MEMO

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Subject **WRAP Phase III oil and gas speciation profiles**

1. Purpose

The purpose of this task is to provide details on how the Western Regional Air Partnership (WRAP) Phase III oil and gas speciation profiles were developed for different well types, processes, and basins in the Rocky Mountain States. The gas composition data were collected through operator surveys in each inventoried oil and gas basin as part of the WRAP Phase III project. These data are not published or otherwise publicly available in any form. Ramboll Environ is under a confidentiality agreement with the project sponsor and each surveyed operator to treat each operator's survey data as confidential information; we are only able to release aggregate survey data. Therefore, we have developed average gas compositions for each basin by well type and process. This document discusses the data sources, averaging methods, and the SPECIATE database formatting for these profiles.

2. Background

The Western Energy Alliance (WEA), formerly the Independent Petroleum Association of Mountain States (IPAMS), sponsored the development of a Phase III regional oil and gas emission inventory for the Inter-Mountain West jointly with the WRAP, to build on the WRAP Phase I and Phase II inventory projects. This effort focused on creating a comprehensive criteria pollutant emissions inventory for

activities associated with oil and gas field operations in the basins throughout the study region for a baseline year (2006 for most basins) as well as future projection years. Most of these basins have significant oil and gas production; other intermountain basins are not shown and were not inventoried due to much less significant oil and gas production activity. The inventory includes all point and area sources related to the oil and gas industry exploration and production operations at well sites and midstream (primarily compressors station and gas plants) sources, known through states' inventory efforts and/or disclosed by operators for the first time in the project data collection effort. Figure 1 shows oil and gas basins covered by the WRAP Phase III work with the state and county boundaries overlaid. The resulting inventories were also allocated into state-managed sources and EPA-managed sources on tribal lands.

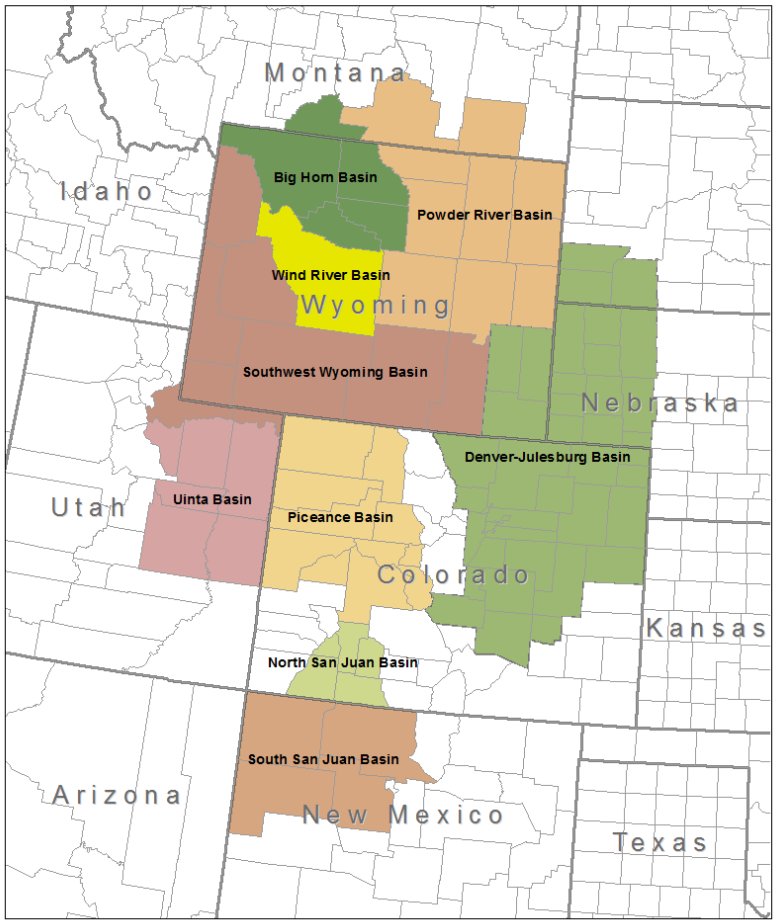

Figure 1. Overlay of the WRAP basins with state and county boundary.

