Simple Approach Smoke Estimation Model (SASEM), Version 4.0:
This program calculates the consumption of fuel, emission of particles, and dispersion of these pollutants produced by prescribed burning of forest and range vegetation.

New SASEM Input
Emission Production Model Input
Meteorology Input
Receptor Input

Exceedence of Standard Output
Visibility Impacts Output

Calculations from: Click on one of the circles to select whether the fuel consumption and emission production calculations are performed using the original (classic SASEM) algorithms, the new SASEM fire efficiency based algorithms, or using the US Forest Service EPM model. While different input information is required by each of the different fuel consumption and emission calculations, the same dispersion and visibility calculations are used in all cases.

Comparison to Standard: The concentration estimates produced by SASEM can be compared to the federal 24 hour particulate standards or to a local standard. The original federal standard was for total suspended particulates (TSP) not to exceed 150 micrograms per cubic meter. This was revised to particulates less than 10 microns in diameter (PM-10), still not to exceed 150 micrograms per cubic meter. The current standard for most areas is for particles less than 2.5 microns in diameter (PM-2.5), not to exceed 50 micrograms per cubic meter. Any combination of these standards can be compared to the downwind concentrations produced by SASEM as well as a local standard. The local standard must be in terms of one of the size categories previously established (TSP, PM-10, PM-2.5). If local standard is selected, a size category and exceedence level in micrograms per cubic meter must be selected. SASEM only supports comparison to 24 hour standards. Two reports are produced by SASEM, one directly comparing concentrations to the standards selected and the converting the concentration to visibility impacts.

New SASEM Inputs: This dialog provides entries for the more detailed new input information for the fire efficiency based calculations including

> <u>Burn Name</u> – A descriptive name,
> <u>Burn Date</u> – The calendar date of the burn,
> <u>Burn Type</u> – Whether the fuel arrangement is broadcast or piled,
> <u>Fuel Model</u> – National Fire Danger Rating System Fuel Model,
> <u>Fine Fuel Loading</u> -- Weight of 0 to ¼ inch diameter fuel per area,
> <u>Small Fuel Loading</u> -- Weight of ¼ to 1 inch diameter fuel per area,
> <u>Large Fuel Loading</u> -- Weight of 1 to 3 inch diameter fuel per area,
> <u>Very Large/Live Fuel Loading</u> -- Weight of 3 to 9 inch diameter and live fuel per area,
> <u>Extra Large Fuel Loading</u> -- Weight of 9 to 20 inch diameter fuel per area,
> <u>Stump Fuel Loading</u> -- Weight of greater than 20 inch diameter fuel per area,
> <u>Duff Fuel Loading</u> -- Weight of duff and litter fuel per area,
> <u>Default Button</u> – Sets all fuel loadings to default for the selected fuel model,
> <u>Fire Duration</u> – Total time fire is expected to produce emissions,
> <u>Burn Area</u> – Total area of the burn site where fuel is expected to be consumed,
> <u>Number of Piles</u> – If piled fuel, number of piles made.

The New SASEM inputs can be used with either the original calculations or the new calculations based on fire efficiency.

Burn Name: A (usually) descriptive name for the burn or burn area. Should be limited to 80 characters

Burn Date: The date when the burn was/will be ignited. Select the month and day and enter the year. Four digit years are preferred.

Burn Type: Select from broadcast or piled fuel arrangement.

Piled fuels have been collected from the site into a few very large piles (which are usually fairly close together so they can be treated as a single smoke source) for more efficient burning. Pile burning efficiency is independent of fuel loading so it is disabled when the piled burn type is chosen. For piled fuels the pile volume and number of piles are also needed.

Broadcast fuels have been left as naturally distributed across the site or have been collected into many small piles distributed over the entire area or windrowed. If the fuel is in many small piles or windrowed, the fuel information should be entered as though it were still distributed over the area. Thus, for broadcast fuels, the fuel loading and burn area are required.

The Emission Production Model does not currently support piled fuels so the burn type option is disabled if EPM is chosen as the consumption and emission calculation method.

Fuel Model: National Fire Danger Rating System fuel model. Each fuel model represents a typical combination of sizes and types of fuels produced by particular plant communities and forest/range management activities. These are used to select burn efficiencies for the fuels. Clicking the <u>Default button</u> after the fuel model list will set the fuel loading for all size categories to typical values for the currently selected fuel model.

