
7 Beaumont
8 Houston

Estimating Fuel Weights

Estimating total available fuel weights is the responsibility of the burn manager. To do this, an estimate must first be made of the fuel loading on the particular site. Fuel loading is defined as tons per acre of total fuel. Prescribed burns, however, do not totally consume all the fuel present. The amount that is actually consumed is available fuel. Available fuel loading is therefore not only dependent upon the amount of fuel present, or fuel loading, but also is dependent on weather and fuel conditions. Once available fuel loading is estimated, an estimate of total available fuel weight can be determined by multiplying loading by acres.

The process of estimating total available fuel weights in the Smoke Management System will be a major source of error and inaccuracy due to (1) the inherent difficulty in accurately estimating the amount of fuel present on a particular site, (2) the difficulty in estimating the proportion of fuel present that will actually be consumed, and (3) the lack of adequate relevant data for East Texas fuels.

Three sources of data are presented here for the burn manager to use in estimating fuel loading.

The South Carolina System provides typical total fuel loadings for eleven fuel types. Fuel loadings are given for three loading ranges—low, medium, and high. The table on page 24 presents these loadings.

The best source of data for total fuel loadings in East Texas is a 1988 publication by Hershel C. Reeves entitled *Photo Guide for Appraising Surface Fuels in East Texas*. This guide is published by the Center for Applied Studies—School of Forestry, Stephen F. Austin State University. Color photographs show different levels of fuels ranging from open grassy conditions to dense pine plantations. All four of the major pine species (loblolly, shortleaf, longleaf, and slash) are included. An inventory of both dead and living fuel on the floor or within the understory accompanies each photograph. A subjective evaluation of potential fire behavior under an average bad fire weather day is given for each site shown. The table on pages 25-27 summarizes some of the information given in the guide.

Another valuable source is *Photos for Estimating Residue Loadings Before and After Burning in Southern Appalachian Mixed-Pine Hardwood Clearcuts* by Bradford M. Sanders and David H. Van Lear. This publication was published in 1988 as USDA Forest Service, Southeastern Forest Experiment Station, General Technical Report SE-49. Although the Southern Appalachian Mountains are different from East Texas, this photo guide provides useful information for determining available fuel loadings. Photos are provided before and after site preparation burns along with accompanying fuel weights by component. The table on page 28 summarizes data from the eight stands included in the guide. On average, 55 percent of the logging slash was consumed while 68 percent of the live fuels, litter, and duff was consumed. Overall, the average for available fuel when slash and live fuel, litter, and duff are added together is 59 percent. This publication also provides data on when and how the sites were burned along with weather conditions during the burns.

If estimated fuel weights are not provided by the burn manager, the Smoke Management System uses default values according to the type of burn as given in the following table.

Default Values for Available Fuel Loading

Type of burn	Available fuel loading
	tons / acre
Openland	2
Understory	4
Site Prep—slash in place	9
Windrows	12

South Carolina System's Typical Total Fuel Loadings

Fuel Type	Loading range Low	Medium	High
	----- total tons/acre -----		
Grass / Herbaceous—This fuel type includes coastal bermuda and other grasses grown for grazing or hay production	2	3	4
Grass / Brush—First fuel type to appear on site prepared, burned, or cut-over areas. Grass is the major fuel component. Tree/brush species present include pine, gum, maple, oak, wax myrtle, and sumac.	2	4	8
Hardwood litter—Overstory usually composed of oak-hickory with a mixture of other hardwoods. Amount of litter will vary with age of the stand, degree of crown closure, species, and age of rough.	3	5	7
Pine / Hardwood litter—Overstory composed of both pines and hardwoods. Amount of litter will vary with the age of the stand, degree of crown closure, species, and age of rough.	3	6	8
Pine litter—Overstory composed of loblolly, shortleaf, slash, or longleaf pine. Amount of litter will vary with the age of the stand, degree of crown closure, species, and age of rough.	3	8	14
Palmetto / Yaupon—This fuel type occurs mostly near the coast. Overstory is usually pine. Yaupon and palmetto form a brush type understory. Pine litter is a significant component in this fuel type.	5	10	15
Slash in place—This fuel type normally flows a clear-cut or heavy thinning when the debris is not piled. Limbing gate piles should be excluded because of residual smoke production.	8	12	16
Bay—A typical bay is characterized by heavy brush on a site with considerable organic soil. Primary species are various bays, maple, gum, waxmrytle, and loblolly pine. Some species present have waxy leaves with a high content.	10	15	20
Windrows / Piles—This fuel type normally follows a clear-cut operation when the debris is windrowed or piled. Due to fuel arrangement and larger fuel size, inefficient burning produces greater amounts of smoke and particulate matter for much longer time periods.	10	15	20

Fuel Loadings by Component for Surface Fuels in East Texas

Taken from *Photo Guide for Appraising Surface Fuels in East Texas* by Hershel C. Reeves

Cover type	Age	Understory	Remarks	Down & dead woody fuel loadings by size class				Other fuel data		
				0-¼"	¼-1"	1-3"	3"+	Litter and herbaceous	Hardwoods ≤ 2"	Duff weight
	yrs			tons / acre						
Grass										
Bluestems								2.05		
Lovegrass			planted lovegrass pasture					2.59		
Clearcut										
scrub oak		white oaks, sumac, sassafras, Vaccinium	shortleaf pine clearcut 6 yrs ago; no attempt at regeneration	4.49	1.47	0.17	2.03	1.44	3.38	6.81
loblolly p.		white oaks, beautyberry	2-yr-old cut-over pine beetle killed stand; much natural regen.	5.97	4.15	0.53	31.5	1.91	2.75	1.36
shortleaf p.		sweetgum, sumac	2-yr-old shortleaf pine clearcut	5.44	2.88	0.98	5.40	2.97	0.46	6.81
Seed Tree										
loblolly p.		yaupon, beautyberry, sweetgum	seed tree cut	6.15	2.38	0.91	8.30	0.80	0.32	
Loblolly Pine										
loblolly p.	2	Baccharis, red oaks	windrowed and machine planted plantation		0.28	0.32	1.11	1.56	0.03	1.00
	4	red oaks, white oaks, sweetgum	machine planted pine plantation	0.30	0.35	0.11	4.31	1.78	4.98	
	7	sumac, sweetgum, Vaccinium, beautyberry	clearcut, injected, burned and planted in loblolly pine	3.17	4.29	1.05	9.26	2.19	2.32	0.60
	8	sassafras, sweetgum, sumac	planted loblolly on upland site	0.18	0.56	0.14	1.93	3.22	4.34	3.27
	14	sumac, red oaks, beautyberry	Plantation—sheared and windrowed before machine planted	0.24	0.35	0.03		2.64	1.01	5.29
	15	beautyberry, yaupon, waxmyrtle		4.06	2.04	0.03		1.81	0.03	
	24	beautyberry, dogwood, yaupon, sassafras	thinning slash common	3.88	3.44	0.35	1.77	2.08	1.14	11.54
	27	beautyberry, yaupon, maple	unmanaged research pine plantation	1.20	0.84	0.25		2.14	0.09	15.83
	28	Baccharis, hickory, waxmyrtle	machine planted plantation	1.79	1.76	0.28	0.17	2.30	0.27	11.85

continued on next page

Fuel Loadings by Component for Surface Fuels in East Texas — *Continued*

Taken from *Photo Guide for Appraising Surface Fuels in East Texas* by Hershel C. Reeves

Cover type	Age	Understory	Remarks	Down & dead woody fuel loadings by size class				Other fuel data		
				0-¼"	¼-1"	1-3"	3"+	Litter and herbaceous	Hardwoods ≤ 2"	Duff weight
	yrs			tons / acre						
	40	yaupon, waxmyrtle, red oaks white oaks	wilderness area; scattered longleaf pine	1.61	1.26	0.14	4.51	2.68	2.31	11.69
	43	white oak, beautyberry, red oak, hickory	managed natural stand; prescribed burned 7 yrs ago	3.00	0.90	0.16	1.14	2.72	1.54	12.55
	45	maple, waxmyrtle, red oaks	thinning slash present	1.85	2.53	0.46	3.80	2.52	0.06	6.10
	50	white oaks, sweetgum, palmetto	palmetto flat, mixed pine and hardwood	4.71	2.18	0.21	0.90	3.61	0.12	0.36
Shortleaf Pine										
shortleaf p.	15	waxmyrtle, sumac, red oaks, sweetgum	old field natural regeneration; selective cutover	3.23	2.04	0.25	0.36	1.25	0.04	0.35
	22	sassafras	dense natural stand on rolling to steep slope	3.88	2.60	0.77	1.66	1.39		20.77
	35	beautyberry, sweetgum, Vaccinium		2.60	1.11	0.16	0.3	1.91	1.44	7.10
Loblolly/Shortleaf Pine										
loblolly-shortleaf p.	36	dogwood, yaupon, red oaks, beautyberry	includes a few scattered longleaf pine	1.02	1.26	0.17	0.19	1.64	1.19	9.23
	43	red oaks, sweetgum	most older hardwoods removed in TSI	1.11	6.02	0.07	2.73	2.21	1.28	6.02
Slash Pine										
slash p.	11	sweetgum, waxmyrtle, Baccharis	Intensively prepared site and machine planted		0.21	0.03	0.12	1.21	2.04	1.00
	26	sweetgum, waxmyrtle, white oaks	thinned 2 year ago	13.14	2.88	0.74	0.61	2.63	0.86	11.79
	30	yaupon, sassafras, white oaks	deep sandy soil	1.67	0.84	0.17	3.53	3.25	0.06	3.37
Longleaf Pine										
longleaf p.	16	red oaks	rolling sandy hills, intensively managed	0.30	0.56	0.03		3.68	0.06	7.00
	40	waxmyrtle, sassafras	sandy, rolling hills	0.18	1.54	0.21	0.73	3.53	0.07	9.88
	40	sassafras	managed natural stand on deep sandy hills	0.12	0.56	0.04		4.55		2.72

continued on next page

Fuel Loadings by Component for Surface Fuels in East Texas — *Continued*

Taken from *Photo Guide for Appraising Surface Fuels in East Texas* by Hershel C. Reeves

Cover type	Age	Understory	Remarks	Down & dead woody fuel loadings by size class				Other fuel data		
				0-¼"	¼-1"	1-3"	3"+	Litter and herbaceous	Hardwoods ≤ 2"	Duff weight
	yrs			tons / acre						
Hardwood										
scrub oak	25	white oaks, yaupon, sweetgum, Vaccinium	dense stand of younger hardwood interspersed with older trees	7.16	2.11	0.14	0.44	1.87	6.17	2.99
oak-hickory	35	hickory, white oaks, dogwood		5.06	1.61	0.03	0.38	1.65	0.64	1.54
	45	sweetgum	terrace slope	2.39	1.12	0.07	7.29	1.85	2.02	6.55

Fuel Loadings Before and After Site Preparation Burns in Southern Appalachian Clearcuts

Taken from *Photos for Estimating Residue Loadings Before and After Burning in Southern Appalachian Mixed Pine-Hardwood Clearcuts* by B.M. Sanders and D.H. Van Lear

Stand information	Slash			Live fuels[†], litter, and duff			Total		
	Before	After	Available[‡]	Before	After	Available[‡]	Before	After	Available[‡]
	- - - - tons / acre - - - -		percent	- - - - tons / acre - - - -		percent	- - - - tons / acre - - - -		percent
125-yr-old shortleaf pine with numerous hardwoods	16.0	7.9	51	16.3	3.2	80	32.3	11.1	66
125-yr-old shortleaf pine with numerous hardwoods	17.5	4.6	74	22.1	11.6	48	39.6	16.2	59
90-yr-old shortleaf pine with numerous hardwoods	22.4	8.2	63	14.3	7.8	45	36.7	16.0	56
90-yr-old shortleaf pine with numerous hardwoods	27.8	11.5	59	18.0	6.3	65	45.8	17.8	61
89-yr-old hardwoods with shortleaf, Virginia, and white pine	31.2	16.8	46	28.2	6.2	78	59.4	23.0	61
90-yr-old shortleaf pine with numerous hardwoods	33.0	19.1	42	27.2	7.6	72	60.2	26.7	56
125-yr-old shortleaf pine with numerous hardwoods	42.7	15.0	65	16.3	2.7	83	59.0	17.1	71
89-yr-old hardwoods with shortleaf, Virginia, and white pine	51.5	32.6	37	15.9	4.2	74	67.4	36.8	45
Average	26.4	14.5	55	19.8	6.2	68	50.0	20.6	59

[†] Includes sprouts, grasses, vines, and weeds.
[‡] Percent of fuel loading consumed by site preparation burn.

TFS Smoke Management Computer Program

The Texas Forest Service Smoke Management System is available as a computer program. This menu-driven interactive computer program is used by each TFS Area Office to coordinate smoke management in their respective areas. A step-by-step description of how to enter the necessary data into the program is given in a separate booklet entitled *Texas Forest Service Smoke Management Computer Program*. This section serves only as a summary on the basics of the program.

The program's primary input data include (1) forecasted weather information, (2) information on each planned burn including location, amount of fuel to be consumed, and start and end times, and (3) locations of pertinent smoke sensitive areas.

It is the responsibility of the burn manager reporting the planned prescribed burn to provide the necessary information on total available fuel weight, location of the burn, and location of the nearest smoke sensitive area within the projected smoke impact area. However, the TFS dispatcher will make every effort to ensure that all pertinent smoke sensitive areas are accounted for. This is especially important where overlapping smokesheds exist. If fuel weight is not provided by the burn manager, a default value will be used depending on the type of burn being done.

Minimum hardware requirements to run the program include a microcomputer (PC) equipped with an 8088 microprocessor (e.g. IBM XT compatible), a 10-megabyte hard disk, and 512K of free memory (RAM). The actual program files require approximately 1 megabyte of hard disk space.

The following page shows examples of the major screens for entering data or receiving recommendations including (1) the Main Menu Screen, (2) the Dispersion Information Screen (or pop-up box, (3) the Fire Information Screen, (4) the Smoke Sensitive Area Information Screen, (5) a Recommendation Screen (or pop-up box) for PROCEED AS PLANNED, and (6) a Recommendation Screen (or pop-up box) for REDUCE ACREAGE OR POSTPONE FIRE.

Example Screens for Smoke Management Computer Program

MAIN MENU

```
TFS SMOKE MANAGEMENT SYSTEM
Version 2.1 -- Feb95

DATA ENTRY
  A. Dispersion Conditions
  B. Fire Data
  C. Sensitive Areas

REPORTS
  D. Run Calculations
  E. Reports Menu

MAINTENANCE
  F. Configure Printers
  G. Backup Data Files
  H. Restore Data Files
  I. Re-Index Data Files
  J. Purge Year-to-Date Files

INFORMATION
  02/22/95  11:01 am  163K Free

  Record Count is   TODAY  YEAR
  Fires          =      2     7
  Sensitive Areas =     1     9

Enter Selection A-H, or X to quit X
```

DISPERSION INFORMATION

```
TFS SMOKE MANAGEMENT SYSTEM
DISPERSION INFORMATION SCREEN

Enter today's dispersion conditions. If Dispersion
Index, Ventilation Rate, or Stability Class are not
available or you want to calculate them, enter '0'.

Dispersion Index ..........................>     60

Ventilation Rate ..........................> 11100
    Transport Windspeed (m/s) .............>   3.0
    Tran. Wind Direct. (0-360 or N NE E etc).> S 180
    Mixing Height (m) .....................>  3700

Use Stability Class? (y or n) .............>     Y
  Stability Class .........................>     2
    Opaque Cloud Cover (tenths) ...........>     4
    Cloud Ceiling Height (ft) .............>  8000
    Surface Windspeed (mph) ...............>     7
    Solar Elevation Angle (degrees) .......>    42

<<< Dispersion Index will be used in calculations. >>>
PRESS ANY KEY TO CONTINUE
```

FIRE INFORMATION

```
FIRE INFORMATION SCREEN

FIRE ID #:  1  Contact: Darb Rebrab      Phone: (409)555-1234

Affiliation: Trees R Us                  Cooperator?: Y (Y/N)

Block & Grid: S-233-A- 1        County Code: 457 (Tyler)

Acres:  100                     Fire Width: 0.25 miles

Type of Burn (? for List): S  Start Time: 10:00  End Time: 12:00

Understory Restriction in effect?: N (Y/N)

                 Total Fuel Weight----Tons
                 Initially Reported:   900 (Default Value)
                   Max. Recommended:  1740
                              Final:   900

SAVE  ABORT  EDIT  -SKIP  +SKIP  CALCULATE  DELETE  MOD SSA
Save this Fire record
```

SMOKE SENSITIVE AREA

```
Smoke Sensitive Area Information

Area ID #:  1  Block & Grid:  S-134-A- 1

Description: USH 287

SAVE  ABORT  EDIT  -SKIP  +SKIP  DELETE
Save this Fire record
```

RECOMMENDATION—PROCEED

```
FIRE INFORMATION SCREEN

FIRE ID #:  1  Contact: Darb Rebrab      Phone: (409)555-1234

Affiliation: Trees R Us                  Cooperator?: Y (Y/N)

RECOMMENDATION
  The maximum recommended fuel weight is:  2,144 Tons.

  *** PROCEED AS PLANNED ***

  However, burn manager on site should account for current
  local conditions before making final decision to burn.

  Press Any Key to continue...

                 Max. Recommended:  2144
                            Final:   900
```

RECOMMENDATION—POSTPONE

```
FIRE INFORMATION SCREEN

FIRE ID #:  1  Contact: Darb Rebrab      Phone: (409)555-1234

Affiliation: Trees R Us                  Cooperator?: Y (Y/N)

RECOMMENDATION
  The maximum recommended fuel weight is:    799 Tons
  The maximum recommended area is:            88 Acres

  Most limiting SSA (ID):                      1
  Limiting fires (ID):

      *** REDUCE ACREAGE OR POSTPONE FIRE ***

  Enter Final Fuel Weight or 0 to Postpone    900
```

Basic Procedure for Determining FW_{max}

Step 1. Determine location, size, total available fuel weight (available fuel loading × acres), and start and end times. This information should be provided by burn manager reporting. If total available fuel weight is not provided, the computer program will use default values for available fuel loading depending on type of burn. End time should be the estimated time when the area will be "burned-over".

Step 2. Determine probable daytime smoke impact area

a. Using TFS Block and Grid System, locate and mark planned fire on map.

b. Place overlay over map showing projected smoke impact area (60-degree sector having 20-mile radius) in direction to which transport wind will be blowing.

Step 3 Determine nighttime down-drainage smoke impact area (for burn manager's own use)

Step 4. Identify nearest smoke sensitive area within projected smoke impact area

a. Identify and mark on map the nearest smoke sensitive area, which may include

- Airports, highways, communities, recreational areas, schools, hospitals, nursing homes, and other known health-related sites.

- Farm-to-market road segments with average daily traffic counts of 500 or more. However, the burn manager should treat segments with less than 500 per day with caution and place warning signs and flagmen if these roads are covered in smoke. Burns involving these excluded road segments should be completed by 4:00 pm to better ensure against smoke visibility problems during the high traffic flow.

b. Determine distance of burn to closest point of smoke sensitive area. This need not be done if using computer program.

Step 5. Identify nearest smoke sensitive area occurring within overlapping portions of smokesheds from multiple fires as done in Step 4.

Step 6. Determine recommended maximum fuel weight

a. Obtain dispersion index (or ventilation rate if index not available) from local TFS Area Office. These smoke dispersion measures are calculated from data given in prescribed burning weather forecasts provided by the National Weather Service via the USFS.

b. Determine if "special" understory burning conditions pertain to the planned burn. These special conditions are met if any of the following applies for understory burns:
   - backing fires
   - heading fires in 3-year rough or less
   - mass ignition where all lines are fired by 3:00 pm and burned by 5:00 pm (or 4:00 pm if forecasted nighttime dispersion index is 12 or less

c. Determine the recommended maximum fuel weight from Tables 1, 2, 3, or 4, whichever if appropriate depending on whether dispersion index or ventilation rate is used, and whether special understory burning conditions apply. These tables are found in Appendix F. These values can also be determined using either the computer program or a calculator.

d. If a smoke sensitive area is common to more than one burn, continue on to Step 7. If not, skip to Step 8.

