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# **UINTA BASIN COMPOSITION STUDY REVIEW**

## **TECHNICAL REPORT**

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## ABBREVIATIONS

API	American Petroleum Institute
AST	Alliance Source Testing
ASTM	American Society for Testing and Materials
CDPHE	Colorado Department of Public Health and Environment
EOS/PSM	Equation of State Process Simulation Modeling
FGOR	Flash Gas-to-Oil Ratios
GPA	Gas Producers' Association
HRVOC	Highly Reactive Volatile Organic Compounds
IES	Innovative Environmental Solutions
ILR	Isometric Log Ratio transformation
LHC	Liquid Hydrocarbons
OGEI	Oil and Gas Emissions Inventory
psig	pounds per square inch, gauge
P <sub>BP</sub>	Bubble point pressure
P <sub>sc</sub>	Sample condition pressure
PSI	pounds per square inch
PSM	Process Simulation Modeling
RVP	Reid Vapor Pressure
T <sub>BO</sub>	Bubble point temperature
TCEQ	Texas Commission on Environmental Quality
T <sub>sc</sub>	Sample condition temperature
UDAQ	Utah Department of Air Quality
UPA	Utah Petroleum Association
USEPA	United States Environmental Protection Agency
USU	Utah State University
VOC	Volatile Organic Compounds

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## EXECUTIVE SUMMARY

The Utah Department of Air Quality (UDAQ) and Utah State University (USU) jointly published a study of mass emission rates and chemical composition of hydrocarbon emissions from oil and gas operations in the Uinta Basin ("the Study"). Specifically, the Study used Equation of State Process Simulation Modeling (EOS/PSM) coupled with statistical analyses to estimate "flash gas" volumetric and mass emission rates and speciated hydrocarbon vapor profiles. Flash gas is caused from vaporization of pressured liquids entering tanks at ambient atmospheric pressure. The Study showed that measured Volatile Organic Compound (VOC) emissions (per barrel of production) from Uinta Basin well pad operations are significantly higher than reported in the 2017 Oil and Gas Emissions Inventory (OGEI). The authors further suggested that this difference could explain discrepancies between the 2017 OGEI and previous "top down" mass flux emission estimates made in 2013.<sup>1</sup> Ramboll conducted an independent review of the Study methods, results and conclusions, from which we identified concerns in both methods and results that warrant further investigation. Ramboll examined the sampling methodologies and analytical methods and conducted independent EOS/PSM to duplicate the Study results.

While the Study followed Gas Producers' Association (GPA) standards for laboratory analysis, Ramboll identified concerns with the sampling methods and validation including:

- Sampling conducted from sight glass and the oil-water interphase in lieu of proper sampling ports;
- Abnormally high and unexplained separator sample pressures; and
- Abnormally low and unexplained storage tank temperatures.

The Study conducted statistical outlier tests to identify abnormal samples, but did not adequately consider sample proximity to bubble point to determine if the separator was functioning normally. Further, the Study ignored temperature as a critical component of the sampling conditions. Ramboll compared all 83 Study samples to representativeness criteria established by the Colorado Department of Public Health and Environment (CDPHE) and the Texas Commission on Environmental Quality (TCEQ) and eliminated 47 of those samples as unrepresentative and unsuitable for Process Simulation Analysis (PSM).

Ramboll found concerns with the Study PSM modeling methods as described or evidenced in data obtained by Ramboll from UDAQ. The Study's model did not appear to adequately characterize heavy oil (or "decanes plus") nor did it include field-measured American Petroleum Institute (API) gravity or separator gas composition to validate model performance. This undermined the predictive value of the Study's PSM model. The Study reported mass emission rates and flash gas-to-oil ratios (FGOR) based on arithmetic means or maxima by formation. However, Ramboll noted a left-skewed, non-normal distribution and a potential exponential correlation between separator pressure and flash gas emissions. This finding suggests that median is more representative of emissions than arithmetic mean.

Ramboll does not dispute the Study's reported speciation profiles overall, but finds issue with the inclusion of carbonyls. The Study acknowledged that only formaldehyde and acetaldehyde could be reliably detected but failed to provide either a plausible mechanism or independent verification for

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<sup>1</sup> Ahmadov, R., et al., 2015. Understanding high wintertime ozone pollution events in an oil- and natural gas-producing region of the western US. *Atmospheric Chemistry and Physics*, 15(1), 411-429.

their presence. Further study or verification is warranted before including carbonyls in speciation profiles.

Ramboll does not recommend that Study results be used for any policy or regulatory purpose without further analysis. The reliability of Study conclusions and of Ramboll's independent review rest on the degree to which the sampling data represent normal, steady-state operating conditions. The Study sampling and modeling include errors or omissions that should be corrected. Ramboll recommends the following to improve the Study or future efforts to characterize flash gas emissions from tanks in the Uinta Basin.

- Apply well-established industry and regulatory acceptance criteria for samples relative to bubble point to identify samples from normal separator operation;
- Implement pre-sampling protocols to ensure separators function normally;
- Sample from sampling ports only;
- Sample for stock oil API gravity and potentially separator gas composition for comparison to model results, which will provide insight into model performance; and
- Document operational information such as stages and phases of separation, heating conditions, and tank parameters.

Any investigation should take care in reporting net emission factors given the sensitivity of emissions to operational pressures, hydrocarbon compositions by formation, and facility configuration. Generalized emission factors should be used only in the absence of site or operator-specific information. In the absence of site specific information, FGOR and emission factors should be grouped by separator pressure ranges or use correlation curves to account for the pressure sensitivity.

FGOR and emission factors could be further studied by configuration and season as well as formation and liquid type. The Study data did not document the stages and phases, which could account for the variability in the emissions data. The Study could be improved by obtaining and analyzing samples from modern, multi-stage separation distinct from simple separators. Additionally, the data were limited to winter measurements only, and the operating conditions and emissions could deviate from Study results substantially in summer.

## 1. INTRODUCTION

On March 31, 2020, The UDAQ and USU published the Uinta Basin Composition Study ("the Study") in cooperation with the United States Environmental Protection Agency (USEPA) Region 8 and the Ute Indian Tribe. The Study characterized mass emission rates and chemical composition of hydrocarbon emissions from oil and gas operations in the Uinta Basin. The Uinta Basin, located in northeastern Utah, is a prominent domestic energy production region. In addition to coal production, the Wasatch, Green River and Mesa Verde formations of the Uinta Basin produce natural gas, condensate, and paraffin-rich heavy crudes known as waxy crude oil.

The Study showed that measured VOC emissions (per barrel of production) from Uinta Basin well pad operations are significantly higher than reported in the 2017 OGEI. The authors further suggested that the emission factors could be used to explain discrepancies between the "bottom up" 2017 OGEI and "top down" emission estimates derived from 2013 aerial surveys and mass calculations.<sup>2</sup> Considering the ramifications to permitting, compliance, and regulatory development, the Utah Petroleum Association (UPA) retained Ramboll to conduct an independent review of the Study methods, results and conclusions. However, Ramboll's review identified concerns in both methods and results that warrant further investigation.

### 1.1 Study Summary

The Study defined condensate as "hydrocarbon liquids from gas wells", which is separated (or condensed) from the associated "wet gas" in oil formations. Wet gas can also have very high water to oil ratios making it difficult to sample. The Study defined waxy crude as "unrefined oil that is solid at room temperature, often resembling the texture of peanut butter, due to high paraffin content". These paraffins are long-chain alkanes and are solid at typical atmospheric conditions. UDAQ also defines waxy crude by its relatively high paraffin content<sup>3</sup>.

The Study provided speciation profiles of methane, ethane, aromatics, VOCs, and Highly Reactive Volatile Organic Compounds (HRVOC) based on analysis of raw gas and pressurized liquid samples from selected sites in Uinta Basin collected between October 2018 and June 2019. The Study used EOS/PSM to predict volumetric and mass emission rates of speciated hydrocarbon vapors evolved from pressurized hydrocarbon liquids entering atmospheric storage tanks from production separators (also known as "flash gas"). The Study applied a statistical technique to the composition data to define speciation profiles of raw gas (overhead gas from separator) and flashed gas (gas evolved from the storage tank). The Study included a compendium of multiple reports from several contributing organizations as follows:

- Report A: Hydrocarbon Sampling – Alliance Source Testing (AST) described the sampling, analysis, and analytical methods of the 78 wells across the Uinta Basin.
- Report B: Hydrocarbon Sampling Data Quality – Innovative Environmental Solutions (IES) described bubble point and statistical analysis to validate sampling data.
- Report C: Measurement of Carbonyls, Speciation Profile Analysis, and High Flow Emissions Sampling and Analysis – USU reported on carbonyls found in a subset of 10 wells and grouped sample results into speciation profiles.

<sup>2</sup> Ahmadov, R., et al., 2015. Understanding high wintertime ozone pollution events in an oil- and natural gas-producing region of the western US. *Atmospheric Chemistry and Physics*, 15(1), 411-429.

<sup>3</sup> Utah Department of Environmental Quality, "Petroleum: Black and Yellow Wax", <https://deq.utah.gov/general/petroleum>

- Report D: Supplemental Speciation Profile Analysis – UDAQ provided alternate method to group composition data into speciation profiles.
- Report E: Speciation Profile Comparison – UDAQ provided the previous Uinta Basin speciation profile comparison.
- Report F: Verification Sampling – AST discussed resampling of 5 wells and physical flash composition analysis.
- Report G: Process Simulator Comparison and Analysis – UDAQ compared EOS/PSM results from various models based on composition data from Report F to the Utah 2017 OGEI.

## **1.2 Ramboll Approach and Objectives**

Ramboll conducted a peer review and critique of the Study methods and its conclusions by independently validating the data collected in the Study and attempting to reproduce the Study results. Ramboll's tasks in this review included:

- Identifying, gathering, and evaluating the raw data sets used in the EOS/PSM analysis including laboratory report and recorded sampling conditions;
- Reviewing sampling and analysis protocols and procedures for conformance to industry-accepted practices and standards such American Society for Testing and Materials (ASTM), GPA, API, or relevant environmental regulatory agencies;
- Evaluating the selection of sampling locations and analytes of concern; and
- Conducting an EOS/PSM and statistical analysis to develop FGOR, flash gas composition profiles, and mass emission rates of VOC for comparison to the Study results.

The purpose of this evaluation was to identify trends in the results, potential gaps in the Study, recommendations for further analysis, and considerations for use of the Study's findings in regulatory and policy implementation.

## 2. METHODS OF ASSESSMENT

### 2.1 General Approach and Method

Ramboll sought to independently reproduce the Study results given the same set of field data and using industry and regulatory standards and practices and other relevant studies. We conducted this evaluation in three initial phases:

- Review the Study protocols and methods for adherence to industry guidelines;
- Review and validate the Study sample data sets to verify if they were representative of normal operating conditions and samples were not compromised; and
- Simulate mass emission rates and FGOR using an alternative method to compare to the Study results.

Ramboll evaluated the mass emission rates, FGOR, and speciation profiles generated by our independent EOS/PSM using regression analysis curve fits to determine correlation between these parameters and operating conditions.

### 2.2 Sampling and Analysis

The Study selected a distribution of condensate and waxy crude wells from legacy assets across five formations. The 78 total wells sampled included 27 condensate sites and 51 waxy crude sites.

Ramboll did not have sufficient information on sample site equipment and processes to assess whether the selected sites fully represent the suite of possible operating configurations.

The Study followed a variety of GPA methodologies for collecting and analyzing the samples. The Study obtained natural gas samples using GPA 2166, which describes equipment and procedures for obtaining and preparing representative gas samples.<sup>4</sup> The Study obtained liquid hydrocarbon samples using GPA 2174, which describes equipment and procedures for obtaining and preparing representative liquid samples.<sup>5</sup> The Study obtained an extended gas analysis using GPA 2286, which describes how to determine chemical composition of hexanes and heavier components.<sup>6</sup> The Study obtained an extended liquid analysis using a modified version of GPA 2103/2186, which both describe how to determine chemical composition of hexane and heavier components for liquids.<sup>7</sup> The Study described laboratory modifications to GPA 2103/2186 consisting of adding a network of heat tubing to the gas chromatograph's plumbing to ensure that the waxy crude samples remained in a liquid phase (Report F, p. 112). Ramboll deemed these laboratory analyses appropriate as they adhered to industry guidelines.

The Study further discussed the liquid hydrocarbon sampling protocol, stating that on-site sampling followed methodology in GPA 2174. Samples were collected at a rate of 60 ml/min or less, sample collection temperature and pressure were recorded with highly calibrated gauges at the start and end of each sample collection and were monitored throughout, the samples were collected in constant pressure cylinders filled to approximately 80% volume, and the sample probe was fully purged with

<sup>4</sup> GPA, "GPA 2166: Obtaining Natural Gas Samples for Analysis by Gas Chromatography", [https://infostore.saiglobal.com/en-au/standards/GPA-2166-2005-R2017--557720\\_SAIG\\_GPA\\_GPA\\_1272271/](https://infostore.saiglobal.com/en-au/standards/GPA-2166-2005-R2017--557720_SAIG_GPA_GPA_1272271/)

<sup>5</sup> GPA, "GPA 2174: Obtaining Pressurized Liquid Hydrocarbons Samples", [https://infostore.saiglobal.com/en-us/standards/GPA-2174-2014-557722\\_SAIG\\_GPA\\_GPA\\_1272275/](https://infostore.saiglobal.com/en-us/standards/GPA-2174-2014-557722_SAIG_GPA_GPA_1272275/)

<sup>6</sup> GPA, "GPA 2286: Method for the Extended Analysis of Natural Gas and Similar Gaseous Mixtures by Temperature Programmed Gas Chromatography", <https://infostore.saiglobal.com/en-us/search/all/?searchTerm=GPA%202174>

<sup>7</sup> GPA, "GPA 2103: Tentative Method for Analysis of Natural Gas Condensate Mixtures Containing Nitrogen and Carbon Dioxide by Gas Chromatography", <https://infostore.saiglobal.com/en-us/search/all/?searchTerm=GPA%202103>

pressurized oil before introducing liquid into the cylinder. Additionally, the probe and cylinder were kept around 70°F up to the time of sampling. The Study stated that a number of on-site parameters were recorded including storage tank temperature, well names, probe pressure, probe temperature, gauge pressure, gauge temperature, ambient conditions, sample times, sampler's initials, dates, number of tanks, and any other important notes or changes (Report F, p. 112).

Similarly, the sampling protocol for natural gas samples followed methodology in GPA 2166. The Study stated that a purge and trap method was used on-site, which consisted of blowing out any material through a source valve before hooking up the gas sample container to the source, then allowing the container to slowly purge. After purging, the outlet was closed, allowing pressure to rapidly build up, and then the outlet was opened, allowing the sample container to vent to atmospheric pressure. This cycle was repeated multiple times to allow the sample container to fill. The same on-site parameters listed for liquid samples were collected and recorded for natural gas samples (Report F, p. 112).

While these methods followed appropriate sampling protocols, Ramboll did not receive all the data that the Study claims to have recorded, most notably any field sampling notes.<sup>8</sup> A lack of field observations makes it difficult to develop and validate emission factors and it introduces a challenge when attempting to replicate the Study's findings. Additionally, Table A-1 from page 16 of the Study indicates that AST did not collect stock tank oil API gravity or any field measurements of flash gas in order to validate the accuracy of their PSM. Rather, API gravity of the sales oil, flash gas composition, and FGOR values were modeled in the EOS/PSM, VMGSim, from Schlumberger. API gravity and flash gas measurements are crucial for validating models, and Ramboll recommends performing on-site or in-lab analyses to test for these, rather than modeling in a PSM.

The Study noted a potential sampling error for condensate wells employing vertical two-phase separators containing high water-to-oil ratios (Report A, p. 18). In some cases, water needed to be drained from the separators prior to obtaining a condensate sample, which introduced the possibility of light end hydrocarbon vaporization and corresponding disturbance in the gas/condensate equilibrium. The Study identified ten condensate samples with abnormally low ratios of bubble point pressure to sample condition pressure ( $P_{BP}/P_{Sc}$ ), likely due to this sampling methodology. The Study recommended rejecting these samples as they were "not reasonable representations of the liquid hydrocarbons (LHC) at equilibrium at the sample collection temperature and pressure" (Report A, p. 18). Ramboll agrees with this decision to reject these ten samples. However, Ramboll recommends that the Study provide a record of how much time elapsed after purging water from the separator to assess whether the separator was able to stabilize and re-equilibrate.

The study explained that "before condensate samples could be collected at the sight glass, large volumes of water needed to be drained from the separators to bring the condensate to the sight glass level for sample collection," which implies that AST sampled for condensate at the sight glass (Report A, p. 18). Ramboll does not recommend sampling at the sight glass because of how disruptive it can be to the system. If the sampler does not allow enough time for the fluids to settle before initiating the pull, or if the sample is being pulled in a region close to gas or water interface, the components being pulled would not accurately represent the contents of the oil being flashed from the separator to

<sup>8</sup> UPA submitted a request to UDAQ under the Government Records and Management Act (GRAMA) for records related to the Study on October 26, 2020 and November 25, 2020. These requests included all electronic data of model inputs and outputs (first request) and additional sampling data and sample condition information (second request) including: 1) sampled API gravity at the time of sampling; 2) number and location of flash stages in the process flow of each sample; 3) analysis of water phase; and 4) all sampling or field notes. UDAQ did not provide this information for either request.

oil storage tanks. It would be useful to publish the sampling protocols used by AST to ensure that mixed phase liquids were not collected.