Fuel Loading: Estimated weight of air dried fuel per ground area for all available fuel sizes and duff. Estimates are made by comparisons to photographs of areas of known fuel loading, by counting and measuring plants and downed fuels along a transect, or by collecting and weighing samples along a transect or within quadrats. The units in which the fuel loading is recorded can be chosen from the list after the fuel loading entry box including T/A, lb/sq ft and kg/ha. If the values are entered in one unit and the units are changed, the values will be converted automatically.

Fine Fuel Loading: Estimated weight of air dried 0 to ¼ inch diameter fuel per ground area. This represents the 1 hour lag fuel moisture size class fuels. Estimates are made by comparisons to photographs of areas of known fuel loading, by counting and measuring plants and downed fuels along a transect, or by collecting and weighing samples along a transect or within quadrats. The units in which the fuel loading is recorded can be chosen from the list after the fuel loading entry box from T/A, lb/sq ft and kg/ha. If the values are entered in one unit and the units are changed, the values will be converted automatically.

Small Fuel Loading: Estimated weight of air dried ¼ to 1 inch diameter fuel per ground area. This represents the 10 hour lag fuel moisture size class fuels. Estimates are made by comparisons to photographs of areas of known fuel loading, by counting and measuring plants and downed fuels along a transect, or by collecting and weighing samples along a transect or within quadrats. The units in which the fuel loading is recorded can be chosen from the list after the fuel loading entry box from T/A, lb/sq ft and kg/ha. If the values are entered in one unit and the units are changed, the values will be converted automatically.

Large Fuel Loading: Estimated weight of air dried 1 to 3 inch diameter fuel per ground area. This represents the 100 hour lag fuel moisture size class fuels. Estimates are made by comparisons to photographs of areas of known fuel loading, by counting and measuring plants and downed fuels along a transect, or by collecting and weighing samples along a transect or within quadrats. The units in which the fuel loading is recorded can be chosen from the list after the fuel loading entry box from T/A and kg/ha. If the values are entered in one unit and the units are changed, the values will be converted automatically.

Very Large and Live Fuel Loading: Estimated weight of air dried live and 3 to 9 inch diameter fuel per ground area. This represents the 1000 hour lag fuel moisture size class fuels. In calculating fuel consumption, live fuels act similarly to 1000 hour lag fuels and are thus added together for input to this program. Fuel loading estimates of live plants and downed fuels are made by comparisons to photographs of areas of known fuel loading, by counting and measuring plants and downed fuels along a transect, or by collecting and weighing samples along a transect or within quadrats. The units in which the fuel loading is recorded can be chosen from the list after the fuel loading entry box from T/A and kg/ha. If the values are entered in one unit and the units are changed, the values will be converted automatically.

Extra Large Fuel Loading: Estimated weight of air dried 9 to 20 inch diameter fuel per ground area. This represents the 10000 hour lag fuel moisture size class fuels. Estimates are made by comparisons to photographs of areas of known fuel loading, by counting and measuring plants and downed fuels along a transect, or by collecting and weighing samples along a transect or within quadrats. The units in which the fuel loading is recorded can be chosen from the list after the fuel loading entry box from T/A and kg/ha. If the values are entered in one unit and the units are changed, the values will be converted automatically.

Stump Fuel Loading: Estimated weight of air dried 20+ inch diameter fuel per ground area. This represents the greater than 10000 hour lag fuel moisture size class fuels. Estimates are made by comparisons to photographs of areas of known fuel loading, by counting and measuring downed fuels along a transect, or by collecting and weighing samples along a transect or within quadrats. The units in which the fuel loading is recorded can be chosen from the list after the fuel loading entry box from T/A and kg/ha. If the values are entered in one unit and the units are changed, the values will be converted automatically.

Duff Fuel Loading: Estimated average depth of the duff layer. Duff is usually measured as depth from the surface. Since it can vary over the burn area several measurements are usually made along a transect or by some other random sampling method. While depth measurements are most common, the program also accommodates the use of duff loading per area measurements. If the values are entered in one unit and the units are changed, the values will be converted automatically. A typical duff bulk density of 6 lb/cu ft is used to convert from depth to duff fuel loading. A litter layer is sometimes present between the duff layer and the surface. Since this layer does not usually contain very much fuel and it burns very completely and efficiently, it contributes little to air pollution and can be ignored.

