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FINAL

Development of 2000-04 Baseline Period and 2018 Projection Year Emission Inventories

WESTERN GOVERNORS ASSOCIATION / WESTERN REGIONAL AIR PARTNERSHIP

PROJECT NO. 178-8
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EXECUTIVE SUMMARY

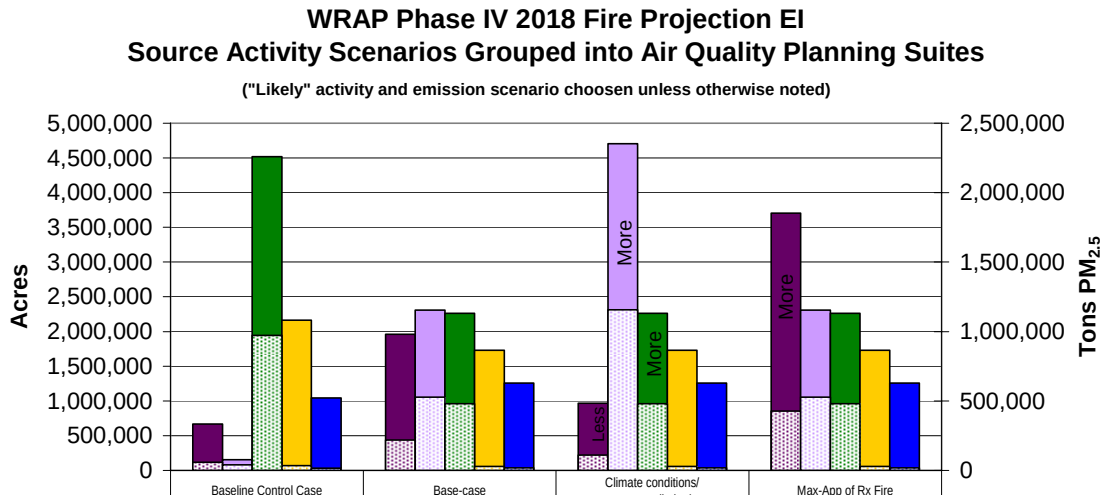
The Fire Emissions Joint Forum (FEJF) of the Western Regional Air Partnership (WRAP), through a contract issued by the Western Governors Association (WGA) to Air Sciences Inc. and EC/R Incorporated, has prepared "Phase III" baseline period (2000-2004) and "Phase IV" projection year (2018) fire emission inventories. This document is a summary of the technical methodology, activity data, and calculated emissions for baseline and projection inventories of wildfire, prescribed burning, wildland fire use (WFU), agricultural burning, and non-federal prescribed rangeland burning (NFR).

The purpose of this project ("Development of 2000-04 Baseline Period and 2018 Projection Year Emissions Inventories") is to develop fire emissions inventories (EIs) for regional haze planning purposes. The inventories are intended to be representative of fire emissions during the Regional Haze Rule's (Rule) baseline monitoring period (2000-04) and to describe potential fire activity scenarios for the Rule's initial projection year of 2018. Projection inventories were prepared for "less," "likely," and "more" activity scenarios for each fire type. Then individual EI files for each fire type were combined to form three distinct air quality planning suites for fire emissions:

- Base-case – Likely projection activity scenarios for all fire types.
- Climate Conditions/Resource Limited – More occurrences of wildfire and Wildland Fire Use with less application of prescribed burning in wildlands.
- Max-Application of Prescribed Fire – Highest level of application of prescribed burning with likely activity levels for all other fire types.

The EI data files and air quality planning suites produced for this project are to be used for regional dispersion modeling analyses and to populate the WRAP's Emissions Data Management System (EDMS). In addition, the deliverables for this project are intended to provide necessary, timely, and sufficient documentation for use by WRAP members for use in assessing the need, structure, and scope of fire and smoke emissions management programs in the implementation plans due by the end of 2007. Figure ES-1 and its associated data table present a summary of the results of the baseline and projection emission inventories.

Figure ES-1: Baseline and Projection Emission Inventory Results



	Baseline Control Case	Base-case	Climate conditions/ resource limited	Max-App of Rx Fire
Prescribed Acres	669,348	1,959,700	966,191	3,704,327
WFU Acres	153,697	2,311,067	4,703,922	2,311,067
Wildfire Acres	4,517,818	2,263,069	2,263,069	2,263,069
Agricultural Acres	2,164,166	1,730,333	1,730,333	1,730,333
NF Rangeland Acres	1,042,003	1,257,004	1,257,004	1,257,004
Prescribed PM2.5	59,635	219,298	110,091	427,028
WFU PM2.5	41,171	526,636	1,155,633	526,636
Wildfire PM2.5	971,453	480,269	480,269	480,269
Agricultural PM2.5"	34,590	29,591	29,591	29,591
NF Rangeland PM2.5	15,454	18,643	18,643	18,643

The methodologies for creating the baseline inventories for each fire source, along with a presentation of the results of the baseline inventory work appear in Section 2. The methodologies and results for the projection inventories are presented in Section 3.

SECTION 1

INTRODUCTION

The Fire Emissions Joint Forum (FEJF) of the Western Regional Air Partnership (WRAP), through a contract issued by the Western Governors Association (WGA) to Air Sciences Inc. and EC/R Incorporated, has prepared "Phase III" baseline period (2000-2004) and "Phase IV" projection year (2018) fire emission inventories. This document is a summary of the technical methodology, activity data, and calculated emissions for baseline and projection inventories of wildfire, prescribed burning, wildland fire use (WFU), agricultural burning, and non-federal prescribed rangeland burning (NFR).

The purpose of this project ("Development of 2000-04 Baseline Period and 2018 Projection Year Emissions Inventories") is to develop fire emissions inventories (EIs) for regional haze planning purposes. These wildfire, wildland fire use, prescribed fire, rangeland fire, and agricultural fire EIs will be representative of fire emissions during the Regional Haze Rule's (Rule) baseline monitoring period (2000-04) and describe potential inventory scenarios for the Rule's initial projection year of 2018. The objective is to build event-based inventories comprised of realistically sized, placed, and timed fires that add up to equal activity targets that have been determined to be representative of the baseline and projection periods. The source of the fire events used to populate the baseline and projection inventories are the fire event records from the WRAP's Phase II (historical 2002) fire emission inventory.

In order to gather data and develop appropriate assessment and analysis techniques, Air Sciences directed two Phase III/IV Technical Workshops (Workshops) in August and November 2005. The Workshops were attended by federal land managers, Smoke Management Program personnel, and any other stakeholders that wished to participate. The primary purpose of the Workshops was to agree on the baseline and activity targets for each fire type (wildfire, Wildland Fire Use, prescribed burning, agricultural burning, and non-federal rangeland burning). In the Workshops, participants were presented Strawman approaches for their consideration and then participants and the contractors would work together to refine and approve the technical approaches to be employed to build the baseline and projection inventories. The details of the Workshop #1 (August 2005) can be reviewed at http://www.wrapair.org/forums/fejf/meetings/050810fc/index.html and the details for Workshop #2 (November 2005) can be reviewed at http://www.wrapair.org/forums/fejf/meetings/051101m/index.html.

Results from prior and ongoing FEJF emissions inventory work, air quality sensitivity modeling results, and source attribution analyses will provide additional information on the appropriate considerations and framework to conduct the preparation of the baseline and projection years' fire EIs.

The EI files for this project are expected to serve as input to the WRAP Emissions Data Management System (EDMS). The EDMS is expected to be capable of producing output EI files that can be used in regional modeling analyses to quantify the air quality improvements associated with emissions reductions due to smoke management programs being implemented by WRAP states and Tribes. In addition, the deliverables for this project are intended to provide necessary, timely, and sufficient documentation for use by WRAP members for use in assessing the need, structure, and scope of fire and smoke emissions management programs in the implementation plans due by the end of 2007.

For regional dispersion modeling purposes, the baseline and projection inventory files have been delivered in SMOKE Model Format (PT/IDA). For emission inventory purposes, the baseline and projection inventory files have been delivered in database file (DBF) format.

There are many technical methodologies that are common to the development of the Phase II events that are used to build both the baseline and the projection fire emission inventories. These methodologies are described in detail in the documentation for previously completed WRAP/FEJF projects. These projects are listed below and the posted documentation is available on the FEJF project pages of the WRAP's website (url's are provided in parentheses). In addition, for ease of reference as reviewers read this document, descriptions of several critical technical methodologies are included in this report in Appendix X.

- WRAP Phase I Fire Emission Inventory. (http://www.wrapair.org/forums/fejf/tasks/FEJFtask7PhaseI.html)
- WRAP 2002 Phase II Fire Emission Inventory. (http://www.wrapair.org/forums/fejf/tasks/FEJFtask7PhaseII.html)

1.1 Fire Inventory Calculation Tool

Air Sciences Inc. developed an EXCEL-based spreadsheet tool to generate the nominal (i.e., not actual) fire event databases for the baseline and projection inventories. The essential functions of the Calculation Tool include:

- Store Phase II fire events (actual fire events) as "seed" data to be used to build the nominal, event-based inventories.
- Accommodate entry of state- and agency-specific fire activity targets (in acres) for the inventory planning years (Phase III – 2000-2004 representative year; Phase IV – 2018).
- Perform database processing tasks that populate the nominal fire inventory with seed data until the state- and agency-specific fire activity targets are reached.

The Calculation Tool, while developed to prepare the baseline and projection inventories for this project, will be modified and made available to WRAP states and Tribes to facilitate preparation of custom nominal inventories of prescribed fire. It is anticipated that the Calculation Tool will be available to states and Tribes in the spring of 2007 as a technical tool on the WRAP's web-based Technical Support System.

1.2 Quality Assurance/Quality Control

The Quality Assurance/Quality Control (QA/QC) Plan was implemented as specified in Appendix A of the project Work Plan (Air Sciences and EC/R, August 2005). Specific QA/QC procedures are described in the text of this report. In addition, changes to the inventories that arose out of the implementation of QA/QC procedures are presented and quantified in the text of this report.

1.3 National Inventory Format (NIF) Files

Air Sciences, in consultation with the FEJF, have concluded that NIF files for the baseline and the projected fire inventories will have limited utility for WRAP states and tribes. This finding is based on the fact that the baseline and projection fire inventories are nominal (i.e., not actual) inventories and files in NIF format have historically been used for States and Tribes to fulfill federal requirements for periodic reporting of actual emissions to the National Emission Inventory (NEI). Therefore, the NIF files will not be prepared. Air Sciences will retain the scripts to create the NIF files in the future if required by the WRAP.

SECTION 2

BASELINE (2000 – 04) FIRE EMISSION INVENTORIES

Baseline period (2000-04) inventories were built based upon the FEJF's Phase II (historical 2002) inventories for wildfire, wildland fire use, prescribed burning, agricultural burning, and non-federal rangeland burning completed in 2005 by the FEJF (Air Sciences, July 2005 http://www.wrapair.org/forums/fejf/tasks/FEJFtask7PhaseII.html).

The fundamental steps to build the baseline fire inventory were:

1. Gather relevant activity data to determine emissions estimates; and
2. Apply various assessment and analysis techniques to determine if and where fire emissions for the 2000-04 period are different from the WRAP Phase II "actual 2002" inventory report and EI products at various appropriate geographic scales, using statistical significance tests.

The project team has prepared a 2000-04 baseline period EI similar in scope and scale to the Phase II 2002 fire EI. The process for preparing the baseline period EI included an assessment of whether the temporal and spatial distribution of the Phase II 2002 EIs for all types of fire can be preserved or can reasonably be changed with technical justification. These analyses were presented to the FEJF prior to building the baseline period EI. For WRAP region jurisdictions with Smoke Management Programs (SMP), data were also gathered to allow the calculation of the benefit of applying Emissions Reduction Techniques (ERTs) in each jurisdiction's SMP.

Wildfire, prescribed burning, and WFU baseline emission inventories were each created by "scaling" the respective Phase II inventory up or down based on an analysis of independent activity data across the baseline period. Agricultural burning and non-federal prescribed rangeland burning inventories for Phase II were considered to be representative of annual activity during the baseline period. Therefore, the Phase II EIs for agricultural burning and non-federal rangeland burning were used as is as the baseline inventories.

2.1 Wildfire Baseline Inventory

A single scenario for wildfire activity was developed that represented wildfire in the baseline (2000-04). All events in the wildfire inventory were categorized as "natural" per the WRAP's Fire Categorization Policy.

The WRAP's Phase II wildfire inventory for 2002 (which has been reviewed by state, Tribal, and federal agencies through the Phase II QC process) served as the starting place for the wildfire baseline inventory. The Phase II wildfire inventory was scaled up or down on a state-by-state basis to meet computed baseline levels per the following steps:

1. Air Sciences obtained the Federal Fire History data (Fed-5 data) compiled by the Geospatial Task Group of the National Wildfire Coordinating Group (ftp://ftp.nifc.gov/pub/FireHistoryData/). Fed-5 data is available for the baseline years 2000-2003 but data for 2004 was not compiled at the time of the preparation of the baseline inventories.
2. Developed a summary table of acres of wildfire by state by year.
3. For each state, calculated the mean number of annual wildfire acres over the baseline period 2000 - 2003. This is the average annual activity for the baseline period according to the Fed-5 data.
4. For each state, calculated the difference in Phase II wildfire acres and Fed-5 wildfire acres strictly for year 2002. This difference is intended to emphasize the more resolved data collection and quality control activities in the WRAP Phase II activity data set. The goal for building the baseline inventory for wildfire is to preserve this difference when considering the average annual activity derived from the Fed-5 data.
5. For each state, the Phase II versus Fed-5 difference for 2002 was added to the mean of the Fed-5 wildfire acres. The result represents the "baseline target" in acres for each state. The baseline target divided by the Phase II activity acres is the "baseline scalar" for a state. See Equations 1 and 2.

   Baseline target = [Phase II 2002 – Fed-5 2002] + Average (Fed-5 2000 thru 2003) (1)

   Baseline scalar = Baseline Target / Phase II 2002 (2)

Phase II wildfire events (acres/day for each fire event) were used to build the baseline wildfire inventory on a state-by-state basis (see Figure 1 on page 7). For states with a baseline scalar of less than one, then Phase II events were randomly removed from the Phase II data set for that state until the baseline target in acres was met. If the scalar for a state was greater than one, then wildfire events from the Phase II inventory for that state were randomly repeated until the baseline target was met. Wildfire events added or removed were randomized but fire days comprising an event were kept together. In this way the concept of multi-day events was preserved in the baseline inventory. Similarly, smoldering records were carried over to the baseline inventory (or excluded) according to the outcome of its parent flaming-day record.

In the instances where records from the Phase II inventory were added to the baseline inventory in order to reach the baseline targets, data processing steps were implemented:

- Each event added to the baseline inventory was assigned a random date within the month of occurrence of the original Phase II record.
- All other attributes of the fire event were cloned including acres consumed and tons of each pollutant emitted. The location (latitude and longitude) of the event was not

changed because when the emissions input data are processed by the WRAP's Regional Modeling Center, each emissions event is associated with the 36 km by 36 km grid cell (i.e., the latitude and longitude of the event is not preserved in the results of the model runs). Therefore, the Emissions Task Team of the FEJF determined to not change the latitude and longitude of the event going into the baseline inventory so that the emissions from the event would appear in the same RMC grid cell.

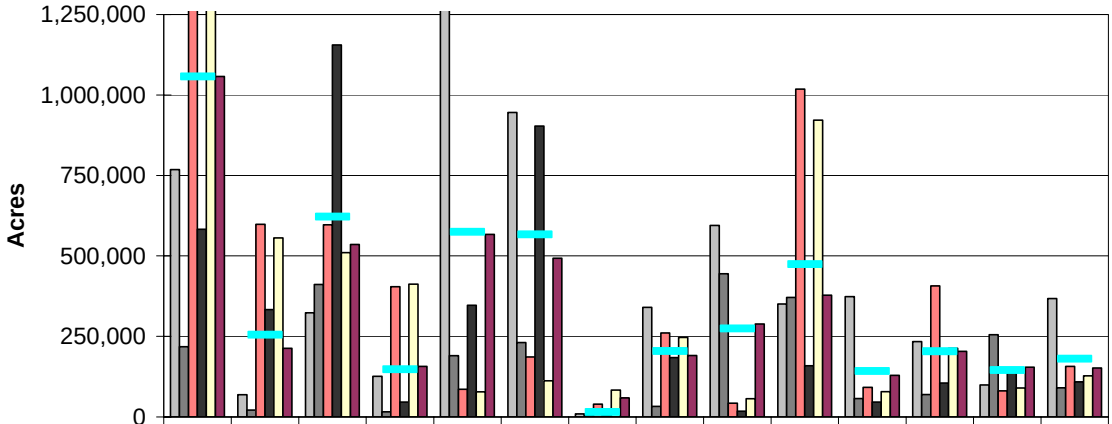
Scaling the Phase II inventory up or down in this manner created a baseline emission inventory with the desired change in emissions magnitude and retention of the overall activity statistics (seasonality, location, fuel types, etc.) of an "actual" year of fire events (the 2002 Phase II inventory). Table 1 presents the WRAP-wide statistics for the baseline inventory (as well as a the Phase II fire statistics for comparison purposes).

Table 1: Summary of Phase II EI and Baseline EI Development

Fire Source	Baseline Adaptation From Phase II	Phase II Acres Burned	Phase II Tons $PM_{2.5}$ Emitted	Baseline Acres Burned	Baseline Tons $PM_{2.5}$ Emitted
Wildfire	Scaled by state	5,276,485	1,489,886	4,517,818	971,453
Prescribed Burning	Scaled by state	649,044	71,421	669,348	72,218
WFU	Scaled by state	201,548	81,505	153,697	41,171
Agricultural	As is + NV	2,162,836	34,571	2,164,166	34,571
NFR	As is	1,042,003	15,454	1,042,003	15,454
Total		9,331,917	1,692,838	8,547,031	1,134,868

Figure 1 and its associated data table show the Phase II wildfire acreage compared to Fed-5 wildfire acreage and the baseline target acreage and lists the scalars used to reach the baseline targets.

Figure 1: Baseline Scalars for Wildfire and Comparison of WRAP Phase II to Fed-5 Database



	AK	AZ	CA	CO	ID	MT	ND	NM	NV	OR	SD	UT	WA	WY
2000 Fed 5	767,707	68,854	323,205	126,301	1,677,150	945,541	9,238	340,445	594,609	350,385	373,416	233,577	99,167	367,077
2001 Fed 5	218,114	21,081	411,334	15,552	190,009	230,694	5,481	32,674	444,329	370,971	57,149	69,382	255,136	90,450
2002 Fed 5	2,660,393	597,932	596,550	404,025	85,614	186,403	39,636	260,990	42,714	1,017,949	91,576	406,698	81,031	156,518
2003 Fed 5	583,214	333,573	1,155,525	45,537	346,840	903,556	5,286	183,991	17,793	158,568	45,992	105,564	145,727	108,374
Phase II Wildfire	1,790,533	555,873	510,140	412,697	77,678	112,413	83,599	247,243	56,218	921,515	78,384	212,853	89,854	127,486
Baseline	1,057,357	213,301	535,244	156,525	566,967	492,559	58,874	190,778	288,365	378,034	128,841	203,805	154,088	151,573
Scalar	0.6	0.4	1.0	0.4	7.3	4.4	0.7	0.8	5.1	0.4	1.6	1.0	1.7	1.2
Average Fed5	1,057,357	255,360	621,653	147,854	574,903	566,549	14,910	204,525	274,861	474,468	142,033	203,805	145,265	180,605

For Alaska and Utah, the 2002 Fed-5 wildfire acreages were at least 1.5 times greater than the 2002 Phase II acreages. Using the 2002 Fed-5 acres in Equation 1 resulted in a baseline target that was less than any individual year of Fed-5 data for the respective state. Upon investigation of the suspected source of the differences in activity levels between the Phase II EI and the Fed-5 data, Air Sciences concluded that the discrepancy is likely to be due to the more rigorous data collection and quality control techniques implemented in the WRAP Phase II project. Implementing the scalar development techniques that were applied to all other states would have produced unreasonably low baseline targets for Alaska and Utah. Therefore, Air Sciences, with concurrence from the Emissions Task Team of the FEJF, elected to use the average of the Fed-5 acres as the baseline targets for Alaska and Utah.

In addition to the "static" baseline inventory for wildfire, a potential range of emissions (from low to high) for wildfire was estimated for the baseline period based on Fed-5 data. The low and high range of wildfire activity was determined from minimum and maximum years of the annual WRAP-wide Fed-5 total acres burned. The low range year of activity was Fed-5 2001 and the high range year was Fed-5 2002. The low and high range of emissions was estimated from the Fed-5 2001 and 2002 activity totals by scaling Baseline $PM_{2.5}$ up or down by the difference between Baseline total acres and the Fed-5 low and high year total acres. As shown in Figure 2,

the low range of emissions was estimated as 512,100 tons $PM_{2.5}$ and the high range as 1,407,100 tons $PM_{2.5}$.

Figure 2: Potential Range of Wildfire Activity and Emissions Estimated From the Baseline Period Fed-5 Data and Comparison to Baseline Activity and Emissions

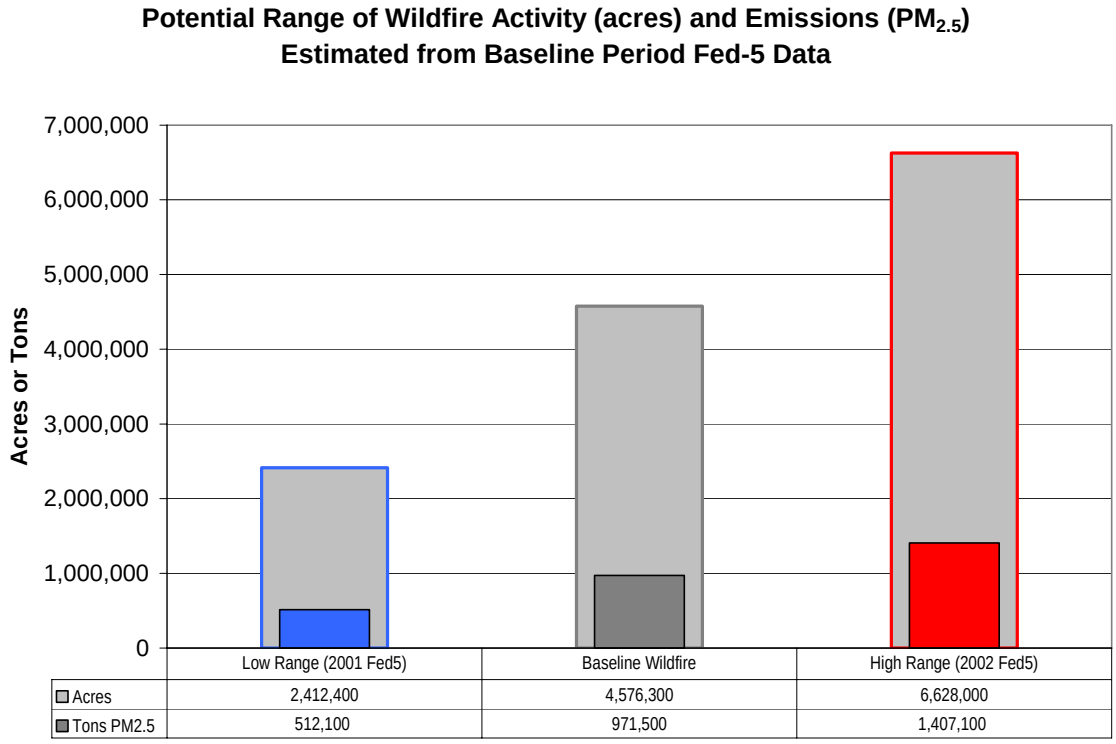
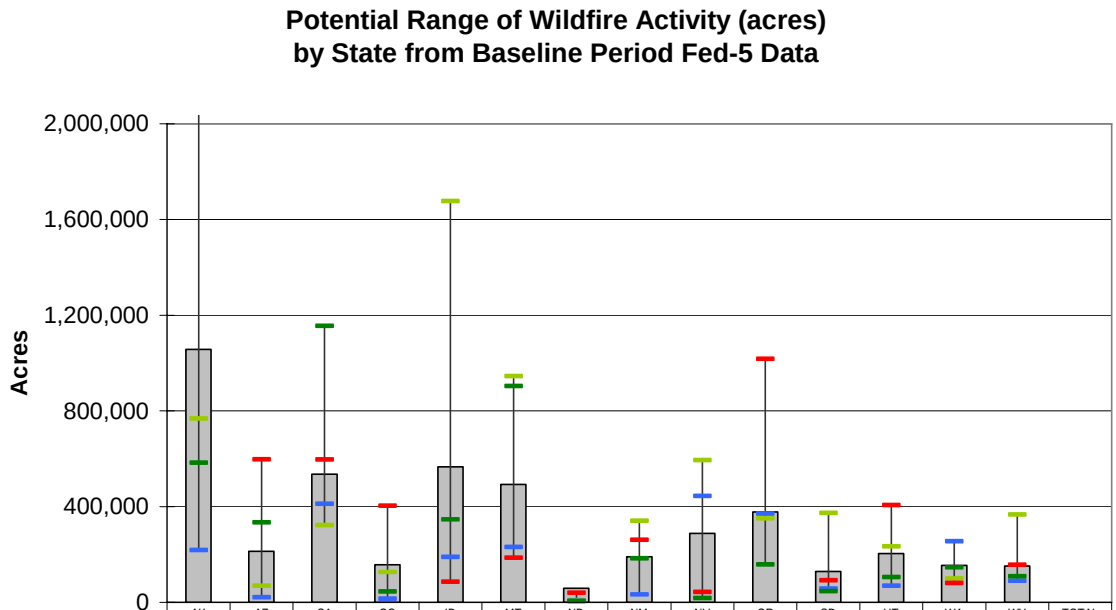


Figure 3 shows the potential range of wildfire activity by state. On a WRAP-wide basis, 2001 was the low range year and 2002 was the high range year. However, for any individual state, any year during the baseline period can have the lowest or highest acres burned. (For example, in Idaho, 2002 was the lowest year and 2000 was the highest year.) The totals shown are the totals for each year. Figure 3 shows the extremes within each state. Note that for the range of emissions estimation, the 2002 emissions do not match the WRAP Phase II 2002 emission inventory because they are estimated from Fed-5 data, not calculated from individual events.