Step 7. Determine adjusted recommended maximum fuel weight (where smoke sensitive areas are common to more than one burn).

a. For the second burn, multiply the proportion of the burn allocation of the first burn that was not "reserved", by the unadjusted allocation for the second burn. (This process is described in detail on page 12.)

b. For a third burn, the adjusted allocation is found by multiplying its unadjusted allocation by the product of the proportions of "unreserved" allocations of the first and second burns.

Step 8. Determine whether the burn is advisable or inadvisable

a. If estimated total available fuel weight is less than the recommended maximum fuel weight (or adjusted value if applicable), then the burn is *not inadvisable* for the conditions given.

b. If estimated total available fuel weight is more than the recommended maximum (or adjusted value if applicable), then the burn is *inadvisable* for the conditions given.

c. If the burn is determined to be inadvisable, recommend that the burn as given be postponed or that the acreage be reduced so as not to exceed the recommended maximum fuel weight.

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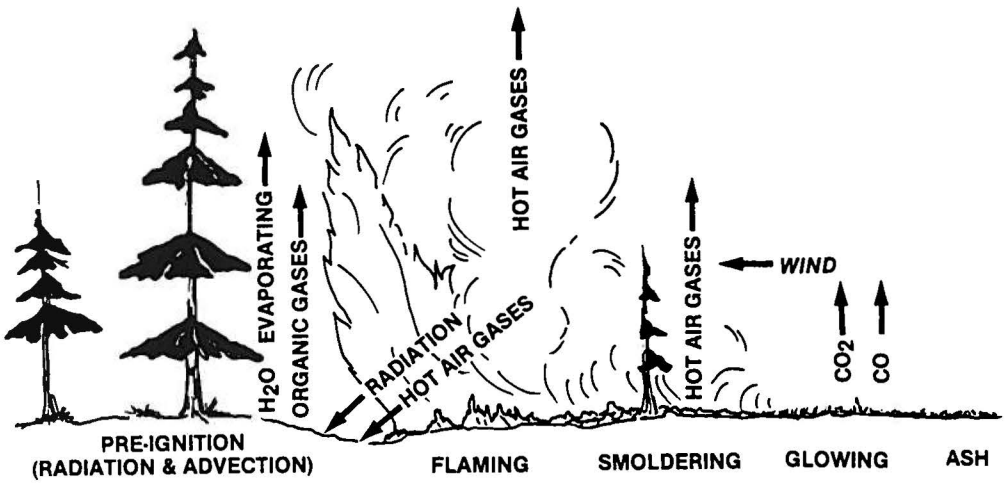
APPENDIX A

Smoke Production Characteristics and Effects†

The Components of Smoke are determined by the fuel and the process that converts this fuel to smoke. Although there are only a few major chemical elements in wood, the complex burning process results in numerous combinations and thereby generates a large number of chemical compounds. The fuels of prescribed fires in the South are mostly understory foliage, small branches, and the upper layers of ground litter. To a lesser extent, fuels also include the large branches and treetops left during land clearing and logging. Wood is composed of about 50 percent carbon, 6 percent hydrogen, and 44 percent oxygen, and less than 1 percent of trace inorganic components. Foliage contains higher levels of the macro- and micro-nutrients.

The Combustion Process

Most observers of forest fires distinguish between flaming and smoldering combustion. Flaming combustion is characterized by the movement of a visible flame through the fuel; smoldering combustion is a much more general and loosely defined term associated with the "die-down" of a fire after the flame front has passed. The burning process, however, is more complicated than this. It is more logical to consider it in four phases: preignition, flaming, smoldering, and glowing. The Prescribed Fire Manager and Burn Boss should understand this process to appreciate how the various smoke components are produced. These phases are illustrated in the following figure.



STAGES OF COMBUSTION

† This section was taken from two publications: (1) Prescribed Fire—Smoke Management Guide, 1985, National Wildfire Coordinating Group, NFES 1279; and (2) Southern Forestry Smoke Management Guidebook, 1976, USDA Forest Service General Technical Report SE-10.

Pre-ignition Phase
In the pre-ignition stage, fuel elements ahead of the fire are heated causing water vapor to move to the surface and escape. As the fuel dries and its internal temperatures rise, certain components of the wood decompose, releasing a stream of combustible organic gases and vapors. This process is called pyrolysis. Because these gases and vapors are very hot, they ignite when mixed with oxygen. This brings the process to its second phase, flaming combustion.

Flaming Phase
At the beginning of the flaming stage, fuel temperature rises rapidly. Pyrolysis accelerates and is accompanied by rapid oxidation (flaming) of the combustible gases, which are now increasing in greater and greater quantities. The products of flaming combustion are prodominantly carbon dioxide (CO_2) and water vapor. This water vapor is not the effect of fuel dehydration (pre-ignition phase), but rather a product of the combustion reaction. Temperatures in this phase range between 600 and 2500 F°. Some of the pyrolyzed substances cool and condense without passing through the flame zone. Others pass through the flames but are only partially oxidized, producing a great variety of emissions. Large-molecule organic compounds are synthesized here. Many organic compounds of low molecular weight remain as gases and move downwind while some compounds with higher molecular weights cool and condense into tar droplets and solid soot particles as they move away from the fire. These particles make up the visible smoke with which we are primarily concerned. The more inefficient the burning, the more soot and tar are produced.

Smoldering Phase
In the smoldering phase, the overall reaction rate of the fire has diminished to a point at which the concentration of combustible gases above the fuel is too low to support a persistent flame envelope. Consequently, the temperature drops and the gases condense. The resulting condensates appear as visible smoke as they escape into the atmosphere. Emissions from a smoldering fire are at least twice that for flaming fire. The heat release rate of a smoldering fire is seldom sufficient to sustain a convective column because the smoke stays near the ground and persists in relatively high concentrations, thereby compounding the impact of the fire on air quality. The smoke evolved during this phase is virtually soot-free, consisting mostly of tar droplets less than a micrometer in size. Near the end of the smoldering phase the evolution of pyrolysis products ceases, leaving the fuel as a black char. The final phase of combustion then takes place.

Glowing Phase
In the glowing combustion phase, all the volatile material in the fuel has been driven off. Oxygen in the air can now reach the fuel, and the surface of the charcoal begins to burn with a characteristic yellow glow. There is no visible smoke. Carbon monoxide and carbon dioxide are the principal products of glowing combustion. This phase continues until the temperature drops or until only noncombustible, gray ash remains.

It is important to recognize that combustion in forest fires, even in the most favorable circumstances, is not a chemically efficient process. First, moisture contained in the fuel absorbs some of the heat energy, thereby reducing the combustion temperature. Second, considerable heat is subsequently lost to the soil and surrounding air. Third, fresh air movement in and around the fire cools the combustion zone. Also, the oxygen required for optimal combustion is sometimes insufficient, resulting in more visible smoke.

Fuel Moisture

The amount of moisture in fuels greatly affects the ease of ignition and the efficiency with which live and dead vegetation burn. By affecting flame temperature, and therefore combustion efficiency, moisture in the fuel affects the amounts and character of emissions. The "*cleanest*" fire is the most efficient fire because, by definition, its combustion is the most complete. On the other hand, though emissions per unit of fuel burned will be greater at higher fuel moistures, the total emission production from a burn may be less if some fraction of the fuel (typically, the larger "round" fuels and the duff) does not totally burn.

Affect of Fuel Properties on Smoke Production

The total volume of smoke produced from a prescribed fire depends primarily upon the amount of fuel consumed. Smoke production can last from less than an hour to several weeks, depending on the method of ignition and nature of the fuel bed. The manner in which combustion and smoke production takes place depends primarily on fuel moisture and such physical fuel properties as particle size, particle arrangement, and fuel weight per unit area.

Particle Size and Arrangements
With a given fuel moisture, the time necessary to ignite and consume an individual fuel particle depends upon the smallest dimension of the particle. A measure frequently used to characterize particle size is the ratio of a particle's surface area to its volume—the greater the ratio the smaller the particle. Size is only part of the information needed when the particle is part of a fuel bed. The arrangement of the particles is also important. Up to a point, the greater the space between particles, the faster the particle will burn. The basic premise applies: the more fuel available to burn, the greater the total smoke production.

Fuel Loading
When using prescribed fire on areas with light fuel loadings under 4 tons per acre (such as grasslands or frequently burned pine stands), total smoke production is low because smoldering combustion is minimal in these types. Rate of smoke production will increase as rate of fire spread increases. The heaviest fuel loadings a prescribed fire manager encounters are normally in piled logging debris. This type of burning can have the most adverse impact on air quality.

Fuel Continuity
Fuel continuity (both horizontal and vertical) affects smoke production because it affects the amount of fuel consumed. Most significantly, sustained ignitions will not occur when the spacing between fuel particle is too large.

Primary Products

The burning of forest fuels emits hundreds, if not thousands, of chemical compounds into the air. Amounts of carbon dioxide and water vapor emitted are indicators of burning efficiency. The more efficient the combustion, the more CO_2 and water vapor produced. As combustion efficiency decreases, the proportion of undesirable emissions increases. Efficiency varies with fuel moisture, fuel loading, type of fire (heading vs. backing), and to a lesser extent, weather conditions. Heading fires produce approximately three times more particulate matter than backing fires. Wet fuels produce substantially more particulate matter than dry fuels.

In forest fires, the two products of complete oxidation—CO_2 and water vapor—make up more than 90 percent of emissions. Under ideal conditions complete combustion of one ton of forest fuels requires 3.5 tons of air and yields 1.84 tons of CO_2 and 0.54 tons of water. Under wildland conditions, however, inefficient combustion produces different yields. As combustion efficiency decreases, less carbon is converted to CO_2 and more carbon is available to form other carbonaceous combustion products. The other 10 percent of emissions includes virtually all of the smoke and potential problem compounds. Products of major concern are carbon monoxide, particulate matter, gaseous hydrocarbons, other organic compounds, and nitrogen oxides. The following table shows the range of emission factors for components of forest fire smoke.

Range of Emission Factors for Compounds of Forest Fire Smoke and Effect Potentials

Components	Range of emission factors (pounds produced per ton of fuel consumed)	Effect potentials
Carbon dioxide	2000-3500 [1]	No direct
Water vapor	500-1500	Visibility
Carbon monoxide	20-500	Health
Total suspended particulate matter	20-180	Visibility &health
Total hydrocarbons	10-40	Visibility & health [2]
Other organics	Unknown	Visibility & health [2]
Nitrogen oxides	1-9	Visibility & health

[1] Values higher than 1 ton occur because of the chemical combination of carbonaceous constituents with oxygen in air to produce carbon dioxide.
[2] Includes effects from secondary photochemical products.

Carbon dioxide is an odorless and colorless nontoxic gas formed abundantly in nature by the decomposition of organic substances. It is exhaled by man and animals during breathing and absorbed from the air by plants for photosynthesis. Its only potential as a pollutant is as a contributor to the overall greenhouse effect that may be causing a rise in the Earth's air temperature.

Water vapor is important because it can affect visibility near a fire, and because it interacts with the other combustion products to reduce combustion efficiency. It is theoretically possible to produce 1720 pounds of water from a ton of fuel at a moisture content of 30 percent. Six hundred pounds are unbound, or free water, and 1120 pounds are from the combustion reaction.

Carbon monoxide is a colorless and odorless toxic gas. Although concentrations can be quite high (100 to 200 ppm) at the fireline, normal atmospheric dilution processes reduce this level to less than 10 ppm approximately 100 feet downwind. In general, concentrations would probably have to exceed 10 ppm for a lengthy period to produce serious effects.

Hydrocarbons are organic compounds containing only carbon and hydrogen in the molecule. Two groups of hydrocarbons are particularly important potential polluters: the low-molecular-weight olefins and unsaturated hydrocarbons and the high-molecular-weight, aromatic-type hydrocarbons. In addition to hydrocarbon compounds, there are literally hundreds of other organic gases and vapors in forest fire smoke. The lower molecular-weight and more soluble aldehydes—such as formaldehyde— are irritants to the mucous membranes of the eyes and upper respiratory tract, while the higher molecular-weight and less soluble aldehydes are deep-lung irritants.

Oxides of nitrogen (NO_x) include both nitric oxide (NO) and nitrogen oxide (NO_2). The formation of oxides of nitrogen is through fixation of atmospheric nitrogen and oxygen in the burning zone, principally at temperatures above 1600 °C. These temperatures can be achieved in piled slash or wildfires. Nitric oxides can also be formed at lower temperatures in the presence of hydrocarbon-free radicals. Significant amounts of nitric oxide may be formed this way in forest fires. Nitrogenous compounds in forest fuels are another potential source of oxides of nitrogen in emissions. Concentrations far exceeding those expected of a forest fire are required for direct effects on man.

Secondary Products

The above-mentioned products have all been primary products of forest fires. However, as smoke plumes travel through the atmosphere, secondary products can be generated through mixing of primary effluents or photochemical activity. For example, ozone is formed in the smoke plume when it is irradiated with sunlight. Some secondary products are more harmful than the primary products, and some are harmless.

Particulate Matter

Particulate matter is defined as any dispersed aggregate matter, solid or liquid (other than water), that for practical purposes is larger than about 0.002 micron in diameter (1 micron = 0.001 millimeter), but smaller than 500 microns in diameter. The size, shape, porosity, density, and other physical properties of particulate matter are highly variable. Aerosol, another often-used term, is small, airborne particulate matter. Particulate matter remains suspended in the air for periods of a few seconds to several months. Suspended particulate matter is that portion that, because of its small size (below 5 to 10 microns in diameter), is transported long distances in the atmosphere and has the greatest potential for environmental impact. Suspended particles are of greatest concern in smoke management.

The EPA standards for particulate matter concern particles less than 10 microns in diameter, sometimes referred to as PM_{10}. Particulate matter of this size is significant because of its especially long residence time in the atmosphere, its contribution to smog formation, its ability to efficiently scatter light, and its ability to penetrate deeply into the lungs. Particles of this size may also act synergistically with gases or other particles.

The most obvious environmental effect of smoke from prescribed fires is a reduction in visibility. This effect is caused by the particles that absorb and scatter light, washing out the contrast that exists between the source and its background. These particles can also scatter the sunlight that illuminates the air between the source and the receiver, again washing out the contrast as distance increases. This temporary reduction in visibility can hinder safe operation of aircraft and automobiles or the enjoyment of scenic vistas. The soiling ability of larger carbon-type particles is another environmental effect of forest fires; but in prescribed burning, these particles tend to fall out of the smoke column close to the fire rather than adding to the general pollution level.

Health effects of particulate matter are determined by three properties: size, sorption, and chemical composition. Sizes of particles are important because of their relation to different parts of the respiratory system. The three main parts of the respiratory system are the nasopharyngeal, tracheobronchial, and pulmonary. Of these, the upper two contain cellular tissue with hairlike outgrowths (cilia) covered with mucous, and the lower one contains moist cellular tissue covered by a surface-active material to prevent the collapse of the air sacs at the end of respiration. Through inertial impaction and gravitational settling, the larger particles are deposited in the upper two parts of the system and then expelled. As the size decreases below 5 microns in diameter, increasing numbers are deposited in the lower respiratory tract—including more than 50 percent of those between 0.01 and 0.1 micron that penetrate this far. Many forest fire smoke particles have a potential for being deposited deep in the lungs.

Sorptive properties of particles make them potential carriers of toxic material. Formaldehyde, which does not itself readily penetrate the upper respiratory tract, is carried to the lungs by adsorption to small particles—causing increased toxic effect.

Solvent extractions with benzene have traditionally been used to estimate the amount of organic compounds in particulate matter. The benzene soluble organic (BSO) fraction of particulate matter from fires in various southern fuels ranges from 40 to 75 percent. Some of this variation is due to type of fire. In comparison, the average BSO fraction of ambient air particulate matter is about 8 percent.

Polycyclic Organic Matter

Polycyclic organic matter (POM) is of special interest in smoke management because it is a class of compounds containing many physiologically active substances. Benzo(a)pyrene (BaP) and other implicated carcinogens are usually found in POM. POM is formed by the pyrosynthesis of small carbon molecules in the low-oxygen region of combustion processes. It is found in virtually all burning that involves carbonaceous fuels. Production of POM is more dependent on the conditions of the fire than the type of fuel. Although heading fires usually produce more particulate matter per ton of fuel at a given fuel loading, backing fires produce substantially more BaP, especially at light loadings. Within heading fires, the smoldering phase produces higher amounts of both BaP and particulate matter than the corresponding flaming phase. The

differences in BaP production can be explained partly by the conditions required for its formation—moderately high temperatures, low oxygen, and long residence times in the reaction zone. Carbon fragments in the slow-moving, backing fires (especially the light loadings) remained under these optimum formation conditions substantially longer than in the heading fires. Within heading fires the carbon fragments in the smoldering phase, even though at less than optimum BaP formation temperatures, are subject to these conditions for substantially longer periods than in the corresponding flaming phase. The BaP levels shown in the following table (from laboratory experiments) are generally in the ranges reported for open burning of landscape refuse, grass clippings, leaves and branches, and hardwood leaves. The one exception is the value for lightly loaded backing fires, which is about 10 times what might be expected from earlier reported values. Data indicate that one should be cautious in declaring backing fires to be the cleanest. Although backing fires produce less particulate matter than heading fires, they produce more BaP than heading fires.

Benzo(a)pyrene and Total Suspended Particulate Matter from Burning Pine Needles [1]

Type of fire or fire phase and fuel loading (pounds per square foot)	Emissions	
	Benzo(a)pyrene	Total suspended particulate matter
	ng/g [2]	Pounds per ton [3]
Backing fire		
Light (0.1)	3500	22
Medium (0.3)	560	8
Heavy (0.5)	240	5
Heading fire		
Light (0.1)	38	22
Medium (0.3)	40	88
Heavy (0.5)	100	129
Flaming phase		
Light (0.1)	33	14
Medium (0.3)	17	17
Heavy (0.5)	36	40
Smoldering phase		
Light (0.1)	100	59
Medium (0.3)	55	143
Heavy (0.5)	140	192

[1] Fuel moisture content for all fires ranged from 18 to 27 percent.
[2] Nanograms of benzo(a)pyrene per gram of fuel burned. A nanogram is 0.000000001 gram.
[3] Pounds of total suspended particulate matter per ton of fuel burned.

Physical Properties

The particulate fraction of forest fire smoke is highly variable. This high variability is not only in the mass produced but also in the size, shape, porosity, density, and other physical properties of individual particles. Particles are responsible for two major smoke problems: respiratory effects and visibility reduction. Reduced visibility is caused by the scattering of light by the particles. All particles do not scatter light to the same degree. Those having diameters between 0.3 and 0.8 micron, cause the maximum scattering. Unfortunately, these sizes of particles remain suspended in the air the longest.

Particle Formation

Most particles in forest fire smoke are formed from the gaseous organic compounds produced by pyrolysis and combustion. Nucleation, condensation, and coagulation form both liquid and solid particles ranging upward in size from about 0.002 micron. From 60 to 70 percent of the total particles produced are liquid. These are formed into spherical shapes by condensation of organic vapors and range from the highly volatile and short-lived to the long-lived, tarry, and viscous. Solid particles created by combustion, particularly the smaller ones, can also assume a spherical shape. More commonly, however, they assume other forms that approximate flattened discs, angular cubes, and long, chainlike agglomerates. Sizes of the solid particles range from 0.01 micron to 5 microns in diameters. Often, the small particles will bind together into larger agglomerates that vary in shape from roughly circular to long, slender, chainlike masses. Particles are also formed by the mechanical action of turbulent forces present in the fire zone. These forces simply break up the fire-weakened fuel and lift small pieces into the heated air column over the fire. Initially, there are fewer mechanically-formed particles but they are usually larger and have more mass than chemically-produced ones.