3. Point and Area Sources

It should be noted that these gas compositions are intended for speciation of VOC emissions from upstream oil and gas sources located primarily at oil and gas well sites. These are described further in Section 7 below. Oil and gas sources include both area sources and point sources, and the definition of each varies according to state permitting and tracking systems (see WRAP technical memoranda: http://wrapair2.org/PhaseIII.aspx). Care should be taken in selecting which source categories should have these speciation profiles applied. In general these speciation profiles are not intended for use with permitted point sources such as compressor stations and gas processing plants. Permit data or other information for these facilities should be used to determine appropriate speciation profiles.

4. Gas Composition Data Collection

The gas composition analyses were collected through operator surveys as part of the WRAP Phase III project. The data are based on oil and gas companies taking Gas Chromatography/Mass Spectrometry (GC/MS) analyses of their produced gas or in some cases running models such as E&P TANK using input measured compositions (again derived from GC/MS tests of hydrocarbon liquids). They either provided the results of these analyses to us in surveys or provided copies of the laboratory testing results or model outputs. The gas composition data were gathered to develop 2006 base year oil and gas inventories, but they are not necessarily samples collected in 2006. The samples could be from a different year, depending on the survey data provided by each operator. Note that the gas composition is not expected to vary much in time for a given basin.

Survey respondents were instructed to provide “representative” gas compositions. It is important to note that no provision was made to assure that the collected compositions were representative, nor was any provision made to assure that the calculated basin-wide gas compositions were statistically valid. Nevertheless, these data represent actual gas compositions collected by multiple companies in each of the WRAP basins and therefore represent an improvement over other potentially available data sources. Table 1 shows the standard deviation for the gas compositions developed in each basin.

Table 1. Standard Deviation for VOC content in WRAP Phase III Gas Compositions.

Basin Name[1]	Molar VOC Content Standard Deviation[2]
Conventional Wells	
Denver-Julesburg	1.45%
Piceance	1.55%
South San Juan	3.57%
Uinta	1.84%
Powder River	4.87%
South West Wyoming	3.43%
Wind River	8.71%
CBM Wells	
South San Juan	0.16%
Uinta	0.79%
Powder River	0.10%

[1] Standard deviation is unavailable for flashing profiles and Permian Basin natural gas and Piceance Basin associated gas profiles.

[2] Standard deviation is on the basis of the entire gas composition whereas the SPECIATE profile includes only organic gases.

5. Approach to Calculate Weighted Average Profile

Generally, gas composition profiles are weighted by production ownership of the survey respondent. Each survey respondent's gas compositions were averaged to obtain a representative operator-specific gas composition. Then, the composite weighted averaged profiles were developed by taking a weighted average of all operator specific compositions using the fraction of gas production ownership for each operator as the weighting factor. Table 2 shows the number of individual profiles across all survey respondents that were used to create the weighted average composite profile. Note that in some cases we have taken a straight average instead of a production weighted average, for example the Denver-Julesburg Basin flashing profile (DJFLA), because information was not available to estimate a weighted average profile.

Table 2. Number of individual profiles averaged to develop composite profile.

P_NUMBER	Name	Number of individual profiles
SSJCB	South San Juan Basin Produced Gas Composition from CBM Wells	4
SSJCO	South San Juan Basin Produced Gas Composition from Non-CBM Gas Wells	15
WRBCO	Wind River Basin Produced Gas Composition from Non-CBM Gas Wells	7
PRBCB	Powder River Basin Produced Gas Composition from CBM Wells	8
PRBCO	Powder River Basin Produced Gas Composition from Non-CBM Wells	11
DJFLA	D-J Basin Flashing Gas Composition for Condensate Tanks	16
DJVNT	D-J Basin Produced Gas Composition from Non-CBM Gas Wells	13
UNT01	Uinta Basin Produced Gas Composition from CBM Wells	3
UNT02	Uinta Basin Produced Gas Composition from Non-CBM Wells	28
UNT03	Uinta Basin Flash Gas Composition from Oil Tanks	1
UNT04	Uinta Basin Flash Gas Composition from Condensate Tanks	5
PNC01	Piceance Basin Produced Gas Composition from Non-CBM Gas Wells	20
PNC02	Piceance Basin Produced Gas Composition from Oil Wells	2
PNC03	Piceance Basin Flash Gas Composition for Condensate Tank	5
SWFLA	SW Wyoming Basin Flash Gas Composition for Condensate Tanks	6
SWVNT	SW Wyoming Basin Produced Gas Composition from Non-CBM Wells	23
PRM01	Permian Basin Produced Gas Composition for Non-CBM Wells	4