Figure 3: Potential Range of Wildfire Activity by State Estimated From the Baseline Period Fed-5 Data and Comparison to Baseline Activity



	AK	AZ	CA	CO	ID	MT	ND	NM	NV	OR	SD	UT	WA	WY	TOTAL
Baseline	1,057,357	213,301	535,244	156,525	566,967	492,559	58,874	190,778	288,365	378,034	128,841	203,805	154,088	151,573	4,576,311
2000 Fed 5	767,707	68,854	323,205	126,301	1,677,150	945,541	9,238	340,445	594,609	350,385	373,416	233,577	99,167	367,077	6,276,673
2001 Fed 5	218,114	21,081	411,334	15,552	190,009	230,694	5,481	32,674	444,329	370,971	57,149	69,382	255,136	90,450	2,412,356
2002 Fed 5	2,660,393	597,932	596,550	404,025	85,614	186,403	39,636	260,990	42,714	1,017,949	91,576	406,698	81,031	156,518	6,628,028
2003 Fed 5	583,214	333,573	1,155,525	45,537	346,840	903,556	5,286	183,991	17,793	158,568	45,992	105,564	145,727	108,374	4,139,540

2.2 Prescribed Burning Baseline Inventory

The WRAP's Phase II prescribed fire inventory for 2002 (which has been reviewed by state, Tribal, and federal agencies through the Phase II QC process) served as the starting place for the prescribed fire baseline inventory. The baseline inventory for prescribed burning was built state-by-state using methods similar to the process implemented to develop the wildfire baseline inventory. The primary difference between the two methods is that the average annual activity for the baseline period (2000 – 2004) for prescribed burning was obtained from the Interagency Situation Report (SIT) Program SIT/ICS-209 reports (not the Fed-5 data used for wildfire).

The Interagency Situation Report (SIT) Program is a web-based application that captures incident activity and resource status information in summary form intended for use by land managers. SIT reports for prescribed and wildland fires are submitted by Dispatch Offices on a daily basis May through October. Reports are also submitted November through April if wildland fires are active or if fire danger is "very high" or "extreme." The SIT Program uses incident information from the ICS-209 Program. Incident Status Summaries (ICS-209) are submitted to the Geographic Area Coordination Centers (GACCs) and are used to report significant fire events on lands under federal protection or federal ownership. Lands administered by states and other federal cooperators may also report to the ICS-209 Program. Significant events are classified as large

wildfires or WFU events that are 100 acres or larger in timber fuel types, 300 acres or larger in grass or brush fuel types, or events when a Type 1 or 2 Incident Management Team is assigned. The ICS-209 is submitted by the agency that has protection responsibility for the incident regardless of who administers the land. GACCs are responsible for ensuring that reports are complete and accurate. The SIT data was the most appropriate data source available at the time that this project was performed for determining average annual activity during the baseline period because the SIT and 209 Programs "capture incident activity" as opposed to cataloging planned activity.

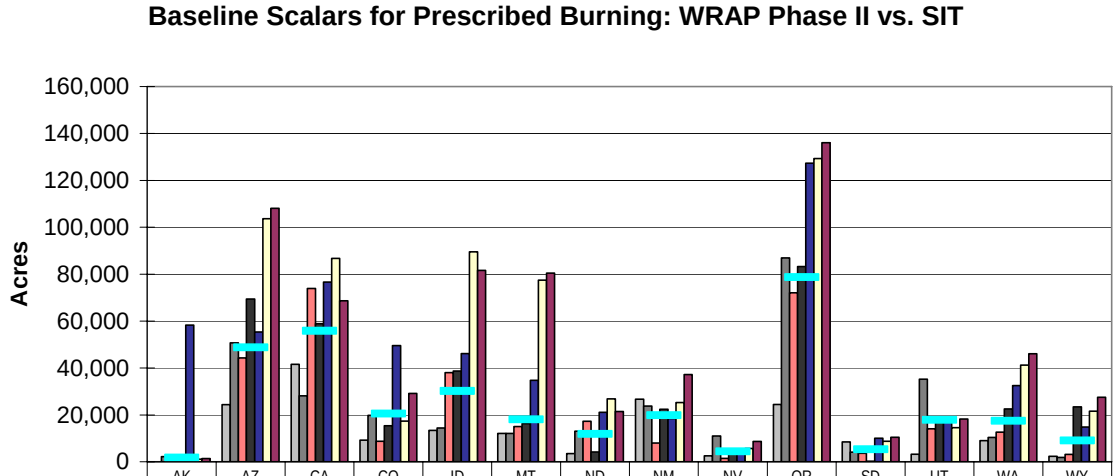
SIT acres were filtered for prescribed burning activity tallied in the "RXACRES" field. The baseline target from prescribed burning was calculated as indicated in Equations 3 and 4.

$$\text{Baseline target} = [\text{Phase II 2002} - \text{SIT 2002}] + \text{Average (SIT 2000 thru 2004)} \quad (3)$$

$$\text{Baseline scalar} = \text{Baseline target} / \text{Phase II 2002} \quad (4)$$

Phase II prescribed burning events were used to assemble the scaled baseline inventory in the same manner as for wildfire. Each event in the Phase II prescribed fire inventory has been categorized as "natural" or "anthropogenic" according the categorization method approved by the ETT and the FEJF. This categorization carried through to the baseline inventory. Figure 4 shows the state-by-state Phase II prescribed burning acreage compared to SIT prescribed burning acreage, as well as the baseline target acreage and the scalars used to reach baseline.

Figure 4: Baseline Scalars for Prescribed Burning and Comparison of WRAP Phase II to SIT Database



	AK	AZ	CA	CO	ID	MT	ND	NM	NV	OR	SD	UT	WA	WY
2000 SIT	0	24,393	41,598	9,235	13,433	12,137	3,506	26,702	2,540	24,427	8,561	3,275	9,080	2,363
2001 SIT	2,280	50,726	28,146	19,769	14,454	12,143	13,071	23,734	11,032	86,951	4,156	35,198	10,430	1,936
2002 SIT	1,560	44,347	73,962	8,762	38,049	15,022	17,269	7,989	1,441	72,005	3,636	14,117	12,624	3,179
2003 SIT	1,555	69,405	58,840	15,398	38,760	16,297	4,235	22,384	3,584	83,260	264	17,886	22,514	23,390
2004 SIT	58,231	55,310	76,586	49,602	46,158	34,802	21,099	18,393	3,630	127,260	10,056	18,840	32,521	14,802
Phase II Rx	1,108	103,619	86,785	17,425	89,477	77,419	26,826	25,292	5,659	129,290	8,811	14,531	41,196	21,605
Baseline	1,346	108,108	68,649	29,216	81,599	80,478	21,393	37,143	8,664	136,066	10,510	18,278	46,006	27,560
Scalar	1.2	1.0	0.8	1.7	0.9	1.0	0.8	1.5	1.5	1.1	1.2	1.3	1.1	1.3
Average SIT	1,798	48,836	55,826	20,553	30,171	18,080	11,836	19,840	4,445	78,781	5,335	17,863	17,434	9,134

For Alaska, review of the 2000 and 2004 SIT acreage during the Workshops by the participants and the contractor resulted in the conclusion that the 2000 and 2004 SIT acreage data were not accurate. Therefore, only 2001, 2002, and 2003 SIT data were used to develop the baseline scalar for Alaska.

2.3 Wildland Fire Use Baseline Inventory

The WRAP's Phase II WFU inventory for 2002 (which has been reviewed by state, Tribal, and federal agencies through the Phase II QC process) served as the starting place for the WFU baseline inventory. The baseline inventory for WFU was built state-by-state analogous to the method used for prescribed burning, also using the SIT database. In this case, the SIT data was filtered for wildland fire use acres identified as "WFURBACRES."

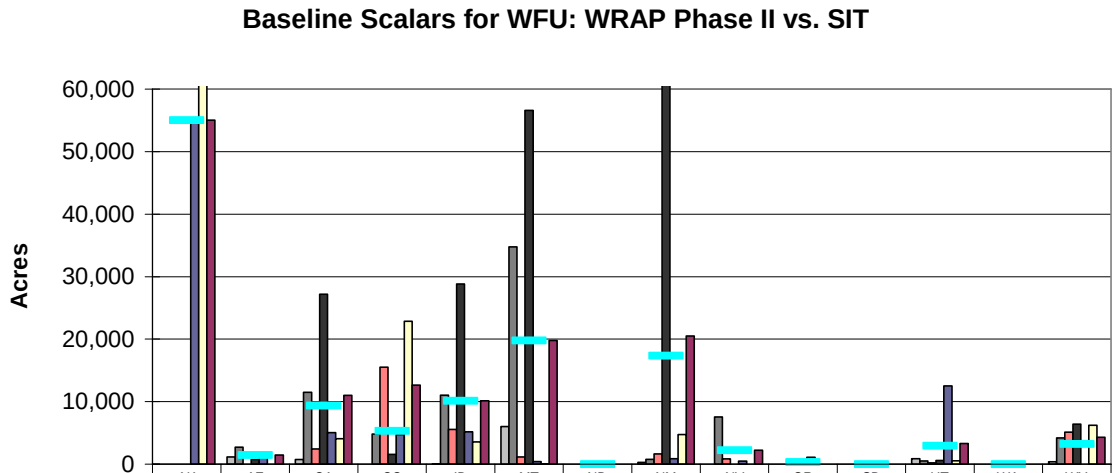
The following special rules were necessary to account for incomplete data in either the Phase II or SIT database.

- The average of the SIT (2000-2004) acres was used as the baseline target if:
  - The Phase II acres were fewer than the SIT 2002 acres (presumed underreporting in Phase II for the affected state).
  - Either Phase II or SIT 2002 has zero acres reported.
- In both North and South Dakota, no WFU acres were recorded in the Phase II inventory or in any year of the SIT data, and therefore baseline targets were zero.
- In Oregon and Washington, the WFU acres burned were negligible (less than 500 acres annually) and therefore the baseline inventories would have been difficult to precisely produce through the standard of using random events to build the inventory until the baseline targets are reached. Therefore, the baseline targets for Oregon and Washington were set to zero.

Phase II WFU events were used to assemble the scaled baseline inventory in the same manner as for prescribed burning: Phase II WFU events were added to the inventory or dropped to meet WFU baseline targets. For states that had a WFU-baseline/Phase II scalar greater than 1.0, new WFU events were created from Phase II *wildfire* events. (This is because there were so few WFU events in the Phase II inventory that building the baseline WFU inventory from Phase II WFU events would have resulted in an unrealistically homogeneous set of events in the baseline WFU inventory). On a state-by-state basis, events from the original Phase II wildfire database were randomly chosen until the baseline target was met. The dates for these adapted wildfire events were shifted to the subsequent month because an analysis of WFU and wildfire activity by month in the SIT database showed that the WFU "season" lagged behind wildfire by about one month.

Each event in the baseline WFU inventory was categorized as "natural" per the categorization method approved by the ETT and the FEJF. Figure 5 shows the Phase II WFU acreage compared to SIT WFU acreage and the baseline target acreage, along with the scalars used to reach baseline.

Figure 5: Baseline Scalars for WFU and Comparison of WRAP Phase II to SIT Database



	AK	AZ	CA	CO	ID	MT	ND	NM	NV	OR	SD	UT	WA	WY
2000 SIT	0	1,175	756	1	19	6,001	0	305	0	0	0	861	0	400
2001 SIT	0	2,717	11,490	4,824	11,049	34,746	0	773	7,566	1	0	530	2	4,196
2002 SIT	0	0	2,421	15,523	5,552	1,155	0	1,643	852	1	0	193	11	5,137
2003 SIT	0	754	27,164	1,563	28,814	56,616	0	83,294	2	151	0	587	1	6,380
2004 SIT	55,021	1,172	5,030	4,707	5,177	433	0	859	494	1,112	0	12,529	27	4
Phase II WFU	159,554	0	4,051	22,852	3,543	25	0	4,759	0	0	0	545	0	6,220
Baseline	55,021	1,455	11,002	12,652	10,122	19,790	0	20,491	2,229	0	0	3,292	0	4,306
Scalar	0.3	0.0	2.7	0.6	2.9	791.6	0.0	4.3	0.0	0.0	0.0	6.0	0.0	0.7
Average SIT	55,021	1,455	9,372	5,324	10,122	19,790	0	17,375	2,229	316	0	2,940	10	3,223

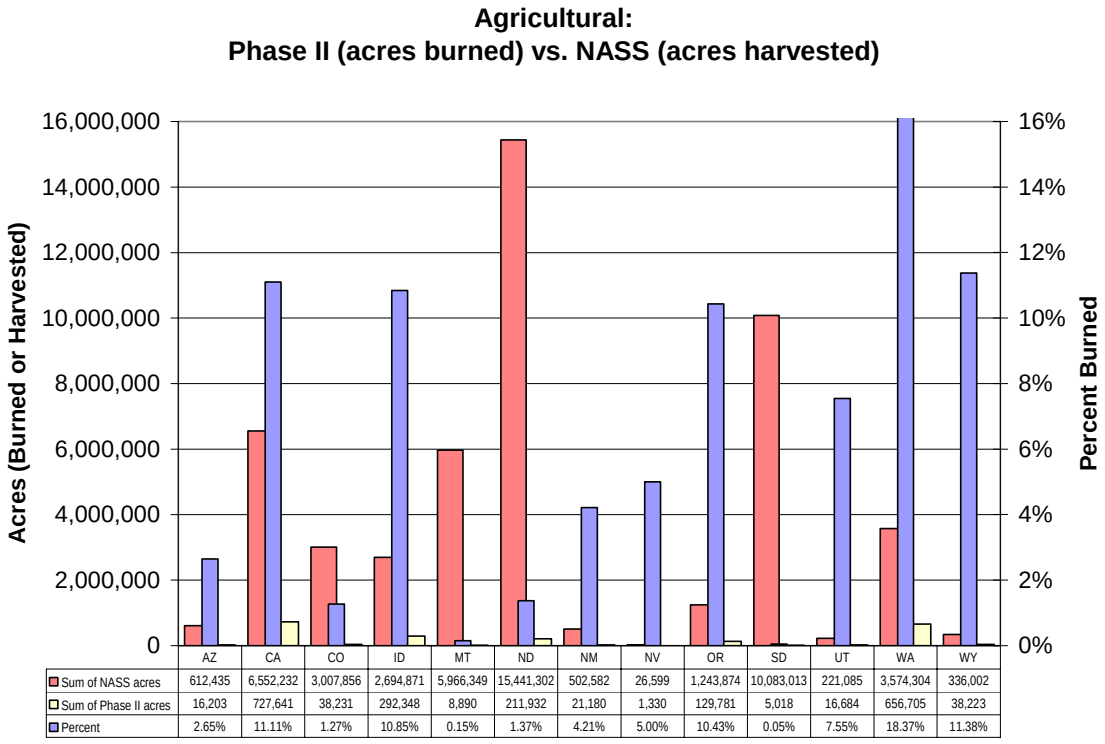
2.4 Agricultural Burning Baseline Inventory

The WRAP's Phase II agricultural burning inventory for 2002 (which has been reviewed by state and Tribal agencies through the Phase II QC process) served as the starting place for the agricultural burning baseline inventory. The Phase II agricultural burning inventory was comprised of a combination of event-based and gap-filled data (i.e., for states with minimal agricultural burning data but where agricultural burning activities are known to occur, agricultural burning events derived from summary statistics such as crop production and crop-specific percentage of acres burned data were allocated to these states. Given the nature of the burning activity data (comprised of actual events and gap-filled events), the Phase II inventory was considered to be representative of any year during the baseline period.

Air Sciences performed a "reality check" of agricultural burning activity in the Phase II inventory and performed additional and essential gap-filling to develop the final baseline inventory for agriculture burning. Air Sciences acquired acres harvested statistics from the 2002 Census of Agriculture published by the USDA – National Agricultural Statistics Service (NASS). This

analysis was for field crops and excluded "forage". The total acres burned by state in the Phase II inventory was divided by the acres harvested by state according to NASS to arrive at a "percent burned" statistic. Figure 6 shows the comparison of Phase II acres burned to NASS acres harvested, as well as the percent burned statistic.

Figure 6: Comparison of WRAP Phase II Burned Agricultural Acres to NASS Harvested Agricultural Acres



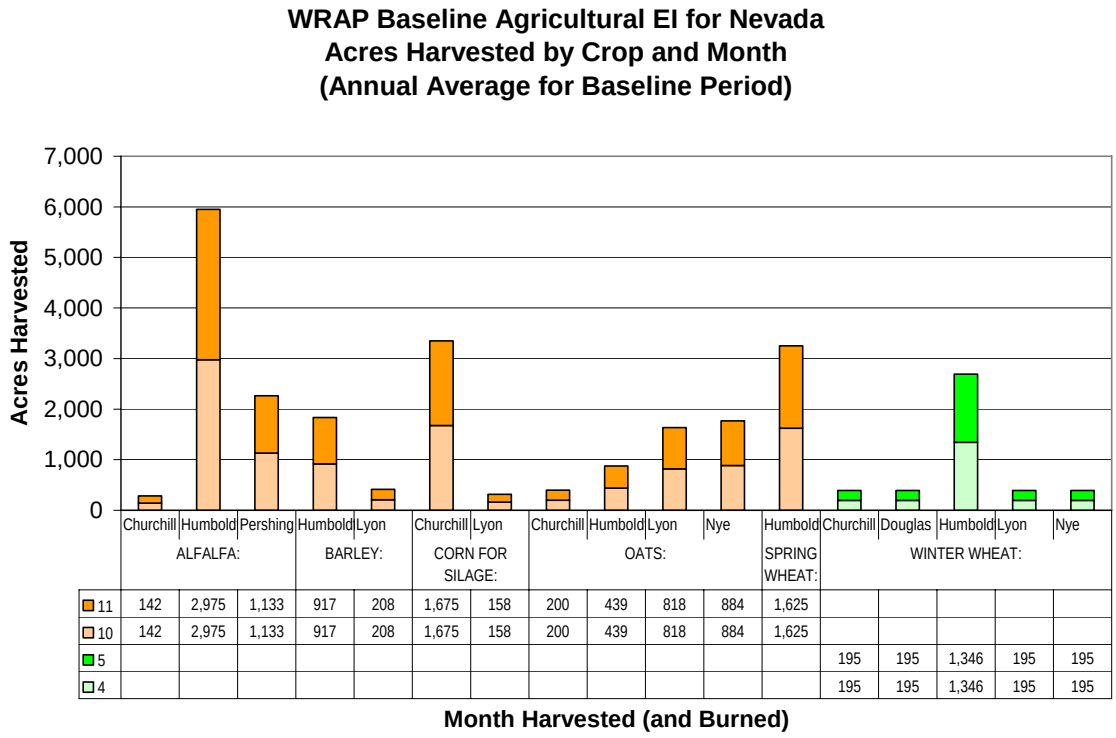
	AZ	CA	CO	ID	MT	ND	NM	NV	OR	SD	UT	WA	WY
Sum of NASS acres	612,435	6,552,232	3,007,856	2,694,871	5,966,349	15,441,302	502,582	26,599	1,243,874	10,083,013	221,085	3,574,304	336,002
Sum of Phase II acres	16,203	727,641	38,231	292,348	8,890	211,932	21,180	1,330	129,781	5,018	16,684	656,705	38,223
Percent	2.65%	11.11%	1.27%	10.85%	0.15%	1.37%	4.21%	5.00%	10.43%	0.05%	7.55%	18.37%	11.38%

Montana, South Dakota and Nevada had the lowest percent burned statistics and their Phase II activity was therefore scrutinized in detail. Air Sciences reviewed correspondence and data augmentation previously performed under the Phase II contract. The Montana Department of Environmental Quality had submitted data during the Phase II "QC process" to bring the activity levels to their satisfaction. Likewise, South Dakota Department of Environment and Natural Resources had participated in the Phase II QC Process and provided activities levels and knowledge of burning practices. Even though Montana and South Dakota had low percent burned statistics relative to other WRAP states, the investigation determined the inventory was reasonable. Phase II activity in the state of Nevada was initially zero acres and this was identified as requiring essential gap-filling.

Chet Sergent at the Nevada Division of Environmental Protection provided annual acres harvested of field crops for 2002 (using NASS as his source), the predominate counties in which agricultural burning occurs, and the typical size of an agricultural burn in each county. The

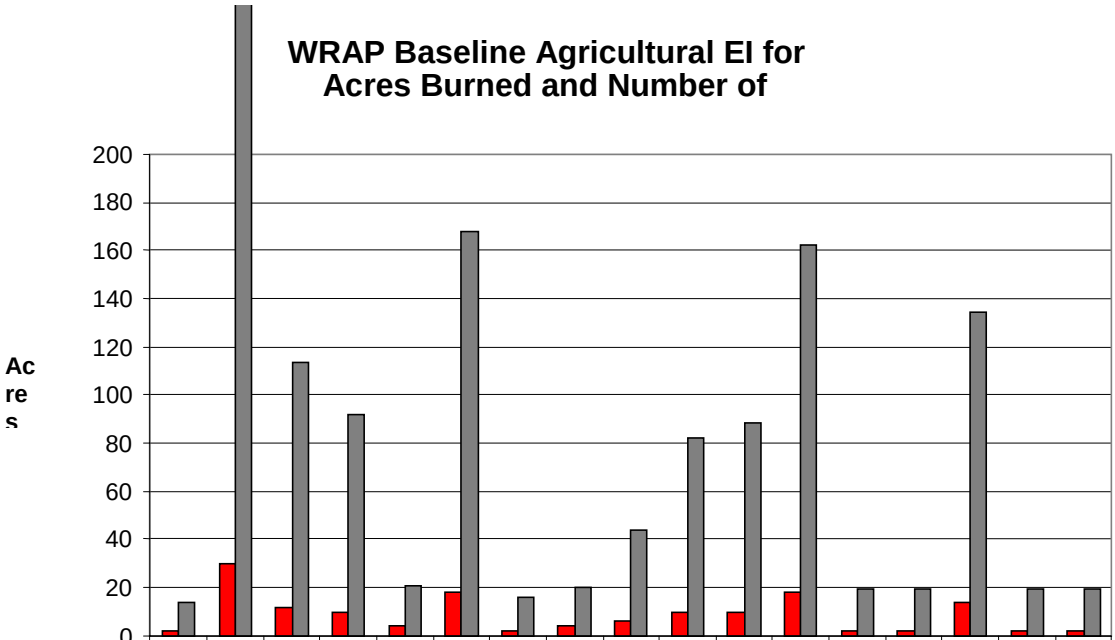
average annual harvest activity by crop for the baseline period was also obtained, where available, from NASS, and merged with the information provided by Mr. Sergent to determine the total acres harvested. This value was then converted to acres burned and subsequently allocated to individual fire events. Mr. Sergent determined that five-percent of the NASS harvest acres was a reasonable assumption to estimate agricultural burning activity for Nevada. This assumption was used in Figure 6. The crops that were presumed to be burned were alfalfa (grown for seed), barley, corn (for silage), oats, spring wheat, and winter wheat. Annual acres harvested per crop were allocated to each "major player" county based on NASS reporting. Those annual county figures were then allocated to monthly totals based on Nevada Department of Environmental Protection general rules. Figure 7 shows the acres harvested by crop by county by month in Nevada. The acres burned (shown in Figure 8) were calculated from the acres harvested using the 5% burning rate provided by Mr. Sergent. The acres of burning by crop by county by month were further broken down into typically sized (10 acres or the remainder thereof) events and assigned to a random day in the month. "Blackout days" per the Phase II agricultural emission inventory allocation, were observed. (For details, please see the report "Integrated Assessment Update and 2018 Emissions Inventory for Prescribed Fire, Wildfire, and Agricultural Burning," Air Sciences Inc. (December 2002) posted at http://www.wrapair.org/forums/fejf/tasks/FEJFtask7.html.) Events were given random coordinates in their county based on the USGS Land Cover characteristics map, per the existing WRAP emission inventory method.

Figure 7: Baseline Acres Harvested by Crop, County, and Month for Nevada



	Churchill	Humbold	Pershing	Humbold	Lyon	Churchill	Lyon	Churchill	Humbold	Lyon	Nye	Humbold	Churchill	Douglas	Humbold	Lyon	Nye
	ALFALFA:			BARLEY:		CORN FOR SILAGE:		OATS:				SPRING WHEAT:	WINTER WHEAT:				
11	142	2,975	1,133	917	208	1,675	158	200	439	818	884	1,625					
10	142	2,975	1,133	917	208	1,675	158	200	439	818	884	1,625					
5													195	195	1,346	195	195
4													195	195	1,346	195	195

Figure 8: Baseline Agricultural Acres Burned and Number of Burn Events by Crop and County for Nevada.