Size Distribution

Particles are produced in a wide range of sizes. The amount of particulate matter in each size category is called the size distribution, which can be expressed as mass or number of particles. A particle's mass, in combination with its size and shape, determines its aerodynamic size. Aerodynamic size equates an irregular shape to a sphere and can be much different than physical size. Aerodynamic size is more closely related to particulate matter dispersion and respiratory effects, while physical size is more related to visibility effects. From a study done in the Southeast on slash pine backing fires, about 70 percent of the particle mass was less than 0.4 micron in diameter, and 95 percent was less than 1 micron. A study done on Douglas-fir in the Pacific Northwest showed 69 percent of the particle mass from smoke produced by a prescribed burn was less than 0.3 micron and 82 percent was less than 1 micron. Studies show that the average diameter of particles in forest fire smoke is approximately 0.1 micron. This is true for fires in all fuel types. In general, only particles smaller than 10 microns can be expected to pose problems at distances greater than ½ to 1 mile from the source. Particles larger than 10 or 20 microns will usually be removed from the atmosphere by gravitational forces within this distance. There are, of course, exceptions caused by extreme windspeeds or by specialized particle growth conditions high in the atmosphere. Particles found by aircraft samplings of forest fire smoke plumes are rarely larger than 10 microns.

Residual Smoke

Residual smoke is defined as the smoke produced from smoldering combustion and not contained in a convection column. During the active combustion stage of almost all prescribed burns, smoldering combustion takes place near flaming fuels. Much of the smoke from the smoldering fuel is entrained into the convection column induced by the flames and carried aloft. When flaming ceases, the convection column dissipates and all subsequent smoke produced from smoldering combustion remains near the ground as residual smoke.

Smoldering combustion frequently causes a sudden visibility problem immediately downwind of a burn area when the convection column dissipates. The lack of vertical movement concentrates the smoke near the ground. If residual smoke production is brief following the completion of flaming combustion, the horizontal and vertical dispersion from air movement may still be adequate to prevent downwind problems.

Special problems arise from a prescribed fire if residual smoke persists into the night or into subsequent burning periods. In relatively flat terrain, wind usually is minimal at night, causing smoke density to build up in the vicinity of the burn area. Any nearby drainages usually further concentrates the smoke. In addition, the particulate matter can serve as nuclei for fog formation if the relative humidity approaches the water saturation point. In complex terrain the residual smoke can flow down drainages at night, causing visibility and other problems if the drainages contain sensitive areas.

Residual smoke that persists for several days poses additional problems because the manager cannot make reliable predictions of the wind speed and direction much beyond the day of the burn. The path long-term residual smoke will follow, therefore cannot be reliably predicted. The best burning plans should contain provisions to minimize residual smoke production. Residual smoke causes more road accidents than any other type of smoke.

APPENDIX B

TNRCC Outdoor Burning Regulations

Texas Air Control Board
Control of Air Pollution From
Visible Emissions and Particulate Matter
Regulation I

OUTDOOR BURNING

§111.101. General Prohibition.

No person may cause, suffer, allow, or permit any outdoor burning within the State of Texas, except as provided by §111.103 of this title (relating to Exceptions to Prohibition of Outdoor Burning). Outdoor disposal or deposition of any material capable of igniting spontaneously shall not be allowed without written permission of the Executive Director of the Texas Air Control Board.

06/16/89

§111.103. Exceptions to Prohibition of Outdoor Burning.

(a) Outdoor burning may be authorized by written permission from the Executive Director of the Texas Air Control Board (TACB) if there is no practical alternative and if the burning will not cause or contribute to a violation of any federal primary or secondary ambient air standard. The Executive Director may also specify procedures or methods to control or abate emissions from outdoor burning authorized pursuant to this rule by requiring that trenches be dug to align with prevailing winds, specifying time for burning, and other related factors. Authorizations to burn may be revoked by the Executive Director at anytime if the burning is causing nuisance conditions, is not conducted in accordance with the specified conditions, violates any provision of an applicable permit, or causes a violation of any air quality standard.

(b) Outdoor burning shall also be authorized in each of the following instances:

(1) Training of fire-fighting personnel when requested by certified mail and when authorized in writing by the local air pollution control agency or local health unit. In the absence of such local entities, the nearest TACB Regional Office shall be notified. The burning shall be authorized if notice of denial from the local air pollution control agency, local health unit, or TACB Regional Office is not received within ten days of the request. In cases of repetitive, routine fire-fighting training, a yearly written notification, with 24-hour advance telephone notice for each training session is sufficient. Authorization to conduct outdoor burning under this provision may be revoked by the Executive Director if this provision is used to circumvent §111.101 of this title (relating to General Prohibition) and §111.103 of this title (relating to Exceptions to Prohibition of Outdoor Burning.)

(2) Domestic waste burning at a property designed for and used exclusively as a private residence, housing not more than three families, when collection of domestic waste is not provided or authorized by the local governmental entity having jurisdiction, and when the waste is generated only from that property.

(3) Campfires and fires used solely for recreational or ceremonial purposes, or in the noncommercial preparation of food, or used exclusively for the purpose of supplying warmth during cold weather. Such burning shall be subject to the requirements of §111.105(7) of this title (relating to General Requirements for Allowable Outdoor Burning).

(4) Diseased animal burning when such burning is the most effective means of controlling the spread of disease.

(5) Rural area on-site burning of trees, brush, grass, and other dry plant growth when no practical alternative to burning exists for right-of-way maintenance, land-clearing operations, and for those forest, crop, and range management purposes not specifically governed by orders issued pursuant to subsection (a) of this section. Such burning shall be subject to the requirements of §111.105 of this title (relating to General Requirements for Allowable Outdoor Burning).

(6) Salt-marsh grass management burning may be conducted only in Aransas, Brazoria, Calhoun, Chambers, Galveston, Harris, Jackson, Jefferson, Kleberg, Matagorda, Nueces, Orange, Refugio, and San Patricio counties and only if the following requirements are met:

(A) All land on which burning is to be conducted shall be registered with the appropriate Regional Office of the TACB and its location identified on a U.S. Geological Survey map or equivalent. The person who owns or controls the land must also submit a legal description of the land boundaries and identify significant points such as roads, canals, lakes, and streams,,and the method by which access is made to the site. For larger acreage, the map should be divided into manageable blocks not larger than a section, with numerical identification for each defined block. The information must be provided for review at least 15 days before the burning takes place.

(B) Prior to any burning, approval must be obtained from the appropriate Regional Office. Notification of the burning may be verbal or written and must identify the specific area and block to be burned, estimated acreage, start and end time of the burn, and a person who can be contacted during the burn period.

(C) The person responsible for the burning must provide access and transportation to the burn site upon request by the Regional Office.

(D) Such burning shall be subject to the requirements of §111.105 of this title (relating to General Requirements for Allowable Outdoor Burning).

(7) Hydrocarbon burning from pipeline breaks and oil spills may be allowed upon proper notification as set forth in §101.6 of this title (relating to Notification Requirements for Major Upset), if the Executive Director determines that the burning is necessary to protect the public welfare.

(8) Municipal solid waste burning may be conducted until such time as it is eliminated by the federal Resource Conservation and Recovery Act and as long as the following conditions are met:

(A) Municipal solid waste burning may be conducted at Texas Department of Health (TDH) permitted Type II or III landfill sites (sites serving less than 5,000 population equivalent) located in any county with a population of 100,000 or less as determined by the latest United States population census if authorization is obtained from the Executive Director of the TACB. Any authorization provided hereunder must be consistent with all TDH regulations and in accordance with 40 CFR 257, Criteria for Classification of Solid Waste Disposal Facilities and Practices.

(B) Brush and demolition or construction wood waste burning may be conducted at TDH permitted Type IV landfill sites, as defined by the TDH, located in the counties described in subparagraph (8) (A) of this paragraph if authorization is obtained from the Executive Director of the TACB. Any authorization provided hereunder must be consistent with the criteria referenced in subparagraph (8) (A) of this paragraph.

(C) Such burning shall be subject to §111.105(7) of this title (relating to General Requirements for Allowable Outdoor Burning).

06/16/89

§111.105. General Requirements for Allowable Outdoor Burning.

Outdoor burning which otherwise is permissible shall also be subject to the following requirements when specified in §111.103 of this title (relating to Exceptions to Prohibition of Outdoor Burning):

(1) Prior to prescribed or controlled burning for forest management purposes, the Texas Forest Service shall be notified.

(2) The burning must be outside the corporate limits of a city or town except when it is necessary to eliminate a naturally occurring fire hazard as determined by the local fire department.

(3) Burning shall be commenced only when the wind will carry smoke and other pollutants away from any city, town, residential, recreational, commercial, or industrial area, navigable water, public road, or landing strip which may be affected by the smoke. Burning shall not be conducted when a shift in wind direction is predicted which could produce adverse effects to persons, animals, or property during the burning period. If at any time the burning causes or may tend to cause smoke to blow onto or across a road or highway, it is the responsibility of the person initiating the burning to post flag-persons on affected roads in accordance with the requirements of the Department of Public Safety.

(4) The burning must be at least 300 feet (90 meters) from any adjacent properties which have residential, recreational, commercial, or industrial use.

(5) The hours and wind conditions for burning shall comply with the following:

(A) The initiation of burning shall commence after 9 a.m. Burning shall be completed on the same day as soon as is reasonably practical prior to 5 p.m.

(B) Burning shall not be commenced when surface wind speed is predicted to be less than six m.p.h. (five knots) or greater than 23 m.p.h. (20 knots) during the burn period.

(6) Burning shall not be conducted during periods of actual or predicted persistent (12 hours or more) low-level atmospheric temperature inversions (nonsurface based) or in areas covered by a current National Weather /Service Air Stagnation Advisory.

(7) Heavy oils, asphaltic materials, items containing natural or synthetic rubber, or any material which may produce unreasonable amounts of smoke must not be burned.

Texas Air Control Board
Control of Air Pollution From
Visible Emissions and Particulate Matter
Regulation I

§111.107 Responsibility for Consequences of Outdoor Burning.

The authority to conduct outdoor burning under this regulation does not exempt or excuse any person responsible from the consequences, damages, or injuries resulting from the burning and does not exempt or excuse anyone from complying with all other applicable laws or ordinances, regulations, and orders of governmental entities having jurisdiction, even though the burning is otherwise conducted in compliance with this regulation.

06/16/89

§101.4. Nuisance.

No person shall discharge from any source whatsoever one or more air contaminants or combinations thereof, in such concentration and of such duration as are or may tend to be injurious to or to adversely affect human health or welfare, animal life, vegetation, or property, or as to interfere with the normal use and enjoyment of animal life, vegetation, or property.

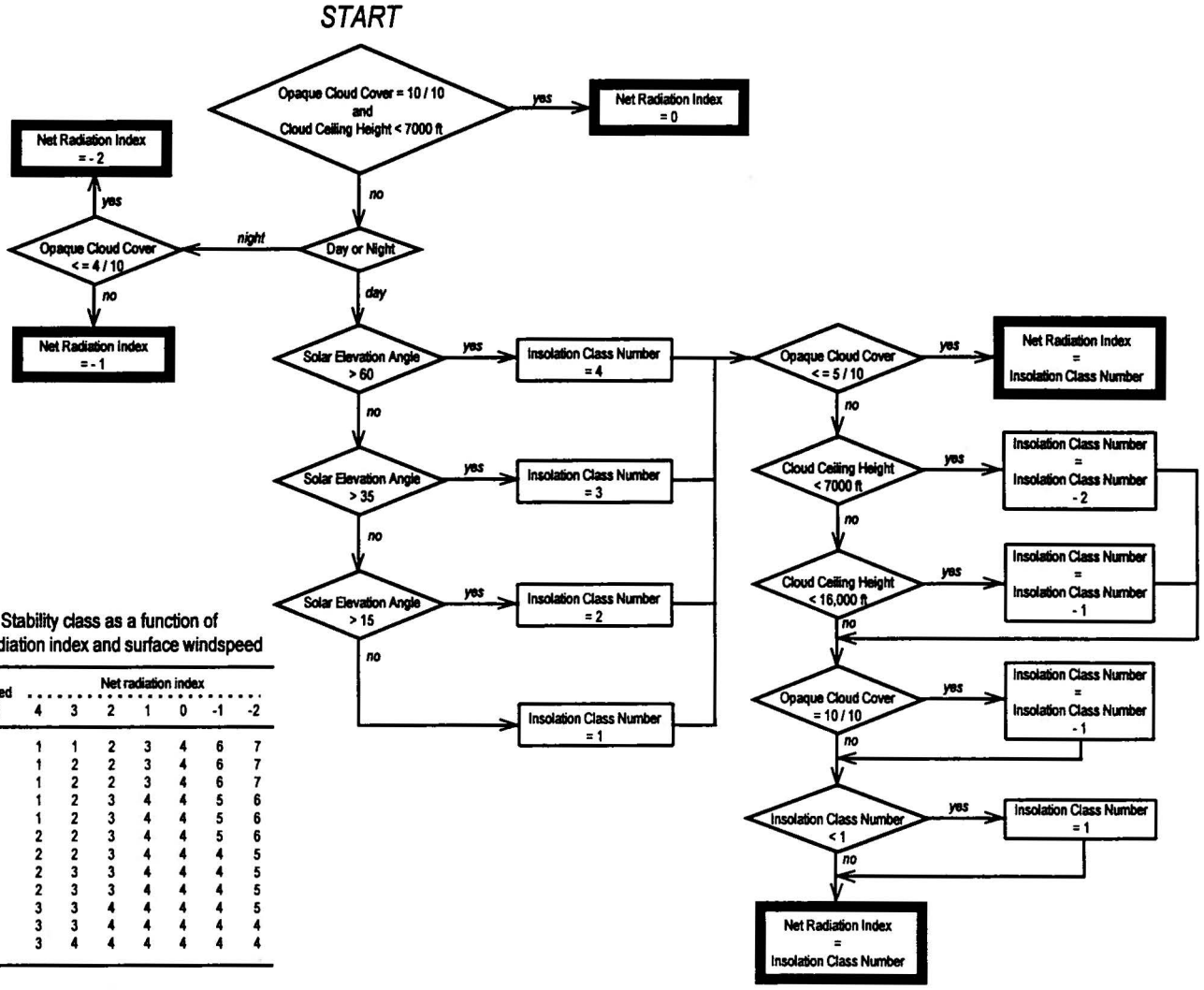
APPENDIX C

Stability Class Estimation Method

This method of estimating stability class is as given in *An Atmospheric Dispersion Index for Prescribed Burning* by Lee Lavdas (USDA Forest Service Research Paper SE-256, 1986). Input data required to determine stability class include solar elevation angle in degrees, total opaque cloud cover in tenths, ceiling height in feet, and surface windspeed in knots (1 mph = 0.869 knots). If ceiling is undefined due to little or no cloudiness, it should be regarded as >99,000 ft; if ceiling is undefined due to surface-based obscuration, consider the sky as totally covered with opaque clouds, and the vertical visibility may be used in place of ceiling height. The other parameters are defined in the same way as in National Weather Service operations (for example, surface windspeed is the windspeed 20 ft above open terrain).

Stability class is determined through an estimate of net radiation and surface windspeed. Net radiation index is obtained by the procedure given in the following flowchart. Stability class is then obtained from the net radiation index and surface windspeed according to the table at bottom left.

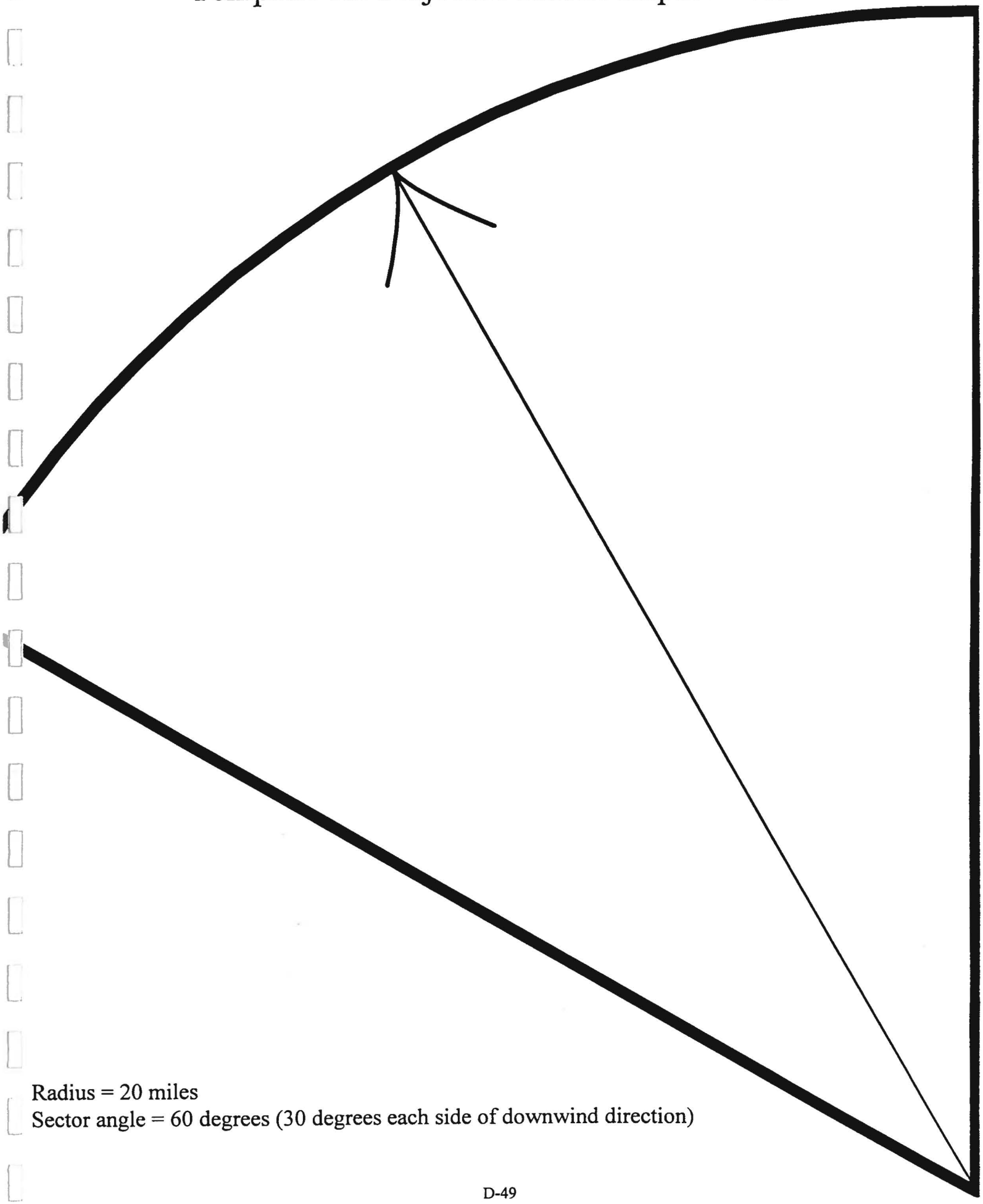
The seven numerical values for stability class may be interpreted as: 1 = very unstable, 2 = moderately unstable, 3 = slightly unstable, 4 = near neutral, 5 = slightly stable, 6 = moderately stable, and 7 = very stable. When used in determining dispersion index from hour-by-hour surface weather observations, the stability class should not be allowed to vary by more than one class per hour. This restriction is imposed to help account for the effects of changing weather conditions on concentrations due to pollutants undergoing transport for several hours.