Default Loading Button: Sets all fuel loadings to defaults determined based on the fuel model specified. The defaults are currently provided in terms of kg/ha. If you are more familiar with T/A values, select those units for each fuel loading category and the loading values will automatically be converted. The defaults used are listed in the table below

	Fuel Model	Fine	Small	Large	Live	Duff
			Fuel Loadings (kg/ha)			
A	Western annual grasslands	1440	0	0	160	0
B	Dense tall brush	15480	25800	0	5160	5160
C	Open pine perennial grass understory	8640	0	0	1080	1080
D	Pine with Palmetto-gallberry understory	15280	0	0	1910	1910
E	Leaf fall from hardwood and mixed	7420	1060	0	1060	1060
F	Mature closed chemise and oakbrush	14800	14800	0	3700	3700
G	Dense conifer with heavy downed and duff	6160	12320	24640	6160	12320
H	Short-needle conifers with thin litter	4260	4260	4260	4260	4260
I	Clearcut conifer slash, > 56030 kg/ha < 6 in	13000	13000	65000	26000	13000
J	Clearcut/heavily thinned conifer > 56030 kg for < 6 in	14340	14340	35850	0	7170
K	Light conifer slash/partial cuts	2690	8070	13450	0	2690
L	Western perennial grasslands	1980	0	0	220	0
N	Reedy marsh fuels	14130	0	0	1570	0
O	Southeast brushlike fuels	13770	18360	4590	4590	4590
P	Closed long-needled southern pine	4040	4040	0	1010	1010
Q	Dense Alaskan black spruce and shrubs	12990	17320	4330	4330	4330
R	Hardwoods after leafout	1340	2680	0	2010	670
S	Alaskan and alpine tundra	3030	2020	1010	2020	2020
T	Sagebrush-grasslands	11070	0	0	1230	0
U	Closed western long-needled pines	9420	3140	0	1570	1570

Fire Duration: The entire length of time the fire is capable of producing significant emissions over a substantial portion of the site. This includes both flaming and smoldering emissions. However, in heavy fuels, while a few stumps may smolder for many hours after the rest of the fire is out, these are not likely to contribute significantly to total emissions and can be ignored. The units for the fire duration can be specified from the list which follows the fire duration entry box including hours, minutes and seconds. If the values are entered in one unit and the units are changed, the values will be converted automatically.

Burn Area: This is the area that is actually expected to be burned, not necessarily the total area of the burn unit. For instance if the burn goal is to open 50 percent of a shrub area for perenial grasses to improve wildlife habitat, then the burn area specified should be 50 percent of the burn unit area. The area units can be chosen from the list which follows the burn area entry box including acres, hectares and square feet. If the values are entered in one unit and the units are changed, the values will be converted automatically.

Number of Piles: The total number of piles on the burn unit. These piles should be near together so that their plumes will likely merge, not remain distinct any great distance from the burn site. When piled fuels are selected for the New Sasem input dialog, the fuel loading by size entries are deactivated fuel size does not affect the efficiency of burning for piled fuels

Emission Production Model Inputs: The Emission Production Model requires three screens of fire description information. The first is the same as the <u>New SASEM</u> Input dialog. The <u>second EPM dialog</u> describes more details of the burn unit. Finally, the third dialog describes the <u>ignition pattern</u> for the unit. EPM was developed by the US Forest Service. For further information on this program contact David V. Sandberg, USDA Forest Service, Pacific Northwest Station, 3200 SW Jefferson Way, Corvallis, OR 97331.

EPM Input Dialog: In addition to the information required by the <u>New SASEM</u> dialog, the Emission Production requires

> <u>Region</u>
> <u>Ownership</u>
> <u>Latitude</u>
> <u>Longitude</u>
> <u>Harvest Date</u>
> <u>Snow Off Month</u>
> <u>Dominant Species</u>
> <u>Terrain Slope</u>
> <u>Fuel Moisture Method</u>
> <u>1000 Hour Fuel Moisture</u>
> <u>10 Hour Fuel Moisture</u>
> <u>Days Since Rain</u>

In addition, EPM requires a simple description of the <u>ignition pattern</u>.