	Churchill	Humbold	Pershing	Humbold	Lyon	Churchill	Lyon	Churchill	Humbold	Lyon	Nye	Humbold	Churchill	Douglas	Humbold	Lyon	Nye
	ALFALFA:			BARLEY:		CORN FOR SILAGE:		OATS:				SPRING WHEAT:	WINTER WHEAT:				
Num Events	2	30	12	10	4	18	2	4	6	10	10	18	2	2	14	2	2
Acres Burned	14.2	297.5	113.3	91.7	20.8	167.5	15.8	20.0	43.9	81.8	88.4	162.5	19.5	19.5	134.6	19.5	19.5

The baseline agricultural inventory was identical to Phase II for all states with the exception of Nevada. Each event in the baseline agricultural burning fire inventory was categorized as "anthropogenic" according the categorization method approved by the ETT and the FEJF.

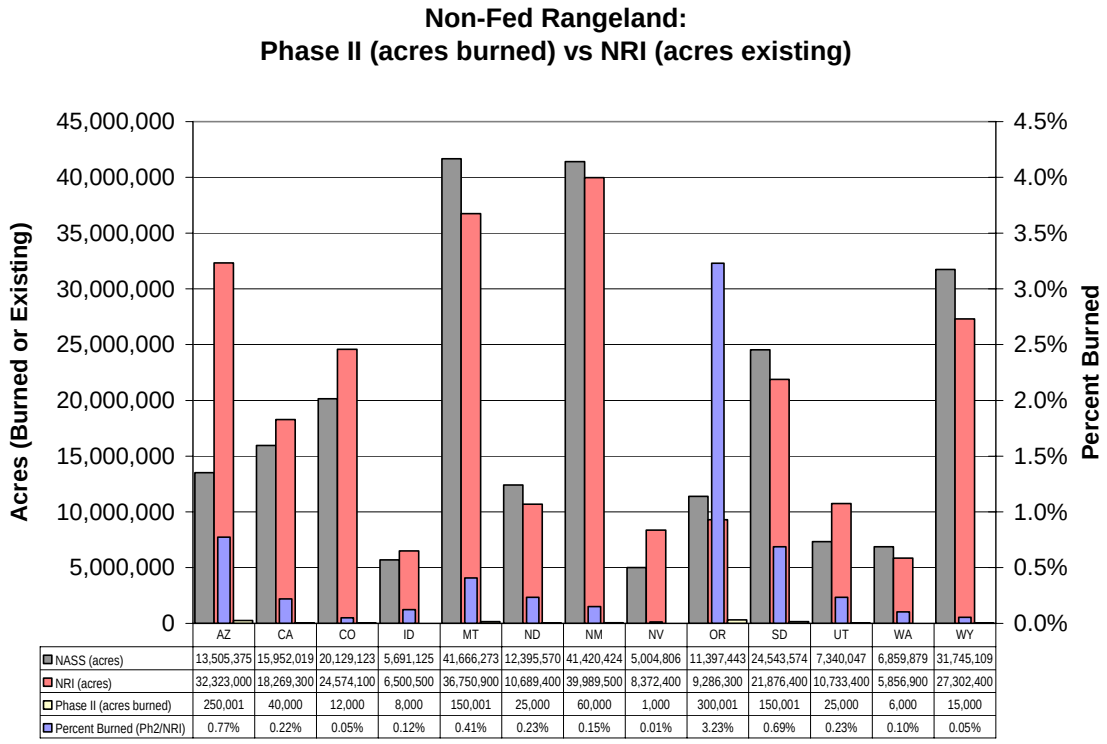
2.5 Non-Federal Rangeland Prescribed Burning Baseline Inventory

The WRAP's Phase II non-federal rangeland prescribed burning inventory for 2002 (the development of which was reviewed and approved by the ETT and FEJF) served as the starting place for the non-federal rangeland burning baseline inventory. Each event in the baseline rangeland burning fire inventory was categorized as "natural" based on the typically low fuel loading levels and the reasonable opinion of the FEJF that non-federal rangeland burning is typically done to maintain natural fuel conditions.

The Phase II 2002 non-federal rangeland burning inventory was comprised entirely of allocated summary data (i.e., gap-filled data) and was assessed to be representative of the baseline 2000-2004 period. The top-down approach to estimate rangeland burning activity was documented in the Phase II report (Air Sciences, July 2005). Because of the nature of the Phase II non-federal rangeland burning level data and the fact that the inventory was "nominal" by design (i.e. no actual event-based rangeland burning data is included in the inventory), the Phase II 2002 non-federal rangeland inventory was used "as is" as the baseline inventory.

To increase confidence in the rangeland inventory, a brief reality check was performed. Air Sciences compared the Phase II 2002 non-federal rangeland acres burned by state to total rangeland existing per state appearing in the 1997 National Resources Inventory (NRI) published by the USDA – Natural Resources Conservation Service. Rangeland acres burned divided by existing rangeland acres created a "percent burned" statistic by state. Figure 9 shows the comparison of Phase II rangeland acres burned to NRI rangeland acres existing, as well as the percent burned statistic.

Figure 9: Comparison of WRAP Phase II Burned NFR Acres to NRI Existing NFR Acres



	AZ	CA	CO	ID	MT	ND	NM	NV	OR	SD	UT	WA	WY
NASS (acres)	13,505,375	15,952,019	20,129,123	5,691,125	41,666,273	12,395,570	41,420,424	5,004,806	11,397,443	24,543,574	7,340,047	6,859,879	31,745,109
NRI (acres)	32,323,000	18,269,300	24,574,100	6,500,500	36,750,900	10,689,400	39,989,500	8,372,400	9,286,300	21,876,400	10,733,400	5,856,900	27,302,400
Phase II (acres burned)	250,001	40,000	12,000	8,000	150,001	25,000	60,000	1,000	300,001	150,001	25,000	6,000	15,000
Percent Burned (Ph2/NRI)	0.77%	0.22%	0.05%	0.12%	0.41%	0.23%	0.15%	0.01%	3.23%	0.69%	0.23%	0.10%	0.05%

The average percent burned of non-federal rangeland acres by state is 0.48%. Oregon was the most apparent outlier and had the highest percent burned with 3.23%. The next highest was Arizona with 0.77%. Nevada had the lowest percent burned with 0.01% and the next lowest were Colorado and Wyoming with 0.05%. If the baseline inventory for non-federal rangeland fire data be used for other emission inventory or regional dispersion modeling in the future, users of the data should consider further examination of the total acres of non-federal rangeland burned in Oregon.

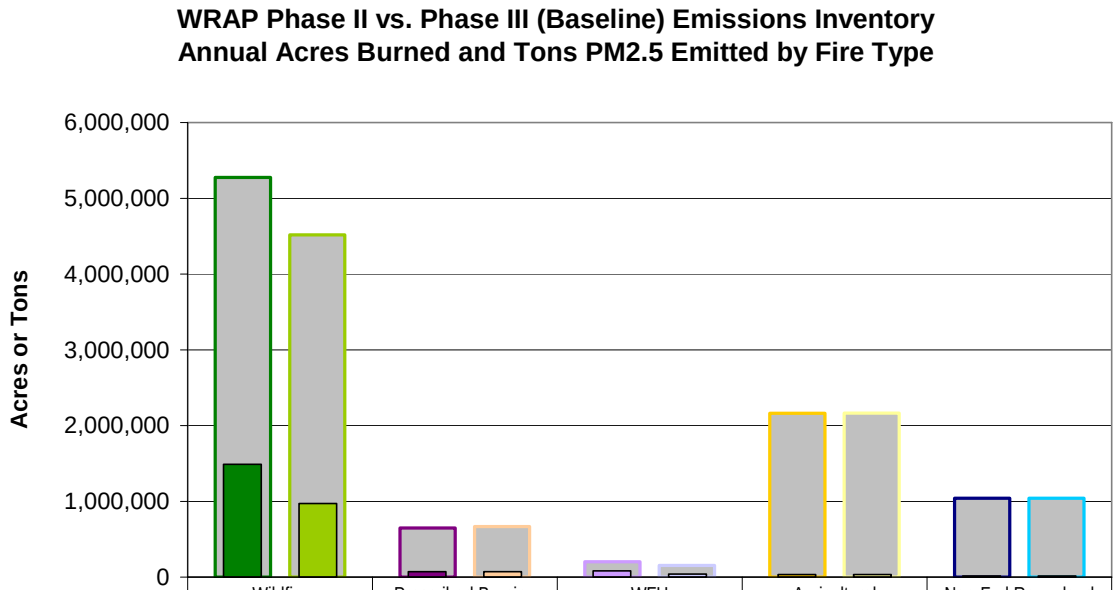
2.6 Baseline Inventory Results and Comparison to Phase II

The baseline inventories for wildfire, prescribed burning, and WFU were created by adding or subtracting events from the phase II inventory to achieve the baseline targets, as discussed above. In that fire days were added or subtracted in their entirety, the baseline target was inevitably over exceeded or not reached by a nominal amount. The fire activity and emissions of the final baseline inventories are presented in this section. Table 2 tabulates, in summary format, the method used to develop the baseline inventories for each fire type. Figure 10 compares Phase II to Phase III (Baseline) acreage totals for each fire source, and Figures 11-15 show the comparison of Phase II to Phase III (Baseline) inventories for each fire source by state.

Table 2: Summary of Baseline Development and Phase II Comparison Methods

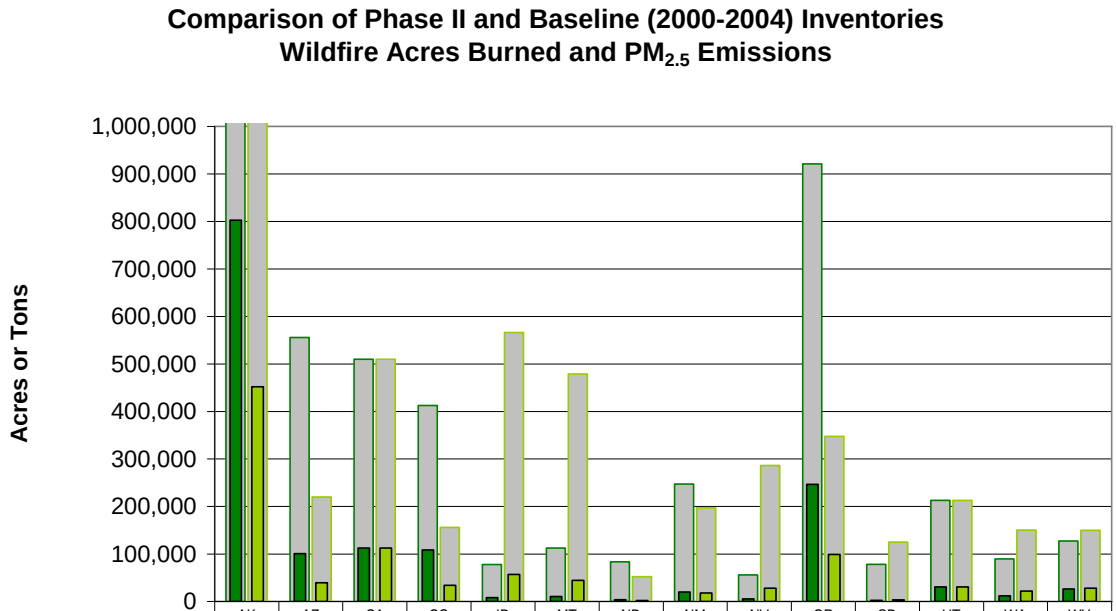
Fire Source	Comparison Data Set	Years of Comparison	Averaging Method	Baseline Target Equation	Adjustments
Wildfire	Fed-5	2000-2003	Mean	[Phase II – Fed-5 2002] + Average (Fed-5)	AK and UT baseline = Fed-5 mean
Prescribed	SIT	2000-2004	Mean	[Phase II – SIT 2002] + Average (SIT)	None
WFU	SIT	2000-2004	Mean	[Phase II – SIT 2002] + Average (SIT)	If Phase II < SIT 2002 then baseline = SIT Average; If Phase II or all SIT years = 0, then baseline = SIT Average; ND, SD, WA, OR apply de minimis, baseline = 0
Agricultural	Phase II Inventory (as Baseline Inventory) plus a supplemental inventory for Nevada.				
Rangeland	Phase II Inventory (as Baseline Inventory).				

Figure 10: Comparison of WRAP Phase II to Phase III Emission Inventories by Fire Type



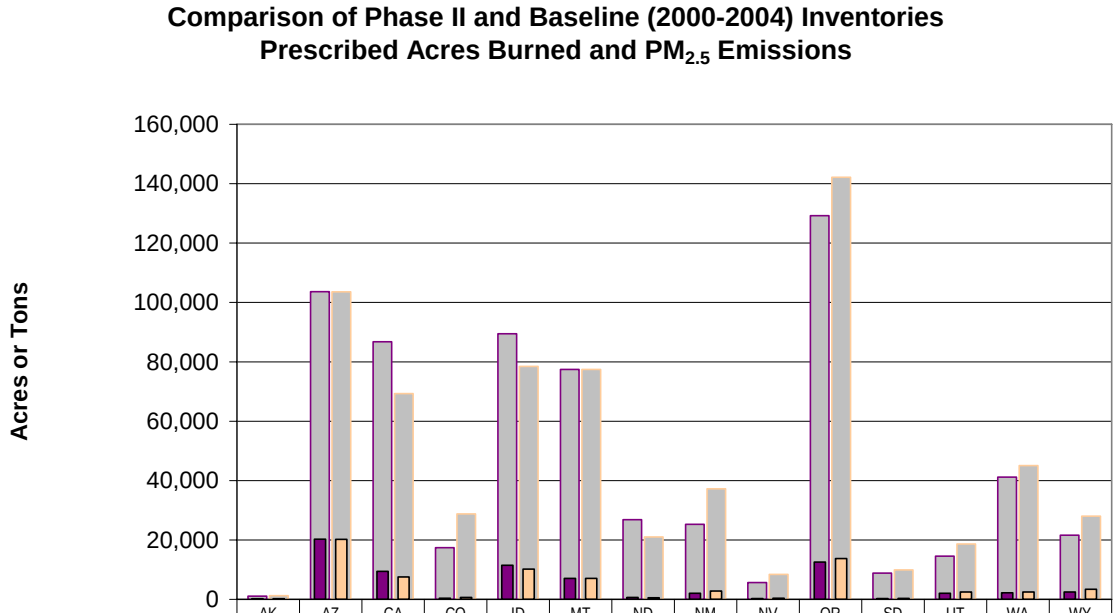
	Wildfire	Prescribed Burning	WFU	Agricultural	Non-Fed Rangeland
Phase II Acres	5,276,485	649,044	201,548	2,162,836	1,042,003
Baseline Acres	4,517,818	669,348	153,697	2,164,166	1,042,003
Phase II PM2.5	1,489,886	71,421	81,505	34,571	15,454
Baseline PM2.5	971,453	72,218	41,171	34,590	15,454

Figure 11: Comparison of WRAP Phase II to Phase III Wildfire Inventory by State



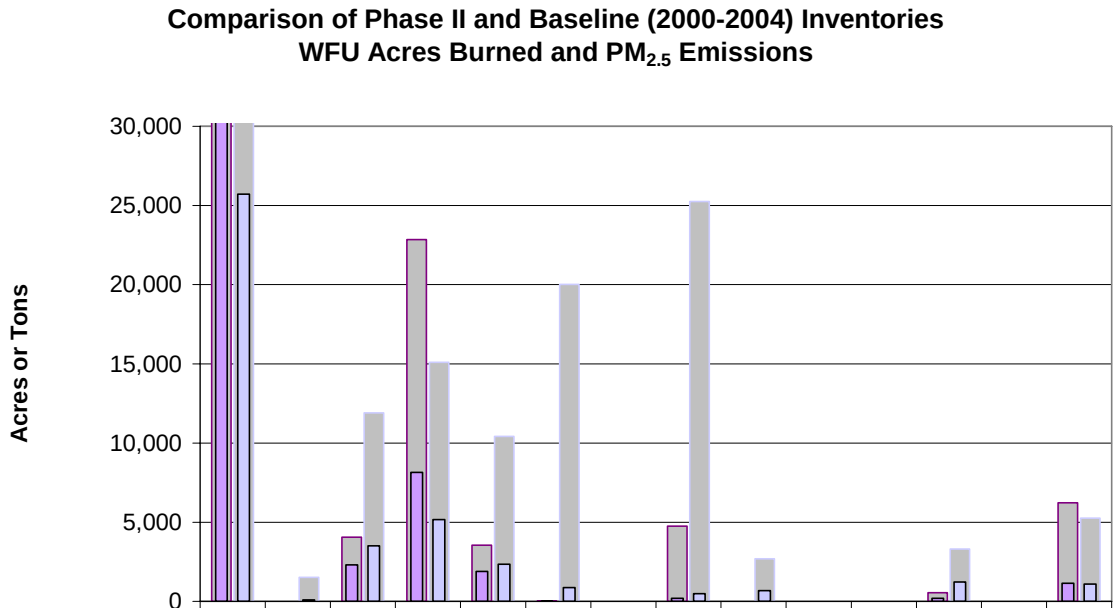
	AK	AZ	CA	CO	ID	MT	ND	NM	NV	OR	SD	UT	WA	WY
Phase II Wildfire Acres	1,790,533	555,873	510,140	412,697	77,678	112,413	83,599	247,243	56,218	921,515	78,384	212,853	89,854	127,486
Baseline Wildfire Acres	1,065,097	220,221	510,092	155,763	566,039	479,068	52,300	197,353	286,362	347,657	124,788	212,828	150,257	149,993
Phase II Wildfire PM2.5	802,701	100,920	112,759	108,436	7,962	10,453	3,665	19,872	5,541	246,411	2,393	30,509	11,854	26,409
Baseline Wildfire PM2.5	452,336	39,491	112,743	34,058	57,046	44,610	2,001	17,886	28,207	98,993	3,560	30,505	22,105	27,912

Figure 12: Comparison of WRAP Phase II to Phase III Prescribed Burning Inventory by State



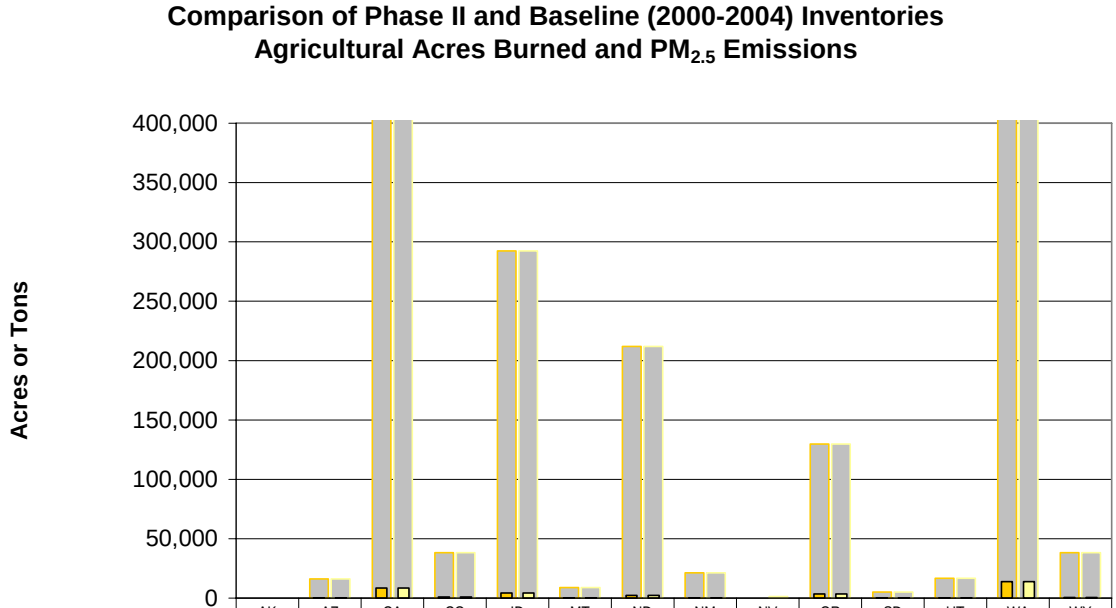
	AK	AZ	CA	CO	ID	MT	ND	NM	NV	OR	SD	UT	WA	WY
Phase II Prescribed Acres	1,108	103,619	86,785	17,425	89,477	77,419	26,826	25,292	5,659	129,290	8,811	14,531	41,196	21,605
Baseline Prescribed Acres	1,244	103,569	69,291	28,746	78,494	77,418	21,030	37,259	8,460	142,153	9,905	18,649	45,109	28,025
Phase II Prescribed PM2.5	177	20,230	9,438	379	11,499	7,067	713	2,029	284	12,568	245	2,021	2,256	2,516
Baseline Prescribed PM2.5	178	20,213	7,564	705	10,222	7,054	555	2,795	397	13,739	332	2,487	2,548	3,428

Figure 13: Comparison of WRAP Phase II to Phase III WFU Inventory by State



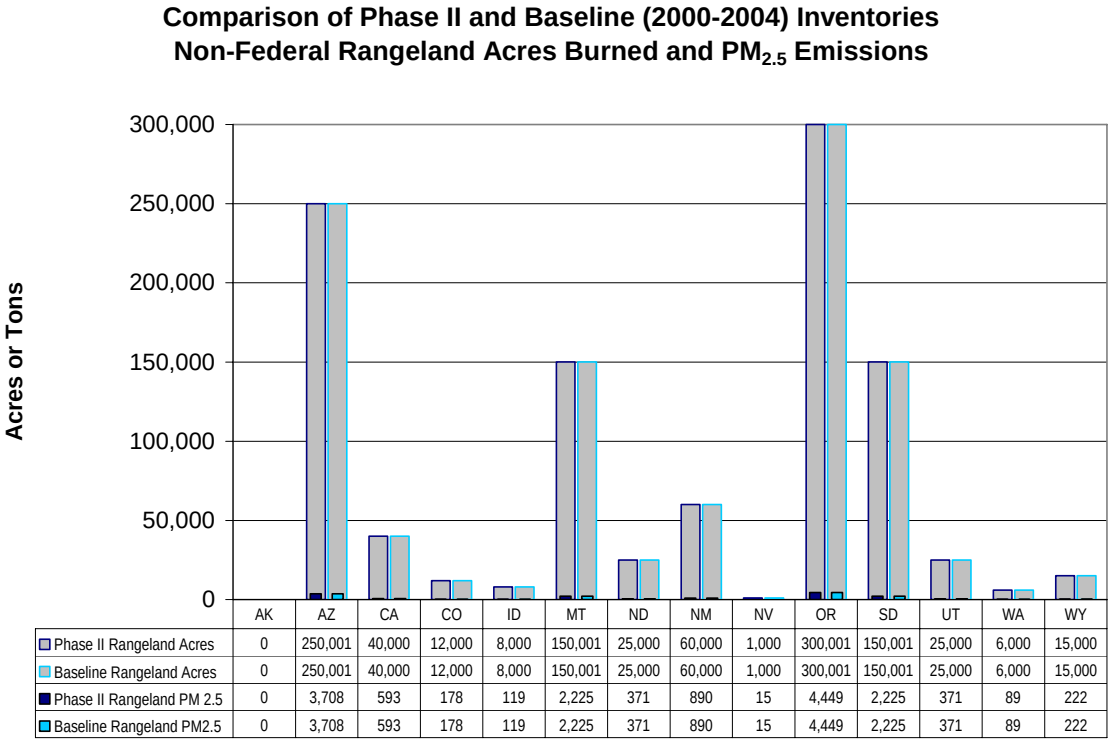
	AK	AZ	CA	CO	ID	MT	ND	NM	NV	OR	SD	UT	WA	WY
Phase II WFU Acres	159,554	0	4,051	22,852	3,543	25	0	4,759	0	0	0	545	0	6,220
Baseline WFU Acres	58,236	1,516	11,914	15,094	10,421	20,017	0	25,262	2,686	0	0	3,302	0	5,250
Phase II WFU PM 2.5	67,616	0	2,304	8,152	1,881	14	0	194	0	0	0	196	0	1,147
Baseline WFU PM2.5	25,710	83	3,510	5,165	2,348	871	0	488	682	0	0	1,221	0	1,092

Figure 14: Comparison of WRAP Phase II to Phase III Agricultural Burning Inventory by State



	AK	AZ	CA	CO	ID	MT	ND	NM	NV	OR	SD	UT	WA	WY
Phase II Agricultural Acres	0	16,203	727,641	38,231	292,348	8,890	211,932	21,180	0	129,781	5,018	16,684	656,705	38,223
Baseline Agricultural Acres	0	16,203	727,641	38,231	292,348	8,890	211,932	21,180	1,330	129,781	5,018	16,684	656,705	38,223
Phase II Agricultural PM2.5	0	209	8,543	852	4,302	195	2,155	190	0	3,407	136	210	13,797	576
Baseline Agricultural PM2.5	0	209	8,543	852	4,302	195	2,155	190	19	3,407	136	210	13,797	576

Figure 15: Comparison of WRAP Phase II to Phase III Non-Federal Rangeland Burning Inventory by State



	AK	AZ	CA	CO	ID	MT	ND	NM	NV	OR	SD	UT	WA	WY
Phase II Rangeland Acres	0	250,001	40,000	12,000	8,000	150,001	25,000	60,000	1,000	300,001	150,001	25,000	6,000	15,000
Baseline Rangeland Acres	0	250,001	40,000	12,000	8,000	150,001	25,000	60,000	1,000	300,001	150,001	25,000	6,000	15,000
Phase II Rangeland PM 2.5	0	3,708	593	178	119	2,225	371	890	15	4,449	2,225	371	89	222
Baseline Rangeland PM2.5	0	3,708	593	178	119	2,225	371	890	15	4,449	2,225	371	89	222

2.7 Base Control Case Inventory

The Phase III Base Control case for fire is the Phase III Baseline inventory with emissions reduced to reflect emission reduction techniques (ERTs) being applied to prescribed fire and agricultural burning throughout the WRAP region.