Stability class as a function of net rediation index and surface windspeed

Windspeed (knots)	Net radiation index 4	3	2	1	0	-1	-2
≤1	1	1	2	3	4	6	7
2	1	2	2	3	4	6	7
3	1	2	2	3	4	6	7
4	1	2	3	4	4	5	6
5	1	2	3	4	4	5	6
6	2	2	3	4	4	5	6
7	2	2	3	4	4	4	5
8	2	3	3	4	4	4	5
9	2	3	3	4	4	4	5
10	3	3	4	4	4	4	5
11	3	3	4	4	4	4	4
≥12	3	4	4	4	4	4	4

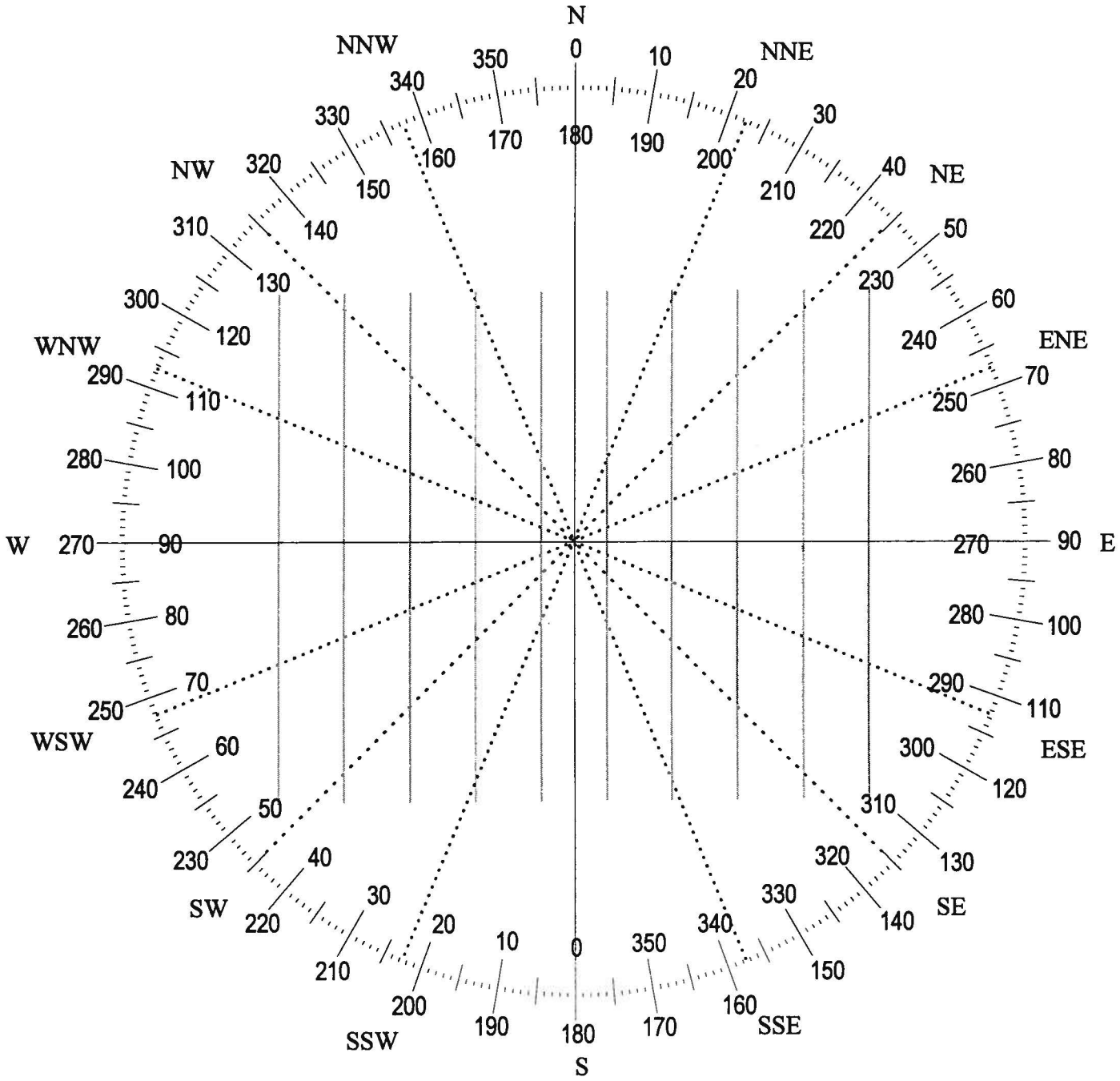
Template for Projected Smoke Impact Area

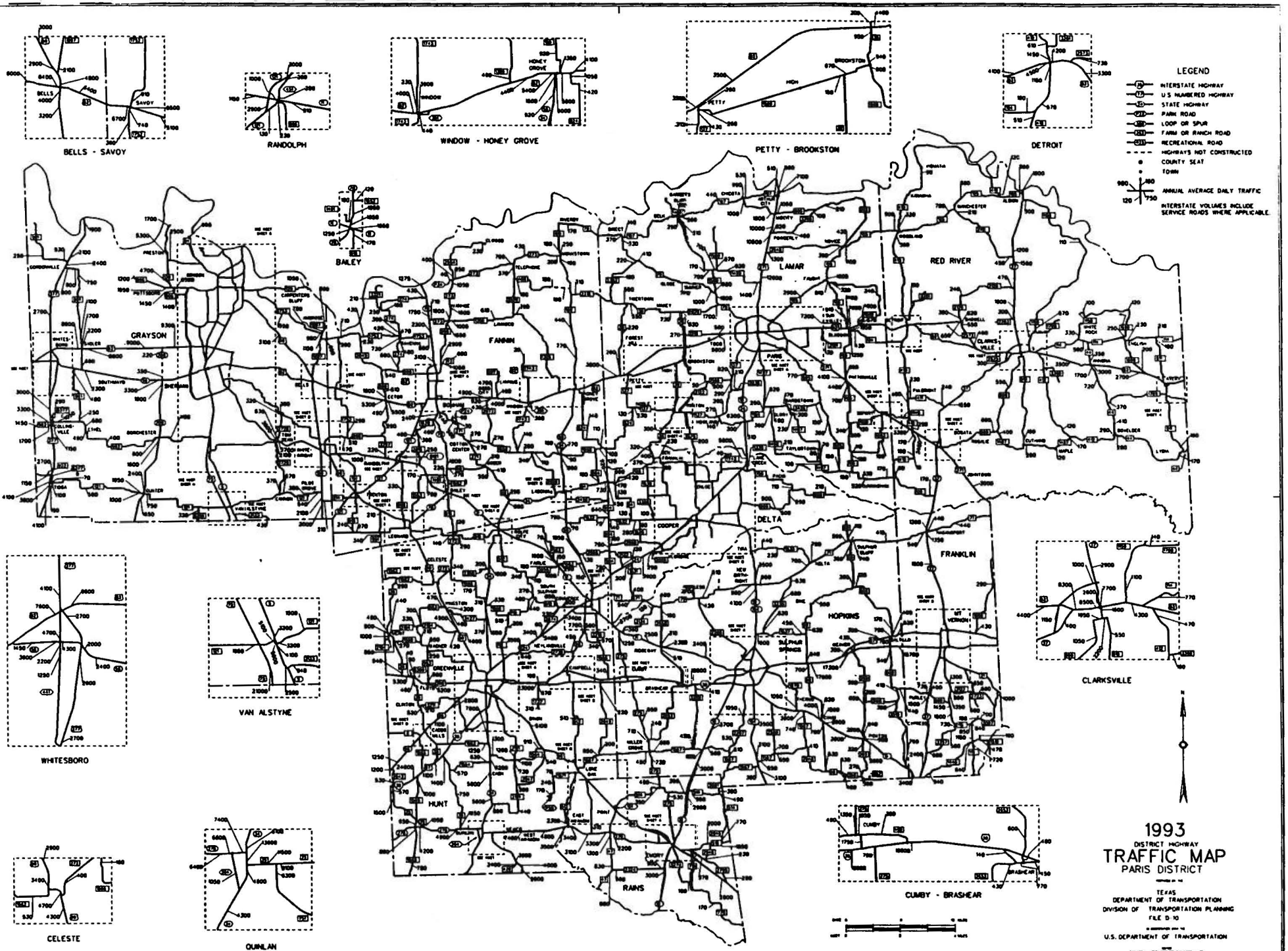


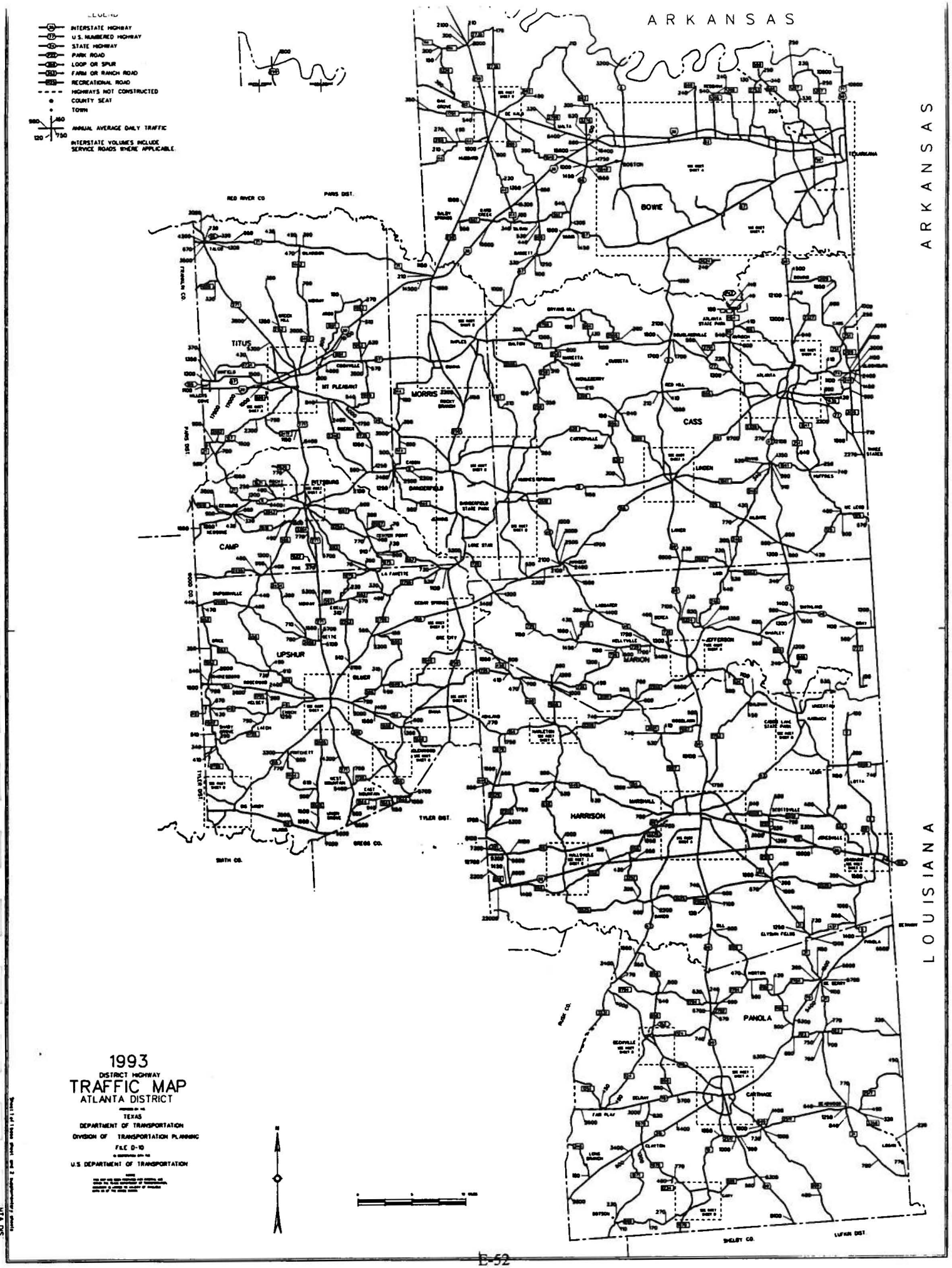
Radius = 20 miles
Sector angle = 60 degrees (30 degrees each side of downwind direction)