Region: The region is used to refine some of the parameters used in the consumption and emission equations in EPM. The regions currently supported are in the Pacific Northwest including Eastern Washington, Western Washington, Eastern Oregon, and Western Oregon. All other areas should use the Other region which uses the Eastern Oregon characteristics. One of these available regions must be selected from the list on the EPM Input form.

Ownership: Like region the land ownership is used to refine some of the parameters used in the consumption and emission equations in EPM and relate primarily to studies done in the Pacific Northwest. The ownership categories are National Forests, State Forests, Other Federal Lands, or Private Forests. One of these available ownership categories must be selected from the list on the EPM Input form.

Latitude: Geographic latitude, currently the program is only set up to handle north latitude as a positive number. Latitude is used to estimate solar radiation available for curing fuels.

Longitude: Geographic longitude, currently the program is only set up to handle west longitude as a positive number. Longitude is only used for identification purposes (if you have latitude, you might as well put in longitude).

Harvest Date: The month and year most representative of when the trees were cut for a harvested burn area. For an underburn of natural fuels, or any case where you want to indicate fully cured fuels, choose a harvest date more than 2 years before the burn. Time since harvest is used to estimate curing and thus the effect of available fuel moisture on fuel consumption, particularly for large fuels.

Snow Off Month: The month when the burn area was last covered with snow is yet another factor used to estimate fuel curing and thus available fuel moisture, particularly in large fuels, and how it affects fuel consumption. The month selected from the list should be the month closest to the burn date when the area is completely free of snow. If the area never has snow, then the unusual month of Never should be selected.

Dominant Species: The dominant or most characteristic species of the burn area is chosen from the list provided. In some cases a single species is not listed, but a more general class of plants such as brush or hardwoods. These are provided for cases where a single dominant species does not characterize the plant community or where detailed measurements of consumption and emission for the various communities which might be contained in this broad plant association are not available. The currently available choices are

> Douglas Fir
> Ponderosa Pine
> Mixed Conifers
> Hardwoods
> Juniper
> Sage Brush
> Brush

Terrain Slope: The average slope of the terrain of the burn area. The slope can be determined from a topographic map or GIS. In either case, this should be determined over as large an area as possible since most burn areas will have a variety of terrain slopes and the intent is to choose one which is most representative of the area, not an extreme.

Fuel Moisture Method: Because of the long time lag for changes, fuel moisture for fuels greater than 9 inches in diameter are seldom measured, but are usually estimated. The most common estimation technique comes from the National Fire Danger Rating System. An adjusted NFDRS large fuel moisture was developed by the US Forest Service Pacific Northwest Fire Lab. And direct sample weight measurement techniques are also available.

1000 Hour Fuel Moisture: Fuel moisture for 1000 hour lag size class fuels (3 to 9 inches in diameter) determined by the method specified previously on the form.

10 Hour Fuel Moisture: Fuel moisture for 10 hour lag size class fuels (1/4 to 1 inch in diameter). For this size class fuel moisture is usually determined from measurement of calibrated fuel sticks, but may be estimated.

Days Since Rain: This is the number of days since the last rain of greater than a trace (usually recorded as 0.01 inch or greater). This is used in estimating how cured harvested timber fuels are.

EPM Input Continued: In addition to the fuel amount and condition, EPM also requires a description of the timing of the burn ignition. Up to 10 separate ignition periods can be specified. For each period, the duration of the ignition period and the time between that ignition and the next must be specified. The percent of the total burn area to be ignited during that period is also required.

Ignition Time: Select the time of day (24 hour clock) when the first ignition will take place.

Ignition Period Number: A new ignition period number is generated by the program each time an ignition period is added (by clicking the add button). After the ignition periods have been added, you can display the ignition duration, ignition wait time, and percent area burned for an ignition period by selecting the appropriate period number from this list. Once a set of ignition conditions has been displayed, you can change them or remove the entire ignition period by clicking the Change or Remove button.

Ignition Period Duration: For each ignition period, enter the time which will be required to ignite that section of the fire. If several sections of the burn area are ignited simultaneously, this is considered one ignition period. The total time of all ignition periods and all <u>wait periods</u> cannot exceed the time entered as the burn duration (in fact the <u>burn duration</u> should be significantly longer as it represents the total time when both flaming and smoldering emissions are expected to occur).

