



**AIR SCIENCES INC.**

DENVER • PORTLAND

**DRAFT**

**Development of a  
Commodity-based Fire  
Emissions Tracking  
System**

**TECHNICAL SUPPORT  
DOCUMENT AND  
USERS GUIDE**

PREPARED FOR:

WESTERN GOVERNORS'  
ASSOCIATION  
WESTERN REGIONAL AIR  
PARTNERSHIP  
FIRE EMISSIONS JOINT FORUM

PROJECT 230-1  
OCTOBER 17, 2007



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## INTRODUCTION

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The Western Regional Air Partnership (WRAP) Policy/Fire Tracking System Executive Summary states that the WRAP is charged with developing technical and policy tools to assist states and tribes with implementing the Regional Haze Rule. The WRAP policy on Fire Tracking Systems (FTS) was developed through a stakeholder-based consensus process to assist the WRAP region states and tribes in addressing emissions from fire sources. It is the position of the WRAP FTS Policy that it is necessary to track fire activity information in the WRAP region using a fire tracking system, which will also provide the information essential to create a fire emissions inventory.

The Fire Tracking System Task Team (Task Team) was charged with evaluating existing fire tracking systems to determine if an existing system, with few or minor modifications, would satisfy the WRAP's requirements. After careful review of seven existing FTS, The Task Team, its contractors, and the WRAP have agreed that a commodity-based Fire Emissions Tracking System (FETS) approach would be the most timely, efficient, cost-effective method to build an operable, stable, and user-friendly FTS. This FETS will be accessible to any of the WRAP states and Tribes and its design is intended to efficiently accommodate data exchanges from state/tribal FTS currently in operation.

In the preparation of this Work Plan and throughout the development of the FETS, the project team of Air Sciences, Wingate Designs, and the Cooperative Institute for Research in the Atmosphere (Project Team) referenced the WRAP Policy – Fire Tracking System (April 2, 2003), the “Needs Assessment for Evaluating and Design of an Emission Data Reporting, Management, and Tracking System” (July 25, 2003 – in particular those sections pertaining to fire tracking), The Evaluation of Existing Fire Tracking Systems Final Report (March 2007), and the Fire Emissions Tracking System White Paper (July 31, 2006). In addition, input was received from numerous stakeholders and potential users of the FETS.

A critical objective of the Project Team was to develop a fire tracking system that met the WRAP's minimum needs and was flexible enough to allow for modifications to accommodate evolving needs of data providers and users and expansions to augment the FETS with additional features. The intent was not to create a “brilliant, new design” but to draw on commodity products and existing systems as appropriate. The primary emphases of this project were:

- Efficient data acquisition;
- Stable data storage and availability;
- Real-time data import and export capabilities;

- An interface to allow for enhanced coordination of planned and unplanned events among regional smoke managers; and
- A system that accommodate cost effective development of fire emission inventories.

## SECTION 2

# PROJECT GOALS AND DELIVERABLES

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The Fire Emissions Tracking System (FETS) provides the following:

- A web-based interface for manual and automatic entry of planned fire events
- Coordination with existing fire tracking databases through automated or manual data assimilation.
- A central coordinating database of planned and unplanned fire events within the WRAP region.
- Options for viewing and reporting fire events from the central database, including the following:
  - A mapping tool capable of displaying and querying chosen events.
  - On-screen summaries of acres burned, emissions, frequency of Natural/Anthropogenic burns,
  - Download of chosen data into MS Excel format for manipulation by users.

In addition to the above mechanical features, the FETS was developed according to specific guiding principles:

- Data acquisition is accomplished by a number of methods in order to accommodate differing data provider and user needs.
- Data acquisition methods are being developed to minimize the burden of additional reporting requirements on data providers.
- Existing software, scripts, designs, and formats from other systems were used where feasible, with the intent of minimizing system and software development costs.
- The FETS was designed so that it is not dependent on, or wedded to, one single platform, software package, or host, especially when it involved costly proprietary licensing.
- The FETS was designed to limit extensive, high-frequency maintenance and attention by a Database Administrator.

Details of the mechanical features and steps to meet the guiding principles are outlined in Section 3 of this document; deviations from features and steps outlined in the Work Plan were minor, and may be compared by referring to the Project Workplan.

## SECTION 3

# HARDWARE AND SOFTWARE COMPONENTS

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The deliverables for the FETS project include several hardware and software components. In choosing and developing components, emphasis was placed on the use of existing tools, software, and hardware to serve the FETS.