Compass Template for Orienting Smokeshed Overlays

Outer numbers: wind direction FROM
Inner numbers: wind direction TO




BELLS - SAVOY
RANDOLPH
WINDOW - HONEY GROVE
PETTY - BROOKSTON
DETROIT
LEGEND
INTERSTATE HIGHWAY
U.S. NUMBERED HIGHWAY
STATE HIGHWAY
PARK ROAD
LOOP OR SPUR
FARM OR RANCH ROAD
RECREATIONAL ROAD
HIGHWAYS NOT CONSTRUCTED
COUNTY SEAT
TOWN
ANNUAL AVERAGE DAILY TRAFFIC
INTERSTATE VOLUMES INCLUDE SERVICE ROADS WHERE APPLICABLE.
BAILEY
GRAYSON
FANNIN
LAMAR
RED RIVER
DELTA
FRANKLIN
HOPKINS
HUNT
RAINS
WHITESBORO
VAN ALSTYNE
CLARKSVILLE
CELESTE
QUINLAN
CUMBY - BRASHEAR
1993
DISTRICT HIGHWAY
TRAFFIC MAP
PARIS DISTRICT
TEXAS
DEPARTMENT OF TRANSPORTATION
DIVISION OF TRANSPORTATION PLANNING
FILE D-10
U.S. DEPARTMENT OF TRANSPORTATION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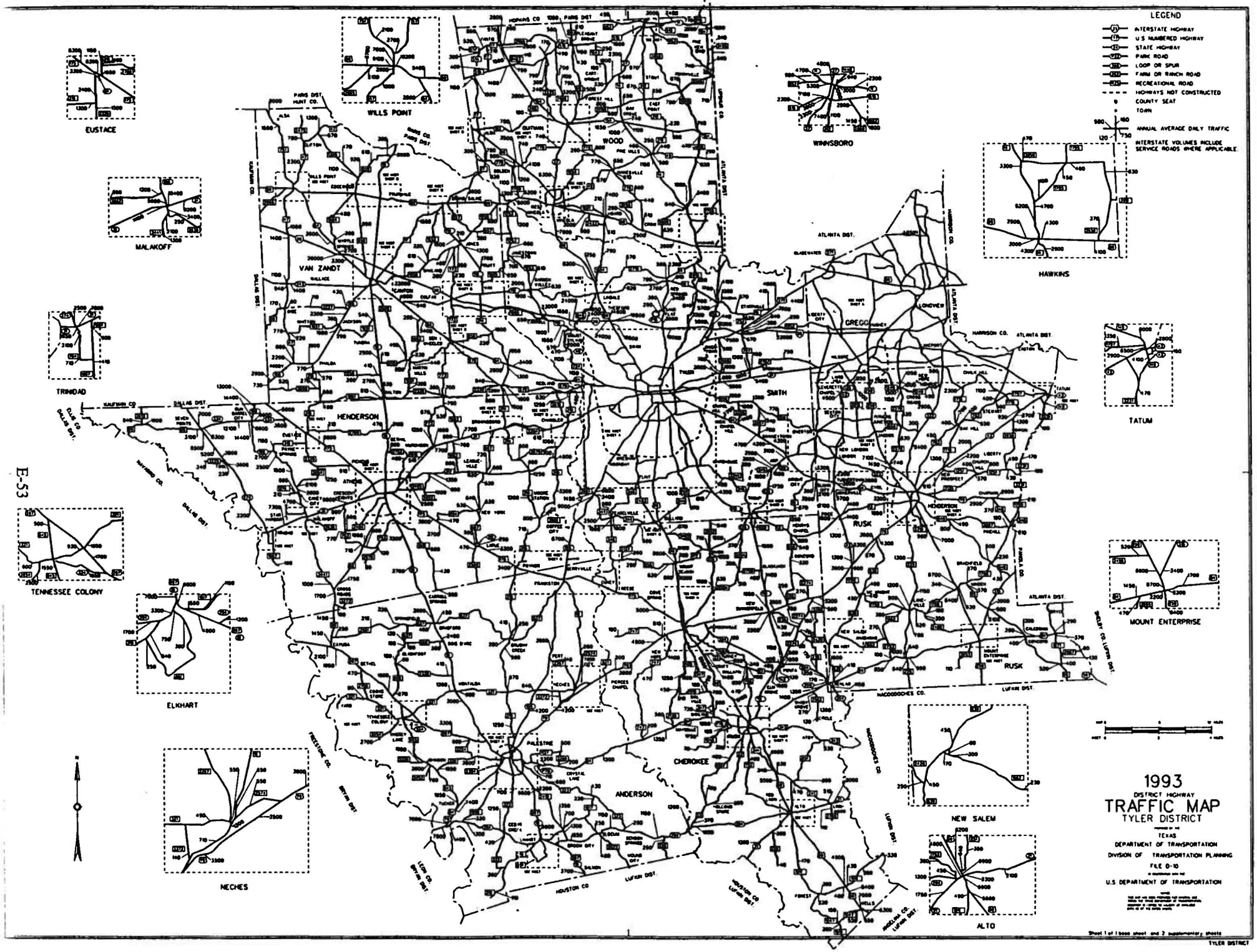
U.S. NUMBERED HIGHWAY
STATE HIGHWAY
PARK ROAD
LOOP OR SPUR
FARM OR RANCH ROAD
RECREATIONAL ROAD
HIGHWAYS NOT CONSTRUCTED
COUNTY SEAT
TOWN
ANNUAL AVERAGE DAILY TRAFFIC
INTERSTATE VOLUMES INCLUDE SERVICE ROADS WHERE APPLICABLE.
ARKANSAS
LOUISIANA
RED RIVER CO
PARIS DIST.
FRANKLIN CO.
TITUS
MORRIS
BOWIE
CASS
CAMP
UPSHUR
MARION
HARRISON
PANOLA
TYLER DIST.
GREGG CO.
SMITH CO.
SHELBY CO.
LUFKIN DIST
1993
DISTRICT HIGHWAY
TRAFFIC MAP
ATLANTA DISTRICT
TEXAS
DEPARTMENT OF TRANSPORTATION
DIVISION OF TRANSPORTATION PLANNING
FILE D-10
U.S. DEPARTMENT OF TRANSPORTATION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STATE HIGHWAY
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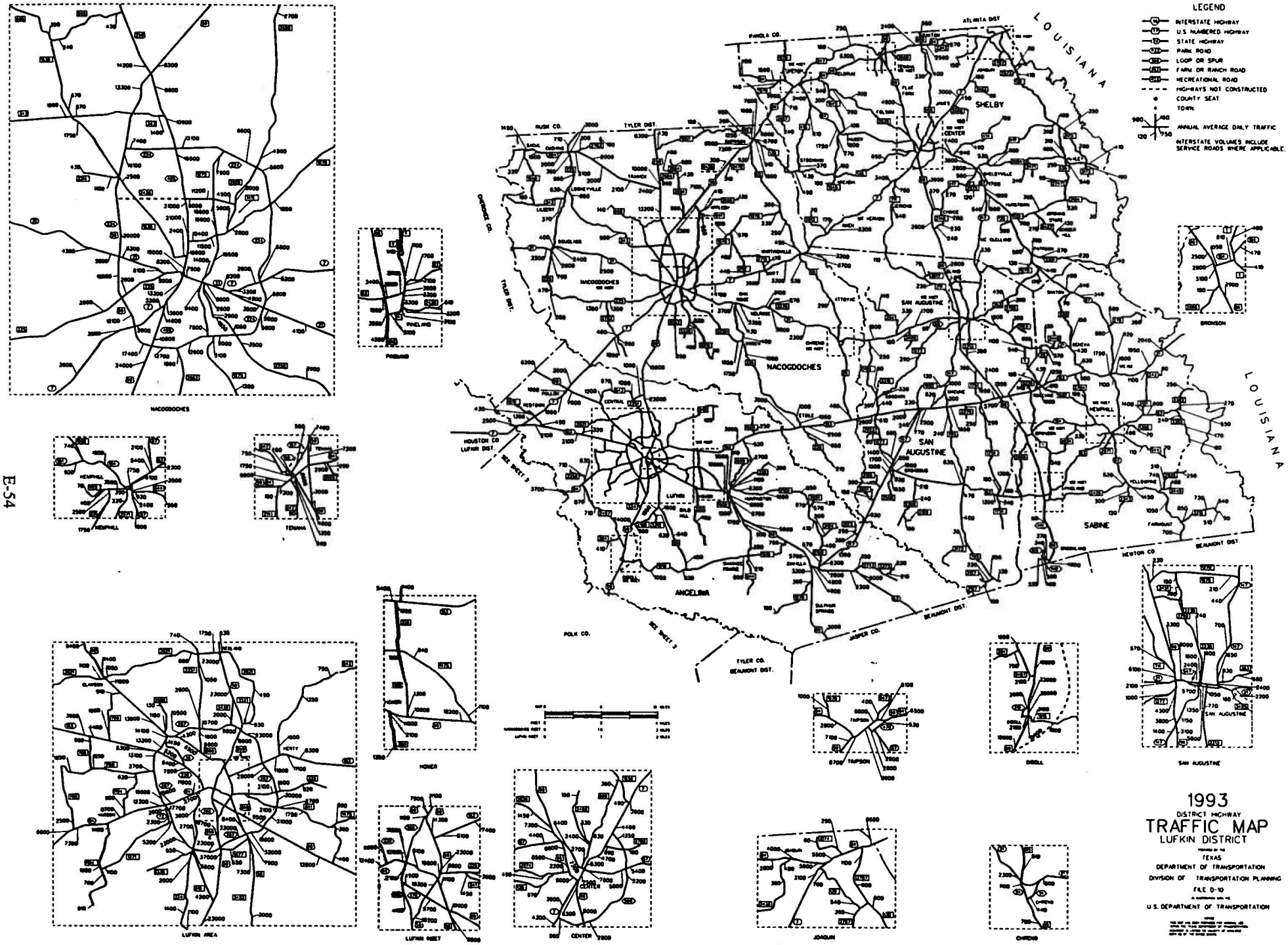
FARM OR RANCH ROAD
RECREATIONAL ROAD
HIGHWAYS NOT CONSTRUCTED
COUNTY SEAT
TOWN
ANNUAL AVERAGE DAILY TRAFFIC
INTERSTATE VOLUMES INCLUDE SERVICE ROADS WHERE APPLICABLE.
EUSTACE
WILLS POINT
WINNSBORO
MALAKOFF
HAWKINS
TRINIDAD
TATUM
TENNESSEE COLONY
MOUNT ENTERPRISE
ELKHART
NEW SALEM
NECHES
ALTO
VAN ZANDT
WOOD
GREGG
SMITH
HENDERSON
RUSK
CHEROKEE
ANDERSON
1993
DISTRICT HIGHWAY
TRAFFIC MAP
TYLER DISTRICT
TEXAS
DEPARTMENT OF TRANSPORTATION
DIVISION OF TRANSPORTATION PLANNING
FILE D-10
U.S. DEPARTMENT OF TRANSPORTATION
Sheet 1 of 1 base sheet and 2 supplementary sheets
TYLER DISTRICT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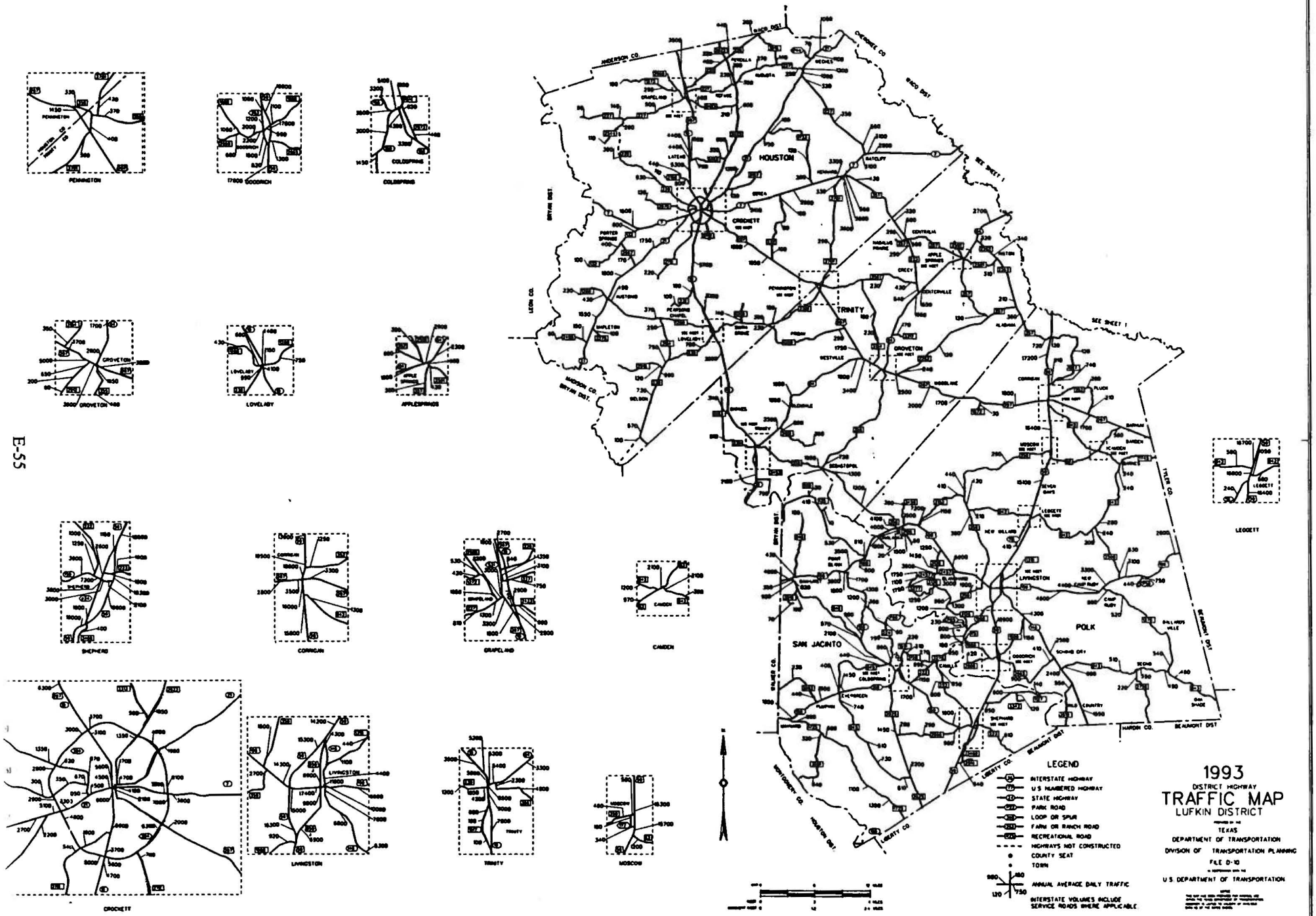
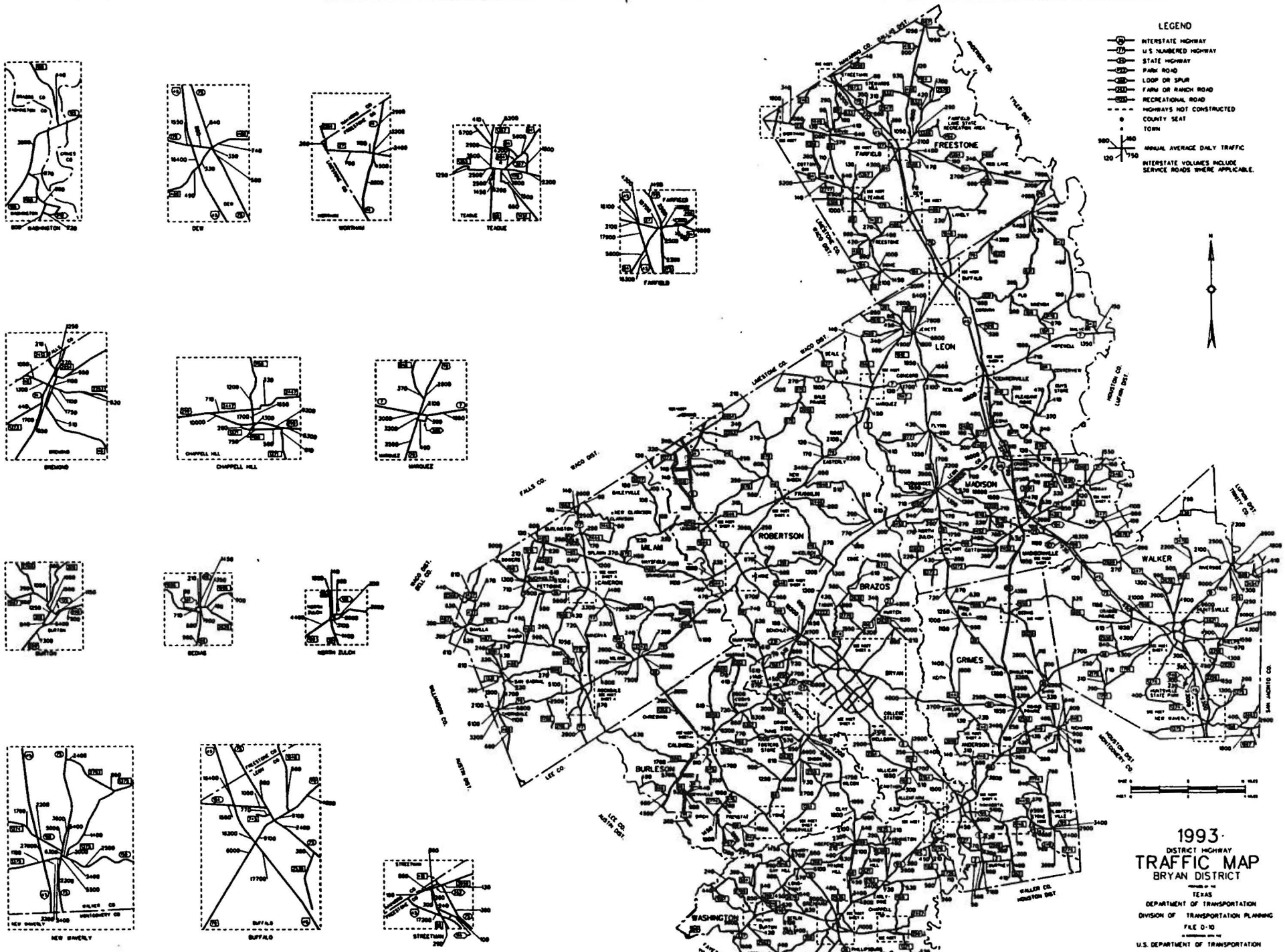
STATE HIGHWAY
PARK ROAD
LOOP OR SPUR
FARM OR RANCH ROAD
RECREATIONAL ROAD
HIGHWAYS NOT CONSTRUCTED
COUNTY SEAT
TOWN
ANNUAL AVERAGE DAILY TRAFFIC
INTERSTATE VOLUMES INCLUDE SERVICE ROADS WHERE APPLICABLE.
LOUISIANA
SHELBY
NACOGDOCHES
SAN AUGUSTINE
SABINE
ANGELINA
TYLER CO.
POLK CO.
JASPER CO.
NEWTON CO.
HOUSTON CO.
RUSK CO.
CHEROKEE CO.
ATLANTA DIST.
TYLER DIST.
BEAUMONT DIST.
LUFKIN DIST.
SEE SHEET 2
NACOGDOCHES
PINELAND
BRONSON
HEMPHILL
TENAHA
HOMER
LUFKIN AREA
LUFKIN INset
CENTER
JOAQUIN
CHIROND
DIBOLL
TAIPSON
SAN AUGUSTINE
1993
DISTRICT HIGHWAY
TRAFFIC MAP
LUFKIN DISTRICT
TEXAS
DEPARTMENT OF TRANSPORTATION
DIVISION OF TRANSPORTATION PLANNING
FILE D-10
U.S. DEPARTMENT OF TRANSPORTATION
Sheet 1 of 2 base sheets and 6 supplementary sheets


1993
DISTRICT HIGHWAY
TRAFFIC MAP
LUFKIN DISTRICT
TEXAS
DEPARTMENT OF TRANSPORTATION
DIVISION OF TRANSPORTATION PLANNING
FILE D-10
U.S. DEPARTMENT OF TRANSPORTATION
LEGEND
INTERSTATE HIGHWAY
U.S. NUMBERED HIGHWAY
STATE HIGHWAY
PARK ROAD
LOOP OR SPUR
FARM OR RANCH ROAD
RECREATIONAL ROAD
HIGHWAYS NOT CONSTRUCTED
COUNTY SEAT
TOWN
ANNUAL AVERAGE DAILY TRAFFIC
INTERSTATE VOLUMES INCLUDE SERVICE ROADS WHERE APPLICABLE
HOUSTON
TRINITY
SAN JACINTO
POLK
PENNINGTON
GOODRICH
COLDSPRING
GROVETON
LOVELADY
APPLESPRINGS
SHEPHERD
CORRIGAN
GRAPELAND
CAMDEN
LEGGETT
CROCKETT
LIVINGSTON
TRINITY
MOSCOW
ANDERSON CO.
CHEROKEE CO.
LEON CO.
MADISON CO.
WALKER CO.
MONTGOMERY CO.
LIBERTY CO.
HARDIN CO.
TYLER CO.
BRYAN DIST.
BEAUMONT DIST.
HOUSTON DIST.
NACO DIST.
SEE SHEET 1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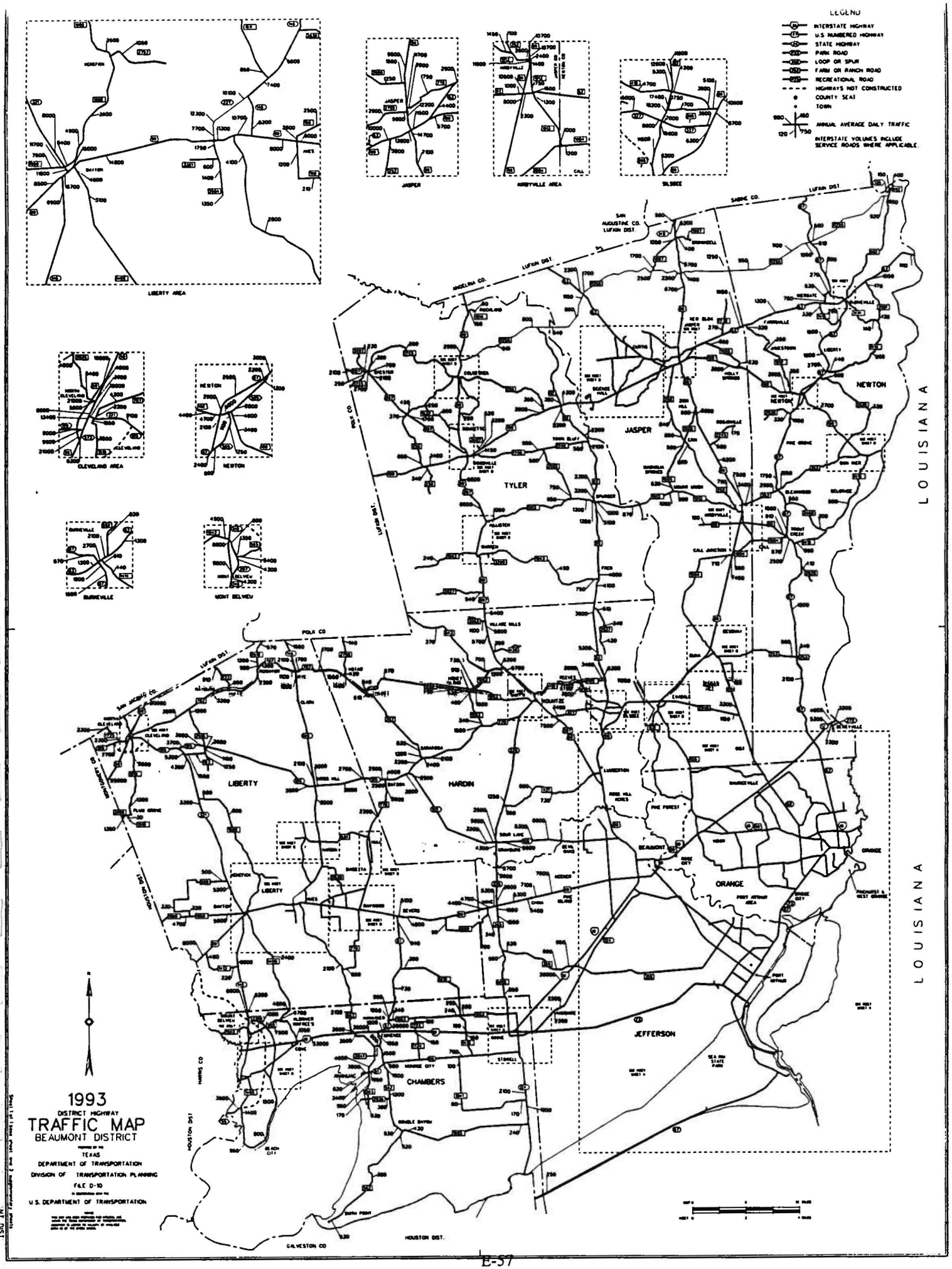
U.S. NUMBERED HIGHWAY
STATE HIGHWAY
PARK ROAD
LOOP OR SPUR
FARM OR RANCH ROAD
RECREATIONAL ROAD
HIGHWAYS NOT CONSTRUCTED
COUNTY SEAT
TOWN
ANNUAL AVERAGE DAILY TRAFFIC
INTERSTATE VOLUMES INCLUDE SERVICE ROADS WHERE APPLICABLE.
FREESTONE
LEON
MADISON
ROBERTSON
MILAM
BRAZOS
WALKER
GRIMES
WASHINGTON
BURLESON
1993
DISTRICT HIGHWAY
TRAFFIC MAP
BRYAN DISTRICT
TEXAS
DEPARTMENT OF TRANSPORTATION
DIVISION OF TRANSPORTATION PLANNING
FILE D-10
U.S. DEPARTMENT OF TRANSPORTATION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STATE HIGHWAY
PARK ROAD
LOOP OR SPUR
FARM OR RANCH ROAD
RECREATIONAL ROAD
HIGHWAYS NOT CONSTRUCTED
COUNTY SEAT
TOWN
ANNUAL AVERAGE DAILY TRAFFIC
INTERSTATE VOLUMES INCLUDE SERVICE ROADS WHERE APPLICABLE.
LIBERTY AREA
JASPER
KIRBYVILLE AREA
SILSBEE
CLEVELAND AREA
NEWTON
BURKEVILLE
MONT BELVIEU
TYLER
JASPER
NEWTON
LIBERTY
HARDIN
ORANGE
JEFFERSON
CHAMBERS
LOUISIANA
LOUISIANA
1993
DISTRICT HIGHWAY
TRAFFIC MAP
BEAUMONT DISTRICT
TEXAS
DEPARTMENT OF TRANSPORTATION
DIVISION OF TRANSPORTATION PLANNING
F&E D-10
U.S. DEPARTMENT OF TRANSPORTATION