A method to develop a lookup table of seasonal ERTs and associated emission reduction factors (ERF) included a Strawman process over the course of several FEJF meetings, Phase III/IV Task Team breakout sessions, and conference calls. The primary resource document for this work is the Smoke Management Guide for Prescribed and Wildland Fire – 2001 Edition (National Wildfire Coordinating Group, Fire Use Working Team). From this document and expert/stakeholder input, several EXCEL worksheet tables were developed. In addition, Federal Land Mangers (FLM) from each geographic region for which seasonal suites of ERTs have been developed provided input to complete the lookup table of seasonal suites of ERTs and the associated ERFs.

The lookup table of ERTs and ERFs generally characterize ERTs by season (winter, spring, summer, fall), by vegetation type category (grass, brush, timber, crop), and by geographic region (northwest [NW], southwest [SW], and intermountain west [IMW]). Air Sciences and the FLMs

who provided input to prepare the lookup table recognize that that the ERT seasonal suites reasonably represent ERTs (and combinations of ERTs) that are typically implemented for the regions and vegetation categories. The ERFs are intended to be general estimates of the overall, average effectiveness of the seasonal suites of ERTs in reducing emissions of $PM_{2.5}$. Each ERF that has been assigned to a seasonal ERT suite for a geographic region is based upon ERF information found in the current literature, estimates of the effectiveness of certain ERTs in reducing available fuel loading, and the professional experience of the FLMs who provided input to the lookup table. The seasonal suites of ERTs and the ERFs are not intended to be prescriptive nor precise in representing the application of ERTs in all cases.

Seasonal suites of ERTs and the associated ERFs were developed for three regions of the WRAP. Each event was classified into a region based on the event's location (state). The regions and associated states are:

- **Northwest region (NW)**: Alaska, Oregon, and Washington
- **Southwest region (SW)**: Arizona, California, New Mexico, Nevada, and Utah
- **Inter-Mountain West region (IMW)**: Colorado, Idaho, Montana, North Dakota, South Dakota, and Wyoming

Seasonal suites of ERTs and the associated ERFs were developed for each of the four seasons. Each event was classified into a season based on the event's date of burn (month). The seasons and associated months are:

- **Winter**: December, January, and February
- **Spring**: March, April, and May
- **Summer**: June, July, and August
- **Fall**: September, October, and November

Seasonal suites of ERTs and the associated ERFs were developed for each of four vegetation categories (grass, brush, timber, crop). The fuel category of a prescribed event was determined by the National Fire Danger Rating System (NFDRS) fuel model code (fuel model A though U) assigned to each event in the Base Case fire inventory. All agricultural burning events were assigned the "crop" fuel type. The vegetation categories and associated NFDRS fuel models are:

- **Grass –**
  - **A** - western grasses (annual),
  - **L** - western grasses (perennial),
  - **N** - sawgrass, and
  - **S** - tundra

- **Brush –**
  - **B** - California chaparral,
  - **F** - intermediate brush,
  - **O** - high pocosin, and
  - **T** - Sagebrush grass
- **Timber –**
  - **C –** pine grass savanna,
  - **D** - southern rough,
  - **E** - hardwood litter (winter),
  - **G** - short needle (heavy dead),
  - **H** - short needle (normal dead),
  - **I** - heavy slash,
  - **J** - intermediate slash,
  - **K** - light slash,
  - **P** - southern pine plantation,
  - **Q** - Alaskan black spruce,
  - **R** - hardwood litter (summer), and
  - **U** - western pines

Accounting for the implementation of ERTs in the Phase III Base Case (2000-2004) fire emissions inventory was accomplished by reducing emissions according to the appropriate ERF based on the location, timing, and vegetation type of each event. The seasonal suites of ERTs and associated ERFs are listed in Table 3. ERFs are defined as the percentage of $PM_{2.5}$ emissions averted due to the application of the seasonal suite of ERTs.

Table 3: ERFs (percent $PM_{2.5}$ emissions averted) for Seasonal Suites of ERTs

		Vegetation Category			
Region	Season	Grass	Brush	Timber	Crop
SW	Spring	55%	45%	45%	50%
SW	Summer	55%	40%	30%	50%
SW	Fall	55%	45%	45%	70%
SW	Winter	55%	45%	60%	70%
NW	Spring	55%	70%	40%	0%
NW	Summer	65%	45%	45%	30%
NW	Fall	65%	65%	52.5%	70%
NW	Winter	10%	70%	25%	75%
IMW	Spring	55%	40%	40%	50%
IMW	Summer	60%	40%	45%	40%
IMW	Fall	65%	60%	60%	70%
IMW	Winter	25%	50%	20%	0%

ERFs were applied to all agricultural burning events, which have all been categorized as "anthropogenic" in the Base Case inventory. ERFs were also applied to prescribed broadcast fires categorized as "anthropogenic" in the Base Case inventory. Prescribed pile burning events in the inventory, also categorized as "anthropogenic," did not have ERFs applied because a unique suite of emission factors for pile burning events (which accounts for the emissions control associated with pile burning) was already applied to burning events in the Base Case prescribed fire inventory. The application of ERFs to prescribed broadcast and agricultural burning events was dependent upon specific data contained in each fire record: location (state, cross-walked to ERT region), time of burn (month, cross-walked to season), and fuel type (NFDRS, cross-walked to fuel category [grass, brush, timber, crop]).

The Base Control case emissions were calculated by multiplying the $PM_{2.5}$ emissions from each qualifying event in the Base (2000-2004) fire inventory times one minus the by-region, by-season, by-fuel category ERF. The application of the ERF is shown in Equation 5.

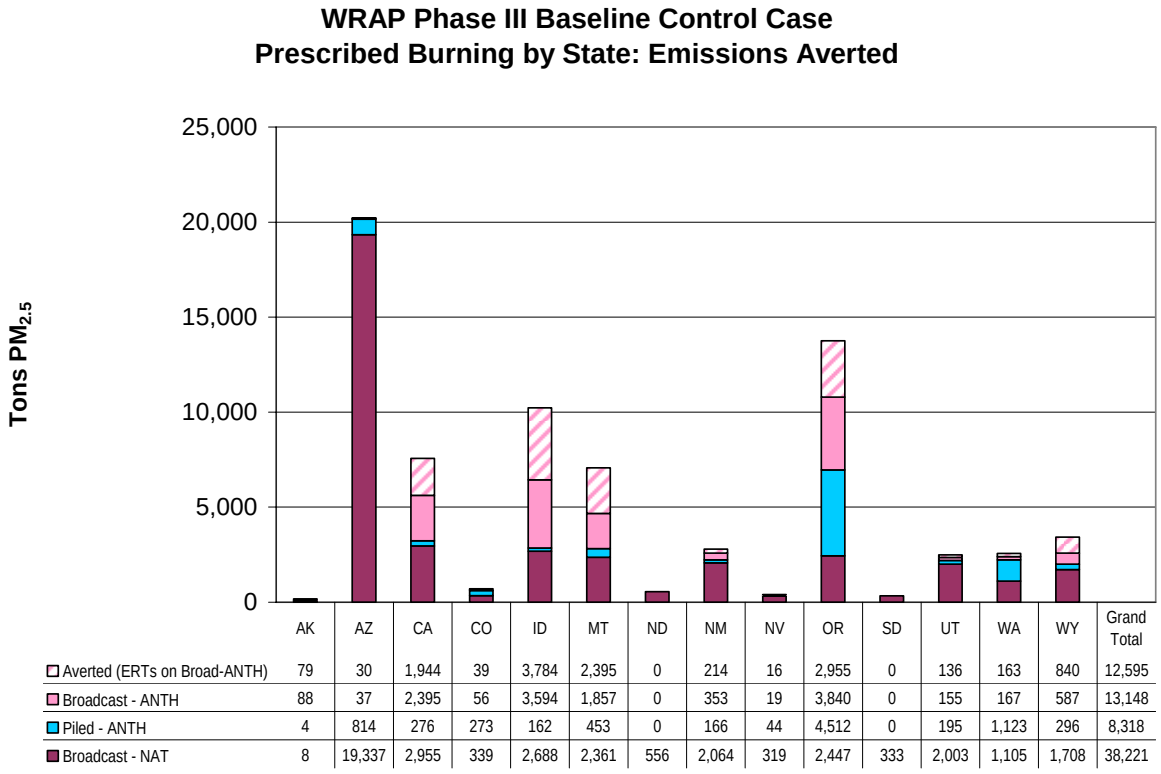
$$\text{Emissions}_{(\text{Base Control})} = \text{Emissions}_{(\text{Base})} \times (1 - \text{ERF}) \quad (5)$$

A step-by-step example of the Base Control emissions calculation for a hypothetical prescribed burning broadcast event is shown below:

1. Base $PM_{2.5}$ emissions from single prescribed broadcast burn event:
    a. Fire type – prescribed fire, broadcast, anthropogenic.
    b. Emissions – 100 tons $PM_{2.5}$.
    c. Fire location – Southwest (Arizona).
    d. Fire timing – Spring (April).
    e. Vegetation category – Grass (NFDRS fuel model A).
2. Look up ERF in the ERT Seasonal Suite lookup Table: 55% (Southwest, spring, grass fire).
3. Calculate $PM_{2.5}$ emissions:
    a. Equation: $\text{Emissions}_{(\text{Base Control})} = 100 \text{ tons } PM_{2.5} \times (1 - 0.55)$
    b. Result: $\text{Emissions}_{(\text{Base Control})} = 45 \text{ tons } PM_{2.5}$
    c. Emissions Averted = 55 tons $PM_{2.5}$

Figures 16 through 18 display the effectiveness in reducing $PM_{2.5}$ emissions due to the application of ERFs associated with the seasonal suites of ERTs to the qualifying events in the Base Control fire inventory.

Figure 16: WRAP Phase III Base Control Case: Wildland Prescribed Burning $PM_{2.5}$ Emissions by State With Emissions Averted Due to the Implementation of ERTs



	AK	AZ	CA	CO	ID	MT	ND	NM	NV	OR	SD	UT	WA	WY	Grand Total
Averted (ERTs on Broad-ANTH)	79	30	1,944	39	3,784	2,395	0	214	16	2,955	0	136	163	840	12,595
Broadcast - ANTH	88	37	2,395	56	3,594	1,857	0	353	19	3,840	0	155	167	587	13,148
Piled - ANTH	4	814	276	273	162	453	0	166	44	4,512	0	195	1,123	296	8,318
Broadcast - NAT	8	19,337	2,955	339	2,688	2,361	556	2,064	319	2,447	333	2,003	1,105	1,708	38,221

Figure 17: WRAP Phase III Base Control Case: Wildland Prescribed Burning $PM_{2.5}$ Emissions and Acres by Vegetation Category With Emissions Averted Due to the Implementation of ERTs

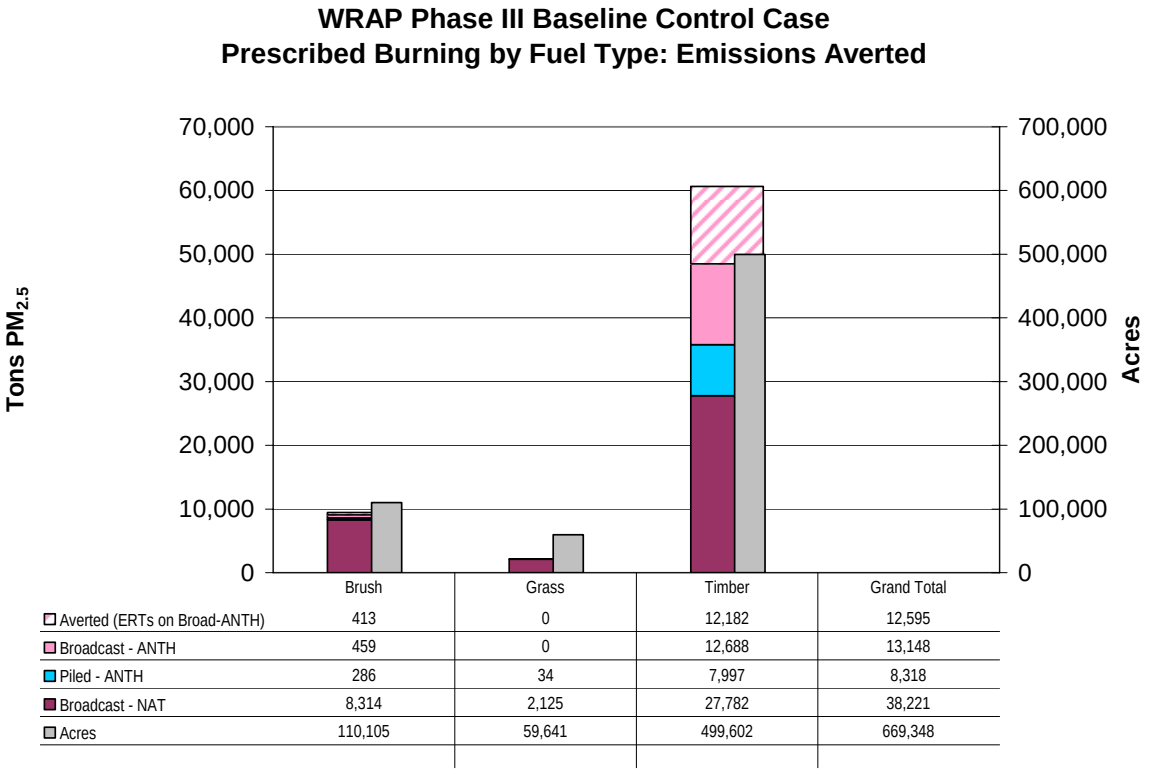
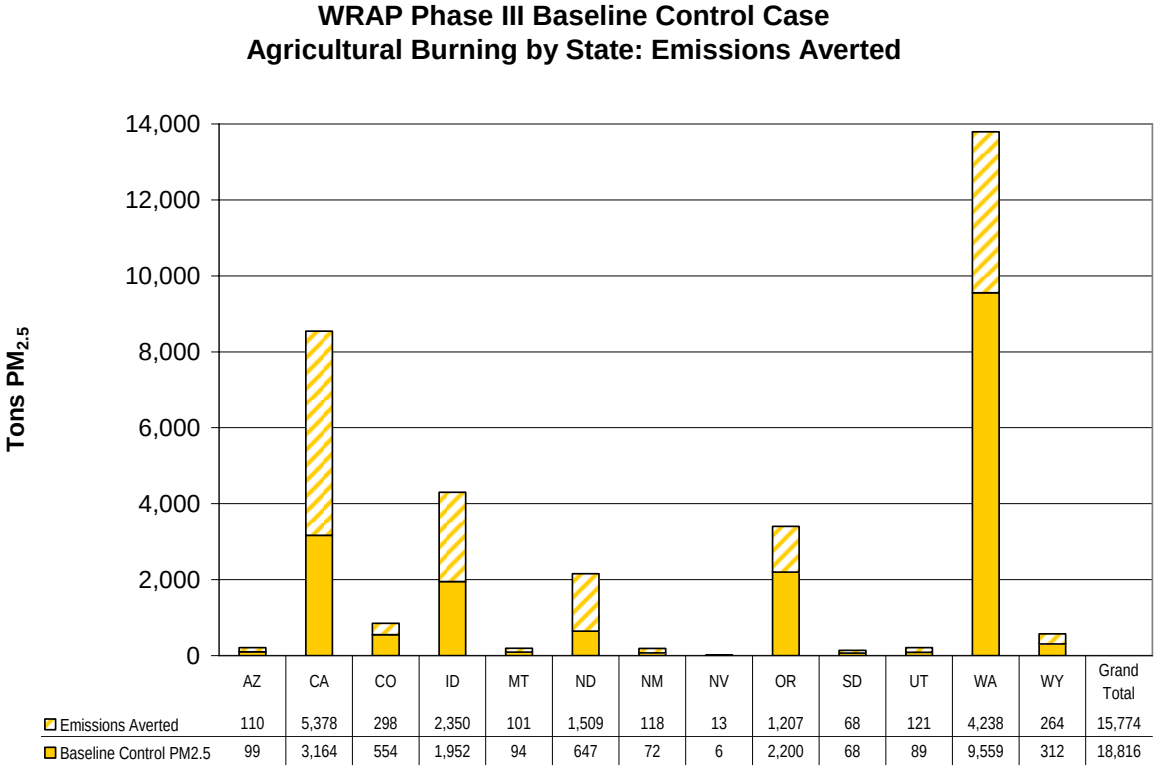


Figure 18: WRAP Phase III Base Case Control: Agricultural Burning $PM_{2.5}$ Emissions by State With Emissions Averted Due to the Implementation of ERTs



SECTION 3

PROJECTION (2018) FIRE EMISSION INVENTORIES

Projection (2018) inventories were built from the baseline inventories for wildfire, wildland fire use, prescribed burning, agricultural burning, and non-federal rangeland burning (described in Section 2).

Prescribed burning, wildfire, and WFU burning projection emission inventories were each created by "scaling" the respective baseline inventory up or down based on input presented during the two technical Workshops that was provided by the Interagency Fuels Committee (IFC) to the FEJF. The non-federal prescribed rangeland burning projection inventory was built by "scaling" the NFR baseline inventory up or down based on input from the USDA - National Resource Conservation Service (NRCS) and FEJF. For each fire type, sets of scalars were developed to create less, likely, and more projection inventories. A likely agricultural burning projection inventory was created by removing events from the baseline inventory to reflect known limits to future agricultural burning. The less, likely, and more scalars for each fire type are shown in Table 4.

Table 4: Summary of 2018 Projection Scalars for the Less, Likely, and More Scenarios

Fire Type	Breakdown	Less	Likely	More
Prescribed	By state and agency	Fed. Agencies = IFC x 0.25 State/Private/Other = baseline	Fed. Agencies = IFC x 0.5 State/Private/Other = baseline x 2	Fed. Agencies = IFC State/Private/Other = baseline x 3
Wildfire	By state	0.9 x (WF base + WFU base)	0.5 x (WF base + WFU base)	0.5 x (WF base + WFU base)
WFU	By state	0.1 x (WF base + WFU base)	0.5 x (WF base + WFU base)	(WF base + WFU base)
Agricultural	By state		Baseline - limits to future burning	
Rangeland	By state	0.5 x NRCS 2018 Estimate	NRCS 2018 Estimate	2.0 x NRCS 2018 Estimate

In addition, the results from the 2018 projection inventories for each fire type were grouped into three air quality planning suites to reflect possible future burning scenarios (see Section 3.5). These suites include,

- Base Case, reflecting the most probable scenario.
- Climate Conditions/Resource Limited, reflecting high rates of wildfire and WFU and resource constraints for prescribed burning.
- Maximum Application of Prescribed Fire, influenced by the IFC's targets for prescribed burning.

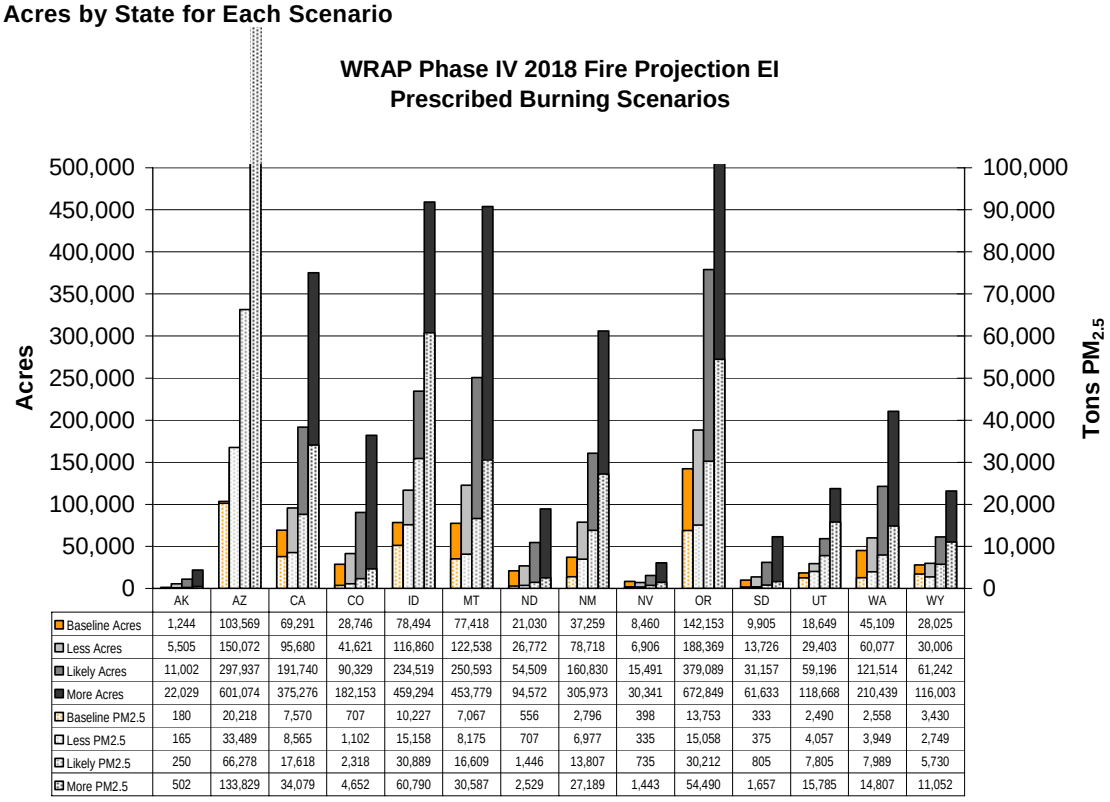
3.1 Prescribed Burning Projection Inventory

The WRAP's Phase III Baseline (2000-2004) prescribed fire inventory (described in Section 2.2) served as the starting place for the prescribed fire projection inventory. The projection inventory for prescribed burning was built by scaling the baseline inventory based on IFC target acres and FEJF scalars.

The IFC provided projected activity targets (in acres) for broadcast and piled burning by state and agency. The participants of the Technical Workshops used the IFC targets to develop the agency- and scenario-specific scalars. The IFC targets were used to establish the "more" prescribed burning scenario scalars for federal agencies. For state, private, and other agencies, the "more" scenario scalar was set to three times baseline. The "likely" scenario scalars were calculated using half of the IFC target acres for federal agencies and twice the baseline values for state, private, and other agencies. The "less" scenario scalars were calculated using one-quarter of the IFC target acres for federal agencies and equal to baseline the baseline values for state, private, and other agencies. For all WRAP states other than Nevada, the scalars for the less scenario were set to ensure that the "less" scenario projections were at least equal to the baseline values for the federal agencies. For Nevada, 2018 prescribed burning levels for the less scenario were established at 1,553 acres below baseline levels.

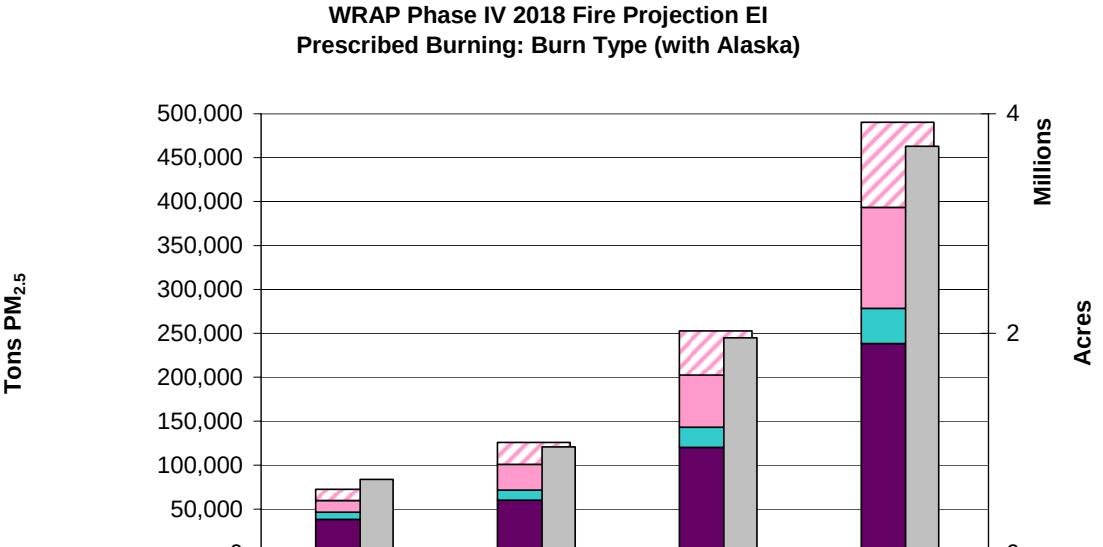
The 2018 scaled projection inventories were assembled by adding events to the baseline prescribed burning inventory based on the by-state, agency, and burn type scalars in the same manner as described for creating the baseline prescribed inventory from Phase II events in Section 2.2, with the exception that a random date was assigned to new, repeated events. For the projection inventories, new repeated events were given a date within seven days before or after the original date. ERTs were applied to the 2018 projection inventory using a similar technical methodology as used for the Base Control case described in Section 2.7. Figure 19 shows the projected prescribed acres compared to baseline prescribed acres. Figure 20 shows the affect on $PM_{2.5}$ emissions of applying ERTs to the prescribed projection inventory.