### **2.3 Model Selection and Validation**

PSM formed the core of both the Study and our evaluation. They are used to predict the volume and mass of speciated hydrocarbon constituents evolved from pressurized liquids as they exit the final separation into storage tanks at ambient pressure. While a variety of PSMs exist, the Study used ProMax, VMGSim, and E&P Tanks, all of which predict the composition and mass flux of the liquid and gas phases at equilibrium based on thermodynamic EOS.<sup>9,10,11</sup> According to UDAQ, the Study selected the PSMs based on availability, prevalence, and usage within oil and gas operations (Report G, p. 116). Report G explained that the Study used VMGsim to model flash gas composition, FGOR, and API gravity of the sales oil, while it used ProMax and E&P Tanks to measure gas properties, storage tank emissions, and FGOR for the five verification wells. E&P Tanks is a dated model that has not been revised by API since 2018 and underperforms relative to more current EOS/PSM models.<sup>12</sup>

Ramboll chose to use BRE ProMax 5.0 for independent review, as it is a sophisticated PSM similar to VMGSim. Both process simulators use equation of state mechanisms and employ a variety of thermodynamic packages and environments.

The Study highlighted a key concern with defining heavy liquids in the simulation environment for ProMax and other PSMs (Report G, p. 126). The Study described a potential error with sample speciation when data for decanes and longer chain alkanes (C10 – C36) are amalgamated into a generic “decanes plus or C10+”, claiming that ProMax “assumes that all hydrocarbons contained in “decanes+ are actually just decanes” (Report G, p. 126). However, the study ignored that ProMax is capable of fully specifying the heavy oil. To resolve this concern, the Study deferred to VMGSim and extended liquid analysis speciation in the environment to C36+. However, the VMGSim environment characterized C36+ as C36. Given that the waxy crude samples in the Study contained upwards of 30% by weight of C36+, this failed to resolve the Study’s stated concern as it remained a poor characterization of the physical properties of density and molecular weight of a large portion of the liquid sample.

The misrepresentation of the pressurized liquid also had consequences for working and breathing emissions because it impacted the simulated liquid vapor pressure. Vapor pressure plays an important role in the equations in AP-42 Chapter 7: Liquid Storage Tanks calculations, specifically in the standing losses.<sup>13</sup> The Study focused mainly on the characterization of flashing emissions, but it also included comparisons and results for working and breathing losses in Report G. Ramboll was unable to replicate Report G findings from the Study given that the report did not include key tank information: quantity, dimensions, colors and conditions.

The Study ignored that ProMax, or any other EOS PSM, can properly specify the physical properties of the heavy oil based on the extended laboratory analysis. As such, Ramboll resolved this issue by specifying the C10+ specific physical properties, including API gravity and liquid molecular weight, in

<sup>9</sup> Bryan Research & Engineering, Inc., “ProMax Foundations,” <https://www.bre.com/PDF/Foundations-Manual-En.pdf>

<sup>10</sup> E&P Tanks, “Production Tank Emissions Model, E&P TANK Version 3.0,”  
[https://www.eptanks.com/pdf\\_files/2014\\_EPTANKv3\\_UserManual.pdf](https://www.eptanks.com/pdf_files/2014_EPTANKv3_UserManual.pdf)

<sup>11</sup> VMGSim is now Schlumberger’s “Symmetry Process Software”, [Symmetry Process Software Platform \(slb.com\)](http://www.slb.com)

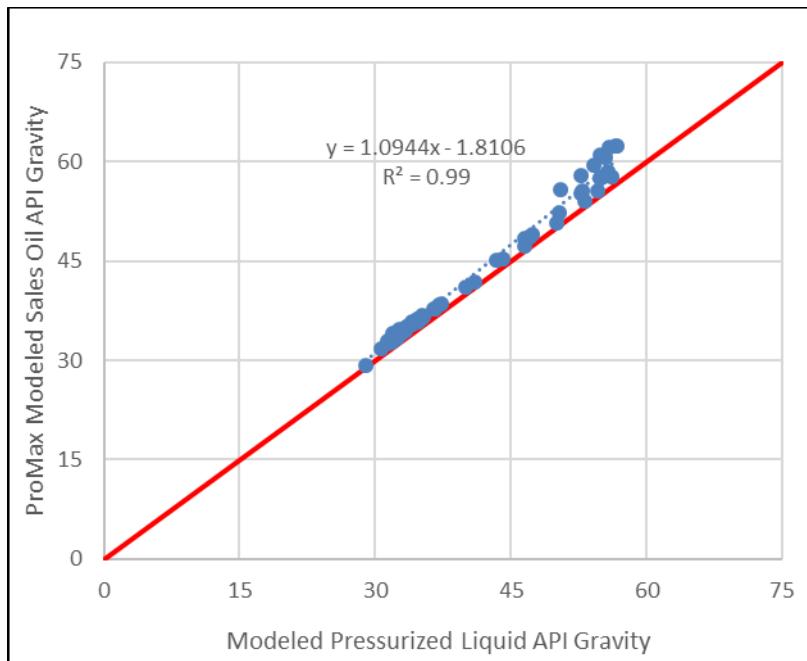
<sup>12</sup> <https://www.tceq.texas.gov/assets/public/implementation/air/am/contracts/reports/ei/20090716-ergi-UpstreamOilGasTankEIModels.pdf>

<sup>13</sup> United States Environmental Protection Agency, “AP 42 Chapter 7: Liquid Storage Tanks”, June 2020,  
<https://www3.epa.gov/ttn/chief/ap42/ch07/final/ch07s01.pdf>

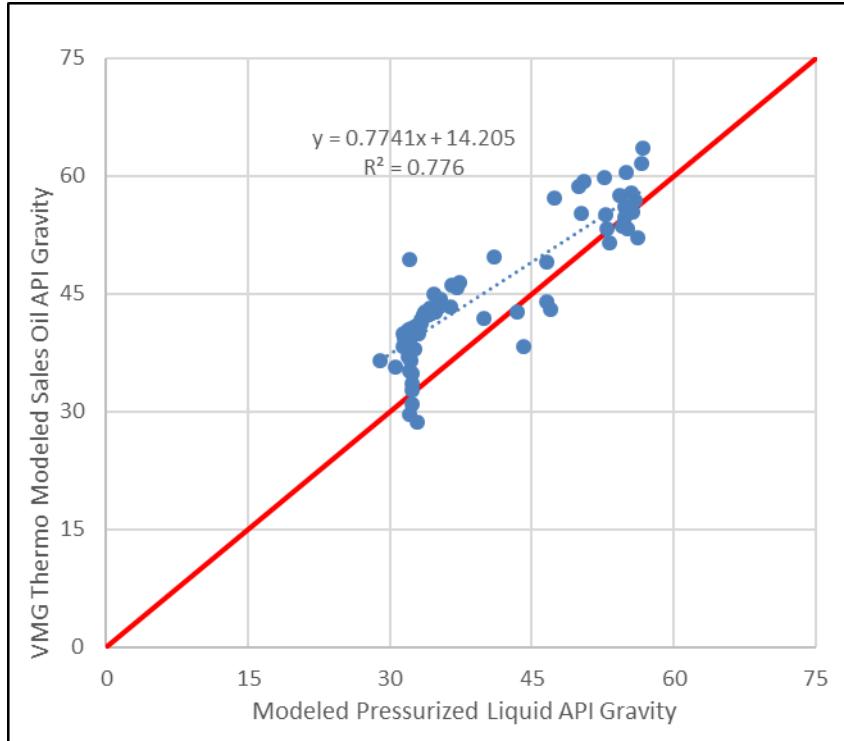
the ProMax environment and summing the individual C10 to C36 mole fractions to specify the total C10+ molar fraction. The UDAQ data provided the C10+ molecular weight and the Study stated that the molecular weight was derived from a gas chromatography analysis following a modified version of GPA 2103M/2186M (Report A, p. 21).

This approach properly accounted for the contributions of all hydrocarbons heavier than C10. Ramboll evaluated the model performance by comparing the model-predicted API Gravity of the pressurized liquid to the model-predicted API gravity of the sales oil. These measures of density should agree if the composition of the pressurized liquid as well as the sample pressures and temperatures in the separator and tank are properly defined. **Figure 2-1** depicts near perfect agreement between pressurized liquid API Gravity and sales oil API gravity, demonstrating a high confidence in the predictive value of the Ramboll model environment. On the other hand, **Figure 2-2** compares the Study's model-predicted pressurized liquid API Gravity to sales oil API gravity and shows much poorer agreement.

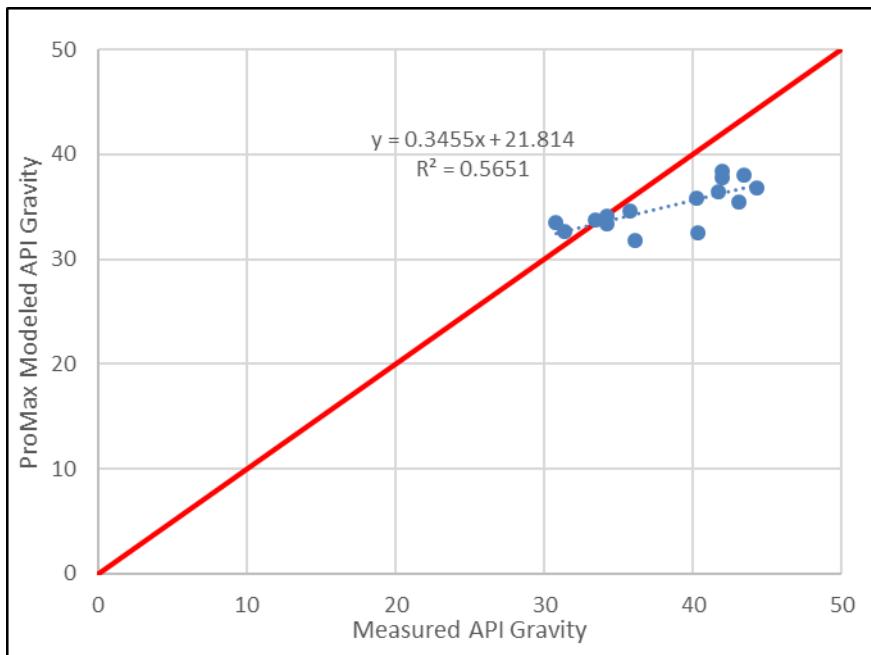
Note that both our evaluation and the Study could have benefitted from comparing the model-predicted sales oil API Gravity to a sampled value taken coincidentally with the pressurized liquid sample. However, the Study did not provide these data. The measured API Gravity at the time of sample is an empirical measurement of density and a surrogate for composition. As such, if the model-predicted sales oil API Gravity agrees with the empirical measurement, then the confidence in the model is high. Company V provided additional operator data that included measured API gravity of the sales oil. **Figure 2-3** compares Ramboll's ProMax results for sales oil API gravity against the measured values. As depicted, the ProMax simulation shows reasonable agreement, but the model-predicted API Gravity tends to be lower or more volatile. This indicates that Ramboll's model tended to slightly over-predict FGOR and emissions.



**Figure 2-1. Ramboll ProMax Modeled API Gravity vs. Modeled Pressurized Liquid API Gravity**



**Figure 2-2. VMG Thermo Modeled API Gravity vs. Modeled Pressurized Liquid API Gravity**

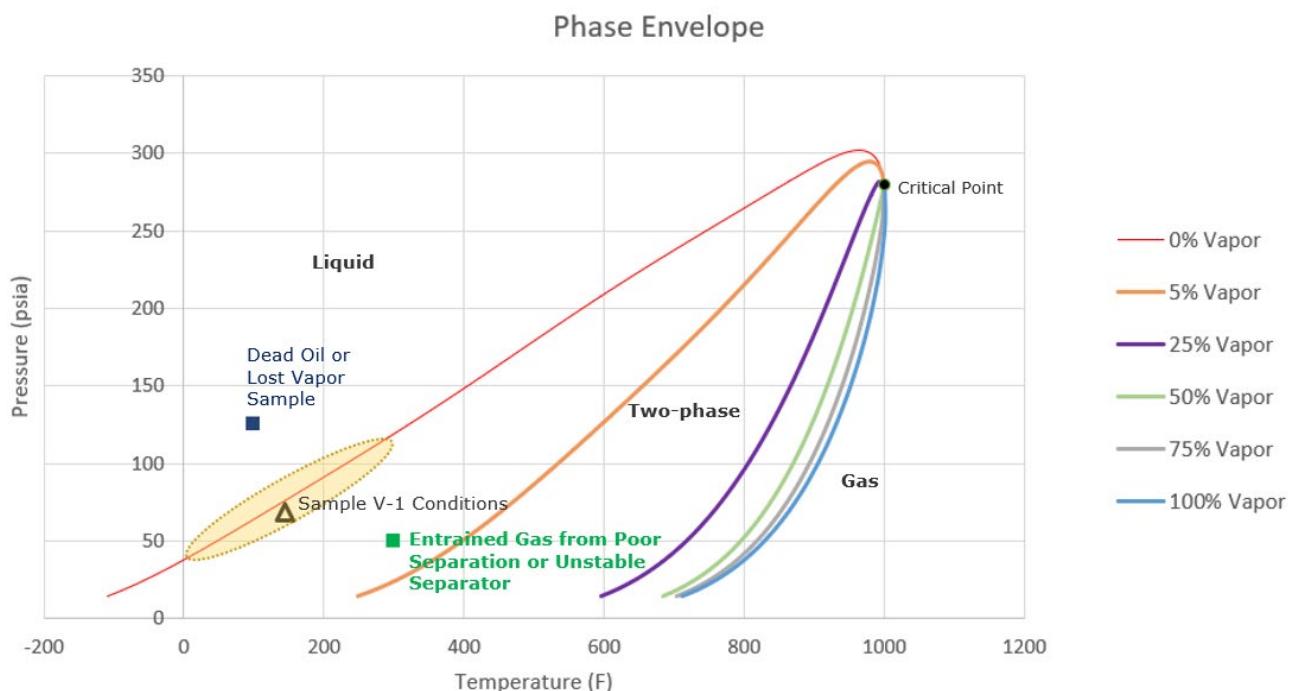


**Figure 2-3. Ramboll ProMax Modeled API Gravity vs. Measured API Gravity**

Ramboll agrees with the Study's Report G Summary that "characterizing accurate temperature of a heated tank is crucial to estimating flashing and [standing, working and breathing] VOC emission rates from that tank", and that "analyzing pressurized liquids from C1 to C36+ (extended analysis) yields lower VOC emission rates than analyzing pressurized liquids from C1 to C10+" especially for waxy crudes. Ramboll suggests continuing the characterization of pressurized liquids to C10+, including the C10+ properties calculated in the laboratory.

## 2.4 Phase Envelope and Acceptance Criteria

A phase envelope illustrates how equilibrium exists between different physical states within a fixed composition sample at various temperatures and pressures.<sup>14</sup> The location where the temperature and pressure of a sample falls on a phase envelope can indicate poor or acceptable sampling methods and abnormal or normal process operation. **Figure 2-4** below is a phase envelope for well V01 created via ProMax with sample conditions plotted.



**Figure 2-4. Phase Envelope Generated via ProMax for Sample V-1**

The red line (or bubble point curve) represents the point at which a liquid first begins to convert into a vapor. The mixture continues to volatilize until it reaches the blue line (or dew point curve), where the last droplet of liquid volatilizes, and the sample exists entirely as a gas. A sample exists in a liquid phase if it falls in the region above and to the left of the bubble point curve and in a gas phase if it falls in the region below and to the right of the dew point curve. If a sample falls into the two-phase region between the bubble and dew point curves it exists as a liquid and gaseous mixture in various proportions, as illustrated by the remaining multi-colored lines indicating vapor percentage amount.

<sup>14</sup> Saeid Mokhatab, William A. Poe and John Y. Mak, "Handbook of Natural Gas Transmission and Processing, Principles and Practices", Fourth Edition, 2019

The bubble point of a sample is a powerful tool in assessing whether a sample represents normal, steady-state operations and provides a quality check on the sampling and laboratory analysis. Once vapor-liquid equilibrium is established in a separator, hydrocarbon liquids exit the separator at the bubble point conditions of temperature and pressure.<sup>15</sup> Laboratory analysis of bubble point pressure and temperature of a sample should therefore correspond well with measured separator conditions in the field, while a lack of agreement between laboratory measurements and field measurements could indicate poor sampling methods or abnormal operation.

The Study recognized the importance of a bubble point analysis and examined  $P_{BP}/P_{SC}$  as a metric for sample validity. The Study elaborated that “ $P_{BP}/P_{SC}$  ratios close to 1.0 (e.g., about 0.7 to 1.3) are considered an indication that the [liquid hydrocarbon] samples were collected at or near gas/liquid equilibrium and that the analytical results are accurate” (Report A, p. 17). Knowing that samples should exist at or very near to the bubble point, the yellow shaded area on **Figure 2-4** represents the area where a valid sample would fall based on the proximity of the sample conditions to bubble point for both pressure and temperature. In the case of sample V-1, this would be considered a good sample as it falls within the yellow shaded area. The blue point above and left of the sample conditions, however, indicates a hypothetical sample with poor sampling or abnormal operations. A sample at this temperature and pressure is either dead oil (i.e. it has no volatile components), or the volatile component was lost during sampling, thereby underreporting emissions. Conversely, the green data point below and right of sample V-1 indicates a hypothetical sample with gas entrainment from poor separator performance or sampling error that pulled separator gas into the sample, thereby overreporting emissions.

**Table 2-1** outlines the CDPHE criteria for sample integrity verification based on  $P_{BP}/P_{SC}$ .<sup>16</sup> Laboratory professionals at FESCO Ltd., APT Laboratory Services (now Alliance Source Testing, who conducted the sampling for the Study) and Zedi established these acceptable percent difference values. Agreement between empirically determined bubble point and the field sample conditions to within these tolerances confirms that the sample was properly collected and has not been compromised before testing. The accuracy of any model based on a sample is highly sensitive to pressure, which is why the allowable range decreases as pressure increases.