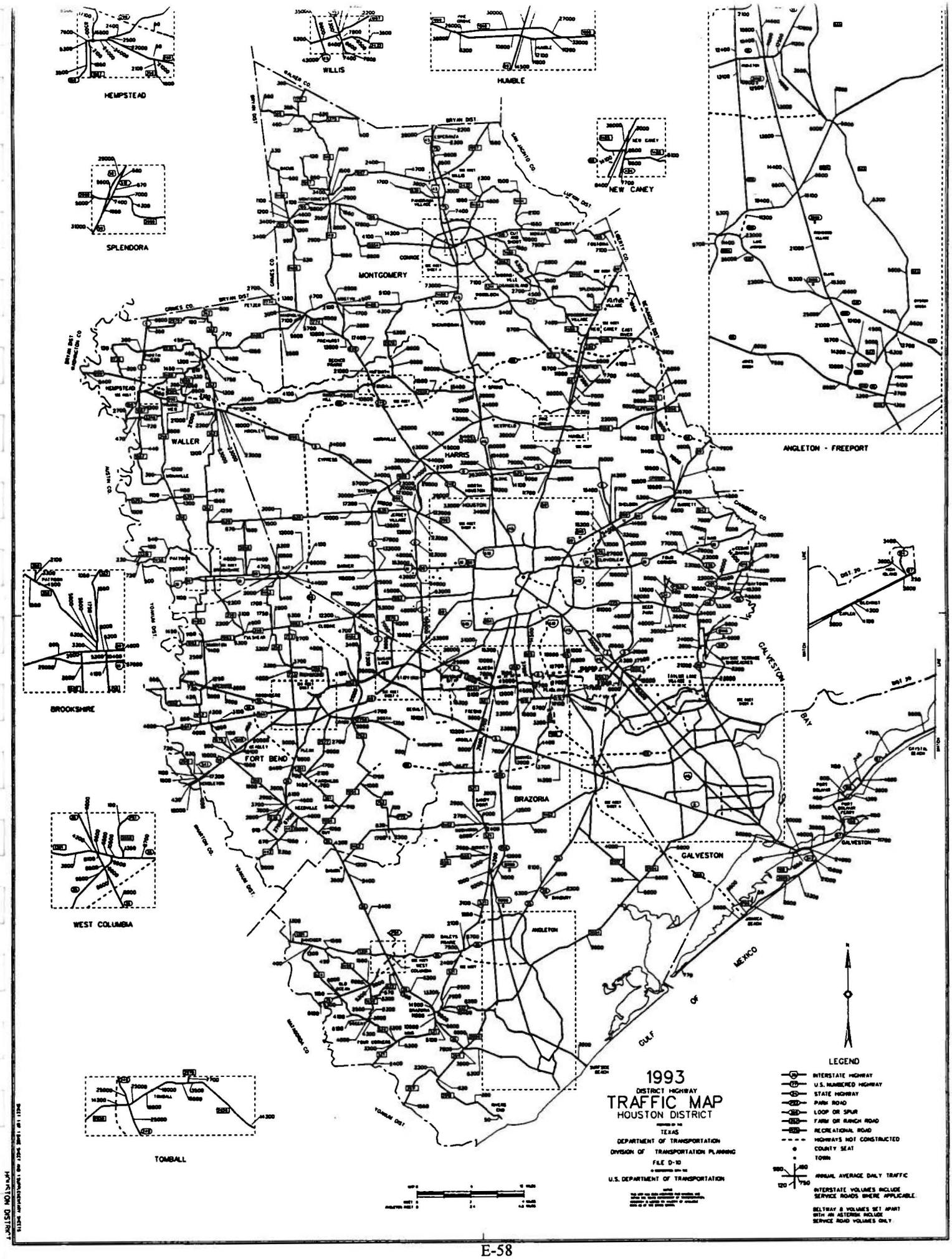
HEMPSTEAD
WILLIS
HUMBLE
NEW CANEY
SPLENDORA
MONTGOMERY
ANGLETON - FREEPORT
WALLER
HARRIS
BROOKSHIRE
FORT BEND
BRAZORIA
GALVESTON
WEST COLUMBIA
ANGLETON
TOMBALL
GULF OF MEXICO
1993
DISTRICT HIGHWAY
TRAFFIC MAP
HOUSTON DISTRICT
TEXAS
DEPARTMENT OF TRANSPORTATION
DIVISION OF TRANSPORTATION PLANNING
FILE D-10
U.S. DEPARTMENT OF TRANSPORTATION
LEGEND
INTERSTATE HIGHWAY
U.S. NUMBERED HIGHWAY
STATE HIGHWAY
PARK ROAD
LOOP OR SPUR
FARM OR RANCH ROAD
RECREATIONAL ROAD
HIGHWAYS NOT CONSTRUCTED
COUNTY SEAT
TOWN
ANNUAL AVERAGE DAILY TRAFFIC
INTERSTATE VOLUMES INCLUDE SERVICE ROADS WHERE APPLICABLE.
BELTWAY 8 VOLUMES SET APART WITH AN ASTERISK INCLUDE SERVICE ROAD VOLUMES ONLY
HOUSTON DISTRICT

Table 1

Recommended Maximum Fuel Weights by Dispersion Index and Distance from Downwind Smoke Sensitive Area

Special Understory Burning Conditions NOT in Effect

Dispersion Index	Miles from downwind smoke sensitive area																					
	<¾	¾	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	tons																					
<31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	12	17	23	29	35	40	45	50	55	59	63	67	70	73	76	79	81	83	85	86	88
32	0	24	34	46	58	70	81	91	100	109	118	126	133	140	147	152	158	162	166	170	173	175
33	0	36	51	70	88	105	121	136	151	164	177	189	200	210	220	229	236	243	249	255	259	263
34	0	49	68	93	117	139	161	181	201	219	236	252	267	281	293	305	315	324	332	339	345	350
35	0	61	85	116	146	174	201	227	251	274	295	315	334	351	367	381	394	405	416	424	432	438
36	0	73	102	139	175	209	242	272	301	328	354	378	400	421	440	457	473	486	499	509	518	525
37	0	85	119	163	204	244	282	318	351	383	413	441	467	491	513	533	551	568	582	594	604	613
38	0	97	136	186	234	279	322	363	402	438	472	504	534	561	586	609	630	649	665	679	691	700
39	0	109	153	209	263	314	362	408	452	493	531	567	600	631	660	686	709	730	748	764	777	788
40	0	122	170	232	292	349	403	454	502	547	590	630	667	702	733	762	788	811	831	849	863	875
41	0	134	187	256	321	384	443	499	552	602	649	693	734	772	806	838	866	892	914	933	950	963
42	0	146	204	279	350	418	483	544	602	657	708	756	801	842	880	914	945	973	997	1,018	1,036	1,050
43	0	158	221	302	380	453	523	590	653	712	767	819	867	912	953	990	1,024	1,054	1,080	1,103	1,122	1,138
44	0	170	238	325	409	488	564	635	703	766	826	882	934	982	1,026	1,066	1,103	1,135	1,163	1,188	1,209	1,225
45	0	182	255	349	438	523	604	681	753	821	885	945	1,001	1,052	1,100	1,143	1,181	1,216	1,247	1,273	1,295	1,313
46	0	194	272	372	467	558	644	726	803	876	944	1,008	1,068	1,122	1,173	1,219	1,260	1,297	1,330	1,358	1,381	1,400
47	0	207	289	395	496	593	684	771	853	931	1,003	1,071	1,134	1,193	1,246	1,295	1,339	1,378	1,413	1,443	1,467	1,488
48	0	219	306	418	526	628	725	817	904	985	1,062	1,134	1,201	1,263	1,319	1,371	1,418	1,459	1,496	1,527	1,554	1,575
49	0	231	323	442	555	662	765	862	954	1,040	1,121	1,197	1,268	1,333	1,393	1,447	1,496	1,540	1,579	1,612	1,640	1,663
50	0	243	340	465	584	697	805	907	1,004	1,095	1,180	1,260	1,334	1,403	1,466	1,523	1,575	1,621	1,662	1,697	1,726	1,750
51	0	255	357	488	613	732	845	953	1,054	1,150	1,239	1,323	1,401	1,473	1,539	1,600	1,654	1,703	1,745	1,782	1,813	1,838
52	0	267	374	511	642	767	886	998	1,104	1,204	1,298	1,386	1,468	1,543	1,613	1,676	1,733	1,784	1,828	1,867	1,899	1,925
53	0	280	391	535	671	802	926	1,043	1,155	1,259	1,357	1,449	1,535	1,613	1,686	1,752	1,812	1,865	1,911	1,952	1,985	2,013
54	0	292	408	558	701	837	966	1,089	1,205	1,314	1,416	1,512	1,601	1,684	1,759	1,828	1,890	1,946	1,994	2,036	2,072	2,100
55	0	304	425	581	730	872	1,006	1,134	1,255	1,369	1,475	1,575	1,668	1,754	1,833	1,904	1,969	2,027	2,078	2,121	2,158	2,188
56	0	316	442	604	759	907	1,047	1,180	1,305	1,423	1,534	1,638	1,735	1,824	1,906	1,980	2,048	2,108	2,161	2,206	2,244	2,275
57	0	328	459	628	788	941	1,087	1,225	1,355	1,478	1,594	1,701	1,801	1,894	1,979	2,057	2,127	2,189	2,244	2,291	2,331	2,363
58	0	340	476	651	817	976	1,127	1,270	1,406	1,533	1,653	1,764	1,868	1,964	2,052	2,133	2,205	2,270	2,327	2,376	2,417	2,450
59	0	353	493	674	847	1,011	1,167	1,316	1,456	1,588	1,712	1,827	1,935	2,034	2,126	2,209	2,284	2,351	2,410	2,461	2,503	2,538
60	0	365	510	697	876	1,046	1,208	1,361	1,506	1,642	1,771	1,890	2,002	2,105	2,199	2,285	2,363	2,432	2,493	2,546	2,590	2,625
61	0	377	527	721	905	1,081	1,248	1,406	1,556	1,697	1,830	1,953	2,068	2,175	2,272	2,361	2,442	2,513	2,576	2,630	2,676	2,713
62	0	389	544	744	934	1,116	1,288	1,452	1,606	1,752	1,889	2,016	2,135	2,245	2,346	2,437	2,520	2,594	2,659	2,715	2,762	2,800
63	0	401	561	767	963	1,151	1,328	1,497	1,657	1,807	1,948	2,079	2,202	2,315	2,419	2,514	2,599	2,675	2,742	2,800	2,849	2,888
64	0	413	578	790	993	1,185	1,369	1,542	1,707	1,861	2,007	2,142	2,268	2,385	2,492	2,590	2,678	2,756	2,825	2,885	2,935	2,975
65	0	425	595	814	1,022	1,220	1,409	1,588	1,757	1,916	2,066	2,205	2,335	2,455	2,566	2,666	2,757	2,838	2,909	2,970	3,021	3,063
66	0	438	612	837	1,051	1,255	1,449	1,633	1,807	1,971	2,125	2,268	2,402	2,525	2,639	2,742	2,835	2,919	2,992	3,055	3,108	3,150
67	0	450	629	860	1,080	1,290	1,489	1,679	1,857	2,026	2,184	2,331	2,469	2,596	2,712	2,818	2,914	3,000	3,075	3,140	3,194	3,238
68	0	462	646	883	1,109	1,325	1,530	1,724	1,908	2,080	2,243	2,394	2,535	2,666	2,785	2,895	2,993	3,081	3,158	3,224	3,280	3,326
69	0	474	663	907	1,139	1,360	1,570	1,769	1,958	2,135	2,302	2,457	2,602	2,736	2,859	2,971	3,072	3,162	3,241	3,309	3,367	3,413
70	0	486	681	930	1,168	1,395	1,610	1,815	2,008	2,190	2,361	2,520	2,669	2,806	2,932	3,047	3,150	3,243	3,324	3,394	3,453	3,501

Continued on next page

Table 1 Continued

Dispersion Index	<¼	¼	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Miles from downwind smoke sensitive area																					
	tons																					
71	0	498	698	953	1,197	1,429	1,651	1,860	2,058	2,245	2,420	2,583	2,736	2,876	3,005	3,123	3,229	3,324	3,407	3,479	3,539	3,588
72	0	511	715	976	1,226	1,464	1,691	1,905	2,108	2,299	2,479	2,646	2,802	2,946	3,079	3,199	3,308	3,405	3,490	3,564	3,626	3,676
73	0	523	732	999	1,255	1,499	1,731	1,951	2,159	2,354	2,538	2,709	2,869	3,016	3,152	3,275	3,387	3,486	3,573	3,649	3,712	3,763
74	0	535	749	1,023	1,285	1,534	1,771	1,996	2,209	2,409	2,597	2,772	2,936	3,087	3,225	3,352	3,466	3,567	3,657	3,734	3,798	3,851
75	0	547	766	1,046	1,314	1,569	1,812	2,042	2,259	2,464	2,656	2,835	3,002	3,157	3,299	3,428	3,544	3,648	3,740	3,818	3,885	3,938
76	0	559	783	1,069	1,343	1,604	1,852	2,087	2,309	2,518	2,715	2,898	3,069	3,227	3,372	3,504	3,623	3,729	3,823	3,903	3,971	4,026
77	0	571	800	1,092	1,372	1,639	1,892	2,132	2,359	2,573	2,774	2,961	3,136	3,297	3,445	3,580	3,702	3,810	3,906	3,988	4,057	4,113
78	0	583	817	1,116	1,401	1,674	1,932	2,178	2,409	2,628	2,833	3,024	3,203	3,367	3,518	3,656	3,781	3,891	3,989	4,073	4,144	4,201
79	0	596	834	1,139	1,431	1,708	1,973	2,223	2,460	2,683	2,892	3,087	3,269	3,437	3,592	3,732	3,859	3,973	4,072	4,158	4,230	4,288
80	0	608	851	1,162	1,460	1,743	2,013	2,268	2,510	2,737	2,951	3,150	3,336	3,508	3,665	3,809	3,938	4,054	4,155	4,243	4,316	4,376
81	0	620	868	1,185	1,489	1,778	2,053	2,314	2,560	2,792	3,010	3,213	3,403	3,578	3,738	3,885	4,017	4,135	4,238	4,328	4,402	4,463
82	0	632	885	1,209	1,518	1,813	2,093	2,359	2,610	2,847	3,069	3,277	3,469	3,648	3,812	3,961	4,096	4,216	4,321	4,412	4,489	4,551
83	0	644	902	1,232	1,547	1,848	2,134	2,404	2,660	2,902	3,128	3,340	3,536	3,718	3,885	4,037	4,174	4,297	4,404	4,497	4,575	4,638
84	0	656	919	1,255	1,577	1,883	2,174	2,450	2,711	2,956	3,187	3,403	3,603	3,788	3,958	4,113	4,253	4,378	4,488	4,582	4,661	4,726
85	0	669	936	1,278	1,606	1,918	2,214	2,495	2,761	3,011	3,246	3,466	3,670	3,858	4,032	4,189	4,332	4,459	4,571	4,667	4,748	4,813
86	0	681	953	1,302	1,635	1,952	2,254	2,541	2,811	3,066	3,305	3,529	3,736	3,928	4,105	4,266	4,411	4,540	4,654	4,752	4,834	4,901
87	0	693	970	1,325	1,664	1,987	2,295	2,586	2,861	3,121	3,364	3,592	3,803	3,999	4,178	4,342	4,489	4,621	4,737	4,837	4,920	4,988
88	0	705	987	1,348	1,693	2,022	2,335	2,631	2,911	3,175	3,423	3,655	3,870	4,069	4,251	4,418	4,568	4,702	4,820	4,921	5,007	5,076
89	0	717	1,004	1,371	1,722	2,057	2,375	2,677	2,962	3,230	3,482	3,718	3,937	4,139	4,325	4,494	4,647	4,783	4,903	5,006	5,093	5,163
90	0	729	1,021	1,395	1,752	2,092	2,415	2,722	3,012	3,285	3,541	3,781	4,003	4,209	4,398	4,570	4,726	4,864	4,986	5,091	5,179	5,251
91	0	741	1,038	1,418	1,781	2,127	2,456	2,767	3,062	3,340	3,600	3,844	4,070	4,279	4,471	4,646	4,804	4,945	5,069	5,176	5,266	5,338
92	0	754	1,055	1,441	1,810	2,162	2,496	2,813	3,112	3,394	3,659	3,907	4,137	4,349	4,545	4,723	4,883	5,027	5,152	5,261	5,352	5,426
93	0	766	1,072	1,464	1,839	2,197	2,536	2,858	3,162	3,449	3,718	3,970	4,203	4,420	4,618	4,799	4,962	5,108	5,235	5,346	5,438	5,513
94	0	778	1,089	1,488	1,868	2,231	2,576	2,903	3,213	3,504	3,777	4,033	4,270	4,490	4,691	4,875	5,041	5,189	5,319	5,431	5,525	5,601
95	0	790	1,106	1,511	1,898	2,266	2,617	2,949	3,263	3,559	3,836	4,096	4,337	4,560	4,765	4,951	5,120	5,270	5,402	5,515	5,611	5,688
96	0	802	1,123	1,534	1,927	2,301	2,657	2,994	3,313	3,613	3,895	4,159	4,404	4,630	4,838	5,027	5,198	5,351	5,485	5,600	5,697	5,776
97	0	814	1,140	1,557	1,956	2,336	2,697	3,040	3,363	3,668	3,954	4,222	4,470	4,700	4,911	5,104	5,277	5,432	5,568	5,685	5,784	5,863
98	0	827	1,157	1,581	1,985	2,371	2,737	3,085	3,413	3,723	4,013	4,285	4,537	4,770	4,984	5,180	5,356	5,513	5,651	5,770	5,870	5,951
99	0	839	1,174	1,604	2,014	2,406	2,778	3,130	3,464	3,778	4,072	4,348	4,604	4,840	5,058	5,256	5,435	5,594	5,734	5,855	5,956	6,038
100	0	851	1,191	1,627	2,044	2,441	2,818	3,176	3,514	3,832	4,131	4,411	4,670	4,911	5,131	5,332	5,513	5,675	5,817	5,940	6,043	6,126

Table 2

Recommended Maximum Fuel Weights by Dispersion Index and Distance from Downwind Smoke Sensitive Area