Figure 19: WRAP Phase IV 2018 Projection Inventory: Prescribed Burning $PM_{2.5}$ Emissions and Acres by State for Each Scenario



	AK	AZ	CA	CO	ID	MT	ND	NM	NV	OR	SD	UT	WA	WY
Baseline Acres	1,244	103,569	69,291	28,746	78,494	77,418	21,030	37,259	8,460	142,153	9,905	18,649	45,109	28,025
Less Acres	5,505	150,072	95,680	41,621	116,860	122,538	26,772	78,718	6,906	188,369	13,726	29,403	60,077	30,006
Likely Acres	11,002	297,937	191,740	90,329	234,519	250,593	54,509	160,830	15,491	379,089	31,157	59,196	121,514	61,242
More Acres	22,029	601,074	375,276	182,153	459,294	453,779	94,572	305,973	30,341	672,849	61,633	118,668	210,439	116,003
Baseline PM2.5	180	20,218	7,570	707	10,227	7,067	556	2,796	398	13,753	333	2,490	2,558	3,430
Less PM2.5	165	33,489	8,565	1,102	15,158	8,175	707	6,977	335	15,058	375	4,057	3,949	2,749
Likely PM2.5	250	66,278	17,618	2,318	30,889	16,609	1,446	13,807	735	30,212	805	7,805	7,989	5,730
More PM2.5	502	133,829	34,079	4,652	60,790	30,587	2,529	27,189	1,443	54,490	1,657	15,785	14,807	11,052

Figure 20: WRAP Phase IV 2018 Projection Inventory: Prescribed Burning $PM_{2.5}$ Emissions and Acres by Scenario With Emissions Averted Due to the Implementation of ERTs



	Baseline	Less	Likely	More
Averted (ERTs on Broad-ANTH)	12,595	24,978	50,385	96,894
Broadcast - ANTH	13,148	29,413	59,396	114,889
Piled - ANTH	8,318	11,256	22,816	40,080
Broadcast - NAT	38,221	60,192	120,281	238,422
Acres	669,348	966,251	1,959,146	3,704,081

3.1.1 Prototype or "Stem Cell" Events

The 2018 prescribed burning inventories were created from the Phase III (baseline) inventory by adjusting the baseline inventory based on the scalars (specific to state, agency, and burn type) developed during the two Technical Workshops. This scaling method resulted in fire activity in areas of some states, agencies, and burn types, which did not exist in the baseline inventory. In order to include this fire activity in the 2018 inventories, prototype or "stem cell" events were created and added to the baseline seed events.

Stem cell fire events were created to create events for each state-agency-burn type combination with acres projected by the IFC activity targets but without acres in the baseline inventory. The stem cell events were then used to augment the baseline events utilized by the Projection Calculation Tool (described in Section 1.1) to create the prescribed burning projection inventories. In order to include fire events in the projection inventory that are spatially and temporally reasonable, a 12 kilometer grid was created for the WRAP region. For each grid cell (based on the location of the centroid of the grid cell), fuel loading, agency jurisdiction, and natural or anthropogenic emissions, along with state, county, and time zone was determined. The fuel loading was calculated from the NFDRS code and the natural or anthropogenic categorization was determined based on the fuel characteristic classification system (FCCS) code at each centroid. By creating the stem cell events from the grid centroids, each event has site-specific fuel information as well as accurate location information.

The average burn size for prescribed broadcast burns in the baseline inventory is 50 acres and for piled burns it is 25 acres. In the baseline inventory, the spring month with the most broadcast acres burned is April and the fall month with the most activity is October. For piled burning, the spring month with the most burned acres is also April and the fall month with the most piled burning is November. For each grid cell with state and agency combinations needing stem cell events, 50 acre broadcast burns and 25 acre piled burns were created with the appropriate site-specific fuel information. To add events to the projection inventory in the appropriate state-agency combinations, an appropriate broadcast burn stem cell event was assigned a random burn date in April and October and added to the projection inventory until the target value of acres was reached. Similarly, stem cell piled events were added to the projection inventory with a random burn date in April and November until the targets are reached. The emissions from each stem cell event were calculated based on site-specific fuel loading and acres burned.

Stem cell events were created for 40 state-agency combinations and comprised approximately 20,000 acres out of 1,000,000 acres in the 2018 prescribed burning "less" projection inventory, about 45,000 acres of the 2,000,000 acres in the "likely" projection inventory, and approximately 90,000 acres out of the 3,700,000 acres in "more" projection inventory. In each inventory, the stem cell events account for approximately 2 percent of the total acres.

3.2 Wildfire and Wildland Fire Use Projection Inventory

The WRAP's Phase III Baseline (2000-2004) wildfire and Wildland Fire Use (WFU) inventories (described in Section 2.1 and Section 2.3, respectively) served as the starting place for the wildfire and WFU projection inventories. The projection inventories for wildfire and WFU were built by summing total baseline wildfire and WFU acres from the baseline inventory and allocating the total acres on a by state basis using the activity targets provided by the IFC and the FEJF projection scalars. The IFC provided projected activity targets (in acres) for WFU by state and agency. In general, the IFC activity targets indicate that Federal Land Managers intend to utilize the WFU designation for more naturally caused wildland fire events in the future. Therefore, the participants in the Technical Workshops elected to represent significantly more wildland fire acres as WFU in the projection inventory.

The wildfire and WFU scalars are presented in Table 4. For all scenarios, WFU acres were allocated on a by-state basis by allocating the total wildfire and WFU acres according to IFC activity targets. The IFC activity targets were used to allocate WFU by state by calculating each state's target acres as a percent of the total target acres. [1]

The 2018 scaled wildfire and WFU projection inventories were assembled by combining the wildfire and WFU baseline inventories and randomly selecting events from the combined set for each fire type regardless of the original baseline fire type of each event. This technique ensured that each inventory had spatially and temporally realistic fire events and increased the number of seed events that were available to be pulled from the seed data and added to the projection inventory for the WFU "more" scenario. The scaled 2018 wildfire and WFU inventories were created from events in the baseline inventories in the same manner as the creation of the baseline wildfire inventory from the Phase II wildfire inventory (described in Section 2.1). An exception to this method is that the date given to new, repeated events was plus or minus seven days from the original date. In addition, WFU events were limited to fire events smaller than 50,000 acres (except in Alaska). For wildfire, one abnormally large fire in Arizona was removed from the seed data. Figure 21 shows wildfire and WFU acres and $PM_{2.5}$ for each scenario compared to baseline wildfire and WFU acres and $PM_{2.5}$. Figure 22 shows wildfire and WFU projected acres by state compared to baseline acres.

[1] State-by-state WFU activity targets to not reflect the role that Smoke Management Programs may play in permitting wildland fires to be managed as Wildland Fire Use events.

Figure 21: Comparison of WRAP Phase III to Phase IV Wildfire and Wildland Fire Use Acres and $PM_{2.5}$

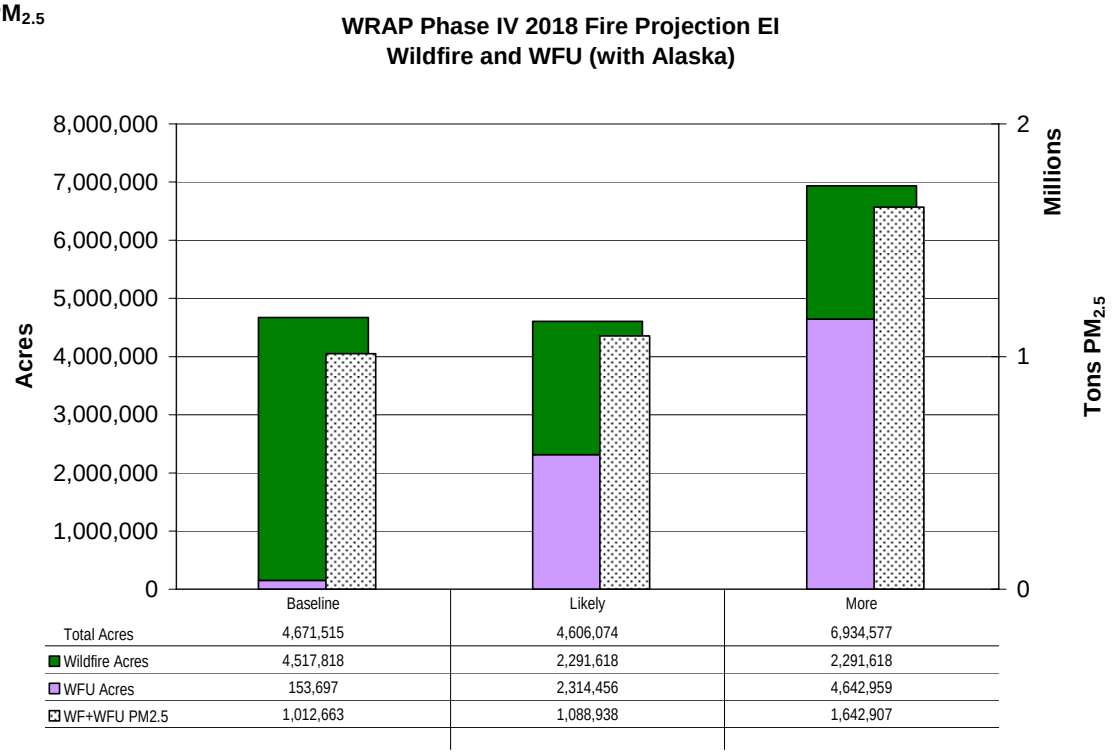
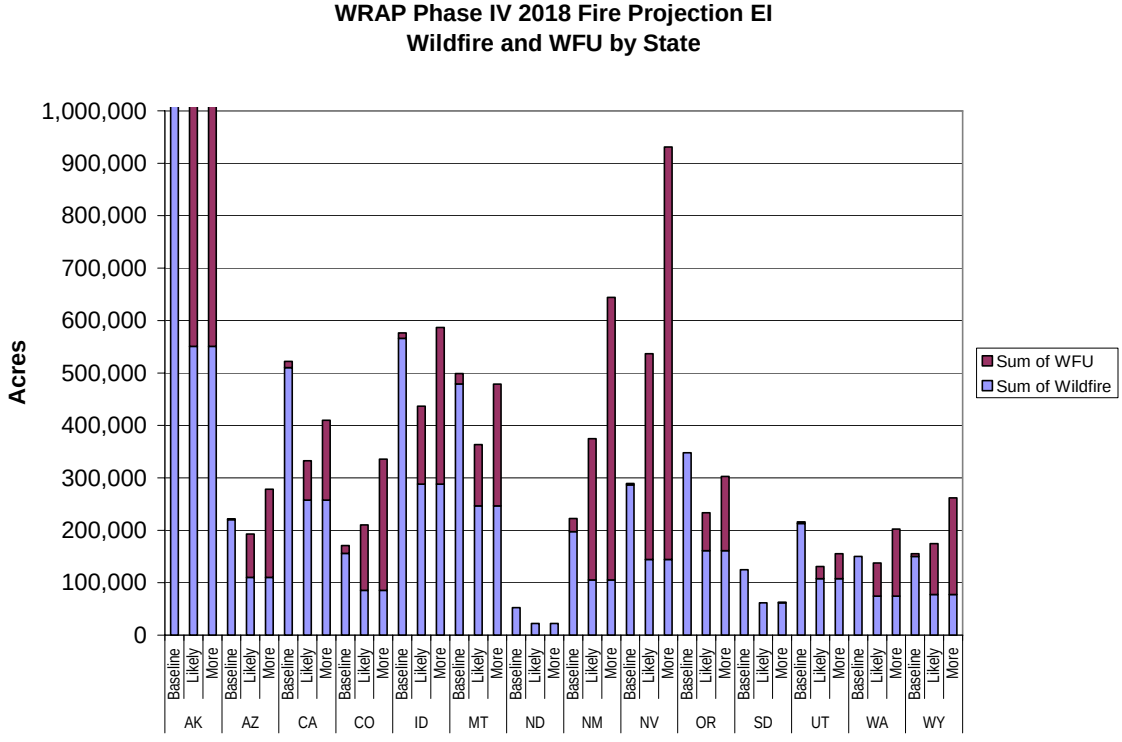


Figure 22: Comparison of WRAP Phase III to Phase IV Wildfire and Wildland Fire Use Acres and $PM_{2.5}$ by State



3.3 Agricultural Burning Projection Inventory

As determined during the two Technical Workshops for developing the projection inventories, only a "likely" scenario that accounts for variations from the Phase III (baseline) for agricultural burning was developed. To determine the extent, if any, the projection inventory should vary from baseline activity levels for agricultural burning, legal documents (such as state and local bills and statutes) were examined for codified limits to present and future agricultural burning. The agricultural projection inventory was created by removing activity from the baseline inventory to reflect the known limits to future agricultural burning. The projected emission inventory was created to reflect realistic burning patterns (on a spatial and temporal scale) with a reasonable projected activity level. In addition, ERTs were applied to the 2018 projection agricultural inventory in the same manner as for the base-control case discussed in Section 2.7.

For agricultural burning, the foreseeable variations from baseline resulted from changes in allowable burning levels throughout the WRAP region. The "likely" inventory was therefore developed by starting with the baseline (2000-2004) agricultural burning inventory and removing agricultural burning activity based on future or current (2005) limitations on burning. The allowable burning levels were gleaned through a search of literature, rules, regulations, and statute of state and local agencies in the WRAP region. Each limit was examined for its effect on the baseline inventory and fire events were dropped accordingly. Specifically, events in the baseline emission inventory were dropped (by geographic area and crop type) as necessary to meet the burning level targets (in acres), identified in the literature search.

The quality controlled baseline emission inventory was created from reported and estimated burning levels centering on 2002, and is therefore deemed accurate for fire size, fuel type, location, and time of burns. By starting with the baseline agricultural burning inventory and then dropping events for regulation changes, the 2018 projection inventory remained realistic on a spatial and temporal basis. That is, fire events in the projected inventory were of realistic size, location and timing.

A summary of the bills, statute, rules, and regulations that were examined is presented in the numbered list that follows. The consequent acres removed from the baseline inventory to arrive at the projected inventory are also identified.

1. **Pima County:** Only tumbleweed can be burned in Pima County, Arizona.

   Area: Pima County, Arizona

   Citation: Pima County Code 17.12.480 - .500

   Implementation Method: Select all burning except ditches and ditch banks in Pima County.

Affected Acres in Baseline: 0 acres

Proposed Acres Removed: 0 acres

2. **Sacramento Valley:** Rice Straw burning limited to 125,000 acres per year in the Sacramento Valley Air Basin.

   Area: Sacramento Valley air basin includes the California counties: Shasta, Placer, Butte, Colusa, Yolo, Sacramento, Tehama, Glenn, Yuba, Sutter, and Solano

   Citation: Connelly-Areias-Chandler Rice Straw Burning Reduction Act

   Implementation Method: Select all rice straw burning in the Sacramento Valley Air Basin counties.

   Affected Acres in Baseline: 155,078 acres

   Proposed Acres Removed: 30,154 acres (randomly chosen events, total acres removed is slightly more than necessary due to randomly removing entire events)

3. **San Joaquin Valley:** Eliminate burning of all agricultural wastes in the San Joaquin Valley starting June 2006.

   Area: San Joaquin Valley air basin includes the California counties: San Joaquin, Stanislaus, Merced, Madera, Fresno, Kings, Tulane, and Kern (western part)

   Citation: Senate Bill 1056

   Implementation Method: Select all burning in the San Joaquin Valley Air Basin counties.

   Affected Acres in Baseline: 402,987 acres

   Proposed Acres Removed: 402,987 acres[2]

4. **Southwest Air District:** Best Management Practices allows very little agricultural burning in Washington's Southwest Clean Air Agency district.

   Area: Southwest Clean Air Agency includes the Washington counties: Clark, Cowlitz, Lewis, Skamania, and Wahkiakum

   Citation: BMP Part II (WAC 173-430)

   Implementation Method: Select all burning in Washington's Southwest Clean Air Agency counties.

   Affected Acres in Baseline: 0 acres

   Proposed Acres Removed: 0 acres

[2] The efforts to quantify the effects on agricultural emissions of regulations that will be implemented in the future did not consider the degree to which exemptions to the regulations would be utilized.

5. **Willamette Valley:** Open field burning limited to 65,000 acres (40,000 acres regular burning, 22,000 acres identified species, 3,000 acres steep terrain) and propane flaming limited to 37,500 acres in the Willamette Valley.

   Area: The Willamette Valley includes the Oregon counties of: Columbia, Washington, Multnomah, Yamhill, Clackamas, Polk, Marion, Linn, Benton, Lane, and Douglas

   Citation: Field Burning Rule 603-077-0101

   Implementation Method: Select all burning in the Willamette Valley counties.

   Affected Acres in Baseline: 51,845 acres

   Proposed Acres Removed: 0 acres

   The agricultural burning inventory does not include information regarding the type of burn (i.e. regular, identified species, steep terrain, propane flaming) and therefore the specific limits by type of burn cannot be assessed. However, from 2002 to 2005 the total average open-field burning in the Willamette Valley was 50,000 acres with an addition average of 1,700 acres of propane flaming. The baseline inventory includes 51,845 acres (including propane flaming) and is therefore deemed average, resulting in no removal of acres from the baseline inventory.

6. **Washington Orchards:** No orchard removal in Washington in 2018.

   Area: Washington State

   Citation: Discussions at Phase III/IV Technical Workshop 2.5 in Seattle

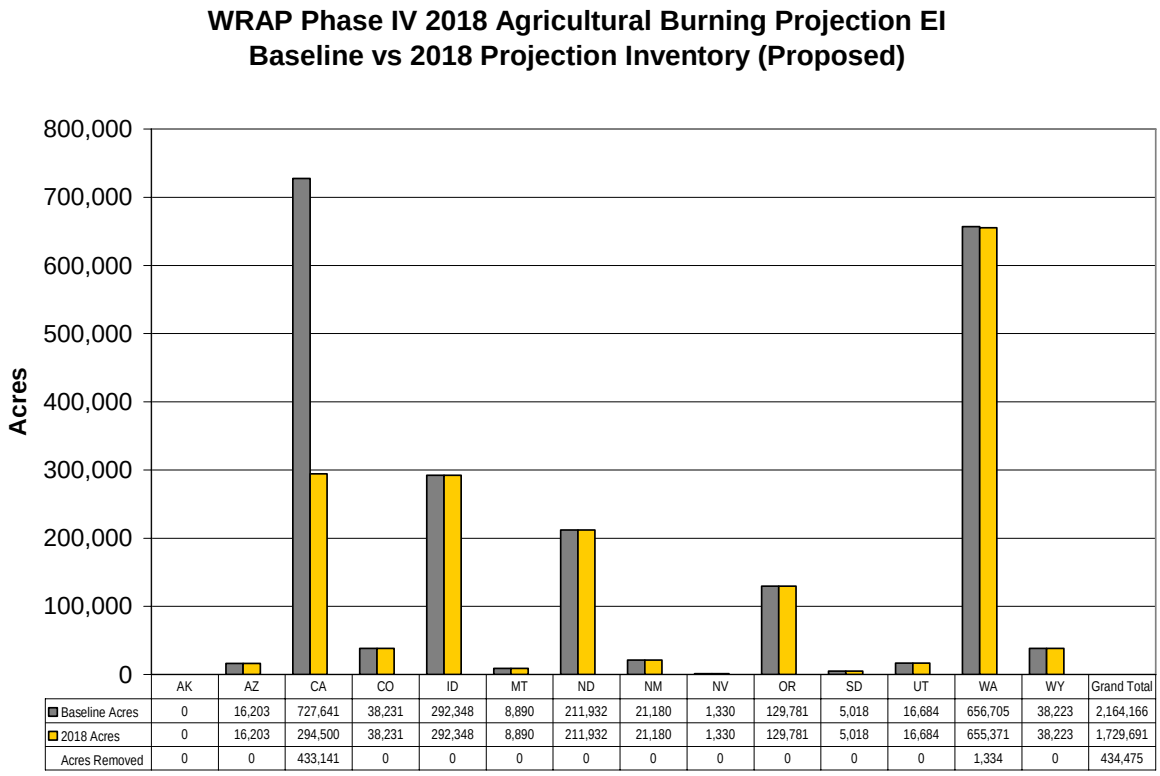
   Implementation Method: Select all orchard removal burning in Washington.

   Affected Acres in Baseline: 1334 acres

   Proposed Acres Removed: 1334 acres

The total fire activity that was dropped for the 2018 projection inventory was 434,475 acres accounting for 4,999 tons $PM_{2.5}$ (Figure 23). Of the agricultural activity that was dropped, 99.7% of acres occurred in California. Within California, a majority (97%) of the activity removed was from the San Joaquin Valley. The only other state with fire activity removed from baseline for the 2018 projection inventory was Washington for orchard removal.

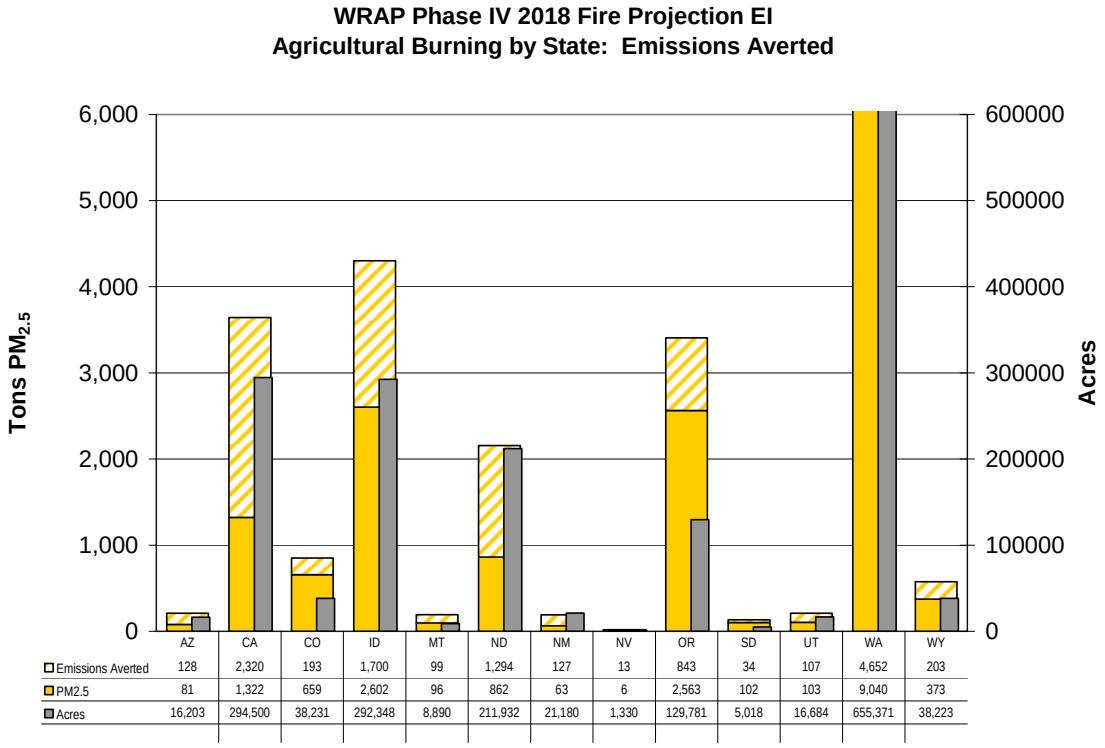
Figure 23: Agricultural Burning Baseline Versus 2018 Projection Inventory



	AK	AZ	CA	CO	ID	MT	ND	NM	NV	OR	SD	UT	WA	WY	Grand Total
Baseline Acres	0	16,203	727,641	38,231	292,348	8,890	211,932	21,180	1,330	129,781	5,018	16,684	656,705	38,223	2,164,166
2018 Acres	0	16,203	294,500	38,231	292,348	8,890	211,932	21,180	1,330	129,781	5,018	16,684	655,371	38,223	1,729,691
Acres Removed	0	0	433,141	0	0	0	0	0	0	0	0	0	1,334	0	434,475

The total agricultural burning activity in the baseline fire inventory was 2,164,166 acres. The total agricultural burning activity in the projected (2018) fire inventory is 1,729,691 acres, or 80% of baseline activity. The total $PM_{2.5}$ emissions and acres in the projected inventory and the emissions averted from the application of ERTs are shown in Figure 24.

