Appendix J
Emission Factors & Calculations

The table below was developed using vegetation type and loading or quantity, and emission factors. The Air Quality Bureau (AQB) used emission factors from EPA (AP-42) and from research done at the Pacific Northwest Research Station of the USDA Forest Service (C.C. Hardy et al.) to develop the table. Additional tables that list these emission factors are included below. As science improvements are made, the best available emission factors will be used in the New Mexico Smoke Management Program.

NM SMP Acreage/Emissions Conversion Table		
Vegetation Type	**One Ton PM_{10}**	
Field Crops	65	Acres
Shrub land	34	Acres
Forest	23	Acres
Grass	100	Acres
Piled material	5000	Cubic feet

Table J.1. Method to determine, by general vegetation type, what acreage or pile volume produces one ton of PM_{10}.

Emission factors have been developed for certain vegetation (fuel) types and represent the mass of pollutant (particulate matter) produced per mass of fuel consumed. Emission factors are different for various fuel types, and are also different for different phases of combustion. Generally, the flaming phase of combustion produces fewer emissions than the smoldering phase. Accordingly, the emission factor for the flaming phase is of a lesser value than that for the smoldering phase. Emission factors allow the calculation of emissions in pounds of pollutant, if vegetation type and loading is known.

Emissions are determined for a particular vegetation or fuel type by multiplying acres burned times fuel loading in tons per acre by percent consumption times the emission factor for that fuel type. Thus, the standard algorithm for estimating emissions is:

Acres x tons per acre x percent consumption x pound per ton = pounds of pollutant

Where: Acres = the area of the burn project
Tons per acre = the fuel loading of the burn project
Percent Consumption = the amount of vegetation actually consumed
Pound per Ton = the emission factor
Pounds of Pollutant = emissions produced

For example: 100 acres x 10 tons/ac x 0.5 (50%) x 22 lbs/ton = 11,000 lbs or 5.5 tons.

For Emission Factors, see the tables on the following pages.

Emission factors for Prescribed fire

		$PM_{2.5}$ (lb/ton)	PM_{10} (lb/ton)	TSP (lb/ton)	CO (lb/ton)
BROADCAST SLASH					
hardwood					
	flaming	12	14	26	88
	smoldering	26	28	40	292
	fire-average	22	24	36	224
CONIFER-short needle					
	flaming	14	16	24	144
	smoldering	28	30	38	452
	fire-average	24	26	34	350
long needle (pine)					
	flaming	12	12	18	90
	smoldering	32	34	50	332
	fire-average	26	26	40	252
LOGGING SLASH, DOZER PILED CONIFER					
no mineral soil					
	flaming	8	8	10	56
	smoldering	12	14	28	232
	fire-average	8	8	12	74
10-30% mineral soil					
	flaming	NA	NA	NA	NA
	smoldering	nd	nd	50	400
	fire-average	NA	NA	NA	NA
25% organic soil					
	flaming	NA	NA	NA	NA
	smoldering	nd	nd	70	500
	fire-average	NA	NA	NA	NA
RANGE FIRE					
juniper slash					
	flaming	14	16	22	82
	smoldering	24	26	36	250
	fire-average	18	20	28	164
sagebrush					
	flaming	30	32	46	156
	smoldering	26	30	46	212
	fire-average	26	30	46	206
chaparral shrub					
	flaming	14	16	32	112
	smoldering	24	26	46	266
	fire-average	20	22	40	202
LINE FIRE (same as Broadcast)					
pine					
	heading	nd	80	100	400
	backing	nd	40	40	250
palmetto/gall berry					
	heading	nd	30	34	300
	backing	nd	30	30	200
chaparral					
	heading	16	18	30	124
grass					
	fire	nd	20	20	150

Forest and Rangeland Emission Factors (Hardy et. al.)

Fuel or Fire Configuration	Combustion Phase[a]	Emission Factors						
		PM	PM_{10}[b]	$PM_{2.5}$	CO	CO_2	CH_4	NMHC
		(pounds emission per ton fuel consumed)						
BROADCAST BURNED SLASH[1]								
Douglas fir/	flaming	24.7	16.6	14.9	143	3385	4.6	4.2
Hemlock	smoldering	35.0	27.6	26.1	463	2804	15.2	8.4
	fire average	29.6	23.1	21.8	312	3082	11.0	7.2
Hardwoods	flaming	23.0	14.0	12.2	92	3389	4.4	5.2
	smoldering	38.0	25.9	23.4	366	2851	19.6	14.0
	fire average	37.4	25.0	22.4	256	3072	13.2	10.8
Ponderosa/	flaming	18.8	11.5	10.0	89	3401	3.0	3.6
Lodge pole pine	smoldering	48.6	36.7	34.2	285	2971	14.6	9.6
	fire average	39.6	25.0	22.0	178	3202	8.2	6.4
Mixed conifer	flaming	22.0	11.7	9.6	53	3458	3.0	3.2
	smoldering	33.6	25.3	23.6	273	3023	17.6	13.2
	fire average	29.0	20.5	18.8	201	3165	12.8	9.8
Juniper	flaming	21.9	15.3	13.9	82	3401	3.9	5.5
	smoldering	35.1	25.8	23.8	250	3050	20.5	15.5
	fire average	28.3	20.4	18.7	163	3231	12.0	10.4
PILE-AND BURN SLASH[1]								
Tractor piled	flaming	11.4	7.4	6.6	44	3492	2.4	2.2
	smoldering	25.0	15.9	14.0	232	3124	17.8	12.2
	fire average	20.4	12.4	10.8	153	3271	11.4	8.0
Crane piled	flaming	22.6	13.6	11.8	101	3349	9.4	8.2
	smoldering	44.2	33.2	31.0	232	3022	30.0	20.2
	fire average	36.4	25.6	23.4	185	3143	21.7	15.2
"Average Piles"	flaming	28.4	19.0	17.1	169	3207	16.6	11.6
BROADCAST BURNED SLASH[2]								
Sagebrush	flaming	45.0	31.8	29.1	155	3197	7.4	6.8
	smoldering	45.3	29.6	26.4	212	3118	12.4	14.5
	fire average	45.3	29.9	26.7	206	3126	11.9	13.7
Chaparral	flaming	31.6	16.5	13.5	119	3326	3.4	17.2
	smoldering	40.0	24.7	21.6	197	3144	9.0	30.6
	fire average	34.1	20.1	17.3	154	3257	5.7	19.6
FOREST WILDFIRE[3]								
	fire average		30.0	27.0				