Special Understory Burning Conditions in Effect†

Dispersion Index	Miles from downwind smoke sensitive area																					
	<¼	¼	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	tons																					
<31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	12	17	23	29	35	40	45	50	55	59	63	67	70	73	76	79	81	83	85	86	88
32	0	24	34	46	58	70	81	91	100	109	118	126	133	140	147	152	158	162	166	170	173	175
33	0	36	51	70	88	105	121	136	151	164	177	189	200	210	220	229	236	243	249	255	259	263
34	0	49	68	93	117	139	169	200	221	241	260	277	294	309	323	335	347	357	366	373	380	385
35	0	61	85	116	146	174	221	272	301	328	354	378	400	421	440	457	473	486	499	509	518	525
36	0	73	102	139	175	209	278	354	392	427	460	491	520	547	572	594	614	632	648	662	673	683
37	0	85	119	163	204	244	338	445	492	537	578	617	654	687	718	746	772	795	814	832	846	858
38	0	97	136	186	234	279	403	544	602	657	708	756	801	842	880	914	945	973	997	1,018	1,036	1,050
39	0	109	153	209	263	314	471	653	723	788	850	907	961	1,010	1,056	1,097	1,134	1,167	1,197	1,222	1,243	1,260
40	0	122	170	232	292	349	543	771	853	931	1,003	1,071	1,134	1,193	1,246	1,295	1,339	1,378	1,413	1,443	1,467	1,488
41	0	134	187	256	321	384	620	898	994	1,084	1,169	1,248	1,321	1,389	1,451	1,508	1,559	1,605	1,645	1,680	1,709	1,733
42	0	146	204	279	350	418	700	1,034	1,145	1,248	1,346	1,437	1,521	1,599	1,671	1,737	1,796	1,848	1,895	1,935	1,968	1,995
43	0	158	221	302	380	453	785	1,180	1,305	1,423	1,534	1,638	1,735	1,824	1,906	1,980	2,048	2,108	2,161	2,206	2,244	2,275
44	0	170	238	325	409	488	845	1,270	1,406	1,533	1,653	1,764	1,868	1,964	2,052	2,133	2,205	2,270	2,327	2,376	2,417	2,450
45	0	182	255	349	438	523	906	1,361	1,506	1,642	1,771	1,890	2,002	2,105	2,199	2,285	2,363	2,432	2,493	2,546	2,590	2,625
46	0	194	272	372	467	558	966	1,452	1,606	1,752	1,889	2,016	2,135	2,245	2,346	2,437	2,520	2,594	2,659	2,715	2,762	2,800
47	0	207	289	395	496	593	1,027	1,542	1,707	1,861	2,007	2,142	2,268	2,385	2,492	2,590	2,678	2,756	2,825	2,885	2,935	2,975
48	0	219	306	418	526	628	1,087	1,633	1,807	1,971	2,125	2,268	2,402	2,525	2,639	2,742	2,835	2,919	2,992	3,055	3,108	3,150
49	0	231	323	442	555	662	1,147	1,724	1,908	2,080	2,243	2,394	2,535	2,666	2,785	2,895	2,993	3,081	3,158	3,224	3,280	3,326
50	0	243	340	465	584	697	1,208	1,815	2,008	2,190	2,361	2,520	2,669	2,806	2,932	3,047	3,150	3,243	3,324	3,394	3,453	3,501
51	0	255	357	488	613	732	1,268	1,905	2,108	2,299	2,479	2,646	2,802	2,946	3,079	3,199	3,308	3,405	3,490	3,564	3,626	3,676
52	0	267	374	511	642	767	1,328	1,996	2,209	2,409	2,597	2,772	2,936	3,087	3,225	3,352	3,466	3,567	3,657	3,734	3,798	3,851
53	0	280	391	535	671	802	1,389	2,087	2,309	2,518	2,715	2,898	3,069	3,227	3,372	3,504	3,623	3,729	3,823	3,903	3,971	4,026
54	0	292	408	558	701	837	1,449	2,178	2,409	2,628	2,833	3,024	3,203	3,367	3,518	3,656	3,781	3,891	3,989	4,073	4,144	4,201
55	0	304	425	581	730	872	1,510	2,268	2,510	2,737	2,951	3,150	3,336	3,508	3,665	3,809	3,938	4,054	4,155	4,243	4,316	4,376
56	0	316	442	604	759	907	1,570	2,359	2,610	2,847	3,069	3,277	3,469	3,648	3,812	3,961	4,096	4,216	4,321	4,412	4,489	4,551
57	0	328	459	628	788	941	1,630	2,450	2,711	2,956	3,187	3,403	3,603	3,788	3,958	4,113	4,253	4,378	4,488	4,582	4,661	4,726
58	0	340	476	651	817	976	1,691	2,541	2,811	3,066	3,305	3,529	3,736	3,928	4,105	4,266	4,411	4,540	4,654	4,752	4,834	4,901
59	0	353	493	674	847	1,011	1,751	2,631	2,911	3,175	3,423	3,655	3,870	4,069	4,251	4,418	4,568	4,702	4,820	4,921	5,007	5,076
60	0	365	510	697	876	1,046	1,812	2,722	3,012	3,285	3,541	3,781	4,003	4,209	4,398	4,570	4,726	4,864	4,986	5,091	5,179	5,251
61	0	377	527	721	905	1,081	1,872	2,813	3,112	3,394	3,659	3,907	4,137	4,349	4,545	4,723	4,883	5,027	5,152	5,261	5,352	5,426
62	0	389	544	744	934	1,116	1,932	2,903	3,213	3,504	3,777	4,033	4,270	4,490	4,691	4,875	5,041	5,189	5,319	5,431	5,525	5,601
63	0	401	561	767	963	1,151	1,993	2,994	3,313	3,613	3,895	4,159	4,404	4,630	4,838	5,027	5,198	5,351	5,485	5,600	5,697	5,776
64	0	413	578	790	993	1,185	2,053	3,085	3,413	3,723	4,013	4,285	4,537	4,770	4,984	5,180	5,356	5,513	5,651	5,770	5,870	5,951
65	0	425	595	814	1,022	1,220	2,113	3,176	3,514	3,832	4,131	4,411	4,670	4,911	5,131	5,332	5,513	5,675	5,817	5,940	6,043	6,126
66	0	438	612	837	1,051	1,255	2,174	3,266	3,614	3,942	4,249	4,537	4,804	5,051	5,278	5,484	5,671	5,837	5,983	6,109	6,215	6,301
67	0	450	629	860	1,080	1,290	2,234	3,357	3,715	4,051	4,367	4,663	4,937	5,191	5,424	5,637	5,828	5,999	6,150	6,279	6,388	6,476
68	0	462	646	883	1,109	1,325	2,295	3,448	3,815	4,161	4,485	4,789	5,071	5,331	5,571	5,789	5,986	6,162	6,316	6,449	6,561	6,651
69	0	474	663	907	1,139	1,360	2,355	3,539	3,915	4,270	4,603	4,915	5,204	5,472	5,718	5,941	6,143	6,324	6,482	6,619	6,733	6,826
70	0	486	681	930	1,168	1,395	2,415	3,629	4,016	4,380	4,722	5,041	5,338	5,612	5,864	6,094	6,301	6,486	6,648	6,788	6,906	7,001

Continued on next page

Table 2 Continued

Dispersion Index	<¼	¼	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Miles from downwind smoke sensitive area																					
	tons																					
71	0	498	698	953	1,197	1,429	2,476	3,720	4,116	4,489	4,840	5,167	5,471	5,752	6,011	6,246	6,459	6,648	6,814	6,958	7,079	7,176
72	0	511	715	976	1,226	1,464	2,536	3,811	4,217	4,599	4,958	5,293	5,605	5,893	6,157	6,398	6,616	6,810	6,981	7,128	7,251	7,351
73	0	523	732	999	1,255	1,499	2,597	3,902	4,317	4,708	5,076	5,419	5,738	6,033	6,304	6,551	6,774	6,972	7,147	7,297	7,424	7,526
74	0	535	749	1,023	1,285	1,534	2,657	3,992	4,417	4,818	5,194	5,545	5,871	6,173	6,451	6,703	6,931	7,134	7,313	7,467	7,596	7,701
75	0	547	766	1,046	1,314	1,569	2,717	4,083	4,518	4,927	5,312	5,671	6,005	6,314	6,597	6,855	7,089	7,297	7,479	7,637	7,769	7,876
76	0	559	783	1,069	1,343	1,604	2,778	4,174	4,618	5,037	5,430	5,797	6,138	6,454	6,744	7,008	7,246	7,459	7,645	7,806	7,942	8,051
77	0	571	800	1,092	1,372	1,639	2,838	4,265	4,719	5,146	5,548	5,923	6,272	6,594	6,890	7,160	7,404	7,621	7,812	7,976	8,114	8,226
78	0	583	817	1,116	1,401	1,674	2,898	4,355	4,819	5,256	5,666	6,049	6,405	6,734	7,037	7,312	7,561	7,783	7,978	8,146	8,287	8,401
79	0	596	834	1,139	1,431	1,708	2,959	4,446	4,919	5,365	5,784	6,175	6,539	6,875	7,184	7,465	7,719	7,945	8,144	8,316	8,460	8,576
80	0	608	851	1,162	1,460	1,743	3,019	4,537	5,020	5,475	5,902	6,301	6,672	7,015	7,330	7,617	7,876	8,107	8,310	8,485	8,632	8,751
81	0	620	868	1,185	1,489	1,778	3,080	4,627	5,120	5,584	6,020	6,427	6,805	7,155	7,477	7,770	8,034	8,269	8,476	8,655	8,805	8,926
82	0	632	885	1,209	1,518	1,813	3,140	4,718	5,221	5,694	6,138	6,553	6,939	7,296	7,623	7,922	8,191	8,432	8,643	8,825	8,978	9,101
83	0	644	902	1,232	1,547	1,848	3,200	4,809	5,321	5,803	6,256	6,679	7,072	7,436	7,770	8,074	8,349	8,594	8,809	8,994	9,150	9,276
84	0	656	919	1,255	1,577	1,883	3,261	4,900	5,421	5,913	6,374	6,805	7,206	7,576	7,917	8,227	8,506	8,756	8,975	9,164	9,323	9,451
85	0	669	936	1,278	1,606	1,918	3,321	4,990	5,522	6,022	6,492	6,931	7,339	7,717	8,063	8,379	8,664	8,918	9,141	9,334	9,496	9,626
86	0	681	953	1,302	1,635	1,952	3,382	5,081	5,622	6,132	6,610	7,057	7,473	7,857	8,210	8,531	8,821	9,080	9,308	9,504	9,668	9,802
87	0	693	970	1,325	1,664	1,987	3,442	5,172	5,723	6,241	6,728	7,183	7,606	7,997	8,356	8,684	8,979	9,242	9,474	9,673	9,841	9,977
88	0	705	987	1,348	1,693	2,022	3,502	5,263	5,823	6,351	6,846	7,309	7,740	8,138	8,503	8,836	9,136	9,404	9,640	9,843	10,014	10,152
89	0	717	1,004	1,371	1,722	2,057	3,563	5,353	5,923	6,460	6,964	7,435	7,873	8,278	8,650	8,988	9,294	9,567	9,806	10,013	10,186	10,327
90	0	729	1,021	1,395	1,752	2,092	3,623	5,444	6,024	6,570	7,082	7,561	8,006	8,418	8,796	9,141	9,451	9,729	9,972	10,182	10,359	10,502
91	0	741	1,038	1,418	1,781	2,127	3,683	5,535	6,124	6,679	7,200	7,687	8,140	8,558	8,943	9,293	9,609	9,891	10,139	10,352	10,531	10,677
92	0	754	1,055	1,441	1,810	2,162	3,744	5,626	6,225	6,789	7,318	7,813	8,273	8,699	9,089	9,445	9,767	10,053	10,305	10,522	10,704	10,852
93	0	766	1,072	1,464	1,839	2,197	3,804	5,716	6,325	6,898	7,436	7,939	8,407	8,839	9,236	9,598	9,924	10,215	10,471	10,692	10,877	11,027
94	0	778	1,089	1,488	1,868	2,231	3,865	5,807	6,425	7,008	7,554	8,065	8,540	8,979	9,383	9,750	10,082	10,377	10,637	10,861	11,049	11,202
95	0	790	1,106	1,511	1,898	2,266	3,925	5,898	6,526	7,117	7,672	8,191	8,674	9,120	9,529	9,902	10,239	10,539	10,803	11,031	11,222	11,377
96	0	802	1,123	1,534	1,927	2,301	3,985	5,988	6,626	7,227	7,791	8,317	8,807	9,260	9,676	10,055	10,397	10,702	10,970	11,201	11,395	11,552
97	0	814	1,140	1,557	1,956	2,336	4,046	6,079	6,727	7,336	7,909	8,443	8,941	9,400	9,822	10,207	10,554	10,864	11,136	11,370	11,567	11,727
98	0	827	1,157	1,581	1,985	2,371	4,106	6,170	6,827	7,446	8,027	8,569	9,074	9,541	9,969	10,359	10,712	11,026	11,302	11,540	11,740	11,902
99	0	839	1,174	1,604	2,014	2,406	4,167	6,261	6,927	7,555	8,145	8,695	9,207	9,681	10,116	10,512	10,869	11,188	11,468	11,710	11,913	12,077
100	0	851	1,191	1,627	2,044	2,441	4,227	6,351	7,028	7,665	8,263	8,821	9,341	9,821	10,262	10,664	11,027	11,350	11,634	11,879	12,085	12,252

† Table 2 can be used in place of Table 1 if any of the following techniques are used for understory burns.

- backing fires
- heading fires in three-year rough or less
- mass ignition where all lines are fired by 3:00 pm CDST and burned out by 5:00 pm (or 4:00 pm if Dispersion Index is less than 47 and forecasted nighttime Dispersion Index is less than 13.

Table 3

Recommended Maximum Fuel Weights by Ventilation Rate and Distance from Downwind Smoke Sensitive Area

*Special Understory Burning Conditions **NOT** in Effect*

Ventilation Rate	Miles from downwind smoke sensitive area																					
	<¼	¼	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	tons																					
<4,500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4,500	0	147	205	280	352	421	486	547	606	661	712	760	805	846	885	919	950	978	1,003	1,024	1,042	1,056
4,650	0	151	211	288	362	432	499	562	622	679	732	781	827	870	909	944	976	1,005	1,030	1,052	1,070	1,085
4,800	0	155	216	296	371	444	512	577	639	697	751	802	849	893	933	969	1,002	1,032	1,057	1,080	1,098	1,114
4,950	0	159	222	303	381	455	526	592	655	715	770	823	871	916	957	994	1,028	1,058	1,085	1,108	1,127	1,142
5,100	0	163	228	311	391	467	539	607	672	733	790	843	893	939	981	1,019	1,054	1,085	1,112	1,136	1,155	1,171
5,250	0	167	233	319	400	478	552	622	688	751	809	864	915	962	1,005	1,044	1,080	1,112	1,140	1,164	1,184	1,200
5,400	0	171	239	326	410	490	565	637	705	769	829	885	937	985	1,029	1,070	1,106	1,138	1,167	1,191	1,212	1,229
5,550	0	175	244	334	420	501	578	652	721	787	848	905	959	1,008	1,053	1,095	1,132	1,165	1,194	1,219	1,240	1,258
5,700	0	179	250	342	429	513	592	667	738	805	868	926	981	1,031	1,077	1,120	1,158	1,192	1,222	1,247	1,269	1,286
5,850	0	183	256	349	439	524	605	682	754	823	887	947	1,003	1,054	1,102	1,145	1,184	1,218	1,249	1,275	1,297	1,315
6,000	0	187	261	357	448	535	618	697	771	841	906	968	1,025	1,077	1,126	1,170	1,210	1,245	1,276	1,303	1,326	1,344
6,150	0	191	267	365	458	547	631	712	787	859	926	988	1,047	1,100	1,150	1,195	1,236	1,272	1,304	1,331	1,354	1,373
6,300	0	195	272	372	468	558	645	727	804	877	945	1,009	1,069	1,124	1,174	1,220	1,261	1,298	1,331	1,359	1,383	1,402
6,450	0	199	278	380	477	570	658	742	820	895	965	1,030	1,091	1,147	1,198	1,245	1,287	1,325	1,358	1,387	1,411	1,430
6,600	0	203	284	388	487	581	671	756	837	913	984	1,051	1,112	1,170	1,222	1,270	1,313	1,352	1,386	1,415	1,439	1,459
6,750	0	207	289	395	496	593	684	771	854	931	1,004	1,071	1,134	1,193	1,246	1,295	1,339	1,378	1,413	1,443	1,468	1,488
6,900	0	211	295	403	506	604	698	786	870	949	1,023	1,092	1,156	1,216	1,270	1,320	1,365	1,405	1,440	1,471	1,496	1,517
7,050	0	215	300	411	516	616	711	801	887	967	1,042	1,113	1,178	1,239	1,295	1,345	1,391	1,432	1,468	1,499	1,525	1,546
7,200	0	219	306	418	525	627	724	816	903	985	1,062	1,134	1,200	1,262	1,319	1,370	1,417	1,459	1,495	1,527	1,553	1,574
7,350	0	223	312	426	535	639	737	831	920	1,003	1,081	1,154	1,222	1,285	1,343	1,395	1,443	1,485	1,522	1,554	1,581	1,603
7,500	0	227	317	433	544	650	751	846	936	1,021	1,101	1,175	1,244	1,308	1,367	1,420	1,469	1,512	1,550	1,582	1,610	1,632
7,650	0	231	323	441	554	662	764	861	953	1,039	1,120	1,196	1,266	1,331	1,391	1,446	1,495	1,539	1,577	1,610	1,638	1,661
7,800	0	235	328	449	564	673	777	876	969	1,057	1,139	1,217	1,288	1,354	1,415	1,471	1,521	1,565	1,604	1,638	1,667	1,690
7,950	0	239	334	456	573	685	790	891	986	1,075	1,159	1,237	1,310	1,377	1,439	1,496	1,547	1,592	1,632	1,666	1,695	1,718
8,100	0	243	340	464	583	696	804	906	1,002	1,093	1,178	1,258	1,332	1,401	1,463	1,521	1,572	1,619	1,659	1,694	1,723	1,747
8,250	0	247	345	472	592	708	817	921	1,019	1,111	1,198	1,279	1,354	1,424	1,488	1,546	1,598	1,645	1,686	1,722	1,752	1,776
8,400	0	251	351	479	602	719	830	936	1,035	1,129	1,217	1,299	1,376	1,447	1,512	1,571	1,624	1,672	1,714	1,750	1,780	1,805
8,550	0	255	356	487	612	731	843	951	1,052	1,147	1,237	1,320	1,398	1,470	1,536	1,596	1,650	1,699	1,741	1,778	1,809	1,834
8,700	0	259	362	495	621	742	857	965	1,068	1,165	1,256	1,341	1,420	1,493	1,560	1,621	1,676	1,725	1,769	1,806	1,837	1,862
8,850	0	263	368	502	631	753	870	980	1,085	1,183	1,275	1,362	1,442	1,516	1,584	1,646	1,702	1,752	1,796	1,834	1,865	1,891
9,000	0	267	373	510	641	765	883	995	1,101	1,201	1,295	1,382	1,464	1,539	1,608	1,671	1,728	1,779	1,823	1,862	1,894	1,920
9,150	0	271	379	518	650	776	896	1,010	1,118	1,219	1,314	1,403	1,486	1,562	1,632	1,696	1,754	1,805	1,851	1,890	1,922	1,949
9,300	0	275	384	525	660	788	910	1,025	1,134	1,237	1,334	1,424	1,508	1,585	1,656	1,721	1,780	1,832	1,878	1,917	1,951	1,978
9,450	0	279	390	533	669	799	923	1,040	1,151	1,255	1,353	1,445	1,530	1,608	1,681	1,746	1,806	1,859	1,905	1,945	1,979	2,006
9,600	0	283	396	541	679	811	936	1,055	1,167	1,273	1,373	1,465	1,552	1,631	1,705	1,771	1,832	1,885	1,933	1,973	2,008	2,035
9,750	0	287	401	548	689	822	949	1,070	1,184	1,291	1,392	1,486	1,574	1,655	1,729	1,797	1,858	1,912	1,960	2,001	2,036	2,064
9,900	0	291	407	556	698	834	963	1,085	1,200	1,309	1,411	1,507	1,596	1,678	1,753	1,822	1,884	1,939	1,987	2,029	2,064	2,093