Ignition Wait Period: For each ignition period, enter the time which will occur between the end of this ignition period and the beginning of the next ignition period. The total time of <u>all ignition periods</u> and all wait periods cannot exceed the time entered as the burn duration (in fact the <u>burn duration</u> should be significantly longer as it represents the total time when both flaming and smoldering emissions are expected to occur).

Percent Area Burned: For each ignition period, enter the percent of the <u>burn area</u> to be ignited during this time. The total for all burn periods must total 100 percent.

Meteorology Input: The meteorology input is usually determined by the burn prescription. If the prescription determined by safety and the burn goals does not produce unacceptable air quality impacts, then the analysis is complete. If air quality impacts are produced, the prescription should be modified to eliminate these impacts. The easiest changes to make are to restrict the meteorological conditions for the burn. Otherwise, burn size or firing techniques which will affect burn duration are required. In more extreme cases, other means of fuel reduction may be required such as removal or chipping. The meteorology information required from the prescription is

> <u>Minimum and maximum wind speed</u>
> <u>Minimum and maximum wind direction</u>
> <u>Minimum and maximum atmospheric stability</u>
> <u>Mixing height</u>, and
> <u>Wind speed and stability combinations to be used</u>

Wind Speed: The minimum and maximum wind speed from the burn prescription should be entered. The program will check if the minimum entered is less than the maximum wind speed. If the prescription has not yet been completed, the wind speed range can be taken from a climatology of the area. The wind speed increment is chosen to provide a reasonable number of wind speed intervals from which to analyze impacts. The measurement units for the wind speed minimum, maximum, and increment can be chosen from mi/hr, m/s, and km/hr. If the values are entered in one unit and the units are changed, the values will be converted automatically.

Wind Direction: The minimum and maximum wind direction from the burn prescription should be entered. The maximum is clockwise from the minimum wind direction. Wind directions are specified on a 16 point compass. The wind direction is only used in regard to visibility impacts to the sensitive receptors entered. Thus, if the prescription is to burn during winds that avoid the receptors, but the level of impact if the wind shifts is also wanted, the wind directions specified should be toward the receptors. The wind directions adjacent to that directly toward the receptor are also considered to cause impacts. Wind directions are the direction the wind is blowing from, the receptor directions are the direction the fire would be, seen from the receptor. Thus, when there is an impact the two directions are the same (or one of the adjacent directions).

Stability: The minimum and maximum stability from the burn prescription should be entered. The stability type should be chosen first as P-G (Pasquill-Gifford) Stability or Dispersion Day. For Dispersion Day, Excellent is the lower stability and Poor is higher. For P-G Stability A is lower and F is greater stability.

Mixing Height: The height of the layer in the atmosphere where the smoke plume will be dispersed. This information is usually obtained from a National Weather Service office or calculated from radiosonde measurements. For burn planning, the climatological value for the location and time of year of the burn should be used. The mixing height units can be selected from the list beside the mixing height entry box. If different units are selected after the mixing height is entered, it will automatically be converted to the new units.

Meteorology Limitation: Not all combinations of wind speed and stability are likely to actually occur in nature. You can select whether the program displays results of all combinations of wind speed and stability or only results for the combinations which are likely to occur together. The ranges used are somewhat revised from the original SASEM program.

Receptor(s) Input: Receptors are areas sensitive to air quality impacts where exceeding the federal or local standard may not be the only limitation or where visibility restrictions are important. Up to 10 receptors can be entered. The two methods for calculating visibility impacts give similar results under many circumstances. However, the one labeled P&V, for Packham and Vines, is more reliable at long distances, generally greater than 30 km from the burn. The technique labeled Kosh for Koshmeider is more reliable at shorter distances, especially less than 20 km from the burn. The second technique is also sensitive to variation stability while the first is not. The information needed to describe a receptor is

> <u>Receptor Name</u> – A descriptive name
> <u>Receptor Distance</u> – Distance between fire and receptor
> <u>Receptor Direction</u> – Direction of fire seen from the receptor

The values for the receptor information are entered, then the <u>Add Button</u> is pushed. The name of any existing receptor can be chosen from the receptor name list and the other receptor values corresponding to that receptor name are presented. Those values can then be edited and if the <u>Change Button</u> is then pressed, those changes will be made permanent. If no receptors are desired, the <u>None Button</u> should be pushed and execution will continue without calculating visibility or other receptor impacts. Otherwise, when the receptor information has been entered, the <u>Run Button</u> should be pushed and program calculations will begin.