### Hardware:

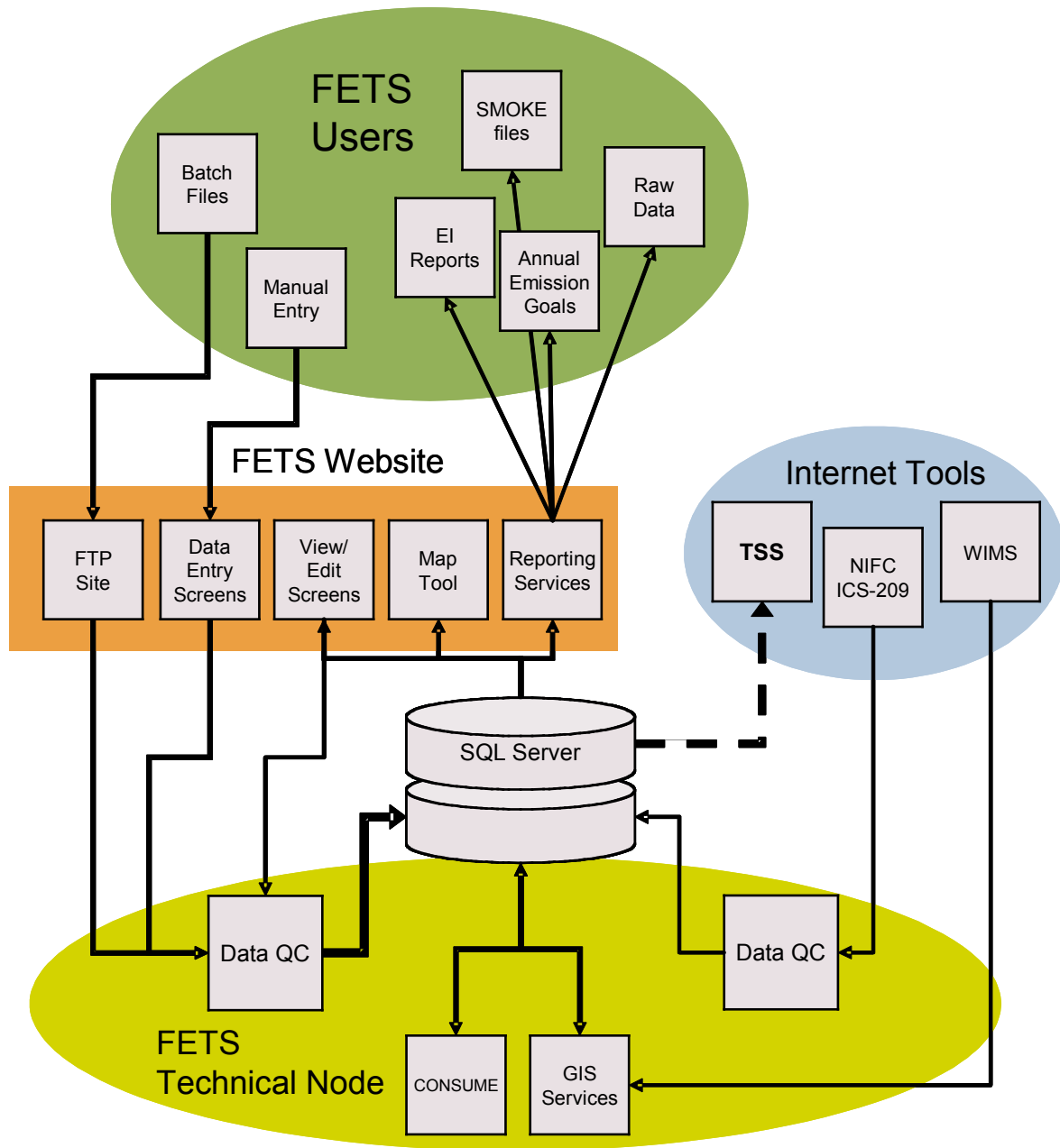
- A MS-SQL database server hosted by CIRA, which provides security and server maintenance, adequate storage space, and a convenient link to the WRAP Technical Support System.
- A secure Virtual Private Server (VPS) hosted by Wingate Designs. The VPS is the home of the FETS website and provides adequate storage, software packages and flexible web-developing capabilities, such as file transfers, not available from a third-party host (e.g. Yahoo! or GoDaddy.com).
- A dedicated Linux machine, dubbed the Technical Node, that resides at Air Sciences and serves as a platform for fire science needs of the FETS, GIS operations, and data acquisition from outside systems.

### Software:

- Cold Fusion, available through the VPS, acts as the communicator between the website and the database,
- Python 2.4.4, an open-source, object-oriented programming language, is used to manage data acquisition and communication between the database and the technical services provided by the Linux machine,
- GRASS 6.2, an open-source GIS platform, performs spatial calculations to determine fuel bed type, fuel moisture, and duff moisture for data stored in the FETS (described in more detail in Section 4),
- CONSUME 3.0, developed by the Fire and Environmental Research Applications Team (FERA), is freely available as a Java executable and is used for emissions calculations.



Figure 1: Diagram of system configuration and component interaction.



## SOFTWARE DEVELOPMENT AND STRUCTURE

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### 1: Database Architecture

Seven minimum elements are required for storing and tracking fire events, consistent with WRAP FTS policy. These elements include,

- Date of Burn
- Location of Burn (Lat/Lon)
- Size of Burn (acres)
- Fuel Type
- Fuel Loading (pre-burn and actual)
- Type of burn (wildfire, prescribed, WFU) [broadcast/piled]
- Natural/Anthropogenic<sup>1</sup>

Additional elements, not listed as essential in the FTS Policy but considered by WRAP, state, and tribes to be important as fire-related elements of Regional Haze SIPs are developed and implemented, are also handled by the FETS:

- Emissions Calculations
- Annual Emissions Goals
- Projections
- Emission Reduction Techniques

Elements not required by the FETS but capable of being stored include:

- Fuel moisture (10- and 1000-hour)
- Number of Days Since Significant Rainfall (used by CONSUME 3.0)
- Agency responsible for burn
- User-provided Emission Reduction Factors (ERFs)
- Pile information, including volume and quantity.