**Table 2-1. CDPHE Sample Integrity Criteria**

Acceptable Percent (%) Difference	For Field Sample Pressures (psig) in the Following Range
+/- 5%	$\geq 500$ psig
+/- 7%	250 – 499 psig
+/- 10%	100 – 249 psig
+/- 15%	50 – 99 psig
+/- 20%	20 – 49 psig
+/- 30%	< 20 psig

The TCEQ Representative Analysis Criteria states that for one facility’s sample to be representative of another, the sampling conditions must be within  $\pm 20$  psi (pounds per square inch) pressure and  $\pm 20$

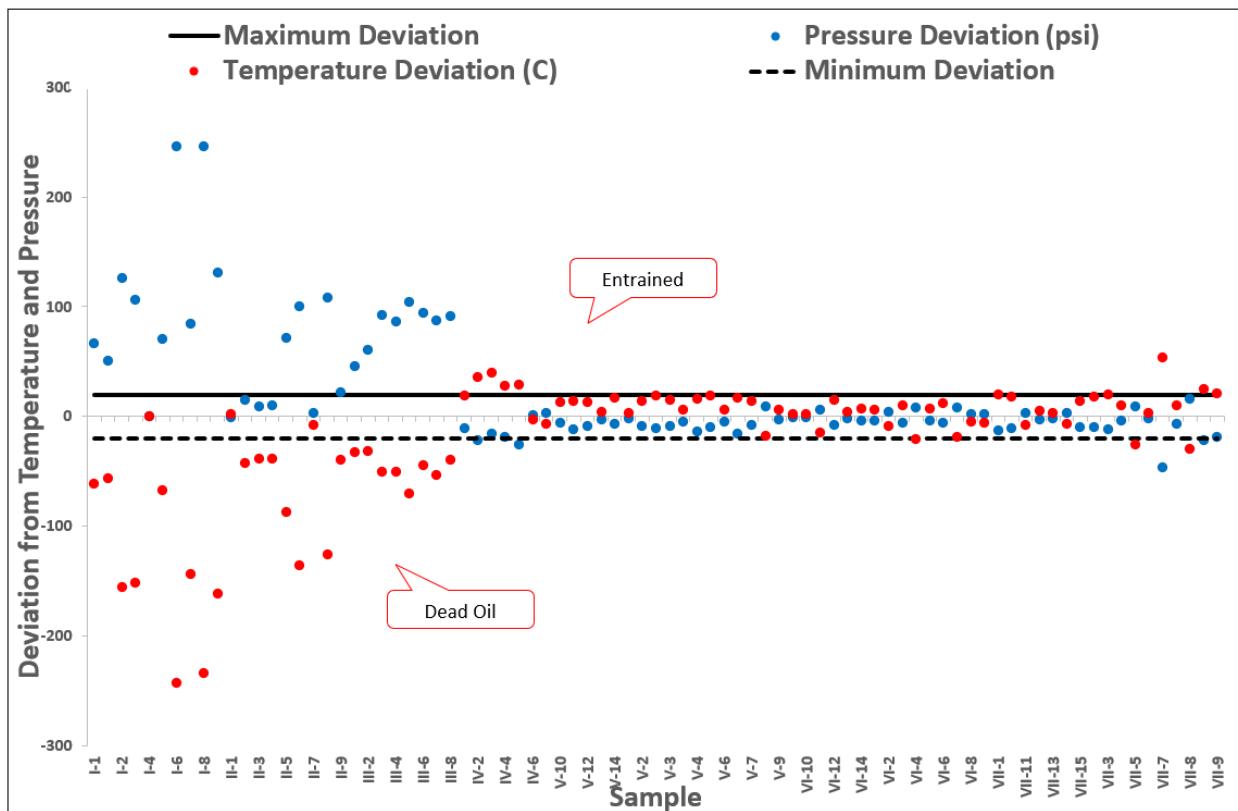
<sup>15</sup> Bryan Research & Engineering, “Air Emissions Modeling Advances for Oil and Gas Production Facilities”, <https://www.bre.com/PDF/Air-Emissions-Modeling-Advances-for-Oil-and-Gas-Production-Facilities.pdf>

<sup>16</sup> Colorado Air Pollution Control Division, Department of Public Health & Environment, “PS Memo 17-01”, <https://oitco.hylandcloud.com/Pop/docpop/docpop.aspx>

degrees Celsius of each other.<sup>17</sup> This logic can be extended further to conclude that for a sample to be considered representative of field conditions, it should be within  $\pm 20$  psi pressure and  $\pm 20$  degrees Celsius of the sample's theoretical bubble point based on its composition. As the temperature is a critical component of the phase envelope that is not addressed by CDPHE criteria, Ramboll considered the temperature criterion as well to assess if a sample represents normal, steady-state conditions.

Ramboll analyzed bubble point in ProMax to evaluate sample representativeness. Table A-1 in Appendix A provides results and evaluation of each sample including operating conditions and bubble point analysis. Information is categorized by company and whether the sample was rejected by IES in the Study or rejected by Ramboll according to either CDPHE or TCEQ criteria. Table A-1 further indicates whether the sample conditions would result in over- or under-reporting of flash gas emissions based on the deviation from the theoretical bubble point as previously discussed.

**Figure 2-5** depicts the variance from acceptance criteria for each sample and illustrates that a positive temperature difference between the sample and bubble point temperatures ( $T_{BO}$ ) indicates entrained gas (and therefore overreported emissions), while a negative temperature difference indicates dead oil (underreported emissions). In total, Ramboll eliminated 47 samples: all 47 samples failed CDPHE criteria, 36 failed TCEQ temperature benchmarks, and 25 failed TCEQ pressure criteria. All samples not passing TCEQ standards also failed CDPHE standards.



**Figure 2-5. Dual Temperature/Pressure Sample Representativeness Validation**

<sup>17</sup> Texas Commission on Environmental Quality (TCEQ), "Representative Analysis Criteria", <https://www.tceq.texas.gov/assets/public/permitting/air/NewSourceReview/oilgas/rep-analysis-criteria.pdf>

## 2.5 Abnormal Sampling Data

The Study reported the range of sample pressure and temperature for each operating company anonymously (Report B, p. 22). In the Study's Table B-1, which is reproduced below in **Figure 2-6**, the Study shows high sample collection pressures, particularly for condensate samples from Companies I, II, and III. The separator pressures reported for these companies reached as high as 357 psig, which is unusual and unlikely as this would result in a host of operational problems from gas carryover including high tank pressures that would breach thief hatch seals or activate pressure relief valves. Moreover, these high operating pressures would increase sales oil Reid Vapor Pressure and increase sales oil API gravity resulting in sales oil rejection by customers. UPA operators confirmed these operating pressures are abnormally high. Additionally, the Study data set indicated that storage tank temperatures for Company I and Company III showed bulk liquid temperatures below 27 °F, the mean freezing point for light crude oil, which is quite surprising. Company I data showed all tanks operating below freezing and Company III had one sample with tank temperature as low as 7 °F. These abnormalities have significant implications on the model results presented in the Study.

Further investigation is warranted to confirm these abnormalities.

**Table B-1. Summary of Samples Collected and Process Conditions**

Production Company	Number of Samples	Condensate (C) or Waxy Crude (W)	Sample Collection Temperature (°F)	Sample Collection Pressure (psia)	FGOR (scf/bbl)
I	10	C	49 - 86	89 - 339	10 - 49
II	9	C	60 - 116	37 - 203	5 - 33
III	8	C	64 - 72	204 - 357	77 - 154
IV	6	W	115 - 135	44 - 67	5 - 74
V	15	W	111 - 185	48 - 94	9 - 63
VI	15	W	110 - 163	44 - 64	10 - 30
VII	15	W	111 - 159	44 - 88	7 - 43

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**Figure 2-6. Excerpt of Table B-1, Report B**

## 2.6 Statistical Analysis

Report B of the Study outlined the steps taken to analyze the distribution, central tendency and variance of  $P_{BP}/P_{SC}$  for each formation as a metric for quality assurance. The Study applied the Chi-Squared ( $\chi^2$ ) test to the waxy crude and condensate data sets and determined that waxy crude samples possessed a normal distribution while condensate samples did not. The Study then applied the Grubbs and Dixon tests to suspected outliers in the waxy crude data set (as it was deemed normal) to determine if suspected outliers should be eliminated. No waxy crude samples were eliminated with these tests. As the condensate data sets were not normally distributed, the Study skipped the outlier tests for these data. Instead, the Study eliminated 10 condensate samples based on the low bias of  $P_{BP}/P_{SC}$  alone. It is important to note that the Study found that the data was not consistently normal.

The  $P_{BP}/P_{SC}$  ratio measures deviation of a sample from equilibrium and is an appropriate metric to determine sample validity (See **Section 2.3**). However, Ramboll disagrees with employing only

statistical methods for sample validation and instead recommends applying established benchmarks that assess whether a sample physically represents stabilized separator operating conditions from the difference between  $P_{BP}$  and  $P_{SC}$  and the bubble temperature and separator temperature at sampling ( $T_{BP}$  and  $T_{SC}$ , respectively). Potential problems with the  $\chi^2$  test of  $P_{BP}/P_{SC}$  are:

- 1) The test requires normally distributed data, which is difficult to assess for small data sets.
- 2)  $P_{BP}/P_{SC}$  is a ratio and therefore likely to follow a tailed distribution rather than a normal distribution.
- 3) The large deviation of a sample might be explained by operating conditions. Although anomalous, a dataset outlier can be perfectly valid under the sampling conditions. If a sample passes field and laboratory quality assurance and meets representativeness standards, it should not be disregarded.

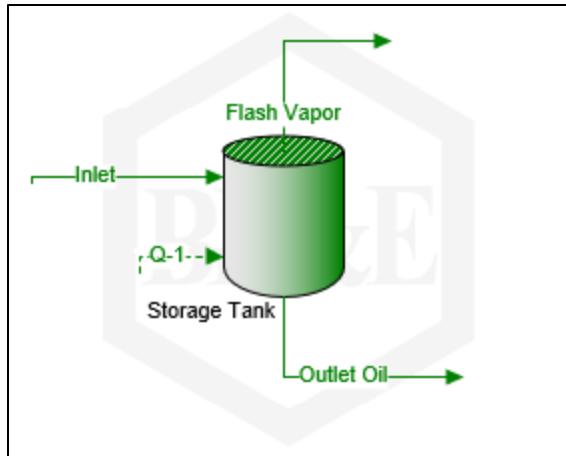
Finally, the Study did not perform such statistical analysis of the emissions modeling results, which would be more appropriate. The Study acknowledged that quantitative analysis of the FGOR results were limited due to the wide range of temperatures and pressures (Report B, p. 26). This is a critical omission given the dependence of liquid-to-vapor partition on pressure and temperature. In this report, Ramboll provides such quantitative analysis to ascertain and disclose this relationship (See Section 2.7).

## 2.7 Emissions Quantification and Results

Using the Peng-Robinson property package, Ramboll input the Study's sample temperature, sample pressure, flashing pressure, tank temperature, and sample composition (using C10+ molecular weight and specific gravity for ProMax's Oil option as discussed in Section 2.7.2) into the ProMax environment. The process model used for these scenarios is depicted in **Figure 2-7**. This procedure, identical to the Study, is appropriate for simulating flash gas assuming the samples used to specify inlet conditions were taken at the last stage of separation. Ramboll added a bubble point analysis to the inlet stream to produce the data necessary to verify sample validity. Ramboll recorded the following parameters for each scenario:

- FGOR;
- Bubble point temperature and pressure;
- Reid Vapor Pressure (RVP);
- Sales oil API gravity;
- Molecular weight and density of each stream;
- Standard liquid and vapor volumetric flows;
- Flash gas composition (mass and molar bases); and
- VOC mass emission rates. Appendix B provides model output data.

Ramboll used ProMax's scenario manager to simulate all 83 scenarios; however, Ramboll only analyzed results from samples that passed validation by IES and by the CDPHE and TCEQ criteria.



**Figure 2-7. ProMax Simulation Process Flow Diagram**

### 2.7.1 VOC Emission Factor and FGOR Development

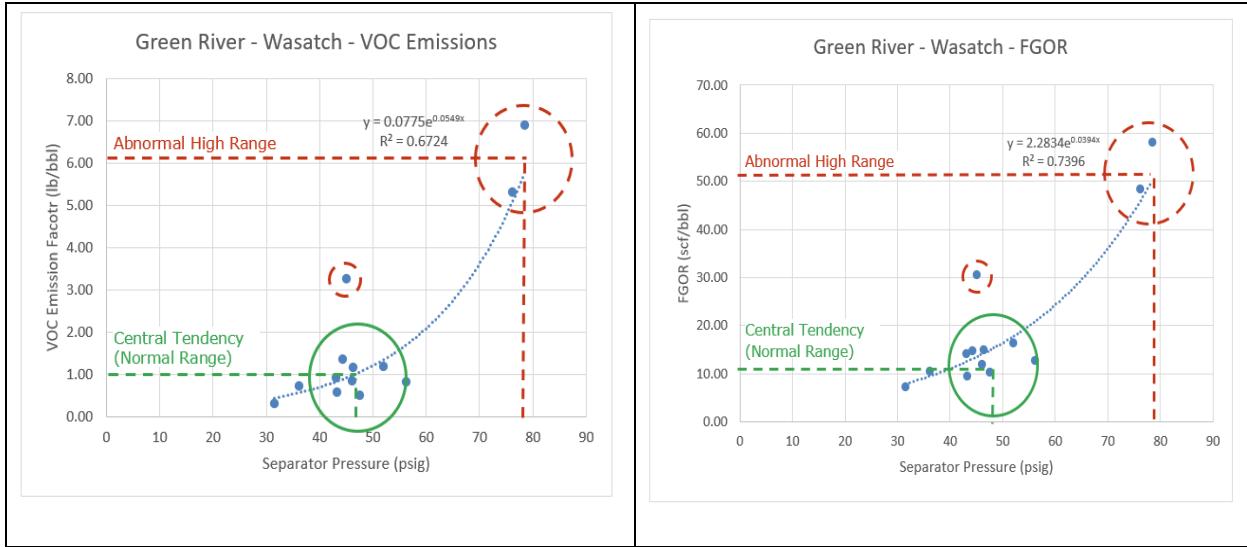
Ramboll grouped results by formation. The criteria rejected all samples in the Mesa Verde formation, so data are only presented for the four remaining formations.

Ramboll hypothesized a dependency between separator pressure and modeled FGOR and mass emission rates. To test this hypothesis, we plotted FGOR and VOC emissions as a function of sample pressure and conducted a least-squares regression analysis to test curve fit. We applied an exponential curve fit to the data, as it provided the best mathematical relationship between both FGOR and VOC emission factors and operating pressure. **Figure 2-8** to **Figure 2-11** show the relationship between sample operating pressure and both FGOR and VOC emissions for all valid samples at each formation. These figures show a potential exponential relationship resulting in higher sensitivity of FGOR and emissions to higher operating pressures. However, any firm conclusion is limited by the small sample sizes after elimination of samples failing the various sample verification criteria.

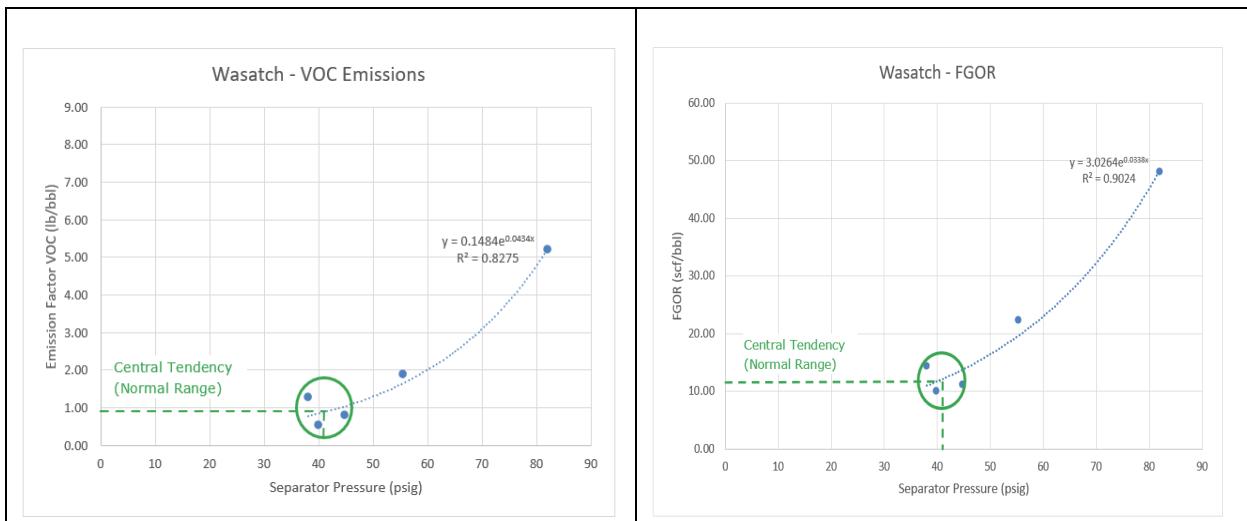
**Figure 2-12** and **Figure 2-13** present frequency distributions of the VOC emissions as a function of separator pressure. These results visually indicate a non-normal distribution and a central tendency of 0.5 to 1.5 lb/bbl for VOC emission factors, which correspond to operating pressures of 35 to 55 psig. This non-normal frequency distribution shows that the arithmetic mean does not necessarily indicate the central tendency. In fact, skewed data sets such as these are better represented by a median, whereas in this case the mean of a left-skewed data set overestimates the central tendency.<sup>18</sup>