Receptor Name: A (usually) descriptive name for the sensitive receptor. Should be limited to 80 characters, only the first 10 will be used in the tables of results.

Receptor Distance: The distance from the receptor to the fire. The units for the distance can be chosen from the list after the Receptor Distance box as miles or kilometers. If the units are changed after a value is entered, the value is automatically converted.

Receptor Direction: The direction of the fire viewed from the receptor. An impact only occurs when the wind is blowing from the fire to the receptor. Because wind variation occurs over any time as long as a fire duration, the two wind directions adjacent to the wind direction toward the receptor are also considered to cause impacts. Wind directions are the direction the wind is blowing from, the receptor directions are the direction the fire would be, seen from the receptor. Thus, when there is an impact the two directions are the same (or one of the adjacent directions).

Exceedence of Standard Output: The primary output from SASEM describes whether the selected air quality standards would be exceeded by the proposed burn and under what conditions any indicated exceedence would occur. A separate table is produced for each air quality <u>standard</u> that was selected in the <u>General Info</u> entry dialog. These results are presented for each combination of <u>stability</u> and <u>wind speed</u> in the prescription (subject to the reasonable <u>meteorology constraints</u> if selected). For each of these combinations, the maximum concentration, the distance downwind of that concentration, and the plume rise are reported. If the maximum concentration for a wind speed and stability does not exceed the standard for that report table, then No Exceedence will also be displayed. If the maximum concentration does exceed the standard, then the minimum and maximum distance downwind where the standard would be exceeded is reported.

The plume rise is useful in analyzing the cause of impacts and making adjustments to prescriptions since it is an indicator of the fire intensity. If the fire prescription developed to meet the land use goals of the burn is for a low slow burn, plume rise should be low and impacts may be high because of this, particularly near the fire. One way to mitigate these air quality impacts is to increase the intensity of the burn to the limit that the land use goals will allow. This should produce a higher plume rise and less impact.

The distance over which an exceedence occurs can help in determining what type of changes to make to the prescription to reduce air quality impacts. If the distance over which the exceedence occurs is short, then maybe a small change in the fire intensity or duration (which in a sense is the same thing) can eliminate the impact. On the other hand, if the distance over which impact occurs is long, then greater changes will be required and burning fewer acres per day or considering alternate methods of fuel reduction such as firewood sales or chipping should be considered.

Visibility Impacts Output: The visibility impact output was not designed to meet specific visibility standards (that may have to be considered soon). It was developed primarily for assessing the potential for nuisance complaints and secondarily for assessing the potential for safety concerns. These results are presented for each combination of <u>receptor,</u> (particularly the receptor direction from the fire), the <u>stability,</u> <u>wind direction</u> and <u>wind speed</u> in the prescription (subject to the reasonable <u>meteorology constraints</u> if selected. Visibility impacts are presented in terms of visual range. Visual range is the distance at which a small dark object can be just discriminated from a light background. In relatively clean air, nuisance calls may occur with relatively small changes in visual range, though they generally require reduction to less than 10 miles. Safety concerns for highways and airports occur at less than visual ranges of less than 1 mile. Since the specific requirements for maintaining safety vary with locality, it is best to contact the highway or airport authority of concern if there is a chance of an impact (and best to establish a prescription which avoids such impacts wherever possible). Two estimates of visual range are provided by SASEM. Both are calculated from the PM-2.5 emissions (the particle size which most affects visibility). The one labeled P&V is calculated using a uniform concentration distribution and based on measurements made on actual fires in Australia made at a distance of about 15 miles. The second estimate (labeled Kosh) is based on the concentration at plume center based on a variety of plume sources (including fires). Thus, the P&V estimate is most representative of conditions at a significant distance from the fire, while the Kosh estimate is more representative of impacts close to the fire. Also, the P&V calculation does not take stability into consideration and so is not as reliable in extremely stable or unstable conditions.