Figure 24: Agricultural Burning Projection EI Acres Burned, Tons $PM_{2.5}$ Emitted, and Emission Averted from the Application of ERTs



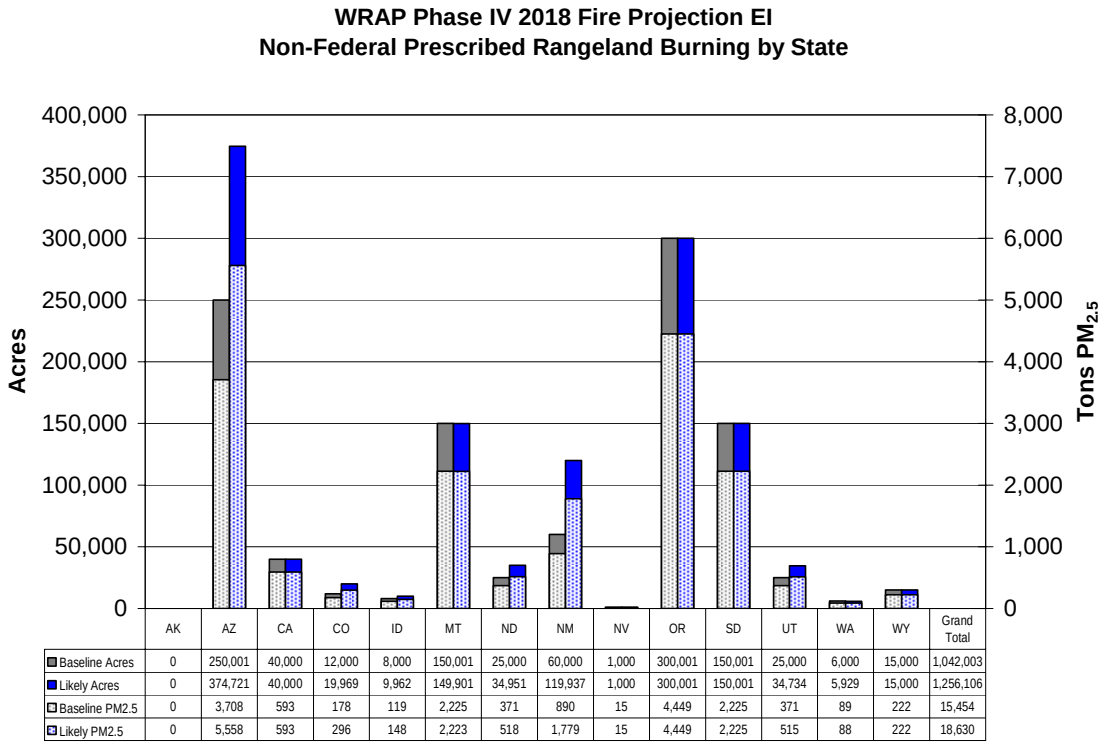
3.4 Non-Federal Rangeland Prescribed Burning Projection Inventory

The WRAP's Phase III Baseline (2000-2004) non-federal rangeland (NF) fire inventory (described in Section 2.5) served as the starting place for the NFR projection inventory. The projection inventory for NFR was built by scaling up the baseline inventory based on NRCS projected acres and FEJF scalars. The NRCS provided projected acres by state, which were determined by the participants of the Technical Workshops as the likely scenario. The Workshop participants determined that the less scenario should be half of the NRCS projected acres by-state and the more scenario should be twice the NRCS projected acres by-state.[3]

The baseline non-federal rangeland events were used to assemble the scaled projection inventory in the same manner as the creation of the baseline wildfire inventory from the Phase II wildfire inventory. Figure 25 shows the projected NFR acres compared to the baseline NFR acres.

[3] In the Air Quality Planning Suites (described in Section 3.5) only the likely scenario was utilized.

Figure 25: Comparison of WRAP Phase III to Phase IV 2018 Non-Federal Rangeland Burning Likely Inventory by State



	AK	AZ	CA	CO	ID	MT	ND	NM	NV	OR	SD	UT	WA	WY	Grand Total
Baseline Acres	0	250,001	40,000	12,000	8,000	150,001	25,000	60,000	1,000	300,001	150,001	25,000	6,000	15,000	1,042,003
Likely Acres	0	374,721	40,000	19,969	9,962	149,901	34,951	119,937	1,000	300,001	150,001	34,734	5,929	15,000	1,256,106
Baseline PM2.5	0	3,708	593	178	119	2,225	371	890	15	4,449	2,225	371	89	222	15,454
Likely PM2.5	0	5,558	593	296	148	2,223	518	1,779	15	4,449	2,225	515	88	222	18,630

3.5 Air Quality Planning Suites

The technical approach to produce projection inventories for each of the fire types included the development of "less," "likely," and "more" scenarios. The projection inventories are intended for use by the WRAP and its Regional Modeling Center (RMC) to estimate future air quality impacts associated with fire emissions. As a practical matter, the resources of the WRAP to have the RMC execute regional dispersion models are limited. Therefore, the FEJF was asked to identify a limited number of combinations of fire emissions (one scenario from each of the five fire types) to serve as the Air Quality Planning Suites for fire. The Air Quality Planning Suites are summarized in Table 5.

Table 5: Summary of Air Quality Planning Suites

Fire Type	Baseline Control Case	Base Case	Climate Conditions/ Resource Limited	Maximum Application of Prescribed Fire
Wildfire	Baseline	Likely	More	Likely
WFU	Baseline	Likely	More	Likely
Prescribed	Baseline with ERT	Likely	Less	More
Rangeland	Baseline	Likely	Likely	Likely
Agricultural	Baseline with ERT	Likely	Likely	Likely

Base Case Planning Suite. This suite reflects the most "likely" fire emissions scenario for 2018. This suites avoids extremes of either mostly prescribed or mostly wildfire burning. As shown in Table 5, the base case suite is comprised of all of the likely inventories. The base case suite can be compared to baseline to estimate changes in emissions and visibility due to fire from the baseline period (2000-2004) to 2018. This suite would reflect favorable conditions for prescribed burning in most states and steady funding for fuels treatment using prescribed fire.

Climate Conditions and Resource Limited Suite. This suite reflects the highest expected levels of wildfire and wildland fire use in 2018. This suite includes low prescribed fire usage (due to unfavorable fuel and weather conditions). This suite is comprised of the "more" inventory for wildfire and WFU, the "less" inventory for prescribed burning, and the "likely" inventory for agricultural and NFR burning. The climate conditions and resource limited suite can be compared to baseline to estimate the potential change in emissions and visibility impacts due to prolonged drought, heaving loadings of dry fuels, and constrained resources.

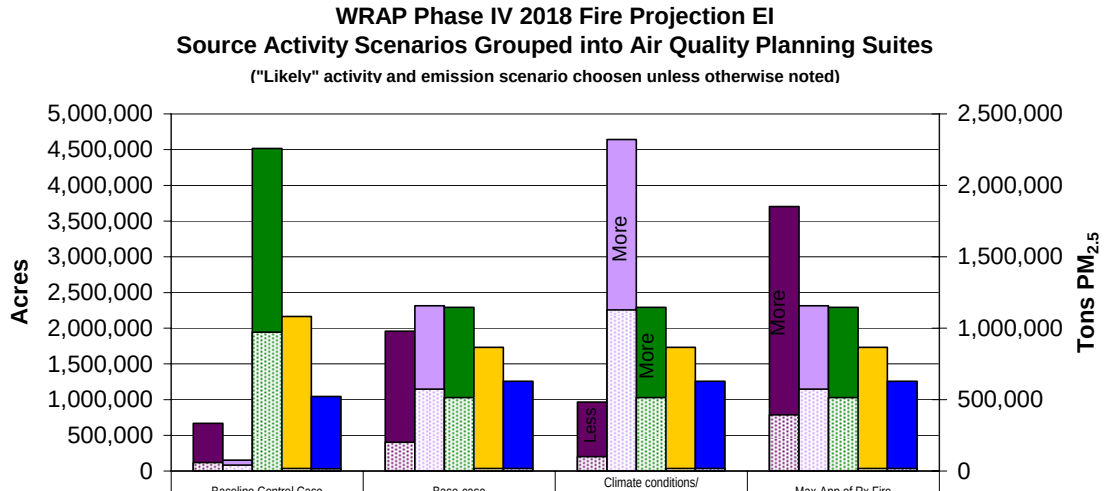
Maximum Application of Prescribed Fire Suite. This suite reflects prescribed burning at the Interagency Fuels Committee's target activity levels. The suite includes the "more" inventory for prescribed burning and the "likely" inventories for wildfire, WFU, agricultural burning, and NFR burning. The maximum application of prescribed fire suite can be compared to baseline to estimate the possible change in emissions and visibility impacts due to the maximum application of prescribed fire. This suite would reflect the maximum funding for treatment and ideal conditions for burning. It could also be used to estimate the maximum potential air quality benefit that could be accomplished through the application of ERTs to prescribed fire events.

3.6 Projection Inventory Results and Comparison to Baseline

The 2018 projection inventories for prescribed burning, wildfire, WFU, and NFR were created by adding or subtracting events from the baseline inventory to achieve the projection targets, as discussed above. These inventories were then compiled into air quality planning suites to reflect

future burning scenarios and allow for comparison to baseline to analyze possible changes in emissions and visibility impacts due to fire. The fire activity and emissions of the final 2018 projection inventories are presented in this section. Figure 26 presents the acreage and $PM_{2.5}$ totals for the Phase III Baseline, Baseline Control, Phase IV Base Case suite, Climate Conditions and Resource Limited suite, and the Maximum Application of Prescribed Fire suite for each fire source.

Figure 26: Summary of Phase IV Projection Inventory Air Quality Planning Suites



	Baseline Control Case	Base-case	Climate conditions/ resource limited	Max-App of Rx Fire
Prescribed Acres	669,348	1,959,146	966,251	3,704,081
WFU Acres	153,697	2,314,456	4,642,959	2,314,456
Wildfire Acres	4,517,818	2,291,618	2,291,618	2,291,618
Agricultural Acres	2,164,166	1,729,691	1,729,691	1,729,691
NF Rangeland Acres	1,042,003	1,256,106	1,256,106	1,256,106
Prescribed PM2.5	59,687	202,493	100,861	393,391
WFU PM2.5	41,173	574,159	1,128,127	574,159
Wildfire PM2.5	971,490	514,780	514,780	514,780
Agricultural PM2.5	18,816	17,871	17,871	17,871
NF Rangeland PM2.5	15,454	18,630	18,630	18,630

APPENDIX A

Technical Methodologies Used to Create Event-Based Fire Records in the 2002 Phase II Fire Emission Inventories

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Tables

Figures

A.1 Fuel Loading and Emission Factors

In the event that fire event-specific fuel loading values were not contained in the database record, fuel loading in tons per acre for the wildfire inventory were assigned using the NFDRS fuel model codes and a table of fuel loading values for NFDRS fuel model categories (Cohen and Deeming, 1985). In addition to the default NFDRS fuel loadings, additional fuel loading was added to each category to adjust for fuel present as duff and tree crowns. Similarly, for prescribed fire events for which no fuel loading value was available, the prescribed fire fuel loading values were the same as those used for the wildfire inventory. "Adjusted" NFDRS fuel loading assignments for wildfire and prescribed burning differed by the percent consumption assumed for live fuels, duff, and crown components. Table A-1 presents the adjusted NFDRS fuel loading assignments for wildfire and prescribed burning.

An emission factor suite was developed to apply to wildfire and prescribed fire activity data. The emission factor suite included one look-up table for wildfire and prescribed broadcast burns and one table for prescribed pile burns. The twelve pollutants included were total suspended particulate matter (TSP), particulate matter less than 10 microns in diameter (PM_{10}), particulate matter less than 2.5 microns in diameter ($PM_{2.5}$), elemental carbon (EC), organic carbon (OC), non-methane volatile organic compounds (VOC), methane (CH_4), ammonia (NH_3), oxides of nitrogen (NO_x), carbon monoxide (CO), sulfur dioxide (SO_2), and coarse particulate matter– defined as the difference between PM_{10} and $PM_{2.5}$ (PMC). The emission factor suite consists of two look-up tables. Two emission factor references were drawn upon: the U.S. Environmental Protection Agency's (U.S. EPA) AP-42 Section 13.1 and an emission inventory methods survey report (Battye, 2001) funded by the U.S. EPA Office of Air Quality Planning and Standards (OAQPS). The emission factor suite is a compilation of emission factors and emission factor relationships (multipliers) from both documents. Table A-2 lists the emission factors used for the Phase II EI.

In addition to smoldering consumption incorporated into the NFDRS fuel loading table, distinct smoldering emissions were added to the emission inventory on the day after certain wildland fire days (see Section A.3).

Table A-1: Summary of Fuel Loading and Consumption by NFDRS Model for Wildfire, WFU, and Prescribed Fire.

Dead and live fuel loadings were based on Cohen and Deeming (1985). Values in parentheses indicate total fuel loading for prescribed fire. An asterisk (*) after the NFDRS model description indicates the wildfire emissions were augmented for smoldering consumption.

NFDRS Abbr.	NFDRS Model Description	Total, WF/WFU (Rx fire) (tons/acre)	Dead Fuels (tons/acre)				Live Fuels (tons/acre)		Additional (tons/acre)	
			1-hour	10-hour	100-hour	1,000-hour	Fine Wood	Herbaceous	Duff	Crown
A	Western grasses (annual)	0.50	0.20	0.00	0.00	0.00	0.00	0.30	0.00	0.00
B	California chaparral	19.5	3.50	4.00	0.50	0.00	11.50	0.00	0.00	0.00
C	Pine-grass savanna	4.7	0.40	1.00	0.00	0.00	0.50	0.80	4.00	0.00
D	Southern rough *	15.6 (10.6)	2.00	1.00	0.00	0.00	3.00	0.75	7.70	8.00
E	Hardwood litter (winter) *	3.8	1.50	0.50	0.25	0.00	0.50	0.50	1.10	0.00
F	Intermediate brush	15.0	2.50	2.00	1.50	0.00	9.00	0.00	0.00	0.00
G	Short needle (heavy dead) *	43.5 (25.6)	2.50	2.00	5.00	12.00	0.50	0.50	18.20	19.20
H	Short needle (normal dead) *	27.5 (15.0)	1.50	1.00	2.00	2.00	0.50	0.50	16.90	18.70
I	Heavy slash *	55.1 (49.1)	12.00	12.00	10.00	12.00	0.00	0.00	18.20	0.00
J	Intermediate slash *	34.0 (31.2)	7.00	7.00	6.00	5.50	0.00	0.00	16.90	0.00
K	Light slash *	14.4 (13.1)	2.50	2.50	2.00	2.50	0.00	0.00	9.70	0.00
L	Western grasses (perennial)	0.75	0.25	0.00	0.00	0.00	0.00	0.50	0.00	0.00
N	Saw grass *	5.0	1.50	1.50	0.00	0.00	2.00	0.00	0.00	0.00
O	High pocosin *	46.1 (45.1)	2.00	3.00	3.00	2.00	7.00	0.00	58.20	0.00
P	Southern pine plantation *	16.4 (10.2)	1.00	1.00	0.50	0.00	0.50	0.50	13.30	10.00
Q	Alaskan Black Spruce	57.6 (48.8)	2.00	2.50	2.00	1.00	4.00	0.50	57.90	26.80
R	Hardwood litter (summer) *	3.1	0.50	0.50	0.50	0.00	0.50	0.50	1.10	0.00
S	Tundra *	19.3 (19.1)	0.50	0.50	0.50	0.50	0.50	0.50	32.60	0.00
T	Sagebrush grass *	4.5	1.00	0.50	0.00	0.00	2.50	0.50	0.00	0.00
U	Western pines *	19.1 (10.3)	1.50	1.50	1.00	0.00	0.50	0.50	10.60	14.20

Table A-2: Summary of Emission Factors

Summary of emission factors (EF) in pounds per ton for prescribed burning. In the case of piled fuels, when two sources are mentioned, the first source refers to the emission factor and the second to the empirical relationship used to derive that emission factor.

Pollutant	Prescribed Fire Piled Fuels		Prescribed Fire Non-Piled	
	EF	Source	EF	Source
TSP	12.0	AP42[4]	34.1	AP42
PM_{10}	8.0	AP42	28.1	OAQPS
$PM_{2.5}$	8.0	AP42	24.1	OAQPS
Elemental Carbon	0.6	AP42, OAQPS $PM_{2.5}$ * 0.072	1.5	OAQPS
Organic Carbon	4.3	AP42, OAQPS $PM_{2.5}$ * 0.54	11.6	OAQPS
VOC	6.3	AP42, OAQPS CO * 0.085	13.6	OAQPS
CH_4	7.7	OAQPS 2*(42.7-43.2*CE)	13.6	OAQPS
NH_3	0.5	AP42, OAQPS CO * 0.0073	1.3	OAQPS
NO_x	6.2	OAQPS	6.2	OAQPS
CO	74.3	AP42	289.0	OAQPS
SO_2	1.7	OAQPS	1.7	OAQPS
PM coarse	0.0	$PM_{10} - PM_{2.5}$	4.0	$PM_{10} - PM_{2.5}$

A.2 Emission Calculations

For wildfire and prescribed burning, daily emissions were calculated as fuel consumed (tons of fuel) multiplied by each emission factor (pounds of pollutant per ton of fuel). Total fuel consumed was either extracted directly from the activity data (more often the case with prescribed fire) or was calculated as the size of the fire (acres burned) multiplied by the "adjusted" NFDRS fuel loading value (tons of fuel per acre burned). For wildfires and prescribed broadcast burns of fuel model types with a fuel loading greater than 5 tons per acre, additional smoldering emissions were assigned to the same location on the following calendar day.

A.3 Day-After Smoldering Emissions Added to Eligible Fires

Emissions due to smoldering were estimated and added to the emissions estimates for wildland broadcast fire events. Fire events associated with heavy fuel loading (based on the National Fire Danger Rating System fuel model assigned to each event) were assumed to produce smoldering emissions on the day after each day of burning (assumed to be flaming-phase days). For smoldering-eligible wildfire and WFU events, smoldering emissions were assumed to be 17 percent of the emissions of the previous day (personal communication with David Sandberg, USDA – Forest Service (retired)). For smoldering-eligible prescribed fire events, smoldering

[4] AP-42, Section 13.1, Table 13.1-3, Logging Slash Debris, No Mineral Soil, weighted average of flaming and smoldering.

emissions were assumed to be 8.5 percent of the emissions of the previous day. Smoldering emissions were not added to pile burning events.

A.4 Plume Profile

A plume profile tailored for wildland fire was assigned to each daily fire event. Normally, plume rise is predicted using hourly pyrotechnical and meteorological information. However, given the unique physical characteristics of wildland fire events and previous experience with dispersion models that indicated questionable performance with regard to dispersing smoke plumes, the FEJF utilized expert opinion to assign plume characteristics to each fire event.

It is important to note that there are alternative methods available to represent smoke plumes in regional dispersion models. In 2007, the FEJF intends to coordinate a stakeholder group to investigate the available methods and any associated research on model performance. The focus of the stakeholder group will be to determine if the FEJF should recommend that the WRAP's plume assignment method be modified or replaced in order to enhance the performance of the WRAP's regional modeling analyses with regard to smoke impacts. Users of the WRAP's modeling results and entities that conduct regional dispersion modeling using the WRAP's fire emission input files should factor these technical realities into the interpretation and use of regional modeling results.

A.4.1 Virtual Acres

Fires were classified into size classes based on "virtual acreage." The virtual acreage was calculated by multiplying the actual fire size by the square root of the normalized pre-burn fuel loading (Equation A-1). This was done in order to relate fuel loading to the characteristic "stack" diameter of the plume. Total fuel loading was normalized to 13.8 tons per acre for wildfire and 5.0 tons per acre for prescribed fire. The normalizer for wildfire was equal to the total surface loading plus a portion of the crown biomass of NFDRS fuel model U (western pines). The prescribed fire normalizer is equal to the surface loading only of NFDRS fuel model U.

$$\text{Acreage}_{\text{virtual}} = \text{Acreage}_{\text{actual}} \cdot \sqrt{\text{Fuel Loading} / \text{Normalizer}} \qquad \textbf{Equation A-1}$$

The plume profile for days added to model smoldering for the day after an original activity day was the same as for the original fire event. In the emission inventory, the smoldering events retained the virtual acreage of the fire event they were created from, and thus the plume calculations were identical.

A.4.2 Diurnal Consumption

A diurnal fuel consumption table was created to allocate daily wildland fire emissions by hour (Table A-3). The table, consisting of a percent of fuel consumed for each hour of the day,

summing to 100, was submitted to the Air Quality Modeling Forum (and the WRAP's Regional Modeling Center [RMC]). The diurnal fuel consumption table was implemented by the RMC within the SMOKE emissions processor to allocate daily emission estimates to hourly emissions.

Table A-3: Standard Diurnal Consumption Template Used to Distribute Fire-Total Heat Production and Emissions

Hour	1	2	3	4	5	6	7	8	9	10	11	12
% Per Hour	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	2.00	4.00	7.00

Hour	13	14	15	16	17	18	19	20	21	22	23	24
% Per Hour	10.00	13.00	16.00	17.00	12.00	7.00	4.00	0.57	0.57	0.57	0.57	0.57

A.4.3 Fire Size Classes and Plume Profile Calculations

Plume values include the top and bottom of the plume (Ptop and Pbot, respectively; both expressed in meters above ground elevation) and the percent of emissions entrained within the surface layer of the atmosphere (Lay1F), defined by the ETT of the FEJF as the first 38 meters above the ground.[5] These three plume parameters are established and assigned for each of the 24 hours of each daily fire event. All of the plume values were assigned based on the limited information available for each fire event, including fire size (fire area grown per day) and either a reported fuel loading or the NFDRS fuel model.

Five plume classes were defined with increasing potential plume heights to reflect the range of "heat release" possible in wildland fires (Table A-4). Plume bottom heights and percent of the plume fumigated to the first layer of the atmosphere were also developed for the five plume classes. Using expert opinion and anecdotal evidence, a table of hourly buoyant efficiency values was derived (Table A-5).

Table A-4: Fire-Related Parameters as Function of Fire Size Classes

Class	1	2	3	4	5
Size (virtual acres)	0 – 10	>= 10 – 100	>= 100 – 1,000	>= 1,000 – 5,000	>= 5,000
BE_{size}	0.40	0.60	0.75	0.85	0.90
Ptop max (m)	160	2,400	6,400	7,200	8,000
Pbot max (m)	0	900	2,200	3,000	3,000

[5] The height of the first (lowest) vertical layer is 38 m in the WRAP's Regional Modeling Center's model setup. The calculation methodology for the Lay1F values have been reviewed (by Air Sciences and the USDA Pacific Wildland Fire Sciences Lab) and assessed to be reasonable with no additional scaling. The maximum bottom of plume values was revised downward for the three largest fire size classes (also based on discussions with the USDA Pacific Wildland Fire Sciences Lab).

Table A-5: Buoyant Efficiency as Function of Hour of Day

Hour	1	2	3	4	5	6	7	8	9	10	11	12
BE_{hour}	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.06	0.10	0.2	0.4

Hour	13	14	15	16	17	18	19	20	21	22	23	24
BE_{hour}	0.7	0.8	0.9	0.95	0.99	0.8	0.7	0.4	0.06	0.03	0.03	0.03

Equations were used to calculate Ptop and Pbot as a function of time of day and size of the fire (expressed in terms of virtual acres). Note that the calculations used an hourly value for buoyant efficiency (Table A-5) and heat release value based on fire size, also referred to as normalized fire growth.

The hourly top of the plume was calculated as follows:

$$\mathrm{Ptop}_{\mathrm{hour}} = \left(\mathrm{BE}_{\mathrm{hour}}\right)^2 * \left(\mathrm{BE}_{\mathrm{size}}\right)^2 * \mathrm{Ptop}_{\max} \quad \text{(A-2)}$$

Where: BE is the buoyant efficiency looked up from the hourly or size class tables. The hourly bottom of plume was similarly calculated as:

$$\mathrm{Pbot}_{\mathrm{hour}} = \left(\mathrm{BE}_{\mathrm{hour}}\right)^2 * \left(\mathrm{BE}_{\mathrm{size}}\right)^2 * \mathrm{Pbot}_{\max} \quad \text{(A-3)}$$

Lastly, an equation was used to calculate Lay1F, the proportion of emissions fumigated into the first atmospheric layer. Lay1F was calculated as the arithmetic inverse of the hour-specific buoyant efficiency multiplied by the size-specific buoyant efficiency.

$$Lay1F_{hour} = 1 - \left(BE_{hour} * BE_{size}\right) \quad \text{(A-4)}$$

Using Equations A-1 through A-4, the bottom and top of the atmospheric plume as well as the proportion of the plume fumigated into the first atmospheric surface layer were all scaled to fire size, fuel loading (incorporated in virtual acres calculation), and hour of the day. Figures A-1 through A-4 illustrate the relationships described above.

Figures A-1 through A-9 illustrate the hourly plume characteristics (Ptop, Pbot, and Lay1F) assigned to each of the five fire size classes into which daily fire events in the Phase II EI have been assigned (Class 1 - less than 10 acres; Class 2 – 10 to 100 acres; Class 3 – 100 to 1,000 acres; Class 4 – 1,000 to 5,000 acres; Class 5 – greater than 5,000 acres). Also shown on Figures A-5 through A-9 is the height (38 m) of the first vertical atmospheric layer (as designated by the WRAP's RMC).

Figure A-1: Buoyant Efficiency

The relationship between buoyant efficiency and time of day.