Continued on next page

Table 3 Continued

Ventilation Rate	<¼	¼	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Miles from downwind smoke sensitive area																					
	tons																					
10,050	0	295	412	563	708	845	976	1,100	1,217	1,327	1,431	1,528	1,618	1,701	1,777	1,847	1,909	1,965	2,015	2,057	2,093	2,122
10,200	0	299	418	571	717	857	989	1,115	1,233	1,345	1,450	1,548	1,639	1,724	1,801	1,872	1,935	1,992	2,042	2,085	2,121	2,150
10,350	0	303	424	579	727	868	1,002	1,130	1,250	1,363	1,470	1,569	1,661	1,747	1,825	1,897	1,961	2,019	2,069	2,113	2,150	2,179
10,500	0	307	429	586	737	880	1,016	1,145	1,267	1,381	1,489	1,590	1,683	1,770	1,849	1,922	1,987	2,045	2,097	2,141	2,178	2,208
10,650	0	311	435	594	746	891	1,029	1,160	1,283	1,399	1,508	1,610	1,705	1,793	1,874	1,947	2,013	2,072	2,124	2,169	2,206	2,237
10,800	0	315	440	602	756	903	1,042	1,174	1,300	1,417	1,528	1,631	1,727	1,816	1,898	1,972	2,039	2,099	2,151	2,197	2,235	2,266
10,950	0	319	446	609	765	914	1,055	1,189	1,316	1,435	1,547	1,652	1,749	1,839	1,922	1,997	2,065	2,126	2,179	2,225	2,263	2,294
11,100	0	323	452	617	775	926	1,069	1,204	1,333	1,453	1,567	1,673	1,771	1,862	1,946	2,022	2,091	2,152	2,206	2,253	2,292	2,323
11,250	0	327	457	625	785	937	1,082	1,219	1,349	1,471	1,586	1,693	1,793	1,885	1,970	2,047	2,117	2,179	2,233	2,280	2,320	2,352
11,400	0	331	463	632	794	949	1,095	1,234	1,366	1,489	1,606	1,714	1,815	1,908	1,994	2,072	2,143	2,206	2,261	2,308	2,348	2,381
11,550	0	335	468	640	803	960	1,108	1,249	1,382	1,507	1,624	1,734	1,836	1,931	2,017	2,096	2,168	2,231	2,287	2,335	2,376	2,409
11,700	0	338	473	647	812	970	1,120	1,262	1,396	1,523	1,642	1,753	1,856	1,951	2,039	2,119	2,191	2,255	2,312	2,360	2,401	2,434
11,850	0	342	478	653	821	980	1,132	1,275	1,411	1,539	1,659	1,771	1,876	1,972	2,060	2,141	2,214	2,279	2,336	2,385	2,427	2,460
12,000	0	345	483	660	829	990	1,143	1,289	1,426	1,555	1,676	1,790	1,895	1,993	2,082	2,164	2,237	2,303	2,360	2,410	2,452	2,486
12,150	0	349	488	667	838	1,001	1,155	1,302	1,441	1,571	1,694	1,808	1,915	2,013	2,104	2,186	2,260	2,327	2,385	2,435	2,477	2,511
12,300	0	352	493	674	846	1,011	1,167	1,315	1,455	1,587	1,711	1,827	1,934	2,034	2,125	2,208	2,283	2,350	2,409	2,460	2,503	2,537
12,450	0	356	498	681	855	1,021	1,179	1,329	1,470	1,603	1,728	1,845	1,954	2,054	2,147	2,231	2,307	2,374	2,434	2,485	2,528	2,563
12,600	0	360	503	688	864	1,031	1,191	1,342	1,485	1,619	1,746	1,864	1,974	2,075	2,168	2,253	2,330	2,398	2,458	2,510	2,553	2,589
12,750	0	363	508	694	872	1,042	1,203	1,355	1,500	1,635	1,763	1,882	1,993	2,096	2,190	2,275	2,353	2,422	2,483	2,535	2,579	2,614
12,900	0	367	513	701	881	1,052	1,214	1,369	1,514	1,652	1,780	1,901	2,013	2,116	2,211	2,298	2,376	2,446	2,507	2,560	2,604	2,640
13,050	0	370	518	708	889	1,062	1,226	1,382	1,529	1,668	1,798	1,919	2,032	2,137	2,233	2,320	2,399	2,470	2,531	2,585	2,629	2,666
13,200	0	374	523	715	898	1,072	1,238	1,395	1,544	1,684	1,815	1,938	2,052	2,157	2,254	2,343	2,422	2,493	2,556	2,610	2,655	2,691
13,350	0	377	528	722	906	1,083	1,250	1,409	1,559	1,700	1,832	1,956	2,072	2,178	2,276	2,365	2,445	2,517	2,580	2,635	2,680	2,717
13,500	0	381	533	729	915	1,093	1,262	1,422	1,573	1,716	1,850	1,975	2,091	2,199	2,297	2,387	2,469	2,541	2,605	2,659	2,706	2,743
13,650	0	385	538	735	924	1,103	1,274	1,435	1,588	1,732	1,867	1,993	2,111	2,219	2,319	2,410	2,492	2,565	2,629	2,684	2,731	2,769
13,800	0	388	543	742	932	1,113	1,285	1,449	1,603	1,748	1,884	2,012	2,130	2,240	2,340	2,432	2,515	2,589	2,653	2,709	2,756	2,794
13,950	0	392	548	749	941	1,123	1,297	1,462	1,618	1,764	1,902	2,030	2,150	2,261	2,362	2,455	2,538	2,612	2,678	2,734	2,782	2,820
14,100	0	395	553	756	949	1,134	1,309	1,475	1,632	1,780	1,919	2,049	2,170	2,281	2,384	2,477	2,561	2,636	2,702	2,759	2,807	2,846
14,250	0	399	558	763	958	1,144	1,321	1,489	1,647	1,796	1,936	2,067	2,189	2,302	2,405	2,499	2,584	2,660	2,727	2,784	2,832	2,871
14,400	0	402	563	769	966	1,154	1,333	1,502	1,662	1,812	1,954	2,086	2,209	2,322	2,427	2,522	2,607	2,684	2,751	2,809	2,858	2,897
14,550	0	406	568	776	975	1,164	1,345	1,515	1,677	1,829	1,971	2,104	2,228	2,343	2,448	2,544	2,631	2,708	2,776	2,834	2,883	2,923
14,700	0	410	573	783	984	1,175	1,356	1,529	1,691	1,845	1,989	2,123	2,248	2,364	2,470	2,566	2,654	2,732	2,800	2,859	2,908	2,949
14,850	0	413	578	790	992	1,185	1,368	1,542	1,706	1,861	2,006	2,141	2,268	2,384	2,491	2,589	2,677	2,755	2,824	2,884	2,934	2,974
15,000	0	417	583	797	1,001	1,195	1,380	1,555	1,721	1,877	2,023	2,160	2,287	2,405	2,513	2,611	2,700	2,779	2,849	2,909	2,959	3,000
>15,000	0	417	583	797	1,001	1,195	1,380	1,555	1,721	1,877	2,023	2,160	2,287	2,405	2,513	2,611	2,700	2,779	2,849	2,909	2,959	3,000

Table 4

Recommended Maximum Fuel Weights by Ventilation Rate and Distance from Downwind Smoke Sensitive Area

Special Understory Burning Conditions in Effect†

Ventilation Rate	Miles from downwind smoke sensitive area																					
	<¼	¼	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	tons																					
<4,500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4,500	0	147	205	280	352	421	486	547	606	661	712	760	805	846	885	919	950	978	1,003	1,024	1,042	1,056
4,650	0	151	211	288	362	432	499	562	622	679	732	781	827	870	909	944	976	1,005	1,030	1,052	1,070	1,085
4,800	0	155	216	296	371	444	512	577	639	697	751	802	849	893	933	969	1,002	1,032	1,057	1,080	1,098	1,114
4,950	0	159	222	303	381	455	526	592	655	715	770	823	871	916	957	994	1,028	1,058	1,085	1,108	1,127	1,142
5,100	0	163	228	311	391	467	552	638	705	769	829	885	938	986	1,030	1,070	1,107	1,139	1,168	1,192	1,213	1,230
5,250	0	167	233	319	400	478	587	700	774	845	910	972	1,029	1,082	1,131	1,175	1,215	1,251	1,282	1,309	1,332	1,350
5,400	0	171	239	326	410	490	622	764	846	922	994	1,062	1,124	1,182	1,235	1,283	1,327	1,366	1,400	1,430	1,455	1,475
5,550	0	175	244	334	420	501	658	831	920	1,003	1,081	1,154	1,222	1,285	1,343	1,396	1,443	1,485	1,523	1,555	1,582	1,603
5,700	0	179	250	342	429	513	695	900	996	1,086	1,171	1,250	1,324	1,392	1,455	1,512	1,563	1,609	1,649	1,684	1,713	1,737
5,850	0	183	256	349	439	524	734	972	1,075	1,172	1,264	1,349	1,429	1,502	1,570	1,631	1,687	1,736	1,780	1,817	1,849	1,874
6,000	0	187	261	357	448	535	773	1,045	1,156	1,261	1,360	1,452	1,537	1,616	1,689	1,755	1,814	1,868	1,914	1,955	1,989	2,016
6,150	0	191	267	365	458	547	813	1,121	1,240	1,353	1,458	1,557	1,648	1,733	1,811	1,882	1,946	2,003	2,053	2,096	2,133	2,162
6,300	0	195	272	372	468	558	854	1,199	1,327	1,447	1,560	1,665	1,763	1,854	1,937	2,013	2,081	2,142	2,196	2,242	2,281	2,313
6,450	0	199	278	380	477	570	897	1,279	1,415	1,544	1,664	1,777	1,881	1,978	2,067	2,148	2,221	2,286	2,343	2,392	2,434	2,467
6,600	0	203	284	388	487	581	940	1,362	1,507	1,643	1,771	1,891	2,002	2,105	2,200	2,286	2,364	2,433	2,494	2,547	2,591	2,627
6,750	0	207	289	395	496	593	984	1,446	1,600	1,745	1,882	2,009	2,127	2,236	2,337	2,428	2,511	2,585	2,649	2,705	2,752	2,790
6,900	0	211	295	403	506	604	1,029	1,533	1,697	1,850	1,995	2,130	2,255	2,371	2,477	2,574	2,662	2,740	2,809	2,868	2,918	2,958
7,050	0	215	300	411	516	616	1,066	1,602	1,773	1,934	2,085	2,226	2,357	2,478	2,589	2,691	2,782	2,864	2,935	2,997	3,049	3,091
7,200	0	219	306	418	525	627	1,086	1,632	1,806	1,970	2,124	2,267	2,401	2,524	2,637	2,741	2,834	2,917	2,990	3,053	3,106	3,149
7,350	0	223	312	426	535	639	1,106	1,662	1,839	2,006	2,162	2,309	2,445	2,570	2,686	2,791	2,886	2,970	3,045	3,109	3,163	3,206
7,500	0	227	317	433	544	650	1,126	1,692	1,872	2,042	2,201	2,350	2,488	2,616	2,734	2,841	2,938	3,024	3,099	3,165	3,220	3,264
7,650	0	231	323	441	554	662	1,146	1,722	1,905	2,078	2,240	2,392	2,532	2,663	2,782	2,891	2,989	3,077	3,154	3,221	3,276	3,322
7,800	0	235	328	449	564	673	1,166	1,752	1,938	2,114	2,279	2,433	2,576	2,709	2,830	2,941	3,041	3,130	3,209	3,276	3,333	3,379
7,950	0	239	334	456	573	685	1,186	1,782	1,971	2,150	2,318	2,474	2,620	2,755	2,879	2,991	3,093	3,184	3,264	3,332	3,390	3,437
8,100	0	243	340	464	583	696	1,206	1,811	2,004	2,186	2,357	2,516	2,664	2,801	2,927	3,042	3,145	3,237	3,318	3,388	3,447	3,494
8,250	0	247	345	472	592	708	1,225	1,841	2,037	2,222	2,395	2,557	2,708	2,847	2,975	3,092	3,197	3,291	3,373	3,444	3,504	3,552
8,400	0	251	351	479	602	719	1,245	1,871	2,070	2,258	2,434	2,599	2,752	2,893	3,023	3,142	3,249	3,344	3,428	3,500	3,561	3,610
8,550	0	255	356	487	612	731	1,265	1,901	2,104	2,294	2,473	2,640	2,796	2,940	3,072	3,192	3,300	3,397	3,482	3,556	3,617	3,667
8,700	0	259	362	495	621	742	1,285	1,931	2,137	2,330	2,512	2,682	2,840	2,986	3,120	3,242	3,352	3,451	3,537	3,612	3,674	3,725
8,850	0	263	368	502	631	753	1,305	1,961	2,170	2,366	2,551	2,723	2,884	3,032	3,168	3,292	3,404	3,504	3,592	3,667	3,731	3,782
9,000	0	267	373	510	641	765	1,325	1,991	2,203	2,402	2,590	2,765	2,928	3,078	3,216	3,342	3,456	3,557	3,646	3,723	3,788	3,840
9,150	0	271	379	518	650	776	1,345	2,021	2,236	2,438	2,629	2,806	2,972	3,124	3,265	3,392	3,508	3,611	3,701	3,779	3,845	3,898
9,300	0	275	384	525	660	788	1,365	2,050	2,269	2,474	2,667	2,848	3,015	3,170	3,313	3,443	3,560	3,664	3,756	3,835	3,901	3,955
9,450	0	279	390	533	669	799	1,384	2,080	2,302	2,510	2,706	2,889	3,059	3,217	3,361	3,493	3,612	3,717	3,811	3,891	3,958	4,013
9,600	0	283	396	541	679	811	1,404	2,110	2,335	2,546	2,745	2,931	3,103	3,263	3,409	3,543	3,663	3,771	3,865	3,947	4,015	4,070
9,750	0	287	401	548	689	822	1,424	2,140	2,368	2,582	2,784	2,972	3,147	3,309	3,458	3,593	3,715	3,824	3,920	4,003	4,072	4,128
9,900	0	291	407	556	698	834	1,444	2,170	2,401	2,619	2,823	3,014	3,191	3,355	3,506	3,643	3,767	3,878	3,975	4,058	4,129	4,186

Continued on next page

Table 4 Continued

Ventilation Rate	Miles from downwind smoke sensitive area																					
	<¼	¼	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	tons																					
10,050	0	295	412	563	708	845	1,464	2,200	2,434	2,655	2,862	3,055	3,235	3,401	3,554	3,693	3,819	3,931	4,029	4,114	4,185	4,243
10,200	0	299	418	571	717	857	1,484	2,230	2,467	2,691	2,900	3,097	3,279	3,448	3,602	3,743	3,871	3,984	4,084	4,170	4,242	4,301
10,350	0	303	424	579	727	868	1,504	2,259	2,500	2,727	2,939	3,138	3,323	3,494	3,651	3,794	3,923	4,038	4,139	4,226	4,299	4,358
10,500	0	307	429	586	737	880	1,524	2,289	2,533	2,763	2,978	3,180	3,367	3,540	3,699	3,844	3,974	4,091	4,193	4,282	4,356	4,416
10,650	0	311	435	594	746	891	1,543	2,319	2,566	2,799	3,017	3,221	3,411	3,586	3,747	3,894	4,026	4,144	4,248	4,338	4,413	4,474
10,800	0	315	440	602	756	903	1,563	2,349	2,599	2,835	3,056	3,262	3,455	3,632	3,795	3,944	4,078	4,198	4,303	4,393	4,470	4,531
10,950	0	319	446	609	765	914	1,583	2,379	2,632	2,871	3,095	3,304	3,499	3,678	3,844	3,994	4,130	4,251	4,358	4,449	4,526	4,589
11,100	0	323	452	617	775	926	1,603	2,409	2,665	2,907	3,134	3,345	3,542	3,725	3,892	4,044	4,182	4,304	4,412	4,505	4,583	4,646
11,250	0	327	457	625	785	937	1,623	2,439	2,698	2,943	3,172	3,387	3,586	3,771	3,940	4,094	4,234	4,358	4,467	4,561	4,640	4,704
11,400	0	331	463	632	794	949	1,643	2,468	2,731	2,979	3,211	3,428	3,630	3,817	3,988	4,144	4,285	4,411	4,522	4,617	4,697	4,762
11,550	0	335	468	640	803	960	1,662	2,497	2,763	3,014	3,249	3,468	3,673	3,861	4,035	4,193	4,335	4,463	4,574	4,671	4,752	4,817
11,700	0	338	473	647	812	970	1,680	2,524	2,793	3,046	3,283	3,505	3,712	3,903	4,078	4,238	4,382	4,510	4,623	4,721	4,802	4,869
11,850	0	342	478	653	821	980	1,697	2,551	2,822	3,078	3,318	3,542	3,751	3,944	4,121	4,282	4,428	4,558	4,672	4,770	4,853	4,920
12,000	0	345	483	660	829	990	1,715	2,577	2,852	3,110	3,353	3,579	3,790	3,985	4,164	4,327	4,474	4,606	4,721	4,820	4,904	4,971
12,150	0	349	488	667	838	1,001	1,733	2,604	2,881	3,142	3,387	3,616	3,829	4,026	4,207	4,372	4,521	4,653	4,770	4,870	4,955	5,023
12,300	0	352	493	674	846	1,011	1,751	2,631	2,911	3,174	3,422	3,653	3,869	4,068	4,250	4,417	4,567	4,701	4,819	4,920	5,005	5,074
12,450	0	356	498	681	855	1,021	1,768	2,657	2,940	3,207	3,457	3,691	3,908	4,109	4,293	4,461	4,613	4,748	4,867	4,970	5,056	5,126
12,600	0	360	503	688	864	1,031	1,786	2,684	2,970	3,239	3,491	3,728	3,947	4,150	4,336	4,506	4,659	4,796	4,916	5,020	5,107	5,177
12,750	0	363	508	694	872	1,042	1,804	2,710	2,999	3,271	3,526	3,765	3,986	4,191	4,379	4,551	4,706	4,844	4,965	5,070	5,157	5,229
12,900	0	367	513	701	881	1,052	1,822	2,737	3,029	3,303	3,561	3,802	4,025	4,232	4,423	4,596	4,752	4,891	5,014	5,119	5,208	5,280
13,050	0	370	518	708	889	1,062	1,839	2,764	3,058	3,335	3,596	3,839	4,065	4,274	4,466	4,640	4,798	4,939	5,063	5,169	5,259	5,331
13,200	0	374	523	715	898	1,072	1,857	2,790	3,088	3,368	3,630	3,876	4,104	4,315	4,509	4,685	4,845	4,987	5,112	5,219	5,310	5,383
13,350	0	377	528	722	906	1,083	1,875	2,817	3,117	3,400	3,665	3,913	4,143	4,356	4,552	4,730	4,891	5,034	5,160	5,269	5,360	5,434
13,500	0	381	533	729	915	1,093	1,893	2,844	3,147	3,432	3,700	3,950	4,182	4,397	4,595	4,775	4,937	5,082	5,209	5,319	5,411	5,486
13,650	0	385	538	735	924	1,103	1,910	2,870	3,176	3,464	3,734	3,987	4,222	4,439	4,638	4,820	4,983	5,130	5,258	5,369	5,462	5,537
13,800	0	388	543	742	932	1,113	1,928	2,897	3,206	3,496	3,769	4,024	4,261	4,480	4,681	4,864	5,030	5,177	5,307	5,419	5,513	5,589
13,950	0	392	548	749	941	1,123	1,946	2,924	3,235	3,528	3,804	4,061	4,300	4,521	4,724	4,909	5,076	5,225	5,356	5,469	5,563	5,640
14,100	0	395	553	756	949	1,134	1,964	2,950	3,265	3,561	3,838	4,098	4,339	4,562	4,767	4,954	5,122	5,273	5,405	5,518	5,614	5,691
14,250	0	399	558	763	958	1,144	1,981	2,977	3,294	3,593	3,873	4,135	4,378	4,603	4,810	4,999	5,169	5,320	5,453	5,568	5,665	5,743
14,400	0	402	563	769	966	1,154	1,999	3,004	3,324	3,625	3,908	4,172	4,418	4,645	4,853	5,043	5,215	5,368	5,502	5,618	5,715	5,794
14,550	0	406	568	776	975	1,164	2,017	3,030	3,353	3,657	3,942	4,209	4,457	4,686	4,896	5,088	5,261	5,415	5,551	5,668	5,766	5,846
14,700	0	410	573	783	984	1,175	2,035	3,057	3,383	3,689	3,977	4,246	4,496	4,727	4,939	5,133	5,307	5,463	5,600	5,718	5,817	5,897
14,850	0	413	578	790	992	1,185	2,052	3,084	3,412	3,721	4,012	4,283	4,535	4,768	4,983	5,178	5,354	5,511	5,649	5,768	5,868	5,949
>15,000	0	417	583	797	1,001	1,195	2,070	3,110	3,442	3,754	4,046	4,320	4,574	4,810	5,026	5,222	5,400	5,558	5,698	5,818	5,918	6,000

† Table 4 can be used in place of Table 3 if any of the following techniques are used for understory burns.

- backing fires
- heading fires in three-year rough or less
- mass ignition where all lines are fired by 3:00 pm CDST and burned out by 5:00 pm (or 4:00 pm if forecasted nighttime dispersion is poor or very poor)