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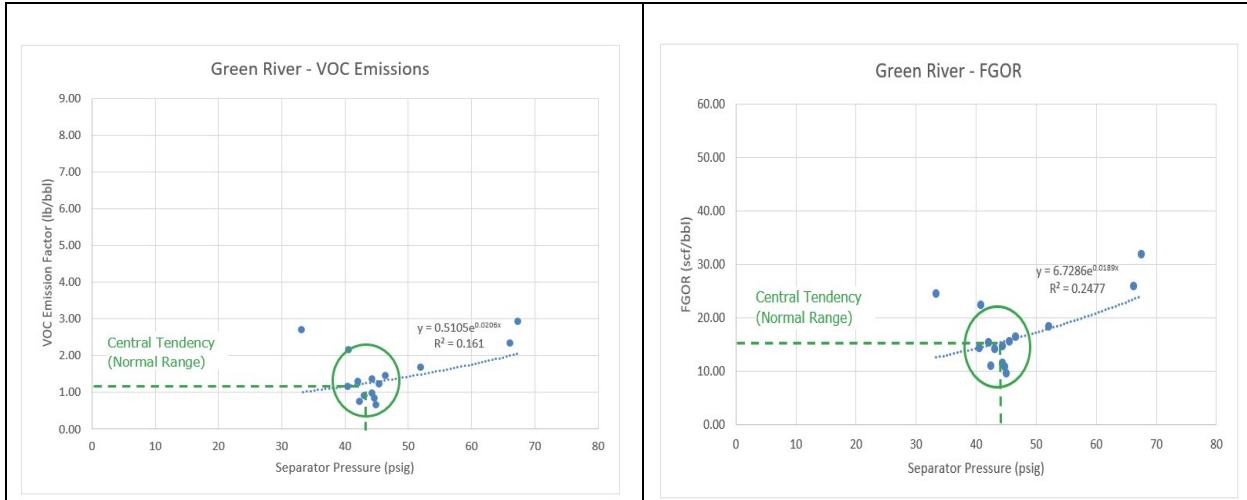
<sup>18</sup> <https://statistics.laerd.com/statistical-guides/measures-central-tendency-mean-mode-median.php#:~:text=When%20you%20have%20a%20normally,your%20measure%20of%20central%20tendency.&text=If%20dealing%20with%20a%20normal,median%20instead%20of%20the%20mean.>



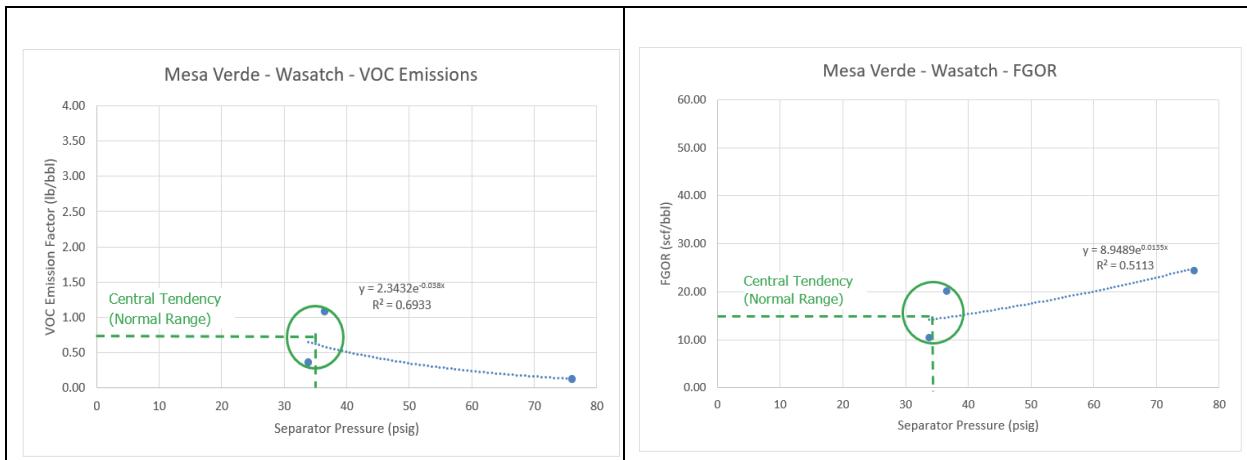
**Figure 2-8. Green River - Wasatch FGOR and VOC Emissions vs Separator Operating Pressure**



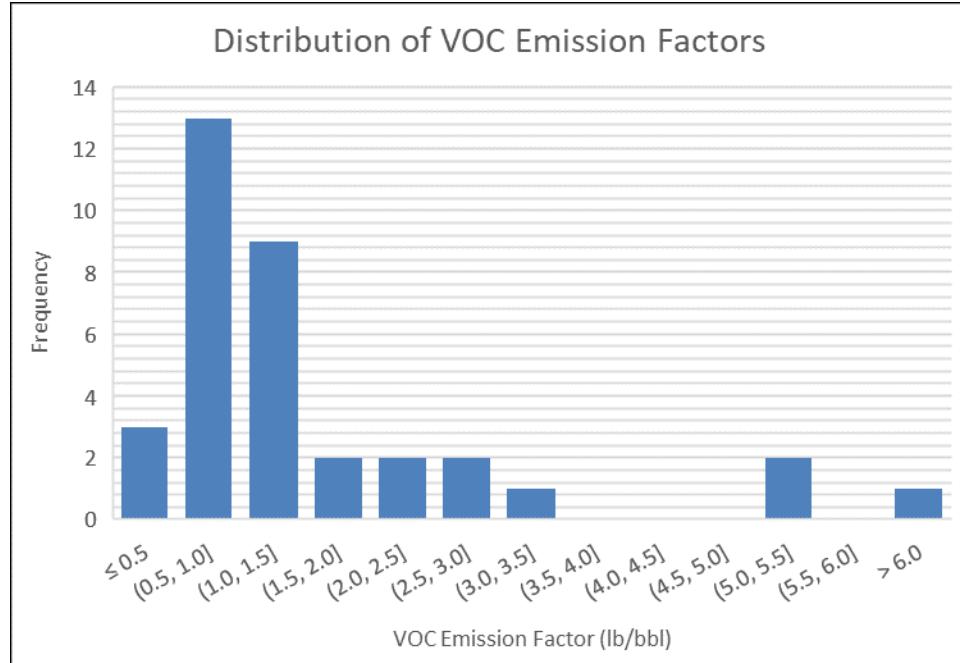
**Figure 2-9. Wasatch FGOR and VOC Emissions vs Separator Operating Pressure**



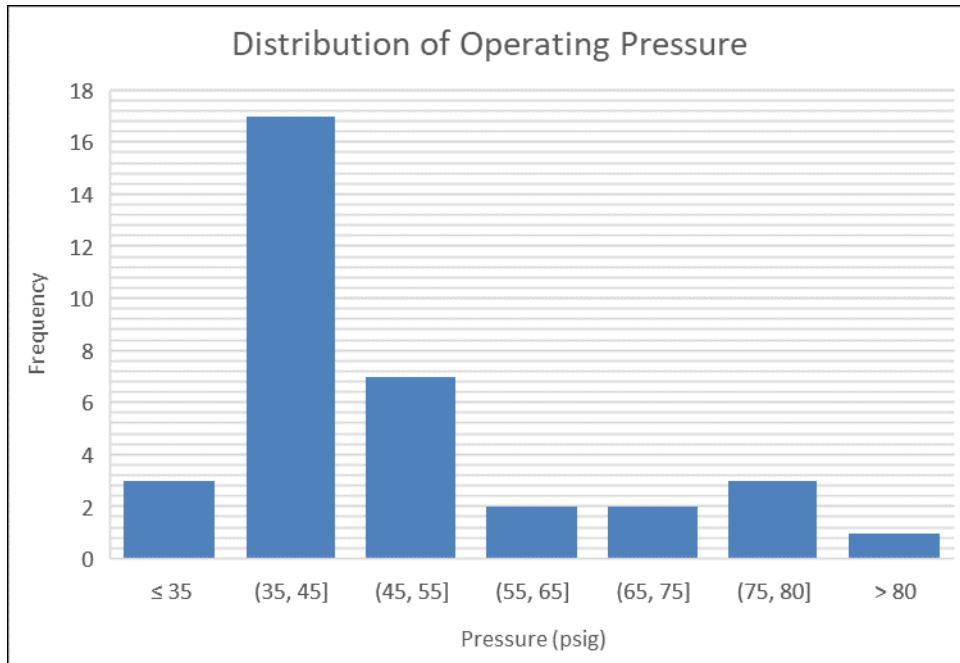
**Figure 2-10. Green River FGOR and VOC Emissions vs Separator Operating Pressure**



**Figure 2-11. Mesa Verde - Wasatch FGOR and VOC Emissions vs Separator Operating Pressure**



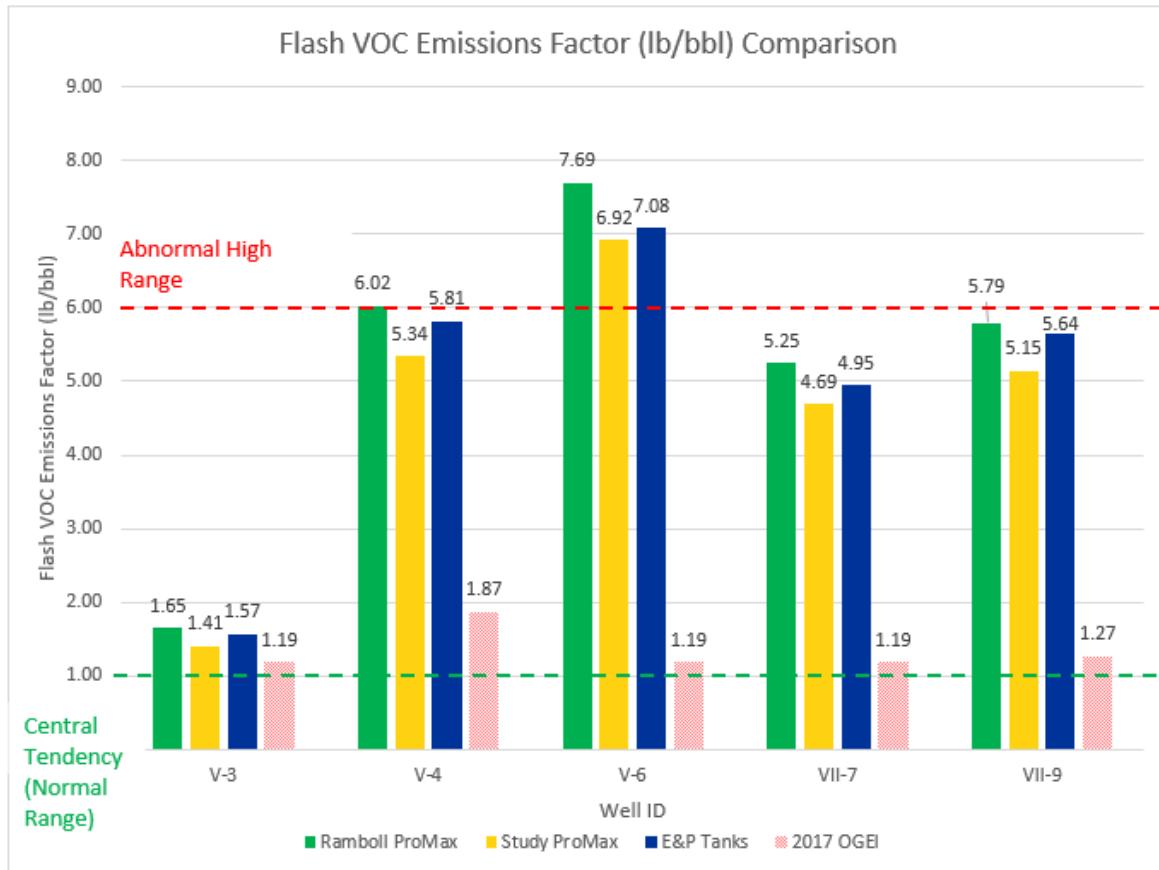
**Figure 2-12. VOC Emission Factor Distribution for All Valid Samples**



**Figure 2-13. Operating Pressure Distribution for All Valid Samples**

The Study selected five waxy crude wells for further verification (IDs: VII-9, V-6, V-3, VII-7, V-4) and presented corresponding VOC emission factors from three sources: ProMax, E&P Tanks, and 2017 OGEI. Ramboll compared independently modeled flash VOC emission rates from ProMax to the data from the Study (Figure G-13) which includes flash gas and working and breathing losses (**Figure 2-**

**14).** Ramboll added working and breathing emissions for heated tanks to its results to allow a consistent comparison to the Study.



**Figure 2-14. Comparison of Modeled and Measured VOC Emission Factors**

The Study reported a large difference between the two modeled emission factors (ProMax and E&P Tanks) and the 2017 OGEI data for four of the five wells measured. Ramboll's modeled emissions agreed with this trend, which was expected as models are inherently conservative and tend to overpredict emissions relative to measured flash samples. Wells V-4, V-6, VII-7, and VII-9 operated at high pressures, in the range of 60-79 psig, whereas well V-3 operated at a lower pressure of 56 psig. As expected from the observed correlation between pressure and flash emissions in **Figure 2-8** to **Figure 2-11**, the four wells with significantly higher modeled emission factors in **Figure 2-14** reflect higher operating pressures. Considering the frequency distribution of pressures in **Figure 2-13**, these four wells may have been operating within abnormally high ranges of pressures, whereas well V-3 is more near the normal operating range. As such, wells V-4, V-6, VII-7, and VII-9 are not representative of normal operating conditions, while well V-3 is more representative of normal operating conditions. **Figure 2-12** demonstrates that the predicted emissions in the normal operating range are around 1 lb/bbl, which is consistent with the 2017 OGEI measurements.

**Table 2-2** presents modeled separator inlet pressure, the difference in pressure and temperature between the measured sample and the modeled sample, whether Ramboll accepted the sample based on acceptance criteria, measured FGOR from the lab, modeled FGOR from the Study's VMG simulation,

and modeled FGOR from Ramboll's ProMax simulation for the five wells selected for further verification.

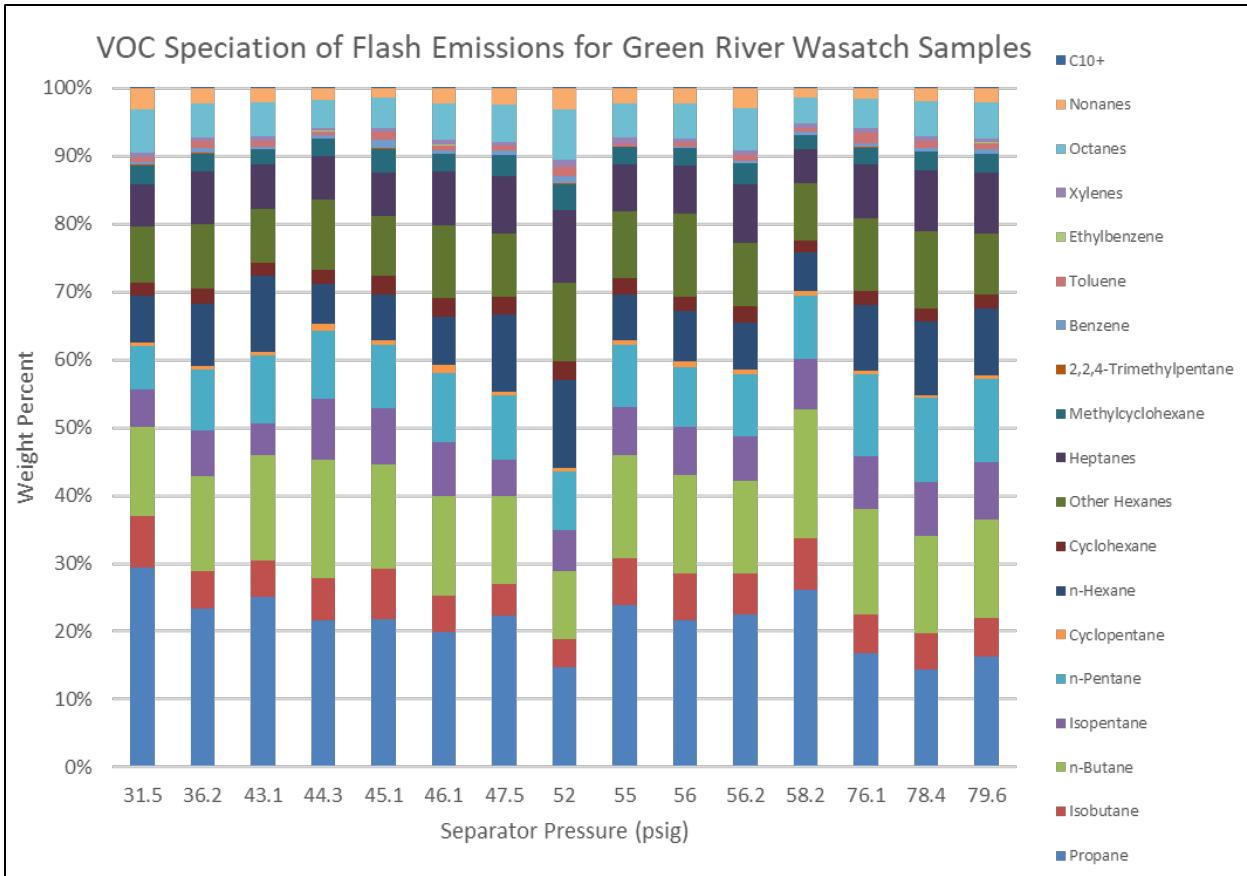
**Table 2-2. Comparison of Modeled and Measured FGOR**

Sample	Modeled Separator Inlet Pressure	$\Delta P/\Delta T$	Ramboll Accept?	Measured FGOR (scf/bbl)	VMG FGOR (scf/bbl)	ProMax FGOR (scf/bbl)
V-4a	76	-5/+6	Yes	39.7	46.3 (16.6%)	48.5 (22.1%)
V-6a	78	-5/+6	Yes	44.4	55.6 (25.2%)	58.1 (30.9%)
V-3b	56	-9/+15	No	12.8	15.7 (22.7%)	18.1 (41.4%)
VII-7a	60	-46/+53	No	27.8	32.7 (17.6%)	46.7 (68.1%)
VII-9b	79	-18/+21	No	35.8	42.8 (19.6%)	48.7 (36.1%)