The basic structure of the database is shown in Figure 2. The table at the top of the hierarchy, the *AirFact3* table, is organized such that each record contains a quantity of emissions of a single pollutant for a single day of a single burn event calculated by a single method. Three methods of emissions calculations are stored: WRAP-modified AP-42, CONSUME, and user-provided. Other information about a single day of burning for a fire, such as fuel type, fuel moisture, date, acres

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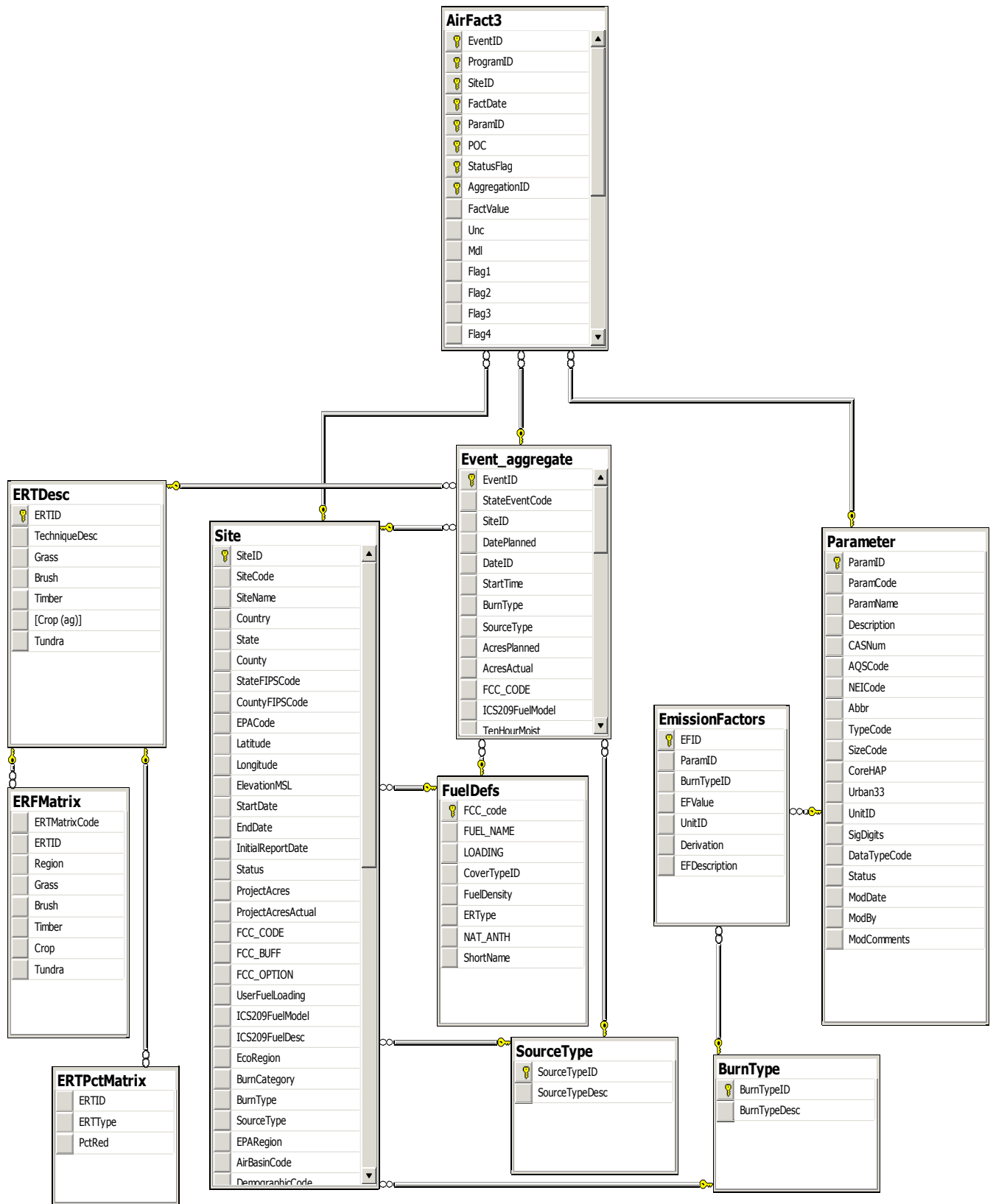
<sup>1</sup> Consistent with "Policy For Categorizing Fire Emissions," Fire Emissions Joint Forum, November 15, 2001. Prescribed fire, Agricultural burning and Wildland Fire For Use (WFU) are considered "Anthropogenic"; Wildfire and Tribal burning are considered "Natural".

burned, etc, is stored in the *Event\_aggregate* table. Information about a fire that applies to all days of burning, such as the point location, burn category, responsible agency, start date, etc, is stored in the *Site* table and is linked by a one-to-many relationship to *Event\_aggregate*. Both the *Event\_aggregate* and *Site* tables are linked to several lookup tables containing all fixed parameters related to each fire, including pollutant definitions, Emission Reduction Technique (ERT) definitions, fuel types and emission factors and other data such as State, County, and Tribal FIPS codes. All editable records contain audit fields that trace the creation date and user name and separately trace the most recent modification date and user name.

