

TECHNICAL MEMORANDUM

FETS EMISSIONS CALCULATOR STRAWMAN

PREPARED FOR: Fire Emissions Tracking System Task Team

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PROJECT NO.: 230-1

COPIES:

DATE: August 13, 2007

This memo presents the Strawman approaches for obtaining supplementary information required to execute emissions calculations using CONSUME 3.0 in the Fire Emissions Tracking System (FETS). The FETS Task Team is asked to review the Strawman Approaches, consider the merits and disadvantages of the approaches, and provide input to the FETS project team. Approaches agreed upon will be incorporated in the FETS Work Plan and implemented in the FETS.

Background

A Strawman technical memo distributed on April 23, 2007 identified CONSUME 3.0 as the best candidate to calculate emissions in the FETS. The FETS Task Team agreed upon an approach of incorporating CONSUME 3.0 into the FETS system, called the "Technical Node," that exists on a stand-alone Linux machine and performs emissions and GIS calculations without the need or ability for user input.

The FETS Emissions Strawman noted that CONSUME requires certain ancillary information to calculate emissions for a fire event. Some of these data elements are available directly from data providers, while others must be obtained from other sources or through established defaults. Air Sciences has attempted to account for each of the additional required elements with accuracy while not deviating significantly from the scope of the current Workplan.

Methods to Obtain CONSUME Parameters

Data sources for each of the additional required elements for CONSUME emissions calculations were compiled and evaluated based on several criteria, including:

- Ease of incorporation into the FETS;
- Consistency of the data source;
- Accuracy gained (or lost) when using a particular method.

For most of the additional required data, the FETS cannot expect data providers to be a primary source of information. The CONSUME 3.0 User's Guide (User's Guide) provides defaults and/or equations to estimate values for several of the additional elements. For other parameters, other solutions were sought. The CONSUME defaults, as well as the proposed parameter sources for the FETS, are shown in Table 1. Further explanation for each parameter, if deemed necessary, is provided below. It should be noted that while the FETS cannot rely on data providers to consistently submit these additional data, user-supplied information for any of the parameters discussed here will always supercede default or derived values.

Table 1. Summary of ancillary data required for CONSUME.

Parameter	CONSUME default	FETS default
10 hr Fuel Moisture	None	GIS/WIMS data ¹
1000 hr Fuel Moisture	None	GIS/WIMS data ¹
Duff Fuel Moisture	None	See "Days Since Rain"
% crown consumed	RX - 0% ; WFU - 40% ; WF - 60%	Use CONSUME default
Shrubland % Blackened	Equation based on wind, slope, 10-hr FM	Use CONSUME default ¹
Ignition duration	Equation based on acres and "intensity"	Use equation, but "intensity" is always the same ¹
Wind Speed (mph)	Max 35 mph	10 mph
Slope (%)	20	Use CONSUME default
Days Since Rain	None	GIS/WIMS data ¹
Harvest?	None	FALSE
Snow off?	None	FALSE
Number of piles	None	$(V \times 0.0057) / \text{Acres}^1$
Pile Shape	None	Half-ellipsoid ¹
Pile Dimensions	None	10'W x 6'H x 9.5'L ¹
Packing Ratio	10% ; 20% ; 30%	20%
Percent of pile that is soil	None	10%
Primary wood density	None	Lookup based on FCC code
Percent Primary Species	None	100%
Secondary wood density	None	0
Percent Secondary Species	None	0
Pile Quality	1 - clean ; 2 - dirty ; 3 - Really dirty	Hand Piles = 1 ; Machine Piles = 2 ; Piles = 2

¹Explained in detail below

10- and 1000-hr Fuel Moisture

The United States Forest Service Wildland Fire Assessment System (WFAS) reports daily fire weather observations from the Weather Information Management System (WIMS). 10-, 100- and 1000-hour fuel moistures are reported at each of several hundred stations throughout the WRAP region.

The Technical Node of the FETS has already incorporated a GIS to perform spatial overlay operations. Fuel moisture data from WFAS may be downloaded and interpolated into RASTER surface moisture maps by the Technical Node on a daily basis for use in the FETS. Maps for each day of the calendar year can be stored in the Technical Node; fire events queried by date may then be overlaid onto the appropriate moisture maps to derive 10- and 1000-hour fuel moisture. Occasionally WIMS data are not available for a particular day; in these cases, the moisture map for the previous day may be used to derive moisture values for relevant fire events. Fire events submitted by a data provider that include 10- and 1000-hour fuel moisture values will supersede the GIS-interpolated WIMS observations.

10- and 1000-hour moisture maps created using a similar technique are posted daily on the WFAS website, and are presumably used by fire managers to report fuel moisture. The above technique has already been implemented in the technical node for the FETS since it follows an existing method for estimating fuel moisture used by the fire community.

Duff Fuel Moisture and Number of Days since Rain

Although duff fuel moisture is a required input to CONSUME 3.0, the parameter is not utilized in subsequent algorithms. Instead, the “Days since Rain” parameter is used to determine one of three moisture regimes – wet, moist, or dry – which then determines the extent of duff layer consumption (duff layer parameters, such as depth, are stored internally in CONSUME by FCC code).

The number of days since the last significant rain is not tracked by any smoke management program. Therefore, the FETS, if it is to obtain such values, must seek them elsewhere. The FETS project team recommends one of two approaches.