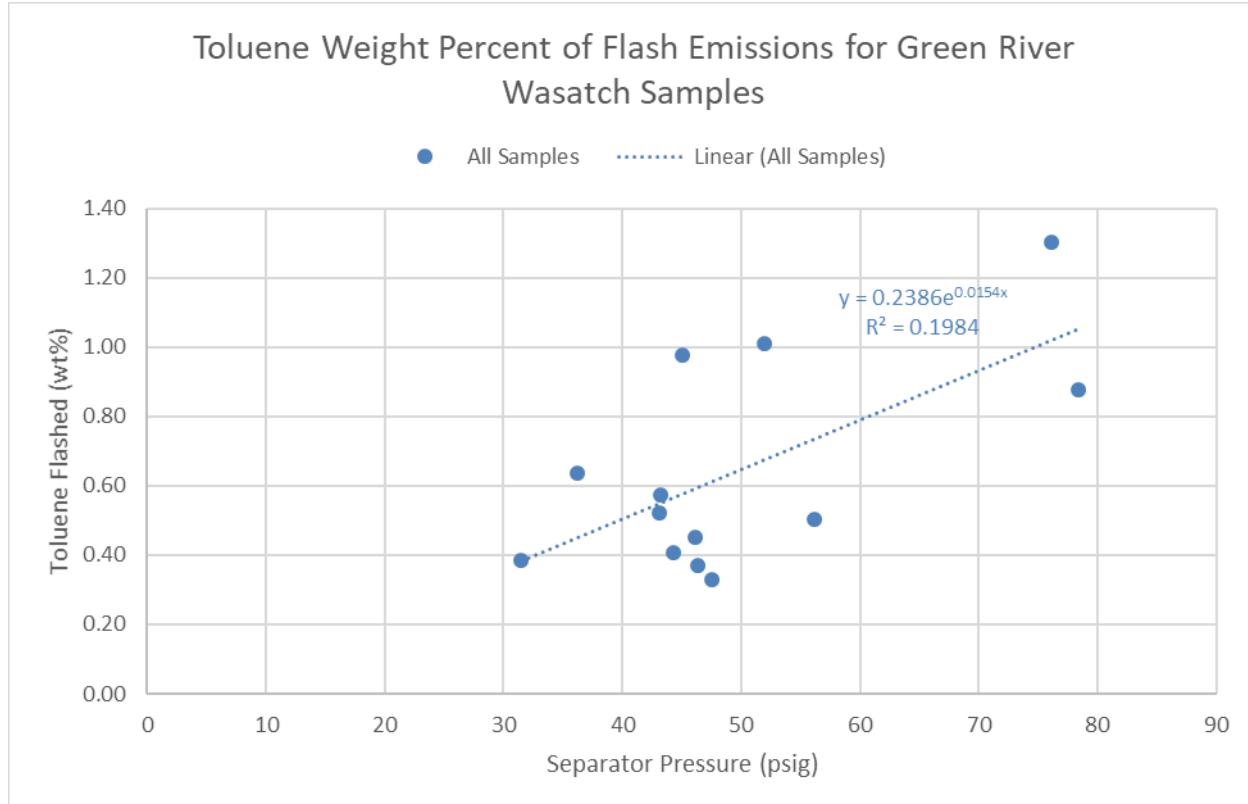
Notably, Ramboll rejected three out of the five samples based on the bubble point criteria, leaving only two valid samples to assess model validity (V-3b, VII-7a, and VII-9b). **Table 2-2** shows that both the Study's VMG modeled FGOR and Ramboll's ProMax modeled FGOR values were significantly larger than the lab measured FGOR. Both EOS models are inherently conservative and will overpredict emissions as they assume complete equilibrium and do not account for factors impacting equilibrium like residence time, solubility, and entrainment. As such, Ramboll expected to observe higher modeled FGOR values. It is difficult to draw conclusive trends with such a small data set, but for the two valid samples, V-4a and V-6a, both models show a 16%-31% overestimation of FGOR compared to the lab measured values. For the remaining rejected samples, however, the variance in Ramboll's modeled values was 2 to 3 times higher than the Study illustrating that divergence from bubble point also exacerbated the deviation of modeled flash emissions from physically measured flash emissions.

### 2.7.2 VOC Speciation of Flash Emissions

Ramboll investigated whether the relative composition of VOC species in the flash emissions (also termed VOC speciation) varied between wells producing from a specific formation. The ProMax simulations described in **Section 2.7** provided VOC speciation as an output, and **Figure 2-15** compares VOC speciation as weight percent of total VOC for flashed gas from wells in the Green River Wasatch formation for each valid sample. **Figure 2-21** orders the samples by separator pressure because, as we showed above (in **Section 2.7**), total flashed VOC emissions depend on separator pressure. The weight percentages of individual VOCs shown in **Figure 2-21** do not appear to vary systematically with separator pressure, and **Figure 2-22** confirms this for toluene, as an example. We found similar results for the other formations and Appendix B provides those results. We conclude that a single VOC speciation profile for each formation is sufficient to characterize the VOC composition of flash emissions.



**Figure 2-15. VOC Composition (Weight %) of Flash Gas Emissions Computed by ProMax in the Green River – Wasatch Formation**



**Figure 2-16. Toluene Weight Percent in Flash Gas Emissions Computed by ProMax for Wells in the Green River – Wasatch Formation**

Ramboll developed representative VOC speciation profiles by averaging several individual profiles, which is commonly performed by averaging the weight percentage of each compound (e.g., average toluene weight percent across all valid samples). This method has advantages of simplicity, making no assumptions about how data are distributed (e.g., normal or otherwise), and giving each sample equal weight in the average. The Study proposed a more complex procedure using isometric log-ratio transformation (ILR) to allow for statistical evaluation that requires unbounded ranges on the data. Ramboll believes that the simpler procedure is adequate considering the small amount of variation between samples (e.g., **Figure 2-15**) and the Study's acknowledgement that average profiles obtained using the ILR method vary only slightly from simple averages (Report D, p. 83).

### 2.7.3 Carbonyls in UDAQ VOC Speciation Profiles

The flash gas VOC speciation profiles developed in the Study (Report D) contained carbonyls (i.e., aldehydes and ketones) including formaldehyde, acetaldehyde, acetone and larger compounds. Ramboll reviewed VOC speciation profiles contained in EPA's SPECIATE database version 5.1 and found that no other crude oil/condensate profiles contain carbonyls. Because including carbonyl compounds is novel, Ramboll recommends that the Study could be improved by discussion of how carbonyls could be present in the flashed gas. Also, Ramboll notes the following statement on page 41 of Report C:

"We only consistently detected formaldehyde and acetaldehyde in duplicate samples, so we only report data from those two compounds here."

Given this statement and lack of independent verification, Ramboll recommends caution before including carbonyls in speciation profiles and, if included, only formaldehyde and acetaldehyde should be considered for inclusion in Uinta Basin flash gas speciation profiles, with sufficient explanation of their presence.

### 3. CONCLUSIONS

Ramboll identified concerns with the representativeness of samples retained in the Study, which ultimately undermine the Study conclusions. Ramboll's evaluation of the remaining valid samples unsurprisingly showed a dependence of emissions and FGOR on the separator pressure. However, the significant and unexplained disparity between the field data sets and the Study sets limited Ramboll's ability to independently replicate the Study results or generate reliable conclusions from the Study data. Ramboll provides more detailed conclusions and recommendations in the following sections.

#### 3.1 Sample Acceptance Criteria and Validation

Ramboll agrees that the proximity of bubble point pressure to sample pressure is a good indicator that the sample was near equilibrium, the sampled separator was functioning as intended, and sample integrity was maintained. However, Ramboll does not concur that the acceptable ratio is uniformly 0.7 to 1.3 (a uniform 30% variance) regardless of separator pressure. In some cases reported in the Study, this criterion considered a sample with a deviation of over 100 psi to be valid. Yet, a demonstrable exponential correlation existed between separator pressure and FGOR that yields much higher sensitivity of emissions and FGOR to sample pressure at high ranges. Accordingly, CDPHE describes a decreasing relative acceptable deviation from bubble point as pressure increases.<sup>19</sup> Additionally, the Study ignored temperature when assessing sample proximity to bubble point. Ramboll considered the TCEQ's representativeness criterion of 20 °C to assess sample representativeness. Ultimately, the CDPHE and TCEQ temperature criteria rejected 47 of 83 samples. While separators operating outside of normal operations can occur, the mostly likely cause of deviation, especially for waxy crude, would be a sampling error.

The Study assessed normality, variance, and central tendency of the data based on the bubble point to sample point ratio. While Ramboll asserts that this analysis is irrelevant to sample validity, the Study did not remove any samples on this basis and therefore this did not affect Study results or conclusions.

#### 3.2 Abnormal Sampling Conditions

Ramboll identified numerous concerns with the quality and treatment of the sample data. Most noticeably, some reported separator pressures were unusually high and storage tank temperatures were unusually low, often below freezing. These conditions do not generally occur under normal operation, and their presence here indicates either potentially faulty data or abnormal operating conditions. We restate here that further investigation is warranted to confirm these abnormalities in separator pressures, separator temperatures, and storage tank temperatures that call into question the integrity of the Study data used for modeling.

#### 3.3 FGOR and Mass Emission Factors

Ramboll's modeling results indicated flash gas VOC emission factors and FGOR are exponentially correlated and highly sensitive to separator pressure. In addition, Ramboll observed that the remaining valid sample results were non-normal and tended to group in lower operating ranges (30 to 50 psi) while higher operating ranges represented the tail. Given that higher pressure samples tended to be rejected according to CDPHE and TCEQ acceptance criteria, this indicates that higher operating pressures were abnormal as the separator was not functioning near equilibrium.

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<sup>19</sup> Colorado Air Pollution Control Division, Department of Public Health & Environment, "PS Memo 17-01", <https://oitco.hylandcloud.com/Pop/docpop/docpop.aspx>

The set of valid samples remaining at high pressure was very small and well outside central tendency. Ramboll's modeling results showed a left-skewed, non-normal distribution of FGOR relative to sample pressures. In this case, the mean overestimated the central tendency as opposed to the more representative median of around 1.0 lb/bbl. Further, we must recognize that emission models are inherently conservative and tend to overpredict emissions relative to physically flashed samples. Therefore, it is unsurprising that all modeled emissions results in the Study exceeded the physically flashed values. The Study did not have sufficient information to refute the operator emission factors provided in the 2017 OGEI, and Ramboll's independent review based on the remaining sample set supports the 2017 OGEI's emission factor of 1.0 to 1.25 lb/bbl VOC for flash gas emissions.

### **3.4 Speciation and Carbonyls**

Ramboll found no evidence of correlation among speciation profiles and operating conditions and has no cause to contest the VOC speciation profiles of most constituents reported by the Study. While Ramboll believes that simpler aggregation procedures for speciation profiles is sufficient, the ILR transformation varied only slightly from simple averages.

However, Ramboll is concerned about reliance on this study to indicate the presence of carbonyls in the VOC profiles. The authors acknowledged that only formaldehyde and acetaldehyde could be reliably detected in duplicates. Further, the Study did not provide a plausible mechanism for the presence of carbonyls or independent verification of their presence. As such, further study is warranted, we caution against reliance on this Study, and disagree with the inclusion of carbonyls in EPA SPECIATE profiles on the basis of this Study alone.

### **3.5 Recommendations**

Based on the issues enumerated by Ramboll in this report, the Study's derived VOC emission factor of 5.0 to 6.0 lb/bbl may not be representative or defensible. Ramboll therefore recommends that such values not be used for any policy or regulatory purpose without further study and resolution of the data sets. While the Study represented an initial effort to characterize the speciated mass emission rates from oil and gas operations in the Uinta Basin, Ramboll's review reveals areas of improvement or further study to improve or verify the characterization.

The highest priority should be to resolve the observed abnormalities in the sample data and to obtain more representative data. The reliability of conclusions in the Study and our independent review rest on the representativeness of the sampling data to normal, steady-state operating conditions. The remaining valid sample dataset is small and incomplete. In fact, no valid data remain for the Mesa Verde formation and the samples only include legacy assets. Ramboll recommends additional sampling with the following improvements to obtain a larger data set of valid samples.

- **Re-evaluate and define the acceptance criteria** including a comparison of sample conditions to historical operating conditions for the separator. One option is the CDPHE guidance, as it has a strong, supported basis and is commonly used within the industry.<sup>12</sup> Ramboll found the outlier analysis of the P<sub>BP</sub>/P<sub>Sc</sub> to be unnecessary, and it should be discarded.
- **It is imperative to have pre-sampling protocols** to ensure separators function normally and that sufficient operating information is obtained to describe operating conditions including the stages, phases, and status of all separators on site.
- **Sample from sampling ports only.** While sampling from the sight glass may be expedient, it can result in sampling from the interphase zone resulting in mixed oil-water samples that compromise the analysis.

- **Obtain sampling during summer and winter seasons.** The Study was limited to samples gathered during summer months. In the Uinta Basin, ambient conditions and operating conditions vary greatly between the summer and winter ozone seasons likely yielding very different emissions factors. This would be even more pronounced in waxy crude formations given its unique properties and sensitivity to ambient temperatures. The Study would be improved by dual sampling campaigns to discern seasonal profiles for the various formations.
- **Obtain sampling from formations lacking valid data** and newer facilities. The newer facilities include multiple stages of heated and unheated separation with vapor recovery that would have significantly different pressurized liquid and flash gas composition than what was included in the Study.

In addition, Ramboll found concerns with the modeling conducted and recommends the following to improve the confidence in the model:

- **The sampling process should be more thorough and include additional sampling to assess model performance** including stock oil API gravity, stages and phases of separation, heating conditions, and tank parameters. Although not essential, sampling separator gas composition for comparison to model results provides insight into model performance.
- **Obtain more field direct measurements of flash gas** as provided in Report C as they are valuable to compare with simulations and correct overpredictions.

Finally, this Study or future study should take care in reporting net emission factors. Given the sensitivity of emissions to operation pressures, hydrocarbon compositions by formation, and facility configuration, Ramboll recommends the following:

- **Generalized emission factors should be used only in the absence of site or operator-specific information.** Ramboll understands the scale of oil and gas operations and the need for inventory information; however, valid measurement or PSM under site-specific conditions will yield more accurate emissions estimates.
- Barring the use of site or operator-specific data, **FGOR and emission factors should be grouped by separator pressure ranges or correlation curve in addition to formation.** This would provide a more accurate representation of emissions from each facility. If this is impractical, then the median should be used rather than the mean.
- **FGOR and emission factors could be further studied by configuration.** The Study data did not document the stages and phases which could account for the variability in the emissions data. The Study could be improved by obtaining and analyzing samples from modern, multi-stage separation separate from simple separators.

## 4. AUTHORS AND CONTRIBUTORS

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Eric Hodek	Principal in Charge	23	MBA, Operations Management BS, Environmental Science
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Chris Emery	Senior Managing Scientist	30	MS, BS, Meteorology
John Grant	Managing Engineer	15	BS, Environmental Resources Engineering
William Hess, EIT	Consulting Engineer	4	BS, Chemical Engineering
Anna Timbers	Consulting Engineer	1	BS, Chemical Engineering
Sydney Shepherd	Consulting Engineer	1	BS, Chemical and Biomolecular Engineering

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## **APPENDIX A SAMPLE VALIDATION**

**Table A-1. Sample Validity Evaluation**

Company I Samples													
ANONID	Condensate (C) or Waxy Crude (W)	Sample Collection Temperature (°F)	Sample Collection Pressure (psig)	Flashing Temperature (°F)	Theoretical BP Temperature (°C)	Theoretical BP Pressure (psig)	P <sub>BP</sub> /P <sub>SC</sub>	Deviation from Theoretical BP Temperature (°C)	Deviation from Theoretical BP Pressure (psi)	Innovative Environmental Solutions Rejected	Ramboll Rejected (CDPHE)	Ramboll Rejected (TCEQ)	Over/Under-Reporting
I-1	C	62	189	21	77.80	122.48	0.65	61.13	-66.52		X	X	underreporting
I-2	C	61	187	24	171.90	61.10	0.33	155.78	-125.90	X	X	X	underreporting
I-3	C	58	166	24	165.83	59.83	0.36	151.38	-106.17	X	X	X	underreporting
I-4	C	49	76	26	9.70	75.80	1.00	0.25	-0.20				underreporting
I-5	C	86	207	24	97.66	136.12	0.66	67.66	-70.88		X	X	underreporting
I-6	C	49	326	20	251.70	79.46	0.24	242.26	-246.54	X	X	X	underreporting
I-7	C	76	125.1	20	167.70	40.36	0.32	143.26	-84.74	X	X	X	underreporting
I-8	C	59	274	20	248.70	28.07	0.10	233.70	-245.93	X	X	X	underreporting
I-9	C	70	196	24	182.25	64.62	0.33	161.14	-131.38	X	X	X	underreporting
I-10	C	68	146.3	24	75.90	95.33	0.65	55.90	-50.97		X	X	underreporting
Company II Samples													
ANONID	Condensate (C) or Waxy Crude (W)	Sample Collection Temperature (°F)	Sample Collection Pressure (psig)	Flashing Temperature (°F)	Theoretical BP Temperature (°C)	Theoretical BP Pressure (psig)	P <sub>BP</sub> /P <sub>SC</sub>	Deviation from Theoretical BP Temperature (°C)	Deviation from Theoretical BP Pressure (psi)	Innovative Environmental Solutions Rejected	Ramboll Rejected (CDPHE)	Ramboll Rejected (TCEQ)	Over/Under-Reporting
II-1	C	107	33.8	120	39.81	34.50	1.02	-1.86	0.70				overreporting
II-2	C	75	44.8	55	66.77	29.75	0.66	42.88	-15.05		X	X	underreporting
II-3	C	87	25	55	69.19	15.66	0.63	38.64	-9.34		X	X	underreporting
II-4	C	116	32.2	50	85.52	21.97	0.68	38.86	-10.23		X	X	underreporting
II-5	C	104	162.6	100	126.81	90.78	0.56	86.81	-71.82	X	X	X	underreporting
II-6	C	94	164.1	100	169.87	63.62	0.39	135.42	-100.48	X	X	X	underreporting
II-7	C	60	36.5	90	23.12	32.86	0.90	7.56	-3.64				underreporting
II-8	C	92	191.5	100	158.95	83.60	0.44	125.61	-107.90	X	X	X	underreporting
II-9	C	89	72	50	70.66	50.42	0.70	38.99	-21.58	X	X	X	underreporting