## **User Database**

The FETS does not have its own User database and registration schema. To enhance integration to the WRAP Technical Support System (TSS), the FETS will query the TSS's User database to establish user authentication. This allows all registered users to the TSS automatic access to the FETS following the permissions hierarchy outlined in the next section. However, because Data Providers require extra permissions to manipulate the FETS database, a table in the FETS will track TSS registered users that are also FETS data providers. This table is updated manually as Data Providers are approved by the WRAP.

Figure 2: Schematic of the FETS database design. Many look-up tables are omitted for clarity.



## 2: Web-based User Interface

### User Permissions

There are three levels of user permissions in the FETS: the general public, TSS registered users, and FETS data providers. Features of the FETS available to each type of user are outlined in Table 1. Data Providers must be approved by the WRAP before access is granted.

**Table 1: User permission hierarchy.**

<b>3-TIER PERMISSIONS</b>	1	2	3
<i>Users</i>	General Public	Registered TSS Users	Data Providers
<i>FETS Features</i>			
Home Page	✓	✓	✓
Map Tool	✓	✓	✓
Methods and Resources	✓	✓	✓
Reporting Tools		✓	✓
Read/Write/Revise Data			✓
Registration	none	automatic with TSS	manual
User Name/Password	none	automatic with TSS	manual (emailed)

### Data Entry

Manual data entry consists of a two-step process, reflecting the structure of the database, and is geared toward planned burn events. A user must first define a “project”, which defines the following (required inputs are **bold**):

- **Source Type**
- Fire Name
- Responsible Agency
- **State**
- **Location (latitude and longitude)**
- **Fuel type**
- **Burn Type (e.g. broadcast)**
- **Burn Category**
- **Start and End Dates**

Start and End dates are required as a housekeeping measure (and therefore do not need to be exact), and allow the user to close-out projects that are no longer active. As long as a project’s end date is in the future, it will continue to show up on the list of projects on the View page.

A separate page allows a user to then define individual days of burning for that project

- **Acres (planned and actual)**
- Fuel Loading
- Pile data (Volume and quantity)
- **Date of Burn**
- Fuel Type (may use Project value)
- **Emission Reduction Techniques**
- Emissions

A user may view and edit information from two View pages: 'View My Projects' and 'View My Burn Days.'

Data may also be submitted in batch form via FTP. A page on the website, available only to Data Providers, instructs users on the procedure. A template Excel file is provided and must be followed for submittal to succeed. Upon submittal, a user will receive a confirmation email with a detailed, record-by-record error report. Any errors in a submitted file results in rejection of the entire data set; the user may re-submit after addressing any errors.

## Mapping

The FETS has the capability to map planned and unplanned fire events for use in regional and intra-agency coordination. A key feature asked for by many states was the ability to view planned and active fire in neighboring as well as their own airsheds. With this as well as stated FTS policy goals in mind, the mapping tool has several minimum capabilities.

Planned and active fires for a user-specified window of time are displayed on the map; the default date range is yesterday to today – this is ensure the previous day's reported wildfires are shown (ICS-209 data is reported one day behind – [see the section on Data Acquisition](#)).

Information about each displayed burn location is viewable by clicking an icon on the map, and includes,

- Area (acres) – planned acres for the period as well as cumulative accomplished acres.
- Estimate of emissions
- Source of data (e.g. ICS-209; MT/ID Airshed Database; FASTER)
- Number of burns to which ERTs were applied

In addition, wildfire, prescribed, WFU, agricultural, and rangeland burns are displayed with unique icons.





Control features of the mapping tool include:

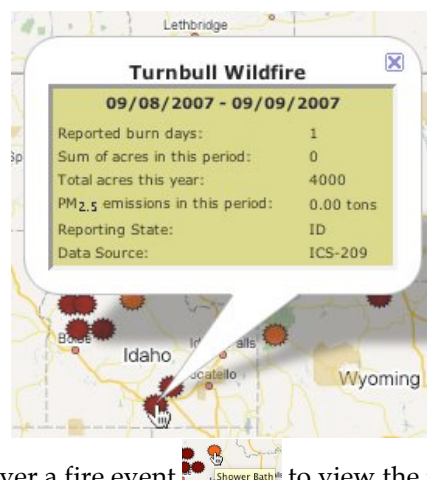
- The ability to Zoom in/out of a desired region and pan to adjacent areas.

- Advance or retreat the date period by one day.
- Sum fire activity by county or by state for the chosen date range; new icons appear at the centroids of the chosen political boundaries.
- Center the map over Alaska or the contiguous WRAP States.