[1]Ward, D.E.; Hardy, C.C.; Sandberg, D.V.; Reinhardt, T.E. 1989. Part III-emissions characterization. In: Sandberg, D.V.; Ward, D.E.; Ottmar, R.D., comp.eds. Mitigation of prescribed fire atmospheric pollution through increased utilization of hardwoods, piled residues, and long-needled conifers. Final report. U.S. DOE, EPA. Available from: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Seattle, WA.

[2]Hardy, C.C.; Conrad, S.G.; Regelbrugge, J.C.; Teesdale, D.T. 1996. Smoke emissions from prescribed burning of southern California chaparral. Res. Pap. PNW-RP-486. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 37p.

[3]Hardy, C.C.; Ward, D.E.; Enfield, W. 1992. $PM_{2.5}$ emissions from a major wildfire using a GIS rectification of airborne measurements. In: Proceedings of the 29th annual meeting of the Pacific Northwest International Section, Air and Waste Management Association: 1992 November 11-13; Bellevue, WA. Pittsburgh, PA: Air and Waste Management Association.

[a] Fire average values are weighted-averages based on measured carbon flux.

[b] PM_{10} values are calculated, not measured, and are derived from known size-class distributions of particulates using PM and $PM_{2.5}$.

Emission Factors for Field Crops *		
Vegetation Type	**PM_{10} ****	**$PM_{2.5}$ ****
Alfalfa	31.8	30.4
Barley	15.4	14.9
Corn	12.4	12.0
Cotton	17.7	17.0
Hay	31.8	30.4
Oats	22.9	21.8
Peanuts	17.7	17.0
Pecans	11.0	10.3
Pistachio	11.0	10.3
Sorghum	21.4	20.4
Wheat	11.5	10.9
Weeds (ditches/ditch banks)	17.7	17.0
Average field crops	17.7	17.0
Average orchard crops	11.0	10.3

*From Integrated Assessment Update and 2018 Emissions Inventory for Prescribed Fire, Wildfire, and Agricultural Burning (Draft). Western Regional Air Partnership, Fire Emissions Joint Forum. Air Sciences, Inc., August 27, 2002. http://www.wrapair.org/forums/fejf/tasks/FEJFtask7.html
** Pounds pollutant per ton of residue consumed.

J.1. Definitions

Algorithm – a step-by-step procedure for solving a mathematical problem

Broadcast burning – intentional burning within well-defined boundaries for reduction of fuel hazard, resource objectives, or both.

Combustion – the rapid oxidation of fuel in which heat and usually flame are produced. Combustion can be divided into four phases: pre-ignition, flaming, smoldering, and glowing

Emission factor – the mass of particulate matter produced per unit mass of fuel consumed (pounds per ton, grams per kilogram)

Flaming phase – this phase follows the pre-ignition phase and precedes the smoldering combustion phase. It is the luminous oxidation of gases evolved from rapid decomposition of fuel in which water vapor, soot, and tar comprise the visible smoke.

Percent consumption – the amount of a specified fuel type or strata expressed as a percentage that is removed through the fire process.

Pile – materials that have been relocated either by hand or machinery and heaped together.

Pyrolysis – the thermal or chemical decomposition of fuel at an elevated temperature.

Residue – the remains after the merchantable material/vegetation has been taken, separated, or removed.

Slash – debris resulting from such natural events as wind, fire, or snow breakage; or such human activities as road construction, logging, pruning, thinning, or brush cutting. It includes logs, chunks, bark, branches, stumps, and broken understory trees or brush

Smoldering combustion phase – combined process of dehydration, pyrolysis, solid oxidation, and scattered flaming combustion and glowing combustion, which occur after the flaming combustion phase of a fire; often characterized by large amounts of smoke consisting mainly of tars. Emissions are twice that of the flaming combustion phase

J.2. References

Regional Haze Rule
Published in the Federal Register on July 1, 1999, 64 FR 35714.
http://www.epa.gov/ttn/oarpg/t1/fr_notices/rhfedreg.pdf

WRAP Policy on Enhanced Smoke Management Programs for Visibility
Approved by the Western Regional Air Partnership, November 12, 2002.
http://www.wrapair.org/forums/fejf/documents/esmptt/policy/030115_ESMP_Policy.pdf

AP-42 Emission Factors for Prescribed Burning, AP-42, Fifth Edition, Volume 1, Chapter 1, 10/96.
http://www.epa.gov/ttn/chief/ap42

Integrated Assessment Update and 2018 Emissions Inventory for Prescribed Fire, Wildfire, and Agricultural Burning. (Draft), August 27, 2002.
http://www.wrapair.org/forums/fejf/documents/emissions/WGA_2018EI_Draft.pdf