Company III Samples													
ANONID	Condensate (C) or Waxy Crude (W)	Sample Collection Temperature (°F)	Sample Collection Pressure (psig)	Flashing Temperature (°F)	Theoretical BP Temperature (°C)	Theoretical BP Pressure (psig)	P <sub>BP</sub> /P <sub>Sc</sub>	Deviation from Theoretical BP Temperature (°C)	Deviation from Theoretical BP Pressure (psi)	Innovative Environmental Solutions Rejected	Ramboll Rejected (CDPHE)	Ramboll Rejected (TCEQ)	Over/Under-Reporting
III-1	C	72	191.7	22	54.74	146.23	0.76	32.52	-45.47		X	X	underreporting
III-2	C	64	265.4	22	48.81	205.15	0.77	31.03	-60.25		X	X	underreporting
III-3	C	72	280.3	22	72.44	188.10	0.67	50.22	-92.20		X	X	underreporting
III-4	C	65	253.8	22	68.49	166.82	0.66	50.16	-86.98		X	X	underreporting
III-5	C	72	270.1	22	92.78	165.62	0.61	70.55	-104.48		X	X	underreporting
III-6	C	71	324	22	66.43	229.67	0.71	44.76	-94.33		X	X	underreporting
III-7	C	67	238	31	72.68	150.31	0.63	53.24	-87.69		X	X	underreporting
III-8	C	67	344.7	7	58.64	253.54	0.74	39.19	-91.16		X	X	underreporting
Company IV Samples													
ANONID	Condensate (C) or Waxy Crude (W)	Sample Collection Temperature (°F)	Sample Collection Pressure (psig)	Flashing Temperature (°F)	Theoretical BP Temperature (°C)	Theoretical BP Pressure (psig)	P <sub>BP</sub> /P <sub>Sc</sub>	Deviation from Theoretical BP Temperature (°C)	Deviation from Theoretical BP Pressure (psi)	Innovative Environmental Solutions Rejected	Ramboll Rejected (CDPHE)	Ramboll Rejected (TCEQ)	Over/Under-Reporting
IV-1	W	133	51	160	36.61	61.59	1.21	-19.51	10.59		X		overreporting
IV-2	W	135	55.6	150	21.08	77.22	1.39	-36.14	21.62		X	X	overreporting
IV-3	W	135	32	155	17.74	47.88	1.50	-39.49	15.88		X	X	overreporting
IV-4	W	125	46	155	23.17	64.41	1.40	-28.49	18.41		X	X	overreporting
IV-5	W	115	53.5	155	16.68	79.12	1.48	-29.43	25.62	X	X	X	overreporting
IV-6	W	128	47.5	155	56.16	46.25	0.97	2.82	-1.25				underreporting
Company V Samples													
ANONID	Condensate (C) or Waxy Crude (W)	Sample Collection Temperature (°F)	Sample Collection Pressure (psig)	Flashing Temperature (°F)	Theoretical BP Temperature (°C)	Theoretical BP Pressure (psig)	P <sub>BP</sub> /P <sub>Sc</sub>	Deviation from Theoretical BP Temperature (°C)	Deviation from Theoretical BP Pressure (psi)	Innovative Environmental Solutions Rejected	Ramboll Rejected (CDPHE)	Ramboll Rejected (TCEQ)	Over/Under-Reporting
V-1	W	145	56.2	172	69.85	52.83	0.94	7.08	-3.37				underreporting
V-2	W	137	53.5	168	43.87	62.47	1.17	-14.46	8.97		X		overreporting
V-3a	W	144	55	165	43.43	65.70	1.19	-18.79	10.70		X		overreporting
V-3b	W	133	56	160	40.72	64.85	1.16	-15.39	8.85		X		overreporting
V-4a	W	129	76.1	160	48.10	80.60	1.06	-5.79	4.50				overreporting
V-4b	W	133	81.7	164	40.00	95.73	1.17	-16.11	14.03		X		overreporting
V-5	W	153	52	170	48.23	61.61	1.18	-19.00	9.61		X		overreporting

V-6a	W	122	78.4	170	43.88	83.37	1.06	-6.12	4.97				overreporting
V-6b	W	111	79.6	168	27.18	95.04	1.19	-16.71	15.44		X		overreporting
V-7	W	150	55.4	166	51.66	63.20	1.14	-13.89	7.80				overreporting
V-8	W	142	56	167	79.11	46.90	0.84	18.00	-9.10		X		underreporting
V-9	W	158	36.2	160	63.74	38.66	1.07	-6.26	2.46				overreporting
V-10	W	145	39.9	165	49.29	45.44	1.14	-13.49	5.54				overreporting
V-11	W	152	82	168	52.82	93.59	1.14	-13.85	11.59				overreporting
V-12	W	152	66.2	165	53.39	74.93	1.13	-13.28	8.73				overreporting
V-13	W	126	67	166	47.90	69.78	1.04	-4.33	2.78				overreporting
V-14	W	185	43.2	170	67.62	50.01	1.16	-17.38	6.81				overreporting
V-15	W	160	38	168	67.46	39.52	1.04	-3.65	1.52				overreporting
<b>Company VI Samples</b>													
ANONID	Condensate (C) or Waxy Crude (W)	Sample Collection Temperature (°F)	Sample Collection Pressure (psig)	Flashing Temperature (°F)	Theoretical BP Temperature (°C)	Theoretical BP Pressure (psig)	P <sub>Bp</sub> /P <sub>S</sub> c	Deviation from Theoretical BP Temperature (°C)	Deviation from Theoretical BP Pressure (psi)	Innovative Environmental Solutions Rejected	Ramboll Rejected (CDPHE)	Ramboll Rejected (TCEQ)	Over/Under-Reporting
VI-1	W	156	46.1	164	67.04	46.92	1.02	-1.85	0.82				overreporting
VI-2	W	146	49.1	164	72.51	44.90	0.91	9.18	-4.20				underreporting
VI-3	W	139	45.1	160	49.53	50.81	1.13	-9.92	5.71				overreporting
VI-4	W	110	32	170	64.10	23.85	0.75	20.77	-8.15		X	X	underreporting
VI-5	W	137	40.5	160	50.83	43.96	1.09	-7.50	3.46				overreporting
VI-6	W	153	46.5	164	55.33	52.46	1.13	-11.90	5.96				overreporting
VI-7	W	152	44.4	164	84.79	36.67	0.83	18.13	-7.73				underreporting
VI-8	W	152	42.7	165	70.93	40.88	0.96	4.26	-1.82				underreporting
VI-9	W	162	45	162	77.76	42.75	0.95	5.53	-2.25				underreporting
VI-10	W	159	42.4	162	68.04	43.48	1.03	-2.52	1.08				overreporting
VI-11	W	143	44.3	164	75.88	37.81	0.85	14.21	-6.49				underreporting
VI-12	W	162	46.3	164	57.06	53.82	1.16	-15.16	7.52				overreporting
VI-13	W	156	44.8	160	64.94	46.51	1.04	-3.95	1.71				overreporting
VI-14	W	142	45.5	160	53.77	49.15	1.08	-7.34	3.65				overreporting
VI-15	W	163	52.1	164	66.59	55.34	1.06	-6.19	3.24				overreporting

Company VII Samples													
ANONID	Condensate (C) or Waxy Crude (W)	Sample Collection Temperature (°F)	Sample Collection Pressure (psig)	Flashing Temperature (°F)	Theoretical BP Temperature (°C)	Theoretical BP Pressure (psig)	P <sub>BP</sub> /P <sub>S</sub> c	Deviation from Theoretical BP Temperature (°C)	Deviation from Theoretical BP Pressure (psi)	Innovative Environmental Solutions Rejected	Ramboll Rejected (CDPHE)	Ramboll Rejected (TCEQ)	Over/Under-Reporting
VII-1	W	151	55.4	158	45.67	67.99	1.23	-20.44	12.59		X	X	overreporting
VII-2	W	125	44.1	150	33.13	54.24	1.23	-18.54	10.14		X		overreporting
VII-3	W	129	40.1	161	33.64	51.36	1.28	-20.24	11.26		X	X	overreporting
VII-4	W	136	31.5	155	47.84	35.00	1.11	-9.94	3.50				overreporting
VII-5	W	125	39.1	157	76.90	29.79	0.76	25.23	-9.31		X	X	underreporting
VII-6	W	111	40.7	140	41.09	42.20	1.04	-2.80	1.50				overreporting
VII-7a	W	140	59.5	160	6.69	106.30	1.79	-53.31	46.80		X	X	overreporting
VII-7b	W	137	67.5	158	48.25	74.66	1.11	-10.08	7.16				overreporting
VII-8	W	159	70.8	160	99.89	54.72	0.77	29.34	-16.08		X	X	underreporting
VII-9a	W	143	75.7	163	36.37	97.05	1.28	-25.30	21.35		X	X	overreporting
VII-9b	W	145	79.1	170	41.31	97.27	1.23	-21.47	18.17		X	X	overreporting
VII-10	W	134	44.6	154	38.13	55.50	1.24	-18.54	10.90		X		overreporting
VII-11	W	125	37.8	148	59.05	34.16	0.90	7.39	-3.64				underreporting
VII-12	W	113	33.3	161	39.55	35.92	1.08	-5.45	2.62				overreporting
VII-13	W	120	43.1	158	45.70	44.61	1.04	-3.19	1.51				overreporting
VII-14	W	116	42.1	158	53.29	39.02	0.93	6.63	-3.08				underreporting
VII-15	W	120	58.2	165	34.32	68.37	1.17	-14.57	10.17		X		overreporting

## **APPENDIX B RESULTS**

**Table B-1. Emissions Modeling Results**

Green River – Wasatch Formation				
ANONID	FGOR (scf/bbl)	API Gravity (degrees)	RVP (psia)	VOC Emission Factor (lb/bbl)
VII-4	7.32	32.93	1.79	0.30
V-9	10.53	34.54	2.31	0.73
VII-13	14.18	34.03	2.35	0.91
V-14	9.58	33.71	1.74	0.57
VI-11	14.83	34.07	2.73	1.36
VI-3	30.63	35.88	3.29	3.28
VI-1	11.92	33.53	2.19	0.85
VI-12	15.00	33.32	2.37	1.16
IV-6	10.31	32.94	1.79	0.50
V-5	16.35	35.80	1.95	1.19
V-1	12.78	31.84	1.85	0.82
V-4a	48.46	38.40	3.17	5.32
V-6a	58.05	38.52	2.92	6.89
Wasatch Formation				
ANONID	FGOR (scf/bbl)	API Gravity (degrees)	RVP (psia)	VOC Emission Factor (lb/bbl)
V-15	14.26	35.82	2.52	1.29
V-10	9.94	32.64	1.80	0.56
VI-13	11.00	33.65	2.21	0.81
V-7	22.30	36.35	2.46	1.90
V-11	47.99	35.19	2.91	5.21

<b>Green River Formation</b>				
<b>ANONID</b>	<b>FGOR (scf/bbl)</b>	<b>API Gravity (degrees)</b>	<b>RVP (psia)</b>	<b>VOC Emission Factor (lb/bbl)</b>
VII-12	24.52	34.09	3.31	2.68
VI-5	14.47	34.45	2.52	1.14
VII-6	22.51	34.65	3.89	2.14
VII-14	15.51	33.91	2.74	1.28
VI-10	11.03	33.60	2.16	0.74
VII-13	14.18	34.03	2.35	0.91
VI-11	14.83	34.07	2.73	1.36
VI-7	11.64	33.62	2.51	0.96
VI-13	11.00	33.65	2.21	0.81
VI-9	9.73	33.80	2.07	0.65
VI-14	15.64	33.79	2.53	1.21
VI-6	16.58	34.16	2.53	1.43
VI-15	18.48	35.05	2.66	1.67
V-12	25.92	33.50	2.64	2.32
VII-7b	31.86	35.05	3.04	2.91
<b>Mesa Verde – Wasatch Formation</b>				
<b>ANONID</b>	<b>FGOR (scf/bbl)</b>	<b>API Gravity (degrees)</b>	<b>RVP (psia)</b>	<b>VOC Emission Factor (lb/bbl)</b>
II-1	10.45	41.90	2.39	0.37
II-7	20.17	48.38	5.14	1.09
I-4	24.41	50.82	3.10	0.13

**Table B-2.**  
ProMax Scenario Tool Inputs

Scenario	ANONID	sample_pressure_psig	sample_temp	flash pressure	flash temp	C10+ specific gravity	C10+ molecular weight	Mol%							
								CO2	N2	METHANE	ETHANE	PROPANE	ISOBUTANE	N-BUTANE	ISOPENTANE
1	I-1	189	62	12.5	21	0.774502249	169.3638788	0.065643757	0	4.335729724	1.221501068	1.242731666	0.714555551	1.156357354	1.353085169
2	I-10	146.3	68	12.5	24	0.782892971	175.0947155	0.035688806	0	3.368072743	1.380154572	1.384475901	0.665971184	1.037911307	1.055044245
3	I-2	187	61	12.5	24	0.771803226	167.2802325	0.035799255	0	2.32032999	0.909795088	0.990353235	0.56988589	0.899347615	1.0681069
4	I-3	166	58	12.5	24	0.805629026	200.3417072	0.043202778	0.006991145	2.371514262	0.69548265	0.669695064	0.372284248	0.637294037	0.768989997
5	I-4	76	49	12.5	26	0.780442833	172.080991	0.046617306	0	3.217164621	0.499962031	0.412231655	0.226066569	0.31973042	0.423288305
6	I-5	207	86	12.5	24	0.800560625	185.4063816	0.055628456	0	4.540736925	0.786548887	0.616729711	0.297361958	0.415774903	0.465328493
7	I-6	326	49	12.5	20	0.7906611	181.260029	0.044461517	0.026522922	2.908999998	0.799418634	0.722950721	0.379224961	0.599709268	0.68880023
8	I-7	125.1	76	12.5	20	0.76153282	160.5928417	0.029039623	0.010159778	1.523017671	0.582255452	0.865884907	0.42380907	0.839370065	0.71224757
9	I-8	274	59	12.5	20	0.773538271	168.3311117	0.019375249	0	1.260619566	0.660403506	1.007306907	0.561384458	1.121200083	1.176040822
10	I-9	196	70	12.5	24	0.784355611	176.6396854	0.035150394	0	2.341906943	1.072997508	1.1705761	0.584878879	0.95472551	0.95376595
11	II-1	33.8	107	11.2	120	0.840381148	240.0763074	0.016071609	0	1.256098202	0.593287645	0.521785381	0.259617273	0.419291249	0.445488335
12	II-2	44.8	75	11.5	55	0.75563049	157.9599413	0.012184261	0	1.317078843	0.555490175	0.531975496	0.260297024	0.451095568	0.464023807
13	II-3	25	87	11.5	55	0.765074021	165.8058917	0.008049288	0	0.84482823	0.402822789	0.391088439	0.18779791	0.333022028	0.338436582
14	II-4	32.2	116	11.4	50	0.770890416	169.7114561	0.007140984	0	0.926544394	0.44808162	0.41967969	0.182330587	0.336516746	0.287804001
15	II-5	162.6	104	11.5	100	0.84155488	242.2383773	0.01007582	0	2.87701284	1.188761024	1.290436445	0.546577335	1.017544159	0.871596422
16	II-6	164.1	94	11.5	100	0.818313647	215.9356643	0.008596144	0	2.140416839	1.096637741	1.195466166	0.555605407	1.006508074	0.97447517
17	II-7	36.5	60	11.2	90	0.821824756	209.5574687	0.01546282	0	1.405803283	0.995480302	1.340539102	0.715078392	1.350869293	1.453145635
18	II-8	191.5	92	11.5	100	0.835298322	237.7098585	0.008874952	0	2.774637521	1.287319112	1.393841368	0.615743543	1.137973802	1.021997127
19	II-9	72	89	11.4	50	0.824425121	217.6303399	0.004787137	0	1.842870043	0.868572224	0.967058677	0.42940167	0.818163008	0.713502474
20	III-1	191.7	72	12.3	22	0.771289098	167.7558993	0.06395423	0	4.70367936	2.13205582	3.666849622	1.78263163	3.665342218	3.124082325
21	III-2	265.4	64	12.3	22	0.78352444	178.671585	0.105913843	0	6.81784717	2.671392628	4.291472055	2.113417847	4.364293531	3.724934408
22	III-3	280.3	72	12.3	22	0.793087923	187.6533181	0.098253774	0	6.055499316	2.703777788	4.344997651	2.086810442	4.33927457	3.492069502
23	III-4	253.8	65	12.3	22	0.795034543	187.1092835	0.095272441	0	5.479680649	2.711517766	4.653266065	2.321951371	4.769402666	4.079275694
24	III-5	270.1	72	12.3	22	0.787458383	180.6619289	0.080025048	0	5.27023815	2.12880576	3.11298599	1.506914518	2.882947591	2.004058141
25	III-6	324	71	12.3	22	0.799952116	191.7118177	0.122073801	0	7.14707679	3.017017764	5.065658967	2.248647817	4.539063534	3.467105901
26	III-7	238	67	12.3	31	0.819693773	213.9609982	0.066220044	0	4.893172486	2.721941524	4.513834688	2.251722843	4.575330946	3.510876641
27	III-8	344.7	67	12.4	7	0.800326063	192.7494703	0.120286866	0	8.264742029	2.878342358	4.42444086	2.089014117	4.249349108	3.040189036
28	IV-1	51	133	11.6	160	0.880166114	322.385963	0.013386762	0	1.893127623	0.518103388	0.826146827	0.283684273	0.955102133	0.739674804
29	IV-2	55.6	135	11.6	150	0.879857994	321.2150884	0.013761189	0	2.451002853	0.232138085	0.346694652	0.144074771	0.421432563	0.386466125
30	IV-3	32	135	11.6	155	0.884621655	332.5233242	0.015121285	0	1.654033506	0.172889883	0.216420761	0.054268184	0.152717303	0.07036232
31	IV-4	46	125	11.8	155	0.877048253	314.2453689	0.012703412	0	1.742831555	1.345401925	2.006636724	0.629594467	1.917730964	1.193923307
32	IV-5	53.5	115	11.9	155	0.874356882	307.6056216	0.024784607	0	1.842206188	2.470888418	4.121564228	1.155716045	3.429374004	1.94723555
33	IV-6	47.5	128	11.8	155	0.879203137	319.4204533	0.020486528	0	1.50102271	0.493031049	0.593869047	0.156886262	0.568912544	0.360670156
34	V-1	56.2	145	11.8	172	0.885386856	336.782313	0.005285253	0	1.558470811	0.700834424	0.810379843	0.255713014	0.71654225	0.498352121
35	V-10	39.9	145	11.8	165	0.879233902	319.8095502	0.004775559	0	1.409820511	0.470518586	0.7289837			