The engine for map creation is the client-side web version of Google Maps API. The tool consists of an embedded Google Map interface. Fire data from the FETS database is queried over the chosen date range and assembled into a XML file. The file is parsed and fed into the Google Map. Burn days with identical coordinates, whether or not they are associated with the same fire, are aggregated and appear on the map as a single icon. The total number of burns at that location is reported in the pop-up window.

### Map Tool Navigation

The mapping tool makes use of the Google Maps API. By default, the map displays the fire activity for today and yesterday. The date range may be adjusted using the **Start:** 1/8/2007 **End:** 9/9/2007 < > bar. The '<' and '>' buttons advance or retreat both dates together by one day. Events may be summed by County or State using the **Display** All Events menu. Pan the map using 1) Use the  tool; 2) Double-click on a point on the map to center around that point; 3) Click-and-drag the map. Zoom in and out with the  slider below the  tool. Fire information is displayed by mousing-over a fire event  to view the fire name, or double-clicking an event, shown at right.



### Reporting Services

The FETS has two reports that are both downloadable and viewable from a web browser. The first, Quick QC, is a series of tables summarizing fire activity:

- Fire Summary by Source Type by Burn Type.
- Source of Fuel Loading by Source Type by FCC derivation option (user-provided, GIS point overlay, or GIS buffer overlay).
- Number of Natural/ Anthropogenic Events By Month and by Source Type.

Only burns marked as 'Accomplished' and that have a valid latitude/longitude are included in this report.

The second report, EI Summary, produces a table of daily emissions for all Accomplished fire events, including those with invalid location values. Both reports have the following query options:

- Date Range
- State (All or one)
- Agency (All or one)
- Emissions Calculation Method (WRAP-modified AP-42 or CONSUME)

Reports may be viewed on-screen in HTML format, or downloaded as a MS Excel spreadsheet.

### 3: Technical Node

Operations performed in the Technical Node are controlled and executed by the Python scripting language. There are three groups of scheduled Python scripts controlled by CRON, the UNIX task scheduler. These groups include:

- Morning Downloads. Scheduled to run at 1 am every day, this series of tasks includes several downloads: BlueSky and ICS-209 data from ftp2.fs.fed.us, a Forest Service FTP site; MT/ID data via a web service query and an HTTPRequest to grab the generated files; batch files submitted to the FETS FTP site; and weather data from the Weather Information Management System (WIMS) for the past 14 days. All downloaded files are then processed and data inserted into the database.
- Daily Tasks. Scheduled to run every 15 minutes, this module looks for new or updated records generated through the website that are flagged for an FCC code from the GIS overlay. It also generates FIPS codes using a script, originally developed by Robert Solomon of the USDA Forest Service Region 6 using PHP and re-written in Python, for records missing that information. In addition, the module looks for new batch files on the FETS FTP site to download and process.
- Weekend Tasks. This module is run every Sunday at 5am, and includes two tasks: applying fuel moisture and rain event data to records in the database with a date within the past 365 days, and running CONSUME for records marked as 'Accomplished' in the database (records are marked 'Accomplished' when the AcresActual field is populated).

Log files are kept continuously for the three groups. For every task, any errors that occur are immediately emailed to the database administrator so corrective action can be taken. Error trapping is in place such that a failure for any individual step (such as downloading an individual file, or sending a query to the database) will not halt the entire task or module. For a detailed map of Python scripts and their interaction, see Appendix C.



## Emission Calculations

The WRAP-modified AP-42 method of emissions calculation was implemented as the default option for calculating emissions in the FETS. As burn days are entered into the FETS database, emissions are calculated instantaneously by a database trigger and made available to mapping and reporting services for use in regional coordination. In addition, it serves as a useful comparison to previous inventories built using this method.

The Project Team recognizes the benefit to moving toward a more resolved and widely-accepted emissions calculator. CONSUME 3.0 was chosen as the most feasible for incorporation into the FETS. At this time, the modified AP-42 method of emissions calculation will continue to be used for estimating PM<sub>2.5</sub> emissions on a regional coordination level as a rough day-by-day guide. CONSUME 3.0 is used to estimate emissions as accomplished acres and other post-burning reporting becomes available. CONSUME is run automatically every Sunday morning.

CONSUME requires certain ancillary information to calculate emissions for a fire event that is beyond the minimum required data elements outlined in Section 1. 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 Workplan. The methods were presented to the FETS Task Team and the CONSUME development team and deemed reasonable.

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 provides defaults and/or equations to estimate values for several of the additional elements. For the remaining parameters, alternate solutions were sought. The CONSUME defaults, as well as the parameter sources for the FETS, are shown in Table 2. Further explanation for some parameters is provided in Appendix A as part of the original Strawman document. It should be noted that while the FETS cannot rely on data providers to consistently submit these additional data, user-supplied data for any of the parameters discussed here always supercede default or derived values.