6. Development of the SPECIATE Profiles

The composite weighted average profiles are normalized for organic gaseous species, excluding inorganic gases like CO_2, H_2S etc., to develop the profiles for the SPECIATE database and Speciation Tool. Subsequently, we assigned the SPECIATE species IDs to profile species based on name and engineering judgment. When there are unknown groups like C10+ in the profile, we have used species ID

for the lowest carbon number species in the group i.e. C10 compounds.

Finally, the WRAP Phase III basin specific oil & gas speciation profiles are converted into the SPECIATE database format. These profiles are provided in an Excel spreadsheet supplement "WRAP_P3_organic_gas_profiles_rev_10apr2015". The spreadsheet has 17 profiles related to oil & gas sector gaseous emissions. We are not so sure about the J-rating (expert judgment) system used in the SPECIATE database so we've assigned 2 to be conservative. Table 3 presents the final WRAP Phase III oil and gas speciation profiles provided in the spreadsheet supplement.

7. Application of SPECIATE Profiles

The SPECIATE profiles provided in Table 3 differ by basin and within basin by the type of gas emitted. The SPECIATE profile for each basin should only be used to speciate emissions for that basin for inventory estimation purposes; moreover, it is important that the profile appropriate to each emission type be used, especially in photochemical grid modeling[1]. Below we have summarized in general terms how we have applied different types of profiles to associated source categories.

- Produced Gas Composition from non-CBM Wells: Applied to vented source emissions from non-CBM oil and gas wells in a basin for source categories such as completions, blowdowns, pneumatic controllers, pneumatic pumps, and fugitive leaks. This type of profile should not be applied to CBM well or tank emissions.
- Produced Gas Composition from non-CBM Gas Wells: Applied to vented source emissions from non-CBM gas wells in a basin for source categories such as completions, blowdowns, pneumatic controllers, pneumatic pumps, and fugitive leaks. This type of profile should not be applied to emissions from CBM wells, oil wells, or tanks.
- Produced Gas Composition from non-CBM Oil Wells: Applied to vented source emissions from non-CBM oil wells in a basin for source categories such as completions, blowdowns, pneumatic controllers, pneumatic pumps, casinghead gas venting, and fugitive leaks. This type of profile should not be applied to emissions from CBM wells, gas wells, or tanks.

[1] Final Emissions Modeling Parameters Technical Memo 13, September 30, 2013

- Produced Gas Composition from CBM Wells: Applied to vented source emissions from CBM gas wells in a basin for source categories such as completions, blowdowns, pneumatic controllers, and fugitive leaks. This type of profile should not be applied to emissions from non-CBM wells or tanks.
- Flashing Gas Composition from Condensate Tanks: Applied to emissions in a basin from condensate tanks. This profile should not be applied to vented source emissions such as completions, blowdowns, pneumatic controllers, pneumatic pumps, and fugitive leaks.
- Flashing Gas Composition from Oil Tanks: Applied to emissions in a basin from oil tanks. This profile should not be applied to vented source emissions such as completions, blowdowns, pneumatic controllers, pneumatic pumps, and fugitive leaks.

Table 3. WRAP Phase III oil and gas speciation profiles.