**Table B-2.**  
ProMax Scenario Tool Inputs

Scenario	ANONID	Mol%														C10+
		N-PENTANE	CYCLOPENTANE	N-HEXANE	CYCLOHEXANE	OTHER_HEXANES	HEPTANES	METHYLCYCLOHEXANE	224_TRIMETHYL PENTANE	BENZENE	TOLUENE	ETHYLBENZENE	XYLENES	OCTANES	NONANES	
1	I-1	1.28898536	0.096029288	3.992143372	1.820218856	4.023229485	7.771383926	7.303045528	0.036748975	0.657264419	4.768209646	0.434842799	8.462264633	15.31058679	11.7963001	22.0471479
2	I-10	0.934625172	0.079055424	2.750415857	1.306034479	2.923862642	5.304165189	4.770109088	0	0.489020425	3.476602536	0.585247691	10.32980022	14.78995167	14.31065143	28.9601917
3	I-2	1.017729891	0.090767322	5.245750992	1.773124045	4.340542503	7.965341199	6.79061701	0.041043545	0.736854892	5.694120251	0.534316238	9.667844465	15.24269398	12.97093904	21.03926415
4	I-3	0.763607466	0.07188723	2.17097048	1.442170309	2.700137007	6.263040156	5.319056797	0.039831029	0.609785539	4.515977365	0.597345786	11.6654674	14.7410685	16.54291386	26.9076793
5	I-4	0.356233145	0.059942788	1.05696919	1.256690662	1.4944857	3.188824635	4.065570211	0.026084994	0.929706043	6.019441563	0.467948971	10.78588123	7.726954829	9.153329762	48.17116881
6	I-5	0.389948796	0.063498155	1.138097239	1.102063068	1.526487826	2.749314204	3.238990116	0.028243043	0.778534083	4.740156545	0.343006899	7.83978958	4.8638417	5.989862555	57.9012821
7	I-6	0.575917611	0.101632515	1.704083333	1.788777109	2.359758966	4.525675677	5.216911415	0.025576395	1.611649385	11.34694514	1.120874266	19.40552838	9.581724931	10.19600748	24.19335149
8	I-7	0.7889569427	0.082240674	1.680415042	1.448842625	2.104279196	6.652404986	6.654569307	0.048586926	0.373221189	3.886845992	0.572438377	9.987805802	18.58769139	17.14371813	24.95293061
9	I-8	1.272096638	0.124218136	5.709477093	2.115330902	4.531800383	7.825041702	8.306255469	0.038445692	0.57586735	4.16136611	0.395675104	7.720689186	16.75647814	12.82017686	21.8184173
10	I-9	0.937127404	0.073424416	2.156573834	1.537726193	2.553430583	7.049280238	6.657576309	0.030808196	0.547248055	4.524725573	0.583208795	9.425697833	17.24894028	13.78328312	25.70536427
11	II-1	0.383304403	0.047902848	1.237558259	0.674230562	1.403708494	3.545055568	3.014370377	0.031744817	0.307492222	2.681743502	0.382080301	5.966148809	8.886427134	9.135489537	58.740202
12	II-2	0.469804657	0.032461657	1.10425187	0.903590202	1.420419781	4.227375227	0.027459005	0.25402357	2.146582582	0.426781829	6.364152219	12.450610312	15.86974758	46.76474438	
13	II-3	0.344366347	0.030856806	0.865308272	1.064285251	3.006507085	2.901857521	0.011859555	0.183603483	1.351769611	0.282213488	4.144036002	8.641882118	12.79031094	61.13036066	
14	II-4	0.305211917	0.027727584	0.63940225	0.530472458	0.748957488	2.077796752	2.031723136	0.016574008	0.133634443	0.918554432	0.460006886	3.448018942	6.241729498	11.6990602	68.09587873
15	II-5	0.903680268	0.071860808	1.569572982	1.19147322	1.849672729	3.275349287	3.588057448	0.021505789	0.258156905	1.37803158	0	2.256184662	6.106420416	5.354941715	64.34014058
16	II-6	0.98494508	0.093017078	1.654359404	1.521115836	2.350444706	5.186363429	5.227471539	0.033613993	0.405902722	2.7395955	0.352781614	6.274354694	11.38180802	12.18986631	42.6068621
17	II-7	1.583790365	0.153097416	3.215394614	2.510285562	4.454599472	7.15253403	6.761789568	0.048395533	0.885196205	4.441337076	0.245933072	4.09442499	8.376033575	6.073406749	42.70515836
18	II-8	1.056241917	0.089788079	1.564901788	1.548948785	2.194921766	4.891069762	5.118004093	0.039005612	0.371847923	2.289136597	0.217245391	4.630475514	10.09827717	9.861403611	47.76418993
19	II-9	0.778014673	0.067631751	1.354756331	1.234217017	1.841530196	3.83866333	4.190229229	0.027576783	0.320065391	0.270200286	0.229348993	4.580241635	8.343287246	8.628788209	56.8353135
20	III-1	3.397248289	0.298404613	3.770184263	2.542244324	5.429436039	7.960375606	7.177190973	0.031571817	0.395971969	2.23009507	0.340262727	4.610401919	14.34002154	10.74877795	17.50790767
21	III-2	3.897237778	0.270807266	4.525945827	2.661489926	5.828270295	8.187548907	7.01544649	0.103737917	0.375906023	1.769825419	0.164766373	3.21545663	11.55426836	9.039958575	17.16401398
22	III-3	3.82052633	0.350643028	3.936575593	2.577665232	5.61916423	7.209823272	6.043207099	0.071006211	0.367696493	1.483451368	0.147896373	2.644582473	9.978467306	8.291371392	24.18527321
23	III-4	4.1020515	0.300578201	3.839502554	2.444431069	5.541420774	7.93674822	6.42309618	0.069267758	0.392099399	2.015138115	0.237056633	3.13784	11.48591125	8.79669219	19.03779114
24	III-5	2.12260958	0.185632591	3.509755735	2.895312938	4.535844668	11.14837348	9.767787159	0.095247085	0.590928792	3.769601871	0.359458535	4.692208772	16.37972031	9.209202295	13.64484015
25	III-6	3.95718111	0.317357496	4.492239588	3.161908751	6.184021999	10.59548887	8.820264424	0.045972347	0.504311701	2.715136633	0.192589532	2.95903722	11.52946891	5.914811976	12.85757097
26	III-7	3.690787728	0.248558532	3.28061074	2.282959342	4.920212759	7.901020931	6.893102096	0.079402042	0.383843537	2.191898256	0.189157764	3.500725234	11.07718722	7.259255883	23.46125169
27	III-8	3.219004825	0.242754757	2.895154199	1.800946263	4.133011661	6.421065825	5.592737131	0.044970372	0.299127571	1.81405363	0.261829873	3.847524456	11.75868682	8.742581387	23.66548209
28	IV-1	1.282445724	0.09905942	2.188512359	0.649026141											

**Table B-3**  
**ProMax Scenario Tool Outputs**

Scenario	ANONID	Mol%												
		BP Press	BP Temp	RVP	CO2	N2	METHANE	ETHANE	PROPANE	ISOBUTANE	N-BUTANE	ISOPENTANE	N-PENTANE	CYCLOPENTANE
		psig	F	psi										
1	I-1	122.4792611	172.0339549	6.207948471	2.403119139	0	76.20043109	12.62028894	4.826142561	1.045718718	1.119860889	0.455093099	0.302930848	0.0155596
2	I-10	95.3337978	168.6203594	6.062494748	1.678795361	0	72.79119187	16.25553645	5.736525382	1.026855861	1.060150599	0.38094973	0.236982897	0.013694817
3	I-2	61.10022178	341.4128923	5.793203322	2.144791285	0	76.75655367	13.04003394	4.386484529	0.899132163	0.92989331	0.37982653	0.253421415	0.01555758
4	I-3	59.82701094	330.4864108	4.35086504	3.066159219	0.285856171	81.00386046	10.17870294	2.951074044	0.581692126	0.653821344	0.268376951	0.186420962	0.012271352
5	I-4	75.79750419	49.45329123	3.100018309	2.911729432	0	86.96849156	6.724497488	1.820743341	0.363811757	0.340335526	0.162658048	0.09637418	0.010563786
6	I-5	136.1150349	207.7850507	3.360174692	2.8505662	0	84.30708594	8.66314968	2.504531739	0.452427614	0.420285093	0.17331674	0.102098994	0.010699634
7	I-6	79.45834455	485.0675953	4.63040486	2.432758661	0.854099527	80.77552044	10.58953649	3.089786127	0.558932527	0.573863201	0.225697013	0.13101627	0.014996546
8	I-7	40.357465844	333.8590425	4.751562266	2.405678176	0.711665205	81.16065412	9.537002758	3.700811436	0.628005349	0.80975213	0.225431444	0.173750879	0.012625333
9	I-8	28.0658782	479.6570452	5.92648547	1.719314937	0	78.9581638	11.31670029	4.377519142	0.820709233	1.051881105	0.374621801	0.281688225	0.019018847
10	I-9	64.62208265	360.046076	5.781484693	2.18397969	0	74.18367844	15.18433414	5.135708729	0.913089384	0.989614841	0.338798277	0.233148217	0.012583526
11	II-1	34.50457538	103.658074	2.392375504	2.730187217	0	59.87208802	17.4658331	7.450462132	1.876720625	2.257409858	1.087184476	0.73397144	0.068644885
12	II-2	29.74929376	152.17953	3.266596951	1.424000415	0	77.99616609	12.90386752	3.956391549	0.788544413	0.93655614	0.361967536	0.268186586	0.012919035
13	II-3	15.65681866	156.5437658	2.68629444	1.409519654	0	81.7887009	11.03869695	3.02867149	0.567334517	0.685753879	0.268135946	0.199665314	0.012204965
14	II-4	21.96907947	185.9399943	2.63167414	1.235813412	0	81.92556337	11.64596417	3.037263066	0.50352622	0.630022439	0.208423977	0.160857283	0.0098231
15	II-5	90.78270909	260.2366749	3.388866737	0.782916832	0	56.42699606	17.93524388	11.48430506	2.671347013	3.761576607	1.474162035	1.189301059	0.070881401
16	II-6	63.62310439	337.7636233	3.961509063	0.641476432	0	52.603151	19.39943114	11.602206	2.840349116	3.840940979	1.658956108	1.299499407	0.09240715
17	II-7	32.86216929	73.61552638	5.141881792	1.039370671	0	45.02864412	20.71933912	13.51488475	3.462555788	4.732384883	2.206645301	1.833985233	0.127813727
18	II-8	83.60063973	318.1041591	3.890467299	0.577059008	0	52.43586598	18.8173316	12.18824586	2.987958256	4.188911874	1.723186925	1.387080919	0.089157146
19	II-9	50.41678587	159.180947	3.991944428	0.549406917	0	71.23642703	16.8282213	6.56380697	1.152833561	1.49791071	0.477090072	0.37741963	0.023843848
20	III-1	146.2309517	130.5399359	11.45967331	1.602265835	0	57.66357588	17.78113555	13.43586724	2.663864091	3.665177174	1.110335563	0.847923738	0.052397418
21	III-2	205.1480434	119.860179	12.35244485	1.822302501	0	56.13737168	16.88977607	14.06761326	3.056772058	4.301063521	1.365419099	1.009133977	0.04929812
22	III-3	188.1001548	162.3957086	12.26724983	1.982496004	0	54.40700196	18.24088808	14.5658764	4.260504988	1.27378753	0.986334224	0.062906712	
23	III-4	166.8245179	155.2801122	13.27046006	1.91610941	0	51.46071059	18.88242062	15.87751978	3.385445087	4.698810638	1.475636747	1.04648065	0.053672185
24	III-5	165.6157599	198.9961619	10.00397596	1.925593935	0	61.72444523	17.3000609	11.44328627	2.239136859	2.876243567	0.709060957	0.526513012	0.03262627
25	III-6	229.671385	151.5682862	13.30225871	1.830242678	0	52.78839397	17.62096203	16.22020201	3.243728845	4.48402979	1.27420897	1.0261522	0.058272812
26	III-7	150.3146947	162.831831	12.1541211	1.546697018	0	47.7935913	20.1393143	17.17069684	3.8243926	5.350479968	1.512539666	1.13562115	0.055530239
27	III-8	253.540137	137.5454678	12.32528513	2.041801495	0	62.35844602	16.31859835	11.97145566	2.281006187	3.085797464	0.763068355	0.55745929	0.029134084
28	IV-1	61.58986732	97.88961385	2.074380199	1.921575764	0	48.27859139	10.5893838	11.34634452	2.492586913	6.815079297	2.870027167	4.11321572	0.24851925
29	IV-2	77.22071951	69.94368162	1.353561205	2.33642005	0	72.76773001	5.25797555	4.897412289	1.224575239	2.8446564652	1.348120787	1.77345257	0.159232983
30	IV-3	47.88498194	63.92508777	0.978270536	4.82513081	0	81.4830854	5.673089391	3.854215596	0.538048957	1.77742161	0.270791115	0.33521791	0.0878495
31	IV-4	64.40634371	73.71312888	3.108072286	0.974916514	0	25.45118634	17.15601721	19.4527323	4.310209706	11.02494196	3.997071787	5.619249595	0.285864659
32	IV-5	79.12139151	62.03182341	3.737568006	0.824617065	0	12.89436844	16.24168079	23.50464774	5.37859086	14.24199637	5.465692081	7.23569975	0.24311152
33	IV-6	46.25168069	133.0839486	1.787										