**Table 2: FETS defaults for additional parameters required by CONSUME.**

Parameter	CONSUME default	FETS default
10 hr Fuel Moisture	None	GIS/WIMS data <sup>1</sup>
1000 hr Fuel Moisture	None	GIS/WIMS data <sup>1</sup>
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 <sup>1</sup>
Ignition duration	Equation based on acres and "intensity"	Use equation, but "intensity" is always the same <sup>1</sup>
Wind Speed (mph)	Max 35 mph	10 mph
Slope (%)	20	Use CONSUME default

Days Since Rain	None	GIS/WIMS data <sup>1</sup>
Harvest?	None	FALSE
Snow off?	None	FALSE
Number of piles	None	(V x 0.0057) / Acres <sup>1</sup>
Pile Shape	None	Half-ellipsoid <sup>1</sup>
Pile Dimensions	None	10'W x 6'H x 9.5'L <sup>1</sup>
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

**(i) Pollutants and User-provided Emission Estimates**

CONSUME 3.0 calculates emissions for PM, PM<sub>2.5</sub>, PM<sub>10</sub>, CO, CO<sub>2</sub>, non-methane hydrocarbons (NMHC), and methane (CH<sub>4</sub>). Additional pollutants calculated in past WRAP emissions inventories include elemental carbon (EC), organic carbon (OC), SO<sub>2</sub>, NO<sub>x</sub>, ammonia (NH<sub>3</sub>) and coarse PM. A complete suite of pollutants for each fire event will be developed by combining CONSUME 3.0 values and WRAP-modified AP-42 method values.

In addition to performing emissions calculations within the database, the FETS accepts user-provided emissions values. User-provided emission estimates are likely to not include all pollutants in the complete suite of pollutants. Therefore, a complete suite of emissions for each fire event may contain estimates from user-provided data, WRAP-modified AP-42 calculations, and CONSUME calculations. All three methods of calculation are stored concurrently in the database, and users may access each method through Reporting Services on the FETS website.

**(ii) Special Purpose Emission Estimates**

For certain end-user applications, the final suite of emissions estimates developed in the FETS may be insufficient or incomplete. For example, a specific modeling application may require speciation of VOCs beyond those reported in the FETS, or require an estimate for mercury emissions. Furthermore, certain applications may benefit from fire emission calculations using perimeter / remotely sensed data or plume characteristics. The FETS is designed to initially provide emissions data equal in quality and integrity to existing inventory methods. However, this focused capability will not preclude the FETS from providing flexibility to applications with additional requirements.

The FETS database is designed such that additional pollutants or calculation methods may be appended without a wholesale revision of the architecture. Emission calculation methods are integrated into the FETS in a modular fashion such that each method operates on a unique set of records in the database: adding a new calculation method will generate a new set of records for all or a specified subset of fire events stored in the FETS while the existing metadata and emissions calculations remain intact. Similarly, emissions for each pollutant are stored as unique records which allows new pollutants to be added and efficiently applied, even retroactively.

### **(iii) Fuel Classification Layer.**

A common feature between all emissions calculation methods is the need for information pertaining to vegetative cover/fuel classification and estimates of fuel loading and fuel consumption. The FETS uses the Fuel Characteristic Classification System (FCCS) (continental United States), and the Canadian Forest Fire Danger Rating System (CFFDRS) cross-walked to FCCS for Alaska. For users entering data via the web interface of the FETS, users can select fuel class directly from a pull-down menu and enter a custom fuel loading for a burn.. For fire emissions data that are mined by the FETS or provided in batch mode by data providers, fuel class information may be missing. Therefore, a GIS routine has been implemented in the FETS to overlay fire events on a 1-km FCCS (or CFFDRS) fuel bed map. At this time, a single fuel classification and associated fuel loading corresponds to a given set of fire event coordinates— fire perimeter information will not be incorporated. Details about this and other GIS services are outlined in the next section.

### **(iv) Emission Reduction Techniques**

The FETS accommodates the use of Emission Reduction Techniques (ERTs). ERT data will likely come in to the FETS at different times for different states, and in many cases ERT data will not be available until after post-burn reporting has been submitted. The following approach is used to handle ERT information:

- For regional coordination purposes, the ERT(s) applied to an event are noted (if available) but no calculations to reduce emissions for the event are performed (only uncontrolled PM2.5 emissions are presented).
- As post-burn reports are submitted and accomplished acres recorded, ERT application will be incorporated into emissions calculations.
- An interface to assist website users with selecting appropriate ERTs are integrated into the data entry/edit screens.
- Final, quality-controlled emission inventory estimates will include emissions averted due to the use of ERTs.
- The **WRAP ERT Technical Package** is available as a reference for users and the WRAP ERT Seasonal Suites are used as a default for the calculation of emissions averted (for

instances for which fire event data indicates that ERTs were applied but no specific information on the ERTs is provided).

Emission reduction techniques and emission reduction factors are stored as look-up tables in the FETS. Based on the level of detail, an Emission Reduction Factor (ERF) is applied to the burn following a hierarchy:

1. The user supplies an ERF for a burn that is applied directly to emissions calculations.
2. The user supplies an emission reduction technique; the ERF is chosen based on the season and region for the chosen technique, as outlined in the ERT matrix developed for the WRAP ERT Technical Package.
3. The user indicates ERTs were applied but gives no further information; an ERF is chosen based the region and season, as outlined in the seasonal suites developed for the WRAP ERT Technical Package.