Species	DJFLA	DJVNT	PNC01	PNC02	PNC03	PRBCB	PRBCO	PRM01	SSJCB	SSJCO	SWFLA	SWVNT	UNT01	UNT02	UNT03	UNT04	WRBCO
2,2,4-trimethylpentane	0.0769	0.0000	0.0191	0.0000	0.1652	0.0000	0.0362	0.0000	0.0000	0.0000	0.6124	0.0676	0.0000	0.0068	0.8122	0.0005	0.0402
2,2-dimethylbutane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0024	0.0000	0.0000	0.0000	0.0000	0.0000
2,2-dimethylpropane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000
2,3-dimethylbutane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0119	0.0000	0.0000	0.0000	0.0000	0.0000
2-methylpentane (isohexane)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0251	0.0000	0.0000	0.0000	0.0000	0.0000
3-methylpentane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0147	0.0000	0.0000	0.0000	0.0000	0.0000
Benzene	0.1298	0.0490	0.0474	0.0424	0.4057	0.0014	0.1405	0.0000	0.0000	0.0000	0.3329	0.0587	0.0000	0.0576	0.3419	0.0333	0.0563
C-6 Compounds	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.2310	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cyclohexane	0.0000	0.0000	0.0516	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cyclopentane	0.0000	0.0392	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	22.8552	16.8833	10.0674	8.8690	16.3049	0.1157	10.3600	12.5764	0.9115	11.8629	18.2114	9.0097	0.6011	9.0760	0.0597	2.8486	7.6932
Ethylbenzene	0.0040	0.0024	0.0018	0.0034	0.2090	0.0000	0.0061	0.0000	0.0000	0.0000	0.0940	0.0078	0.0000	0.0043	0.6449	0.0008	0.0070
Isobutane	7.0392	1.8841	1.1665	9.2713	11.4399	0.0010	1.2016	1.7572	0.0493	3.8658	9.9980	1.5752	0.0257	1.4615	0.0970	3.4587	1.4143
Isomers of decane	0.0061	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000
Isomers of heptane	2.1668	0.0000	0.3218	1.0534	3.0304	0.0000	1.2012	0.0000	0.0000	0.0369	2.6206	0.4316	0.0047	0.5175	37.7530	33.6035	0.3652
Isomers of hexane	1.7125	2.6394	0.5735	3.3074	4.1953	0.0000	0.5779	0.0000	0.0144	3.2904	0.9830	1.5657	0.0042	0.6721	1.0203	10.1358	0.7203
Isomers of nonane	0.0785	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0027	0.0000	0.0000	0.0000	0.0000	0.0000
Isomers of octane	0.2982	0.0000	0.2291	0.1497	1.8126	0.0000	0.8644	0.0000	0.0000	0.0300	0.3338	0.2486	0.0036	0.2467	45.3863	12.4664	0.2559
Isopentane (2-Methylbutane)	5.0434	1.5125	0.6184	7.4792	5.7758	0.0013	0.7794	1.3144	0.0129	2.1124	5.0568	1.0731	0.0070	0.8846	0.4195	6.5062	0.9121
M & p-xylene	0.0469	0.0196	0.0228	0.0102	0.1260	0.0000	0.0358	0.0000	0.0000	0.0000	0.2214	0.0248	0.0000	0.0360	4.3027	0.0108	0.0658
Methane	14.9185	62.7231	81.0324	25.9048	13.1512	99.8666	75.3393	67.5800	98.8658	69.6536	15.3327	75.7638	99.1548	78.1118	0.0083	3.1783	81.0645

Species	DJFLA	DJVNT	PNC01	PNC02	PNC03	PRBCB	PRBCO	PRM01	SSJCB	SSJCO	SWFLA	SWVNT	UNT01	UNT02	UNT03	UNT04	WRBCO
Methyl alcohol (methanol)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0144	0.0000	0.0000	0.0000
Methylcyclohexane	0.0000	0.0000	0.0768	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0093	0.0000	0.0000	0.0000	0.0000	0.0000
N-butane	12.7478	3.6096	1.0518	16.6817	13.0258	0.0010	2.3550	3.9416	0.0139	0.8045	11.8983	2.3383	0.0231	1.9870	0.3524	6.6410	1.7358
N-hexane	1.0730	0.0000	0.2103	1.1704	0.0000	0.0000	0.2156	0.0000	0.0000	0.3838	0.7420	0.3269	0.0000	0.5289	1.4810	7.8883	0.3745
N-pentane	3.8821	1.3737	0.4105	5.8446	4.3688	0.0000	0.3511	1.2563	0.0027	0.2517	3.4745	0.8814	0.0045	0.7390	0.7211	6.9647	0.6297
Propane	27.7569	9.2020	4.0144	20.1801	25.6141	0.0131	6.5280	9.3430	0.1295	7.7080	29.5966	6.4906	0.1713	5.5731	0.2754	6.2303	4.5568
Toluene	0.1643	0.0620	0.0843	0.0324	0.3750	0.0000	0.0079	0.0000	0.0000	0.0000	0.4914	0.0693	0.0000	0.0825	6.3242	0.0328	0.1084