**Table B-3**  
ProMax Scenario Tool Outputs

Scenario	ANONID	Mol%														C10+
		N-HEXANE	CYCLOHEXANE	OTHER_HEXANES	HEPTANES	METHYLCYCLOHEXANE	224_TRIMETHYLPENTANE	BENZENE	TOLUENE	ETHYLBENZENE	XYLENES	OCTANES	NONANES			
1	I-1	0.212416468	0.078672589	0.340224115	0.103757292	0.106693558	0.000573774	0.031334037	0.052450953	0.001268184	0.023596193	0.050044184	0.009311381	0.000512391		
2	I-10	0.161695707	0.060914599	0.272258682	0.078596523	0.077772094	0	0.025233641	0.041912714	0.00189933	0.03204088	0.053789396	0.012768197	0.000435272		
3	I-2	0.298179397	0.081776618	0.389496916	0.115431927	0.106776368	0.000690254	0.037166156	0.067510677	0.001688802	0.02916722	0.054310508	0.011414952	0.000697615		
4	I-3	0.127412451	0.066372899	0.250918179	0.091886973	0.088084864	0.000673313	0.030730337	0.053444697	0.001771669	0.032894998	0.05290081	0.01464055	3.26977E-05		
5	I-4	0.067325573	0.059874945	0.150208051	0.05045985	0.069113938	0.000471895	0.049615923	0.075070956	0.001674523	0.036785406	0.03019413	0.008954278	0.001045411		
6	I-5	0.071830311	0.049609948	0.152695392	0.041522944	0.053702225	0.000491878	0.040057789	0.056185023	0.001124535	0.024620088	0.018156878	0.005550466	0.000290893		
7	I-6	0.090393558	0.069844319	0.200540644	0.060058392	0.073578945	0.000388455	0.066031823	0.107076351	0.002766407	0.045516744	0.02964967	0.00778945	0.000158437		
8	I-7	0.082425647	0.060040672	0.164985227	0.082556103	0.090676291	0.000701638	0.016583091	0.039778215	0.001563053	0.026057552	0.056530378	0.012332963	0.001292342		
9	I-8	0.280785067	0.085410847	0.355281983	0.09614245	0.111961668	0.000556266	0.025803216	0.042884247	0.001067247	0.019940343	0.050441786	0.009246267	0.000508647		
10	I-9	0.124372545	0.071249809	0.233109191	0.102617796	0.107347941	0.000520146	0.027723108	0.053398347	0.001848244	0.028547556	0.061860392	0.012142676	0.000327003		
11	II-1	0.864900366	0.357722184	1.317194001	0.886369737	0.794880705	0.008322039	0.185184882	0.53454226	0.027708317	0.404911598	0.784946112	0.29009883	0.00071617		
12	II-2	0.164876174	0.112091941	0.315225794	0.18027129	0.167239351	0.001294799	0.034637157	0.078816244	0.000500139	0.070670583	0.149237632	0.053819959	0.01829218		
13	II-3	0.132202063	0.086814705	0.241646754	0.127893932	0.131385896	0.000556835	0.02529903	0.049278579	0.003363374	0.046861147	0.10377672	0.043536668	0.011486458		
14	II-4	0.087578262	0.055642443	0.154032525	0.076798372	0.080600371	0.000678833	0.016300789	0.029027477	0.004666876	0.033254959	0.063853311	0.033261874	0.007046871		
15	II-5	0.720129971	0.417012011	1.166375775	0.511043118	0.600016331	0.003585146	0.104597392	0.17389075	0	0.091683398	0.320255265	0.094358134	0.000232761		
16	II-6	0.769164006	0.536589582	1.499710431	0.792715038	0.859300654	0.005479072	0.161712767	0.342672798	0.014990775	0.250185454	0.579925683	0.208017517	0.001118882		
17	II-7	1.238127451	0.712026544	2.392185952	0.862838555	0.866924365	0.006347441	0.28596651	0.432554414	0.007872392	0.123259366	0.327969125	0.077196527	0.001107729		
18	II-8	0.717932919	0.549501836	1.380513529	0.759395496	0.854791276	0.006465543	0.150497734	0.290592688	0.00942009	0.188375291	0.525402563	0.172069199	0.000244289		
19	II-9	0.191009014	0.12845159	0.389840078	0.145942889	0.179896888	0.001175134	0.038516552	0.064187702	0.00202337	0.038161353	0.088445285	0.025320594	7.57256E-05		
20	III-1	0.214334473	0.120059729	0.488625709	0.114622923	0.12994171	0.000534307	0.021461853	0.027847758	0.001116763	0.014507741	0.051528937	0.009264965	0.000538191		
21	III-2	0.271192957	0.130610513	0.550826606	0.122898141	0.11571236	0.001834983	0.021598788	0.023440081	0.000562696	0.010544841	0.04367253	0.008170293	0.000184926		
22	III-3	0.238417451	0.124261696	0.53776458	0.107397225	0.100255717	0.001239103	0.020991707	0.019432432	0.000494617	0.080501028	0.037363384	0.007442746	0.000103335		
23	III-4	0.229050606	0.117678504	0.522579316	0.117670277	0.105444219	0.001205563	0.022110361	0.026033042	0.000782599	0.00995239	0.042762825	0.00783922	8.53718E-05		
24	III-5	0.199883214	0.137300198	0.407145954	0.160823414	0.156948948	0.001632958	0.031318505	0.046172313	0.001140464	0.014276933	0.059259694	0.008015634	0.000114774		
25	III-6	0.27250637	0.156342744	0.589475451	0.161502491	0.147585488	0.000834789	0.029112426	0.036098976	0.000646106	0.009533396	0.044682241	0.005465937	3.82773E-05		
26	III-7	0.259796715	0.142446499	0.603820515	0.161063196	0.157611735	0.001875631	0.028080188	0.000860843	0.015162021	0.059024355	0.009693214	1.3595E-05			
27	III-8	0.109725402	0.054628031	0.257342715	0.056059592	0.055807572	0.000467865	0.010599501	0.03643339	0.00465898	0.006608542	0.023917584	0.003944071	2.26589E-05		
28	IV-1	2.899400617	0.691807111	2.881772397	2.273712791	0.727364875	0.011756159	0.186977372	0.088928488	0	0.069702555	1.106269829	0.386934616	4.9365E-05		
29	IV-2	1.608887895	0.487822154	1.274732137	1.405861511	0.564768761	0.011525073	0.121587964	0.148722127	0.00908028	0.095356895	0.891586503	0.320569835	3.00913E-05		
30	IV-3	0.517446769	0.0973649	0.40850697	0.254010749	0.079759449	0	0	0.021379889	0	0.025582389	0.233868572	0.116882922	2.65273E-05		
31	IV-4	3.083059348	0.715585451	2.9												

**Table B-3**  
**ProMax Scenario Tool Outputs**

Scenario	ANONID	Wt%											
		CO2	N2	METHANE	ETHANE	PROPANE	ISOBUTANE	N-BUTANE	ISOPENTANE	N-PENTANE	CYCLOPENTANE	N-HEXANE	CYCLOHEXANE
1	I-1	4.819884888	0	55.71130388	17.29433194	9.69863308	2.769949528	2.966340843	1.496387843	0.996064407	0.049731911	0.834230798	0.301745925
2	I-10	3.319760806	0	52.47016064	21.96258561	11.36598219	2.68172431	2.768676445	1.234978109	0.768260659	0.043155943	0.626100707	0.203049372
3	I-2	4.34417239	0	56.67114825	18.04570547	8.902000934	2.405144414	2.487429313	1.26121715	0.841487915	0.050209807	1.182595762	0.31674354
4	I-3	6.553098526	0.388882996	63.10768397	14.86337937	6.319476741	1.641877645	1.845468764	0.940328862	0.653174613	0.041794562	0.533212762	0.271268517
5	I-4	6.668913459	0	72.60901303	10.52293843	4.178321124	1.100465431	1.029454035	0.610748176	0.361865616	0.038556625	0.301940102	0.262244148
6	I-5	6.377464231	0	68.75519356	13.24237392	5.614259193	1.336785156	1.241813842	0.635682082	0.374473353	0.038147069	0.314674331	0.21224735
7	I-6	5.240754756	1.171177389	63.43064173	15.58636669	6.669177057	1.590192879	1.632671442	0.797082323	0.4627033	0.051482712	0.381301892	0.287728251
8	I-7	5.162756127	0.972163257	63.49129007	13.98392606	7.957745738	1.779930461	2.295048097	0.793124074	0.611298949	0.043177978	0.346372275	0.246403139
9	I-8	3.550546613	0	59.43787746	15.96734558	9.05767753	2.238333071	2.868811719	1.26820709	0.953654436	0.06258919	1.135404109	0.337294624
10	I-9	4.37156398	0	54.12789507	20.766204038	10.300001002	2.413777015	2.616074173	1.111762431	0.765073042	0.040138944	0.487471731	0.27227264
11	II-1	4.095924126	0	32.74224161	17.90283909	11.19932131	3.718388053	4.472656045	2.673900693	1.805182824	0.164113012	2.540751711	1.026270764
12	II-2	2.910399768	0	58.10858731	18.01920206	8.101973449	2.128454157	2.527970238	1.212815421	0.898591157	0.04207731	0.659837669	0.437816816
13	II-3	3.035723784	0	64.2109297	16.24359139	6.529651347	1.613711652	1.950540626	0.946735613	0.704979193	0.04188929	0.557605453	0.357553488
14	II-4	2.708644074	0	65.45502659	17.44004554	6.670071115	1.45752743	1.82368852	0.748909386	0.577992659	0.034310177	0.375865125	0.233217875
15	II-5	1.169066732	0	30.71391184	18.29801953	17.18214624	5.268046375	7.418040377	3.608705584	2.911374238	0.168667469	2.105577493	1.191029625
16	II-6	0.897381758	0	26.82457331	18.54208876	16.26245558	5.247637972	7.096264194	3.804643641	2.980267008	0.206004862	2.106939945	1.435474155
17	II-7	1.332562054	0	21.04410136	18.14955626	17.36114443	5.862857978	8.012954063	4.638014173	3.854742537	0.261137862	3.108271949	1.745700666
18	II-8	0.806950605	0	26.72881483	17.97886376	17.07721129	5.518919275	7.736126466	3.950405479	3.179882566	0.198681875	1.96583592	1.469442117
19	II-9	1.05141998	0	49.69454994	22.003585	12.58596463	2.913696576	3.785852209	1.496804357	1.18402079	0.07271664	0.715768591	0.470086951
20	III-1	2.571741442	0	33.73796102	19.49958424	21.60767803	5.646773974	7.76932545	2.92165908	2.23116702	0.134022582	0.673630017	0.368507813
21	III-2	2.835674227	0	31.84288957	17.95696287	21.93336693	6.281950784	8.839085429	3.483247991	2.57434798	0.122247949	0.826325097	0.388660683
22	III-3	3.062429422	0	30.63607287	19.25186799	22.54443768	6.154048108	8.691814641	3.225769403	2.497815913	0.154855314	0.721154771	0.367069732
23	III-4	2.866779569	0	28.06559839	19.30211029	23.801574041	6.689372504	9.284479256	3.619395283	2.56677474	0.127967119	0.671030275	0.336688084
24	III-5	3.259229741	0	38.0370352	20.00649573	19.40662647	5.00525853	6.429416134	1.967507494	1.460972129	0.088002105	0.662465492	0.444404081
25	III-6	2.756203595	0	28.97809739	18.13049375	24.474406269	6.451297068	8.918072262	3.145792721	2.533385181	0.139845414	0.803563531	0.450237046
26	III-7	2.225108947	0	25.063414	19.79008891	24.70544269	7.264334556	10.16563201	3.56726491	2.678317516	0.127306606	0.731840363	0.391882543
27	III-8	3.494377442	0	38.90237449	19.0814897	20.52826643	5.155589956	6.97460029	2.140929155	1.564054946	0.079457157	0.367705519	0.17878392
28	IV-1	2.223548616	0	20.364241446	8.372071609	13.15509844	3.809211066	10.41491285	5.444495985	7.802848254	0.458273257	6.569525696	1.530843335
29	IV-2	3.645794518	0	41.39073775	5.605721274	7.656944424	2.523602176	5.862073082	3.448666292	4.536726547	0.395957163	4.915891235	1.455653261
30	IV-3	9.752705829	0	60.0354858	7.834454962	7.805505903	1.436261229	3.143850351	0.897290359	1.110774252	0.282963676	2.047945536	0.376335392
31	IV-4	0.947958056	0	9.020991136	11.3975445	18.95183751	5.534975534	14.15772971	6.37156621	8.957412514	0.442952876	5.870029065	1.330576369
32	IV-5	0.70631376	0	4.025964629	9.504941489	20.20285637	6.084283869	16.11060425	7.674904062	10.16034505	0.331838102	6.566938068	1.234625619
33	IV-6	5.61005688	0	26.69002586	11.91482652	12.46796675	2.542165757	7.268804106	2.931191479	5.29924163	0.370391002	6.29422634	1.42395931
34	V-1	1.108370435	0	19.83845122	13.1735484	14.8492996	3.958972406	8.991665745	4.309062898	5.968365947	0.475765292	4.618272811	1.53234228
35	V-10	1.320239326	0	24.93445297	11.44489077	15.78884129	3.972715171	8.855016561	4.000856686	4.865797126	0.556592648	4.099122099	1.546144475
36	V-11	1.649431676	0	6.860828222	9.43465645								

**Table B-3**  
**ProMax Scenario Tool Outputs**

Scenario	ANONID	Wt%											
		OTHER_HEXANES	HEPTANES	METHYLCYCLOHEXANE	224_TRIMETHYL PENTANE	BENZENE	TOLUENE	ETHYLBENZENE	XYLENES	OCTANES	NONANES	C10+	
1	I-1	1.336174347	0.473815964	0.477422585	0.002986965	0.111544499	0.22024653	0.006135903	0.114166382	0.260521211	0.054425657	0.003954912	
2	I-10	1.054210756	0.353868626	0.343112249	0	0.088564442	0.173519842	0.00906034	0.152844002	0.276079279	0.073581191	0.003424492	
3	I-2	1.544766028	0.532325974	0.482503598	0.003628766	0.133610348	0.286278548	0.008251555	0.14251218	0.285518328	0.067378964	0.005370767	
4	I-3	1.050076147	0.447131881	0.420007149	0.003735054	0.116570792	0.239139291	0.009134178	0.16959646	0.29345562	0.091187982	0.000318122	
5	I-4	0.673649434	0.263135666	0.353161296	0.002805288	0.201695204	0.359973339	0.009251884	0.203242512	0.179495968	0.059767191	0.00936204	
6	I-5	0.6689282	0.211511864	0.268048005	0.002856291	0.159064882	0.263167217	0.006069106	0.132874436	0.105435337	0.03618883	0.002741749	
7	I-6	0.845928949	0.294576575	0.35363217	0.002172017	0.252475087	0.482928347	0.014376256	0.236538005	0.165784069	0.048902359	0.001405747	
8	I-7	0.693307364	0.40338799	0.434151421	0.003908275	0.063165509	0.178724339	0.00809194	0.134900208	0.309873338	0.07713291	0.010120483	
9	I-8	1.436645571	0.452048113	0.515837062	0.002981608	0.094576677	0.185049465	0.005316668	0.099336154	0.270369691	0.055646057	0.004017669	
10	I-9	0.913659372	0.467671194	0.479386015	0.002702348	0.089491919	0.22377439	0.008924472	0.137845345	0.321387536	0.07083222	0.0026217131	
11	II-1	3.869420159	3.027638987	2.660509583	0.032405395	0.493100492	1.67894259	0.100277742	1.465394712	3.056521338	1.26833868	0.005861088	
12	II-2	1.261539784	0.838877978	0.762578231	0.006868674	0.12564789	0.337250492	0.024652417	0.348430479	0.791678764	0.320563526	0.134186407	
13	II-3	1.01908112	0.627149028	0.631310863	0.003112761	0.096708685	0.222199777	0.017474356	0.243466362	0.580121785	0.272359024	0.093204705	
14	II-4	0.661071058	0.383248747	0.394129986	0.003861805	0.063412971	0.133199517	0.024675174	0.175828951	0.363254139	0.212458427	0.059560736	
15	II-5	3.410349078	1.737444385	1.998895736	0.013895003	0.277213874	0.543618814	0	0.330254926	1.241218002	0.410611608	0.001913069	
16	II-6	4.108096306	2.524895013	2.681915395	0.019894436	0.401523782	1.00362273	0.050588936	0.844293641	2.10570239	0.848056231	0.007679958	
17	II-7	6.005492091	2.518698728	2.479713988	0.021122425	0.650732643	1.161053036	0.024347738	0.381216636	1.091385203	0.288431679	0.006724996	
18	II-8	3.780106763	2.417822637	2.666798526	0.023467124	0.373531406	0.850757341	0.031777281	0.635456159	1.906983912	0.7012261	0.001845147	
19	II-9	1.460848773	0.635908658	0.768084768	0.005837105	0.13062777	0.257174709	0.00934098	0.176173585	0.439323975	0.141216095	0.000716635	
20	III-1	1.535697637	0.418884129	0.404624493	0.00222593	0.061140697	0.093578762	0.004324031	0.056172979	0.214670331	0.043337584	0.003292755	
21	III-2	1.678368988	0.435422506	0.401715895	0.007411326	0.059653467	0.076364109	0.002112246	0.039583195	0.176389339	0.037051153	0.001168268	
22	III-3	1.626606989	0.377662381	0.345514529	0.004968087	0.057553529	0.062845654	0.001843136	0.031678176	0.149805613	0.03350543	0.00068063	
23	III-4	1.530956619	0.400839496	0.351956556	0.004681574	0.05871381	0.081544231	0.002824543	0.035919998	0.166061326	0.034180237	0.000543047	
24	III-5	1.349388674	0.619768128	0.588892623	0.007173867	0.094085289	0.163616171	0.004656577	0.0582935	0.260338131	0.039538151	0.000797466	
25	III-6	1.738238174	0.55375264	0.495854139	0.003262959	0.077813637	0.113814109	0.002347177	0.034632947	0.174650546	0.023988316	0.000251102	
26	III-7	1.70095884	0.527560218	0.505868901	0.007003602	0.07154494	0.114693669	0.002987479	0.05261845	0.220396857	0.040638907	9.5085E-05	
27	III-8	0.862392253	0.218443138	0.213084972	0.002078283	0.032196758	0.048884513	0.001923454	0.02783301	0.106243341	0.019671127	0.000169841	
28	IV-1	6.529583289	5.990380615	1.877780568	0.035308776	0.384015365	0.215439013	0	0.194568596	3.322601834	1.304832934	0.000418444	
29	IV-2	5.269848583	4.9947303	1.966137447	0.046677933	0.336744746	0.488585409	0.034180151	0.358944118	3.611032611	1.457775585	0.000342713	
30	IV-3	1.616784644	1.168955082	0.359667815	0	0.090472337	0	0.12473607	1.226919339	0.688486301	0.000405121		
31	IV-4	5.620835843	4.959990391	1.483686128	0.03299202	0.507110918	0.339475028	0	0.32465423	2.724755017	1.022548712	0.000378233	
32	IV-5	6.218818933	5.304229182	1.369614856	0.029245629	0.510493129	0.254596841	0	0.20026673	2.56903197	0.939638194	0.000447285	
33	IV-6	5.246781261	4.720067322	1.67671542	0.046721584	0.398279577	0.330307837	0	0.31331196	3.125979148	1.328503058	0.000424665	
34	V-1	6.100275962	5.698162003	2.047157158	0.069349722	0.205642407	0.503937968	0	0.543675097	4.091566809	1.915765639	0.00043789	
35	V-10	5.831497649	4.240662043	1.847270497	0.057343357	0.248840545	0.424909642	0.090006526	0.518206349	3.64918178	1.706692029	0.000720457	
36	V-11	7.886577671	5.930303895	3.156889188	0.036846887	1.192749986	1.457719115	0.036236978	0.699202515	3.7940786	1.248646383	0.000528687	
37	V-12	8.863138493	4.422141909	1.977920935	0.038001437	0.320468453	0.512002709	0.058260705	0.391980664	3.115170118	1.276360263	0.000461511	
38	V-13												