Approach 1: WIMS Precipitation Interpolation

The daily WIMS dataset, described above, reports precipitation at each station in the WRAP region, and may be useful to determine “Days Since Rain” for any given fire event. Similar to fuel moisture, precipitation values may be interpolated into a surface RASTER map to estimate precipitation throughout the WRAP region. Then, the map may be recoded such that RASTER cell values greater than 0.25 (representing >0.25 inches of rain in 24 hours) are set to 0.0; values 0.0 – 0.24 are set to 1. If two or more maps are created in this manner, they

may be combined together successively to obtain a cumulative “Days Since Rain” map for anywhere in the WRAP region. The map combination equation is as follows:

$$\text{DSRmap1} = (\text{mapDay1} \times \text{mapDay2}) + \text{mapDay2} \quad (1)$$

$$\text{DSRmap2} = (\text{DSRmap1} \times \text{mapDay3}) + \text{mapDay3}$$

...

Since some areas of the WRAP region receive very little precipitation each year, the initial cumulative “Days Since Rain” map (DSRmap) should have its start date several months in the past to establish an accurate baseline. On the occasion that WIMS data are not available for a particular day, the previous day’s map will be used.

The method above, although it includes some additional processing, is essentially the same technique as for estimating fuel moisture and therefore carries a similar level of accuracy. The estimated time to implement this approach is 4 hours.

Approach 2: Default Parameter

The alternative to Approach 1 is assigning a default value to every fire to ensure the CONSUME algorithm always falls into the “dry” duff moisture regime. This approach requires no additional development time.

Shrubland Percent Blackened

The CONSUME 3.0 User’s Guide offers the following equation to estimate percent of the shrub layer burned (%SB):

$$\%SB = e^{(y)} / (1 + e^{(y)}) \quad (2)$$

$$y = [-1.5693 - (0.2453 \times 10\text{-hr FM}) + (0.1697 \times \text{Wind} \times [\text{Slope Category}])] \quad (3)$$

Table 2: Slope Categories.

Slope Category	Slope range (%)
1	0 ≤ Slope < 5
2	5 ≤ Slope < 16
3	16 ≤ Slope < 26
4	26 ≤ Slope < 36
5	Slope ≥ 36

Reporting of wind and slope for fires in the FETS is expected to be sporadic, and therefore %SB in Equation 2 will most often depend only on fuel moisture, with Wind = 10 and [Slope Category] = 3 according to the defaults outlined in Table 1.

Ignition Duration

CONSUME 3.0 uses ignition duration as part of an algorithm to estimate fire intensity and therefore the approximate diameter reduction (DRED) of woody fuels (i.e., the extent to which the diameter of woody fuel is reduced by burning). CONSUME makes no distinction between wildfires and prescribed fires in this regard, and therefore estimates must be made for both fire types. Table 3 outlines the approximate DRED for four possible fire intensities.

Table 3: Diameter reduction for varying fire intensities.

Fire Intensity	Approx. DRED
Extreme	33 %
Very High	22
High	11
Medium	Not Reduced

The User's Guide provides estimates for maximum ignition times that would still be considered "mass ignition" for three fire intensities: "Extreme", "Very-High", and "High". For "High" intensity fires, the maximum ignition time is expressed as

$$\leq 20 \text{ acres: } \text{Ignition Duration (minutes)} = 4 \times \text{acres} \quad (4)$$

$$> 20 \text{ acres: } \text{Ignition Duration (minutes)} = (2 \times \text{acres}) + 40 \quad (5)$$

For ignition times greater than those derived from Equations 4 and 5, the CONSUME algorithm assumes no diameter reduction of woody fuels. The FETS project team recommends using the maximum ignition time for high-intensity fires. This will allow for consumption of woody fuels while assuming a lower intensity burn, although realistically the extent (if any) to which woody fuels are burned during a prescribed fire will vary depending on the particular prescription. For wildfires, the default Ignition Duration will be calculated using equations from the User's Guide similar to Equations 4 and 5 such that the fire intensity will fall into the "Very High" regime.

Number of Piles, Pile Shape, Pile Dimensions

In the process of coordinating data acquisition by the FETS, it appears that several state Smoke Management Programs track information regarding piles, including dimensions and number of piles. Thus, it is anticipated for many pile burning events sufficient data will be available to supply to CONSUME. For events without any pile information, however, defaults must be established.

Median pile sizes reported in 2006 for Arizona (AZDEQ, 2007) are reported below. These dimensions will be used for Piles and Hand Piles when no other information is given. Piles reported as Machine Piles will have double the default hand pile dimensions, shown below.

Table 4: Default Pile Dimensions.

Dimension	Piles/Hand Piles	Machine Piles
H	6 ft	12 ft
W	10	20
L	9.5	19

Pile shape will default to a half-ellipsoid. If no information on number of piles is provided, it will be estimated using the default volume, V , and reported acres:

$$\# \text{ of piles} = \text{Acres} / (V \times 0.0057) \quad (6)$$

Equation 6 is adapted from *Wyoming 2005 Emissions Inventory: Section 3- Fire Data Sources and Inventory Development* (Air Sciences, 2007), and is based on the smoke management plan (SMP) guidelines developed by the states of Wyoming and New Mexico. If a burn is reported as a pile burn and no information is given, including acres, the number of piles will default to 1 and default dimensions and shape will be used.

References

Arizona Department of Environmental Quality (2007). Personal Communication with Mark Fitch. Phone Call, 5/2/2007.

Air Sciences Inc. 2007. Wyoming 2005 Emissions Inventory: Section 3- Fire Data Sources and Inventory Development (Draft, April 2007). Golden, CO.

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