## **GIS Services**

GRASS 6.2 is implemented in the technical node to perform spatial overlays of fire data onto other map layers, and create interpolated surface maps of fuel moisture for the WRAP region.

### **Fuel Moisture Interpolation**

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

Fuel moisture data from WFAS is downloaded and interpolated by a 2<sup>nd</sup>-order Inverse-Distance-Weighted (IDW) transformation 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 are stored in the Technical Node.

### **Number of Days since Rain Interpolation**

The “Days since Rain” parameter as an input to CONSUME 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 daily WIMS dataset, described above, reports precipitation at each station in the WRAP region, and is used to determine “Days Since Rain” for fire events. Similar to fuel moisture, precipitation values is 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) had its start date one year 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 is used.

### **Map Overlay Operations**

Fuel classification, 10-hour moisture, 1000-hour moisture, and Number of Days Since Rain are determined automatically by the FETS using a 1-km FCCS fuelbed map (or equivalent CFFDRS map for Alaska) and the maps described above. An automated routine pulls fire events from the database (with a spatial location), drops the data onto a map layer, and inserts the resulting fuel class, moisture, or rain event information back into the database for each fire event. Fuel classification overlays are done immediately upon entering a new fire; moisture and rain event overlays are done when the fire is listed as Accomplished.

Occasionally WIMS data are not available for a particular day; in these cases, the moisture and rain event map for the previous day is used to derive values for accomplished fire events. In addition, during the interpolation routine each day, the routine looks for WIMS data in the previous two weeks in and retroactively interpolates maps for missing days. This means that, if a map is missing in the previous week, the DSR map is re-calculated for every day starting with the day of the missing map following Equation 1.

*Fire events that have user-provided values always supersede corresponding GIS-derived values..*

### **Data Acquisition and Exchange Interface**

Several methods were developed to assimilate data into the FETS as alternatives to manual entry. For Smoke Management Programs (SMPs) that have or are developing a database for tracking and permitting purposes, streamlined, automated methods of data transfer were investigated. Currently, the following methods are used to gather data from outside systems:

- FASTRACS (OR and WA) – Pulls data files that are sent daily to a Forest Service ftp server by the FASTRACS system, intended for BlueSky – RAINS. Files are then processed by the Technical Node. Each state data set includes three files:
  - “P1” – Proposed burns for the next day (tomorrow).
  - “P2 – Proposed burns for the day after next (two days out).
  - “A” – Accomplished burns, including burned acres and emissions.
- MT/ID Airshed Database – Query the database via a web service, download the files generated by query, and process in the Technical Node. There are three possible files:
  - “Preseason” – Data to define Projects before the burn season begins. Burn proposals are always tied to a project.
  - “Proposed” – Proposed burns scheduled in the near future. Burns may be proposed up to seven days in advance – the query grabs all proposals from the current day onward.
  - “Completed” – Accomplished burn data, including burned acres and emissions.

The Preseason and Proposed data sets are queried every day; the Completed data are queried once a week, grabbing every completed burn from the current day back to ensure gap-filling – this does add some redundancy, but ID filters are in place to avoid any duplicates from entering the database.

- AZ Smoke Management Database – An email containing activity data is sent from the AZ system and read by the FETS Technical Node. To date, a test data set was sent and the processing module is in place. However, the AZ database system is not yet online.

The other primary alternative to manual entry is to submit data via an FTP site. Instructions are provided to registered Data Providers on the website, as well as a template that must be followed; accepted file formats are comma-delimited (.CSV) and Microsoft Excel (.XLS). Once data have been submitted, the Technical Node processes the data files similar to the acquisition methods listed above.

### **Database Quality Assurance / Quality Control**

QA/QC focuses on several aspects of data entry and storage in the FETS. Every data field in the database tables populated by user data carries basic constraints, including

- Data type
- Length (if text)
- Minimum and Maximum (if numeric and applicable)

Effective quality control within the FETS relies upon built-in, automated checks and QC review by Data Providers. Automated QC checks are summarized in Table 3, comparing methods of input. Data input via batch files (which applies to direct data streams outlined in the previous section) go through a more robust set of automated QC checks than manually entered data. For manual entries, the FETS includes a confirmation page after submitting data to allow for review, including a map showing the location of the fire. In addition, for data fields with a limited set of possible choices (such as State), pull down menus (created directly from lookup tables in the database) are in place of keyboard entry.

**Table 3: Summary of automated QC procedures for different methods of data submittal.**

<b>Internal QC Procedure</b>	<b>ICS-209</b>	<b>Batch Files</b>	<b>Website</b>
Duplicity	X	X	
Data types (e.g. proper date formats)	X	X	X
range checks (e.g., negative area?)	X	X	
location checks		X	

### **3: Technical Integration to the WRAP Technical Support System**

Linking the FETS to WRAP’s Technical Support System (TSS) will provide states and Tribes ongoing regional technical support, as well as data access and visualization tools for their regional haze planning. The FETS will be supported by TSS, thus placing software and hardware maintenance issues in a known and tested environment.