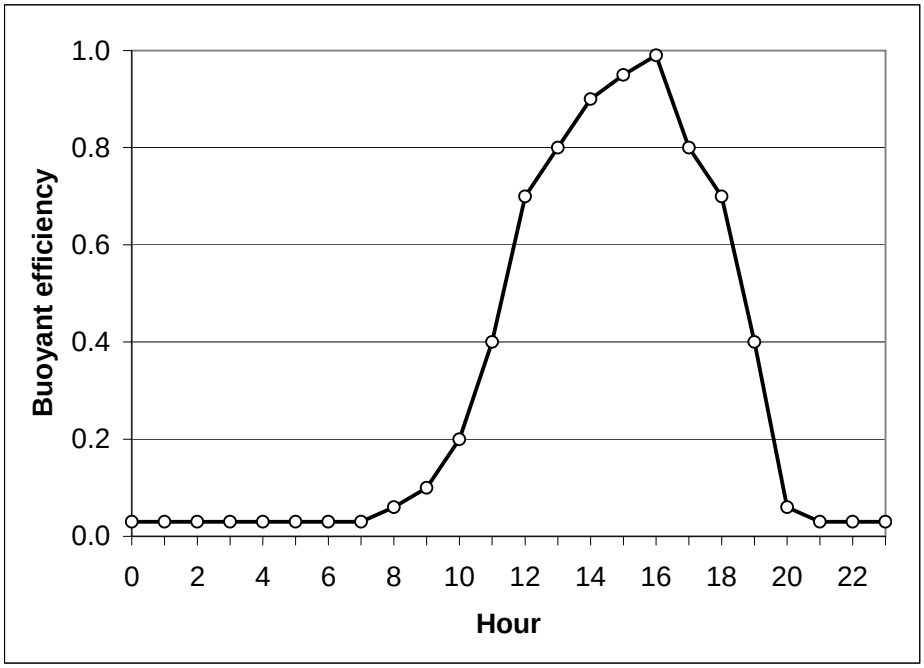


Figure A-2: Projected Top of Plume

The projected top of the atmospheric plume (meters) as a function of time of day and fire size. Fire sizes represent the upper cutoff of the fire size categories. The lowest line represents the 10-acre cutoff. Note the logarithmic scale on the Y-axis.

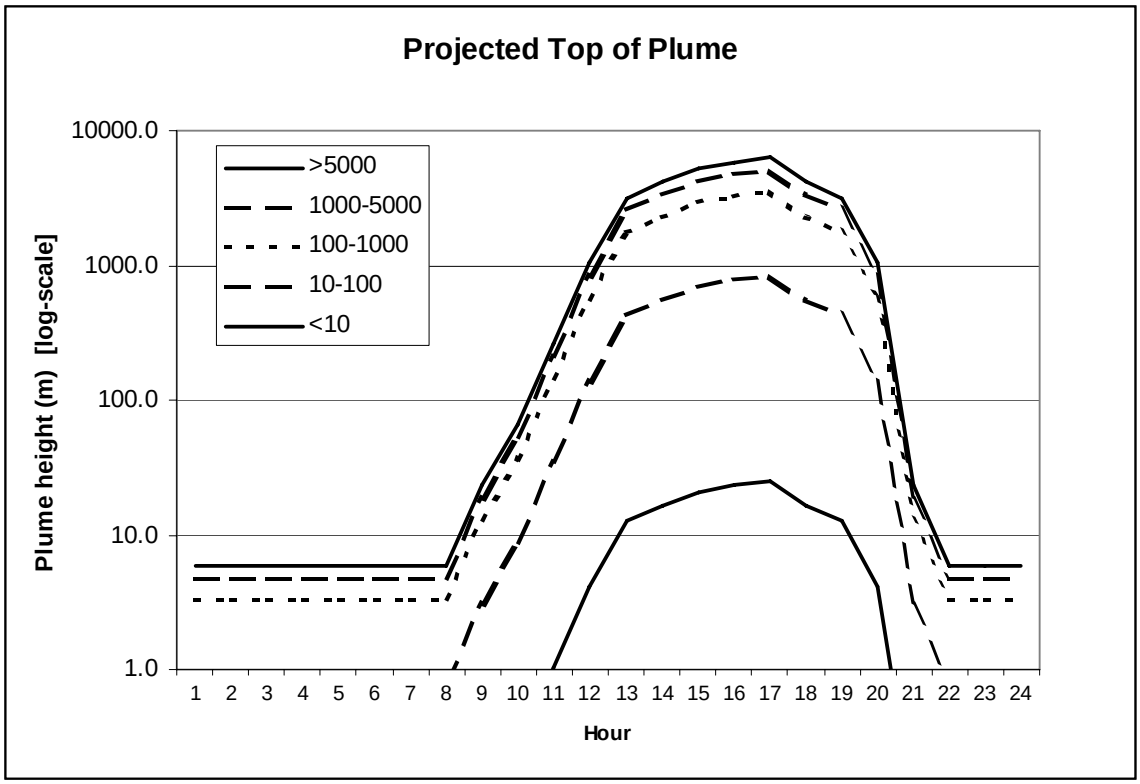


Figure A-3: Projected Bottom of Plume

The projected bottom of the atmospheric plume (meters) as a function of time of day and fire size. Fire sizes represent the upper cutoff of the fire size categories. The line representing the 10-acre cutoff is constant at a value of zero.

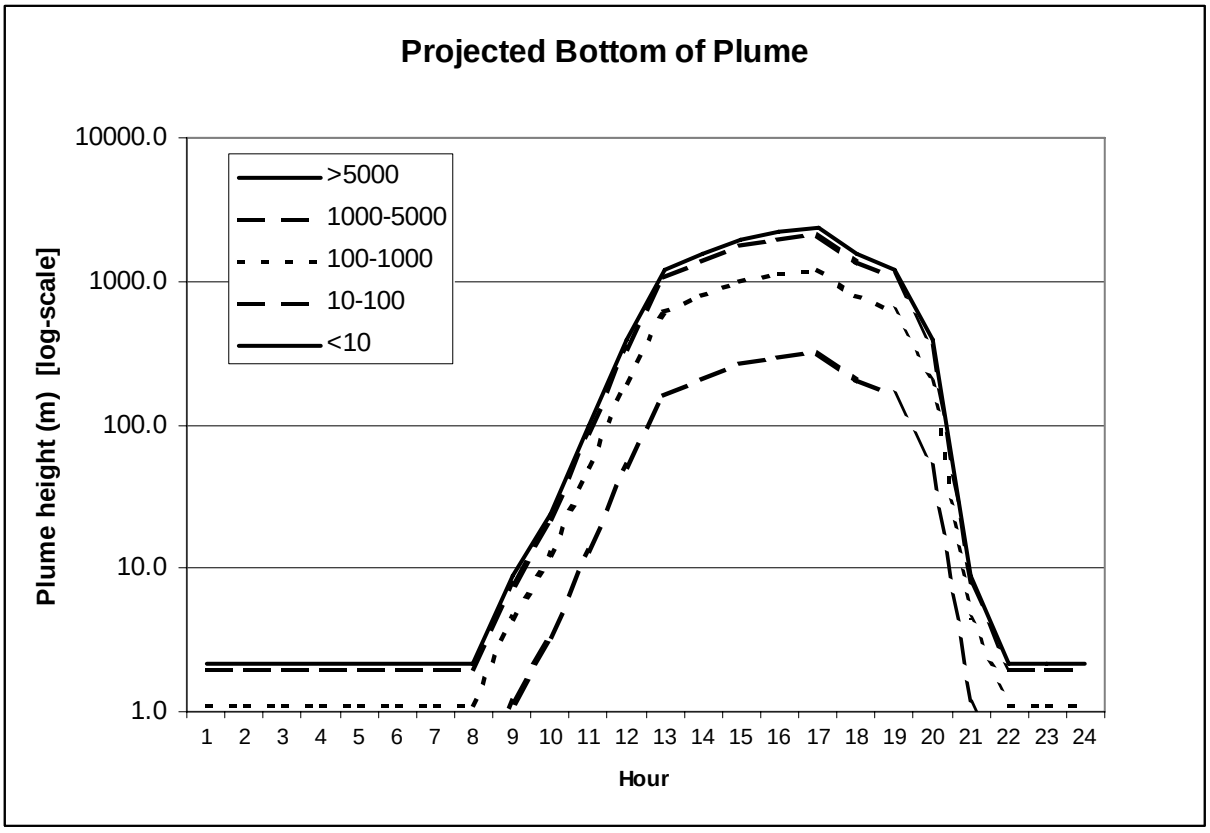


Figure A-4: Proportion of Plume in Surface Layer

The proportion of the plume fumigation to the atmospheric surface layer (<38 m) as a function of time of day and fire size. Fire sizes represent the upper cutoff of the fire size categories. The highest line represents the 10-acre cutoff.

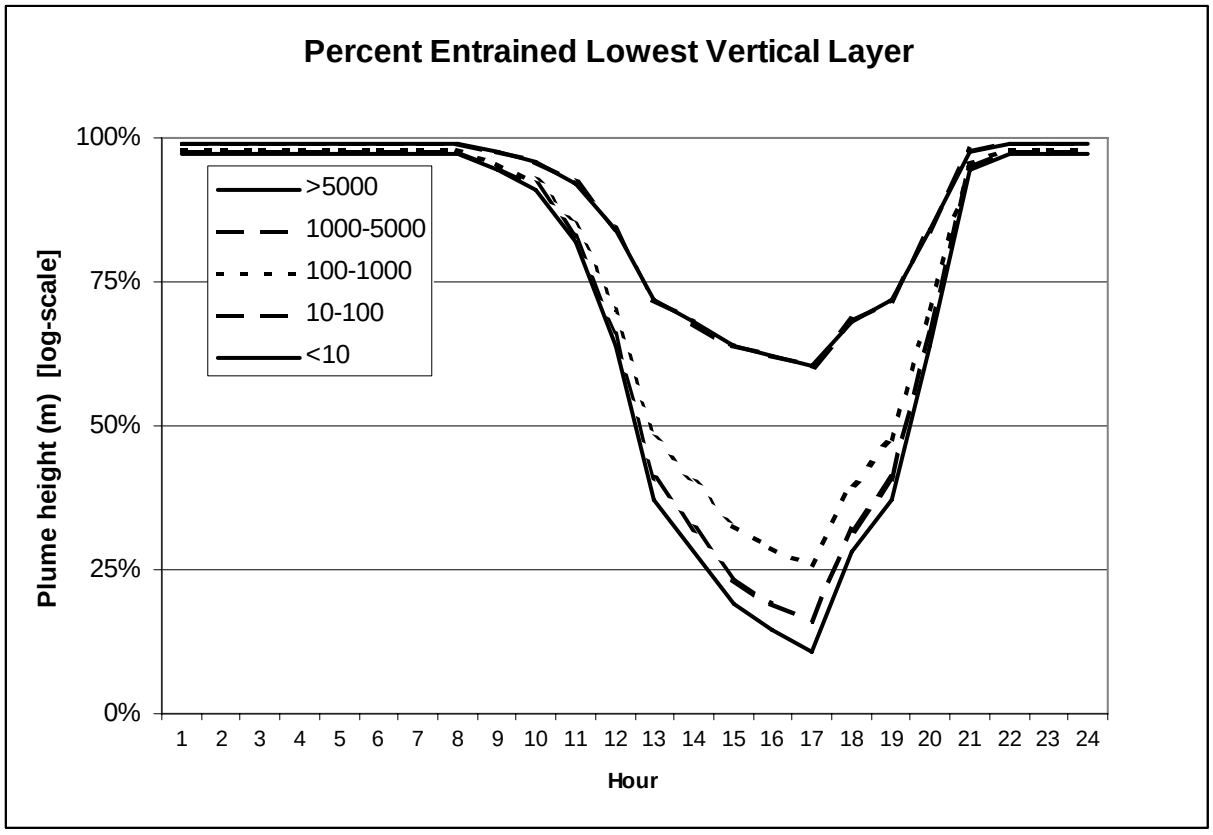


Figure A-5: Fire Size Class 1 Plume Characteristics

This figure shows plume characteristics (Ptop, Bbot, and Lay1F) for Class 1 fires for each hour. Plume height in meters is shown on the left Y-axis (in log-scale), and Lay1F in percent entrained into the lowest vertical layer is shown on the right Y-axis. For reference, the height of the lowest vertical layer (38 m) is shown in red.

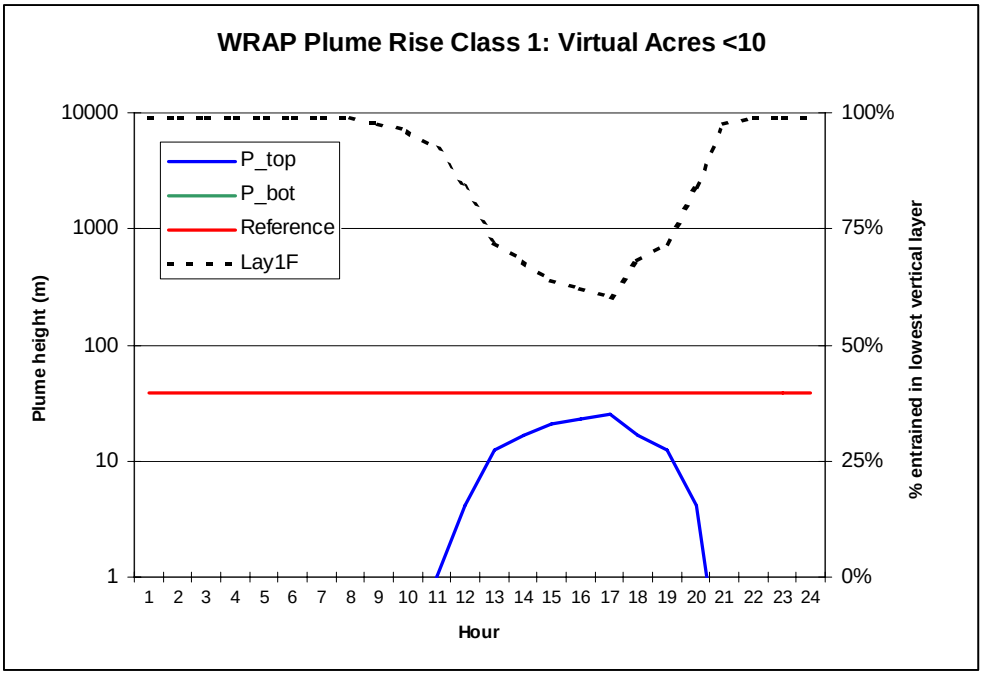


Figure A-6: Fire Size Class 2 Plume Characteristics

This figure shows plume characteristics (Ptop, Bbot, and Lay1F) for Class 2 fires for each hour. Plume height in meters is shown on the left Y-axis (in log-scale), and Lay1F in percent entrained into the lowest vertical layer is shown on the right Y-axis. For reference, the height of the lowest vertical layer (38 m) is shown in red.

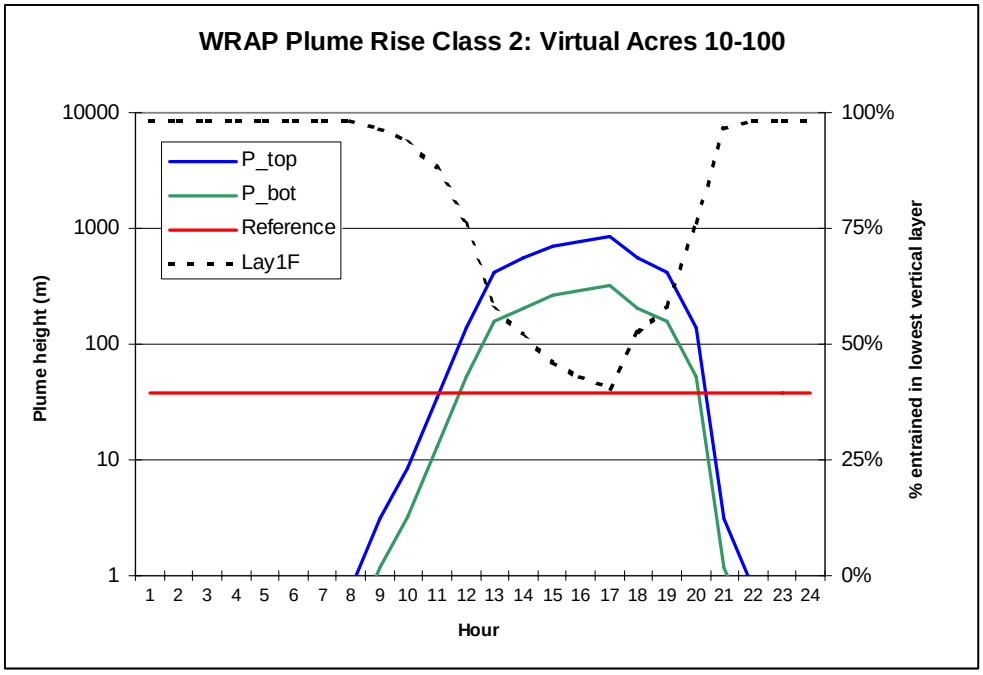


Figure A-7: Fire Size Class 3 Plume Characteristics

This figure shows plume characteristics (Ptop, Bbot, and Lay1F) for Class 3 fires for each hour. Plume height in meters is shown on the left Y-axis (in log-scale), and Lay1F in percent entrained into the lowest vertical layer is shown on the right Y-axis. For reference, the height of the lowest vertical layer (38 m) is shown in red.

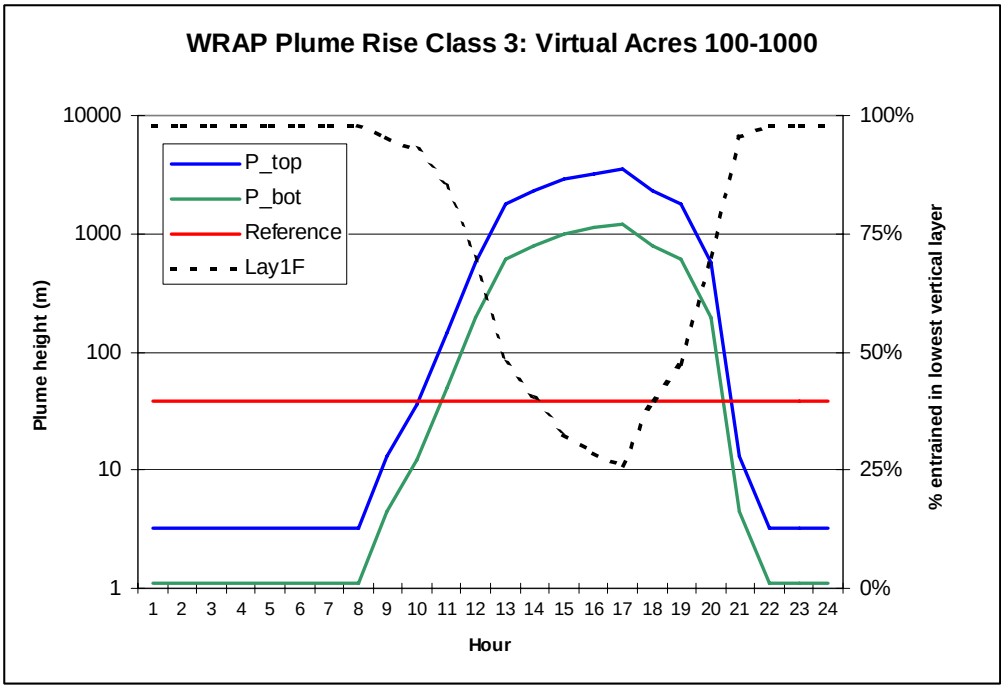


Figure A-8: Fire Size Class 4 Plume Characteristics

This figure shows plume characteristics (Ptop, Bbot, and Lay1F) for Class 4 fires for each hour. Plume height in meters is shown on the left Y-axis (in log-scale), and Lay1F in percent entrained into the lowest vertical layer is shown on the right Y-axis. For reference, the height of the lowest vertical layer (38 m) is shown in red.

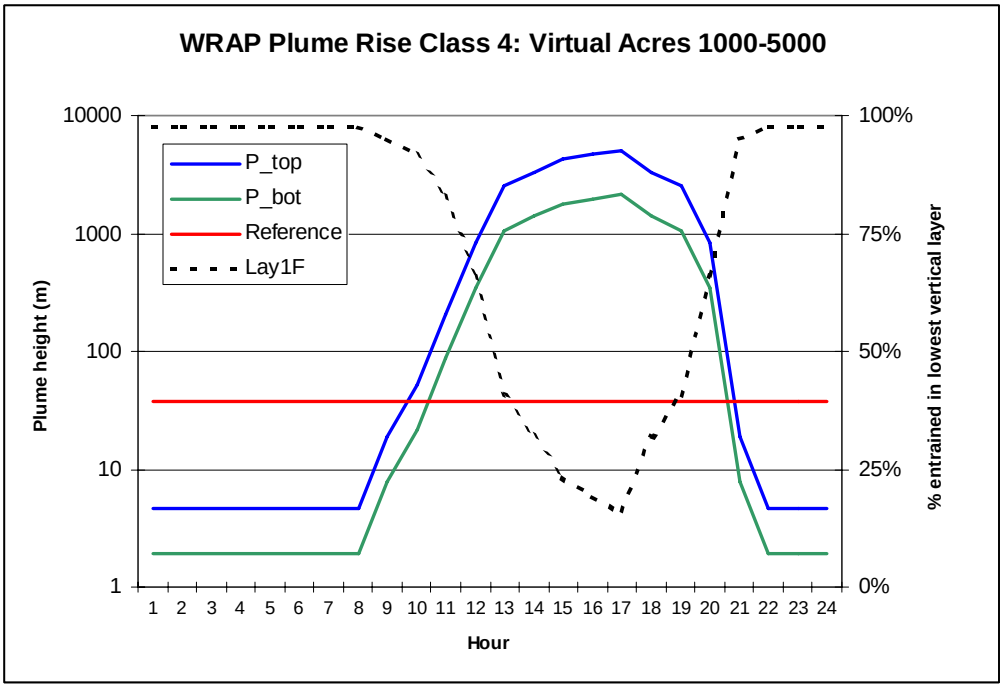
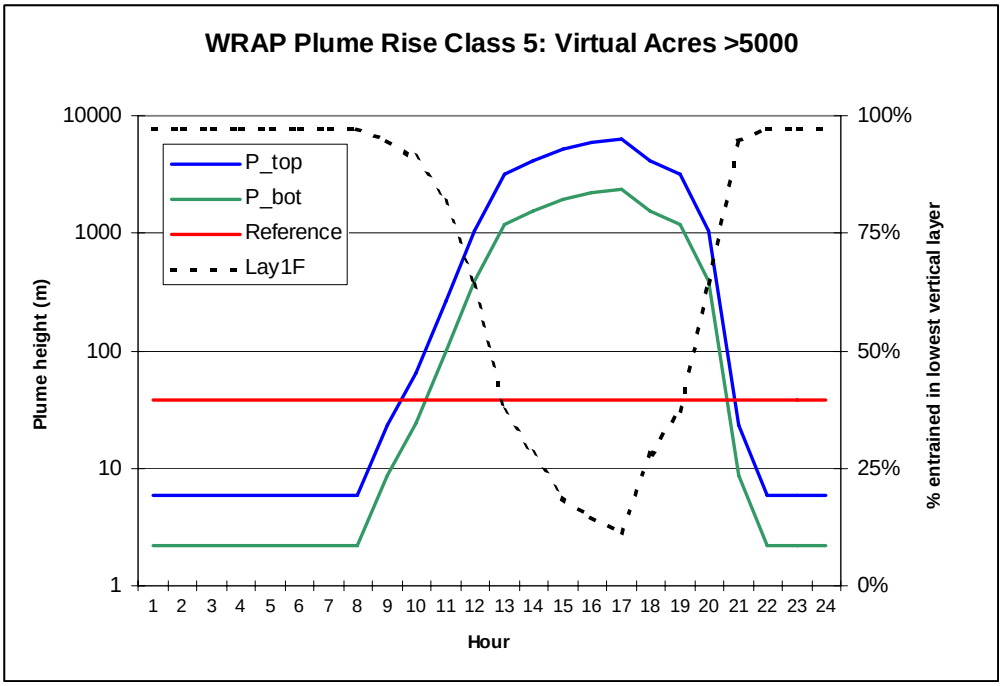


Figure A-9: Fire Size Class 5 Plume Characteristics

This figure shows plume characteristics (Ptop, Bbot, and Lay1F) for Class 5 fires for each hour. Plume height in meters is shown on the left Y-axis (in log-scale), and Lay1F in percent entrained into the lowest vertical layer is shown on the right Y-axis. For reference, the height of the lowest vertical layer (38 m) is shown in red.



A.5 Natural and Anthropogenic Assignments (For All Fire Sources)

Each wildfire, wildland fire use event, prescribed burn, agricultural burn, and non-federal rangeland burn in the baseline and projection emission inventories for fire was flagged as "natural" (NAT) or "anthropogenic" (ANTH). There are two principal reason for categorizing fire events as natural or anthropogenic:

1. To allow the results of the WRAP's regional dispersion modeling to be used to distinguish "natural background" conditions from man-made impacts.
2. To identify anthropogenic fire events in the emission inventories for which the emission reduction effects of applying Emission Reduction Techniques can be estimated.

It is important to note that the results of implementing the NAT/ANTH categorization method in the Phase II (historical 2002), Phase III (baseline) and Phase IV (projection) inventories do not necessarily reflect *actual* emissions that are, in fact, natural or anthropogenic. While the NAT/ANTH categorization criteria are based on sound logic and available information

pertaining to fuel levels and conditions, the application of these criteria to historical or nominal events only produces a representative breakdown of fire emissions into natural and anthropogenic categories. State and Tribal Smoke Management Programs that actively track fires, make burn-no-burn decision, require the application of Emission Reduction Techniques to burns, and who categorize burns as NAT/ANTH at the time of the burn will be able to generate actual inventories of natural and anthropogenic emissions from fire.