Fire emissions inventory work will be integrated into the TSS by definition – providing the opportunity for ESMPs to integrate the fire data into the rest of the regional haze emissions, monitoring, and modeling data. Integrating the FETS into the TSS will support the development of regional haze SIPs, including:

- Support of essential technical SIP documentation pertaining to fire emissions; and
- Technical tools in the TSS that produce technical demonstrations of Regional Haze Section 309 states’ efforts to fulfill Annual Emission Goals requirements.

Short-term integration to the TSS (by mid-2007) involves providing a direct link from the TSS website to the FETS. The long-term goal in the next year is to merge with the TSS so that all states and tribes can share fire activity/emissions data and use the data in TSS analytical and regional planning tools for regional haze SIP planning and preparation. The Project Team has decided to prioritize preparing for full integration from the outset. Mirroring the existing TSS database structure, and identifying areas in the TSS system that need to be adapted to fire data will facilitate integration of the two systems. The TSS will import data from the FETS at an undetermined frequency. Storing data in the TSS separately allows the FETS to maintain some degree of autonomy allowing the system flexibility to evolve over time. In addition, no

additional burden will be placed on the FETS system as it will not need to serve queries from users of both systems.

#### **4: List of Supporting Documentation**

Documentation for this project will be prepared by the Project Team. Specific documentation deliverables will include:

- Technical Support Document (draft and final forms) including: a description of the methods used to evaluate and select any commodity products, methods used to construct the FETS software, assumptions, and limitations. Final version will include specific feedback from beta testers.
- FETS Users Guide (draft and final forms). Complete and explicit. Instructions and protocols on using all aspects of the FETS will be included: manually entering data; batch-loading files (including an example of the correct format); editing and deleting data; using the map tool; and data retrieval.



# Consume 3.0 Supplementary Inputs Strawman

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The Project Team produced two technical memos in the process of FETS development on the topic of emissions calculations. The first memo was incorporated, with feedback from the Task Team, into the final Workplan; the second memo is presented here.

## Background

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.

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 <sup>1</sup>
1000 hr Fuel Moisture	None	GIS/WIMS data <sup>1</sup>
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 <sup>1</sup>
Ignition duration	Equation based on acres and "intensity"	Use equation, but "intensity" is always the same <sup>1</sup>
Wind Speed (mph)	Max 35 mph	10 mph
Slope (%)	20	Use CONSUME default
Days Since Rain	None	GIS/WIMS data <sup>1</sup>
Harvest?	None	FALSE
Snow off?	None	FALSE
Number of piles	None	(V x 0.0057) / Acres <sup>1</sup>
Pile Shape	None	Half-ellipsoid <sup>1</sup>
Pile Dimensions	None	10'W x 6'H x 9.5'L <sup>1</sup>
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

<sup>1</sup>Explained 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:

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

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

...

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):

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

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

**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

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

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

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:

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

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.

Prichard, SJ., RD Ottmar, and GK Anderson (2006). *Consume 3.0 User's Guide*. Pacific Wildland Fire Sciences Laboratory; USDA Forest Service, Pacific Northwest Research Station. Seattle, WA.

# Technical issues for future consideration

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1. Smoldering emissions.
  - a. Evaluate if and how will they be handled and stored in the FETS. CONSUME 3.0 includes smoldering estimates when calculating emissions. However, these estimates cannot be isolated from flaming emissions and stored separately in the database. In addition, the WRAP-modified AP-42 method used in the FETS does not consider smoldering.
2. Enhanced GIS capabilities
  - a. Retroactively integrate fire perimeter data from the Monitoring Trends in Burn Severity (MTBS) project to use, as two examples, with the mapping tool as overlays, or to derive weighted-average fuel loadings.
  - b. Integrate satellite fire detect data into the FETS. This may include a direct application of the MODIS Fire and Thermal Anomalies product, or tapping into the SMARTFire data stream that is anticipated for BlueSky-RAINS.
  - c. Allow users to download historical data into Google Earth. This would be made available from the Reporting Services page in the form of a formatted XML file (as .kml) to populate Google Earth with fire point locations (or, eventually, perimeter data) with viewable information about each fire.
3. Fuel classification.
  - a. How current is the FCCS 1-km fuel bed map for the United States? Devise a scheme to keep the FETS updated with the most current fuel classification layers for GIS services. Similarly, the stored FCCS used by CONSUME must be kept current.
  - b. Allow users to create custom fuel beds on the FETS website for use with CONSUME. In addition, create an additional page on the FETS to allow users to edit ancillary CONSUME input data for any fire event.
  - c. Incorporate fire perimeter data into GIS fuel classification scheme.
4. Historical Data and Projections.
  - a. Import WRAP's event-based fire emissions projection (2018) inventory data into FETS.
  - b. Import historical data. This could be previous emission inventories such as 1996 and 2002, or individual data set provided by states for any year.

Map of Python Scripts used in Technical Node