NAT/ANTH categorization was done using the following approaches, based on the WRAP Fire Emissions Joint Forum's *2001 WRAP Policy for Categorizing Fire Emissions* and *Guidance for Classifying Natural Versus Anthropogenic Fire Emissions*.[6] (Posted at the "Fire Categorization" heading at http://www.wrapair.org/forums/fejf/docs.html). The FEJF database for fire was amended with a field to flag each fire event as natural or anthropogenic. Also, the Source Classification Code (SCC) assignment performed in the database was refined to assign custom SCCs, which accommodate specific fire types discussed in this document. Each SCC present in the emission inventory identifies each event as either natural or anthropogenic. The SCC stays with the fire event in the SMOKE model-ready files delivered to the WRAP Regional Modeling Center (RMC). These SCCs are defined in Table A-6.[7]

Table A-6: SCCs and Their Fire Type and Natural/Anthropogenic Classification

SCC	Fire Type	Natural or Anthropogenic
2810001000	Wildfire	Natural
2810001001	WFU	Natural
2810001002	WFU	Anthropogenic
2801500000	Agricultural	Anthropogenic
2801500001	Agricultural (Native American)	Natural
2810015000	Prescribed	Anthropogenic
2810015001	Prescribed	Natural
2810016000	Non-Federal Rangeland	Anthropogenic
2810016001	Non-Federal Rangeland	Natural

The categorization criteria are summarized in the following bullets:

- Wildfire. All wildfire was categorized as natural (SCC 2810001000). was considered exclusively natural.

[6] Alternative approaches for categorizing natural and anthropogenic fires are discussed in Appendix B.

[7] After reviewing the WRAP's Phase II emission inventories, the US Environmental Protection Agency provided the WRAP with a proposed list of SCC's for all type and categories of fires. The WRAP has not implemented EPA's proposed SSC list and continues to assign SCCs to fire events per the Phase II method described herein. EPA's proposed list is included for reference as Appendix D to this report.

- Wildland Fire Use. All Wildland Fire Use (WFU) incidents were categorized as natural (custom SCC of 2810001001). It is helpful to note that by definition WFU is a distinct fire source from both wildfire and prescribed burning. That is, a WFU incident cannot also be considered wildfire or prescribed burning. In the event that entities within the WRAP modify the categorization of WFU incidents to include anthropogenic events, a custom SCC of 2810001002 has been reserved as a placeholder.
- Agricultural Burning. All agricultural burning in the Phase II EI was categorized as anthropogenic (standard SCC 2801500000). The *2001 WRAP Policy for Categorizing Fire Emissions* states that "vegetative burning conducted by Native Americans for traditional, religious, and ceremonial purposes" is considered natural. All other vegetative burning conducted by Native Americans is classified as "prescribed," with agricultural burning fitting the definition of prescribed fire. Some agricultural fire events in the inventories occur within the exterior boundaries of tribal lands, but the data from which the baseline and projection events are made lack an indication of "traditional, religious, or ceremonial" purpose. Therefore agricultural events falling on tribal lands were categorized as anthropogenic. A custom SCC of 2801500001 has been reserved as a placeholder should agricultural burning determined to be of a natural origin in future inventories.
- Prescribed Fire. Prescribed fire events were categorized as either natural or anthropogenic. The standard SCC of 2810015000 was used for anthropogenic prescribed burns, and a custom SCC of 2810015001 was used for natural burns. Because the raw activity data for prescribed fire do not include a natural or anthropogenic identifier, nor do the raw data contain burning objective information (e.g., "maintenance" or "restoration"), the Emissions Task Team (ETT) of the FEJF elected to base the categorization of prescribed fire as natural or anthropogenic on the National Fire Danger Rating System (NFDRS) fuel model for each incident (Table A-7). For example, heavy fuel loads or "restoration" burns were identified as anthropogenic, while lighter fuel loads or "maintenance" burns were identified as natural.

  An NFDRS fuel model exists for each prescribed burn in the inventories. Each incident has only one NFDRS assignment based on: 1) the observed fuel model reported in the activity database (preferred); or 2) based on NFDRS assignment by overlaying the fire location on the national NFDRS fuel model map using GIS (see the WRAP 1996 Fire Emission Inventory documentation). The NFDRS categorizations as natural or anthropogenic were based on examining the text descriptions of the NFDRS fuel models. If fuel model descriptions indicated a buildup of "above normal" fuel loadings (for example, the short-needle conifer model G), then the NFDRS fuel model was categorized as anthropogenic. If the fuel model descriptions indicated normal fuel loading levels (for example, short-need conifer model (H), then the NFDRS fuel model was categorized as

natural. Regardless of NFDRS fuel model, all piled prescribed burns were categorized as anthropogenic.

Table A-7: Prescribed Fire NFDRS Fuel Model Categorization as Natural or Anthropogenic

NFDRS Fuel Model	Categorization	Short Vegetation Description
A	Natural	Western annual grasslands
B	Anthropogenic	Tall dense older brush
C	Natural	Open pine with grass understory
D	Natural	Southeast fuel types
E	Natural	Hardwood after leaf fall
F	Natural	Mature closed Chamise with Oakbrush
G	Anthropogenic	Dense Conifer with heavy downed duff
H	Natural	Short-needled Conifer with thin litter
I	Anthropogenic	Clearcut Conifer Slash <6"
J	Anthropogenic	Clearcut heavily thinned Conifer Slash <6"
K	Anthropogenic	Light conifer slash partial cuts
L	Natural	Western perennial grasslands
N	Natural	Southeast fuel types
O	Natural	Southeast fuel types
P	Natural	Southeast fuel types
Q	Natural	Upland Alaska Black Spruce
R	Natural	Hardwoods after leafout
S	Natural	Alpine Tundra and grass
T	Natural	Sagebrush and grasslands
U	Anthropogenic	Closed Western Long-Needled Pine
Piles	*Anthropogenic*	*Piled activity fuels*

- Non-Federal Prescribed Rangeland Burning. The ETT elected to assign all non-federal rangeland burning events in the inventory as natural (custom SCC 2810016001). This decision was deemed to be consistent with the intent of the WRAP's categorization policy. The decision is also based on the facts that fuel loading assignments for non-federal rangeland burning events are assigned generally (i.e., there are no event-specific fuel loading data for nonfederal rangeland fire events in the inventory) and fuel loading is low (1.75 tons of fuel per acre). The SCC 281001600 will be reserved for anthropogenic non-federal rangeland burning in case the categorization technique changes for the future fire inventories.

The ETT also acknowledged the following:

- Non-federal rangeland burning should be regarded similarly to wildland prescribed burning in that efforts to control emissions should be implemented when and where possible.
- The FEJF's fire tracking system (to be developed) should accommodate data that indicates the stated objective(s) of non-federal rangeland burning events. The categorization technique for non-federal rangeland burning may be modified for future inventories.

APPENDIX B

Uncertainty Analysis and Exceptions for WRAP Phase IV Fire Event Projection Methodology

CONTENTS

Page

Tables

B.1 "Rounding Error" from Scalars and Activity Targets

Multiplying a baseline fire event level times its scalar produces an activity target in acres. By design, the 2018 Fire Event Projection Calc-Tool populates fire-days (with their complete acres and emissions) up to this activity target. For every jurisdiction for which the Projection Calculation Tool builds an inventory, the event-based projection emission inventory will deviate from the activity targets. This deviation can be thought of as a "rounding error" in the 2018 fire event projection.

B.2 "Rounding Error" Statistics

The "Rounding Error" deviation was assessed by-state or by-agency or by-burn type for all fire types and scenarios, although the assessment did not aim to examine each prescribed state/agency/burn type combination. The average deviation for all 124 scalars needed for the 2018 projection suites is 2.6%. There were 10 projections that had a deviation of over 10%. The projection target of these events was less than 100,000 acres; therefore, these events could be affected by a large fire in the seed data.

B.3 Assignment of Natural vs. Anthropogenic Fire Events

The National Fire Danger Rating System (NFDRS) is the method currently used by the USDA Forest Service, and many other organizations to integrate the effects of topography, fuels, risk conditions and current or predicted weather into numerical indices of fire danger on a day-to-day basis. The fire danger rating of an area gives the manager a tool to assist in the day-to-day "fire business" decisions. The NFDRS is a tool that is considered along with the manager's local knowledge of the area and consequences of the decision when arriving at the best solution to a fire business decision or problem.

Phase II fire events were categorized as Natural or Anthropogenic based on the NFDRS fuel model described above. In this method, heavy fuel loads (restoration mode, where fuel conditions deviate significantly from natural conditions) were classified as "Anthropogenic" fires, while lighter fuel loads (maintenance mode, where fuel conditions approximate natural conditions) were classified as "Natural" events. The NFDRS method has been used in previous fire emission inventories and is described in the Fire Emissions Joint Forum Meeting (September 27-29, 2005) in Missoula, MT (http://www.wrapair.org/forums/ef/meetings/050927/Ph_3-4_MissoulaMT_20050928.pdf).

As an alternative to the NFDRS method, the FEJF with the assistance of Air Sciences Inc. devised the National System of Fuel Characteristic Classification/Fire Regime Condition Class (FCCS/FRCC) method of classifying fire events as Natural or Anthropogenic. Participants at the first Phase III/IV Workshop proposed using the FCCS/FRCC method to categorize events as Natural or Anthropogenic for the WRAP fire models.

The FCCS is a comprehensive software system used to build, characterize, and classify fuel beds to accurately capture the structural complexity and geographical diversity of fuel components across landscapes and provide the ability to assess elements of human (e.g. logging slash) and natural (e.g. insect and disease) change. The FCCS could be characterized as a more resolved version of the NFDRS and a system that is more centered on characterizing vegetation conditions, in general, than on characterizing fuel conditions as they pertain to fire danger. It analyses fuel conditions and assigns each a descriptor name and a fuel loading mass.

The FRCC is an interagency, standardized tool for determining the degree of departure from reference (historical) conditions for vegetation, fuels and disturbance regimes. The FRCC examines FCCS fuel types and assigns each fuel class a certain fire danger level. The three fire regime condition classes are based on no or low (FRCC 1), moderate (FRCC 2), and high (FRCC 3) departure from the central tendency of the reference conditions. Low departure (FRCC 1) describes fire regimes and vegetation-fuel conditions considered to be within the natural range of variability.

The FEJF devised a NAT/ANTH categorization method that utilizes FCCS and FRCC. All FCCS that correspond to FRCC1 are categorized as Natural fire events. FRCC2 events represent moderate departures from reference conditions. The FRCC2 class represents conditions, which may require fire, hand or mechanical treatment to restore conditions to the natural fire regime. The FCCS that correspond to FRCC2 are not considered entirely natural or anthropogenic and fall between maintenance and restoration modes. The Natural or Anthropogenic assignment for this class is based on a review of FCCS fuel model information (fuel loading, duff depth, description, etc.). FRCC3 represents areas having high departures from reference conditions, which may need high levels of restoration to return to natural conditions. All FCCS that correspond to FRCC3 are characterized as Anthropogenic. Further information about FCCS and FRCC is available online at: http://www.fs.fed.us/pnw/fera/fccs/ and http://www.frcc.gov/ respectively.

Although the FEJF and Air Sciences had developed the FCCS/FRCC method to categorize fire events with the intention of implementing the method in the baseline inventory, Air Sciences implemented the NFDRS-based NAT/ANTH classification scheme (in a continuation of the method implemented in the Phase II inventory). The Phase III baseline inventories using the NFDRS scheme have already been used in model runs for the RMC. In order to facilitate the comparison of Phase IV to Phase III model results, Air Sciences decided, with the concurrence of the FEJF, to continue using the NFDRS method for categorizing fire events in the Phase IV inventories as Natural or Anthropogenic. (This exception applies only to prescribed broadcast burns. The NAT/ANTH categorization of other categories of fire events (wildfire, WFU, NFR, agricultural burning, and prescribed pile burns) are based on criteria other than fuel loading.)

In the interest of full documentation of this step in the processing of the Phase IV emission inventory files, Air Sciences has prepared a statistical comparison of the Natural versus Anthropogenic categorization methods using the Phase II (2002) fire emission inventory for prescribed fires. Air Sciences applied the FCCS/FRCC parameters to the Phase II (2002) fire emission inventory and compared those results to the Phase II EI using the NFDRS classification scheme to statistically review how the classification of total fire acres would change. The results are shown in Table B-1.

Table B-1: Total Acres Burned From Prescribed Burns From the Phase II (2002) Emission Inventory When Applying the NFDRS NAT/ANTH Classification Scheme and the FCCS/FRCC Scheme

	Total Acres	
Description	Natural	Anthropogenic
Phase II RX w/ NFDRS	348,000	301,000
Phase II RX w/ FCCS/FRCC	326,000	323,000
Net Change	-6.7%	+6.8%

The table above shows that when using Phase II emission inventory data as a case study, the FCCS method would categorize more total burned acres as Anthropogenic (restoration mode) as compared to the NFDRS method.

B.4 Assignment of Smoldering Values for Fire Event Records

In the baseline and baseline control case inventories, emissions for some wildfire and WFU events were underestimated because some fire events that were eligible to have smoldering records added were not correctly processed in the emissions inventory system. The missing emissions from smoldering events impacted only the baseline and baseline control case. The emissions processing error was corrected for the Phase IV 2018 fire projection inventories. As shown in Table A2 below, emissions from wildfire and WFU events in the Phase III baseline and baseline control inventories were underestimated by 19,148 tons of $PM_{2.5}$ (approximately 4 percent of the entire inventory). When comparing model runs for the baseline and projection cases, the additional emissions of $PM_{2.5}$ not present in the baseline cases should be considered.

Table B-2: Impact of Missing Emissions From Smoldering Events on Baseline total $PM_{2.5}$

Description	Wildfire	WFU
$PM_{2.5}$ Tons	19,147	1.579
Percent of fire-specific $PM_{2.5}$	4%	2%

APPENDIX C

Reviewer Comments and Corrective Actions

Table C-1: Reviewer comments with responses and corrective action taken

Page		Response	Action
2	Where can we get the "EXCEL-based spreadsheet tool to generate nominal fire events database" tool described on page 2	Addressed on page 3: "It is anticipated that the Calculation Tool will be available to states and Tribes in the spring of 2007 as a technical tool on the WRAP's web-based Technical Support System."	None
5	Spatial distribution of future fires is based on a single latitude/longitude coordinate of the original or seed fire event. It might be a better approach to distribute large fire emissions across multiple grids. Such as the Mc Nalley fire that would have burned across a minimum of 17 (36 km x 36 km) grid cells.	Addressed in text on pp. 5-6. The location (latitude and longitude) of the event was not changed (from the 2002 EI) because when the emissions input data are processed by the WRAP's Regional Modeling Center, each emissions event is associated with the 36 km by 36 km grid cell (i.e., the latitude and longitude of the event is not preserved in the results of the model runs). The Emissions Task Team of the FEJF determined to not change the latitude and longitude of the event going into the baseline inventory so that the emissions from the event would appear in the same RMC grid cell.Locations of fire events in the were based on RMC inputs. (continued in the cell below)	none
		(continued from the cell above) A 36x36 km grid cell is equivalent to 320,000 acres and therefore resolving a fire beyond a single lat/lon would not improve accuracy in the vast majority of modeling cases. In the instance addressed by the commenter, the McNally fire perimeter was 150,000 acres, with general dimensions of 48 km north-south x 28 km east-west. In the baseline EI, if the McNally fire from the 2002 EI was pulled randomly to populate the baseline EI, it's location would be represented as a lat/lon coordinate and the RMC would represent the entire event as occurring in a single 36x36km grid cell. This is an acknowledged limitation of the EI and the regional modeling. A more resolved method could potentially distribute a fire like the McNally fire into 2 (at the very most 4) grid cells	
5	What are the calculated "scalars" for CA for WF, WFU and Rx burning, and the supporting values (i.e.: baseline targets and Fed 5 2000-2004 averages)?	Provided in the Figures and supporting tables in Sections 2.1 (Wildfire), 2.2 (Prescribed Burning) , and 2.3 (Wildland Fire Use).	Added reference to figure 1 on page 5

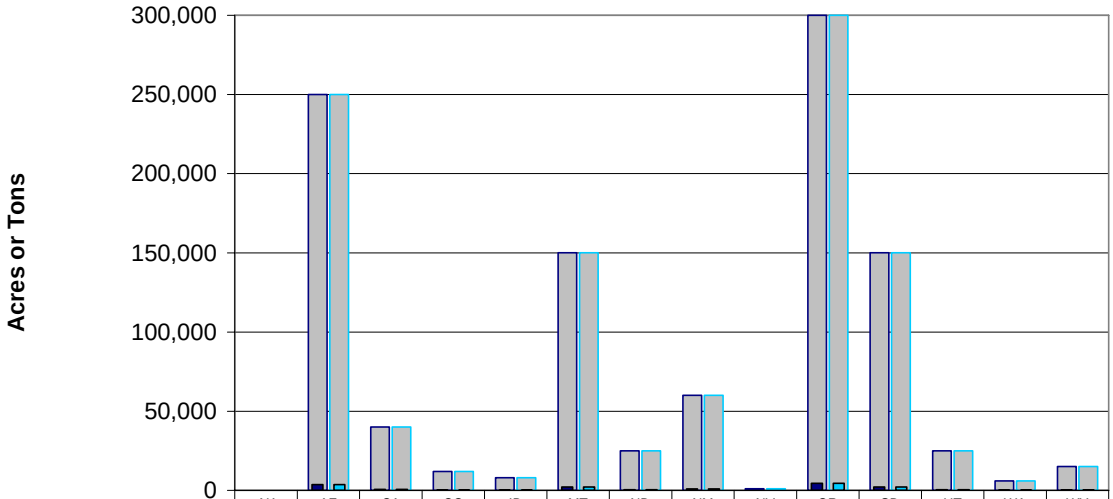
Table C-1: Reviewer comments with responses and corrective action taken			
10	Since SIT data is not generally considered the source for prescribed fire data within the fire community, I'm wondering if you should elaborate on why it was chosen. Isn't it the case that the SIT data was the best available source (most complete record) for the time period? If you were to conduct the same analysis today, for more recent years, I don't think the SIT data would be the source folks would expect you to go to.	The SIT data was the best available source (most complete record) for the time period.	Described in the report.
28	What are the IFC (interagency fuels committee) target acres for Rx burning, in relation to the Rx baseline?	Specifically addressed on page 28, paragraph 2, and shown visually in Figure 19, page 29.	none
34	. The assumption that there will be zero ag burning the San Joaquin Valley in the future in not likely. Exemptions in the San Joaquin Valley rules will allow for future burning of ag material.	The efforts to quantify the effects on agricultural emissions of regulations that will be implemented in the future did not consider the degree to which exemptions to the regulations would be utilized. States, Tribes, and many Federal Land Managers participated in the two technical workshops and several FEJF meetings at which the method to quantify the effect of regulations of future emissions from fire were presented and discussed.	footnote added
Figure 21	The assumption that WFUs will be 15 times higher as the "likely" scenario in 2018 is not reasonable for CA because of our nonattainment areas. Fire permits are required for WFUs in CA and due to poor air quality in adjacent Air Districts; it is not realistic that WFU will be allowed to burn at a rate 15 times higher then the base case in CA. Although the total sum of WF and WFUs are the same in the baseline and likely scenarios, shifting the majority of fire activity from WF category to WFUs category in 2018 is not likely for CA.	Figure 21 shows projection results on a WRAP-wide basis, and is not intended to reflect state-by-state results. Individual state projections for WFU are depicted in Figure 22. The increase in wildland fire is due to the predominant position that clilmate change and worsening fuels conditions will result in a higher incidence of wildfires. The shift to more utilization of WFU to accomplish land management objectives (as opposed to suppression of wildfire) is a predominant position among Federal Land Managers. The "rules of thumb" for each scenario used to split wildland fire into wildfire and WFU were applied uniformly across all states (i.e., the scalars were not developed on a state-by-state basis). State-by-state WFU activity targets to not reflect the role that Smoke Management Programs may play in permitting wildland fires to be managed as Wildland Fire Use events. States, Tribes, and many Federal Land Managers participated in the two technical workshops and several FEJF meetings at which the scalars to develop projections for wildfire and WFU were developed, presented, and discussed	footnote added

Table C-1: Reviewer comments with responses and corrective action taken			
Table 4	This table is confusing. Rx burns are divided into Less, Likely and More categories. However, in the text, WF and WFUs are divided into different scenarios named Baseline, Likely and More. Is the Rx Less scenario go with the WF/WFU Baseline scenario? And how does the description on P 27 line up – "base case," "climate conditions/resource limits," and "maximum application of prescribed fire" with the categories in the table? Also, the fire scenario breakdowns and descriptions in the table are difficult to follow. Recommendation: reformat table, provide clear descriptions of the scenarios beneath the table and provide consistent categorization nomenclature across the fire types in the text.	Table 4 and the quoted description on pg 27 refer to two different things. Section 3.5 of the report describes in detail the air quality planning suites.	Clarifying language added to distinguish the intro of section 3.5 with the individual projection inventories in sec's 3.1-3.4
Table A-1	Are the fuel loading or fuel consumption assumptions the same for WFU, WF and Rx burns the same? This table lists Rx fires only, though the text says the table applies to WF, Rx and WFUs? If fuel loading (consumption) assumptions are the same for WF and Rx, how do you account for WF characteristics that often burn hotter and consume canopy fuels vs. Rx burn that do not?	Table A-1 addresses WF,WFU and Rx fires. Rx fuel consumption values are shown in parentheses when they deviate from WF and WFU values; fuel consumption values for WF and WFU are assumed equivalent.	Clarified language in table to better distinguish WF/WFU and Rx values.
	It does not appear that fires were divided into size classes, like in the previous WRAP 2018 projection methodology. That seemed to be a reasonable and accepted method to project wildfire into the future. Why was this approach not used?	Projection emission inventories were prepared per the methodologies described in detail in the report. The methodologies included the inclusion of realistically sized fires across the domain of the emission inventory. A statistical review of fire events in the projection inventories would reveal that the distribution of fires per size class would be identical to the distribution of fires in the Phase III (Baseline) and Phase II (historical 2002) fire emisison inventories.	none

APPENDIX D

EPA Proposed SCC Codes

Comparison of Phase II and Baseline (2000-2004) Inventories
Non-Federal Rangeland Acres Burned and $PM_{2.5}$ Emissions



	AK	AZ	CA	CO	ID	MT	ND	NM	NV	OR	SD	UT	WA	WY
Phase II Rangeland Acres	0	250,001	40,000	12,000	8,000	150,001	25,000	60,000	1,000	300,001	150,001	25,000	6,000	15,000
Baseline Rangeland Acres	0	250,001	40,000	12,000	8,000	150,001	25,000	60,000	1,000	300,001	150,001	25,000	6,000	15,000
Phase II Rangeland PM 2.5	0	3,708	593	178	119	2,225	371	890	15	4,449	2,225	371	89	222
Baseline Rangeland PM2.5	0	3,708	593	178	119	2,225	371	890	15	4,449	2,225	371	89	222

Proposed EPA SCC Codes & Codes for any Future RPO EIs			WRAP Phase II SCC Codes		
SCC	Code Status	SCC Name (L3/L4)	SCC	Fire Type	Natural or Anthropogenic
2610000500	Clarify Name	Construction, Land Clearing Debris & Other / (Non logging) Unspecified burn method (Note: Use 2810005000 for slash and logging-related debris burning)	N/A		
2810005000	Clarify Name	Managed Burning, Slash (Logging Debris) / Unspecified burn method (Note: Use 2610000500 for non logging (e.g., construction)-related debris burning)	N/A		
2810001000	Clarify Name	Wildfire / Unspecified fire stage, class/purpose, ownership	2810001000	Wildfire	Natural
28100010F0	New	Wildfire / Flaming, Unspecified class/purpose, ownership	2810001000	Wildfire	Natural
2810010S0	New	Wildfire / Smoldering, Unspecified class/purpose, ownership	2810001000	Wildfire	Natural
2810001001	New	Wildland Fire Use / NATURAL (Maintenance), unspecified fire stage, ownership	2810001001	Wildland Fire Use (WFU)	Natural
28100010F1	New	Wildland Fire Use / Flaming, NATURAL (Maintenance), unspecified, ownership	2810001001	WFU	Natural
28100010S1	New	Wildland Fire Use / Smoldering. NATURAL (Maintenance), unspecified ownership	2810001001	WFU	Natural
2810001002	New	Wildland Fire Use / ANTHROPOGENIC (Restoration), unspecified fire stage, ownership	2810001002	WFU	Anthropogenic
28100010F2	New	Wildland Fire Use / Flaming, ANTHROPOGENIC (Restoration), unspecified ownership	2810001002	WFU	Anthropogenic
28100010S2	New	Wildland Fire Use / Smoldering, ANTHROPOGENIC (Restoration), unspecified ownership	2810001002	WFU	Anthropogenic
2810015000	Clarify Name	Prescribed Forest Burning / Unspecified ownership, class/purpose	2810015000	Prescribed	Anthropogenic
2810015001	New	Prescribed Forest Burning / NATURAL	2810015001	Prescribed	Natural
2810015002	New	Prescribed Forest Burning / ANTHROPOGENIC	2810015002	Prescribed (USE in FUTURE)	Anthropogenic
2810020000	Clarify Name	Prescribed Rangeland Burning / Unspecified ownership, class/purpose	NA		
2810016001	New	Prescribed Rangeland Burning / Non-Federal Rangeland NATURAL	2810016001	Non-Federal Rangeland (NFR)	Natural
2810016000	New	Prescribed Rangeland Burning / Non-Federal Rangeland ANTHROPOGENIC	2810016000	NFR	Anthropogenic
2801500000	Clarify Name	Agricultural Field Burning / Unspecified crop, class/purpose	2801500000	Agricultural	Anthropogenic
2801500001	New	Agricultural Field Burning / NATURAL (Native American Fire Use)	2801500001	Agricultural	Natural
2801500002	New	Agricultural Field Burning / ANTHROPOGENIC	2801500002	Agricultural (USE in FUTURE)	Anthropogenic