Before a Decision-Making Committee
Of the Environmental Protection Authority

APP203660

Under	the Hazardous Substances and New Organisms Act 1996
In the matter of	the modified reassessment of methyl bromide
By	**Stakeholders in Methyl Bromide Reduction Inc**
	Applicant

STATEMENT OF EVIDENCE OF DAVID ALAN SULLIVAN

27 JULY 2020

Counsel Acting
M J Slyfield
Stout Street Chambers
(04) 915 9277
morgan.slyfield@stoutstreet.co.nz
PO Box 117, Wellington

INTRODUCTION

1. My full name is David Alan Sullivan.

Qualifications and Experience

2. I received a B.Sc. in Meteorology-Oceanography from New York University in 1972, and a M.Sc. from Pennsylvania State University in 1974. I was designated as a Certified Consulting Meteorologist (#256) in 1980 by the American Meteorological Society.

3. I have 45 years of professional experience in meteorology and air quality analysis, with a focus on exposures to toxic air pollutants. I have managed and served as Principal Investigator on many United States Environmental Protection Agency (**US EPA**) urban-scale air toxics studies.

4. As the Principal Investigator for the US EPA Integrated Environmental Management Project I led urban air toxics studies on a national scale, and authored reports referred to as the "*35 County Study*" and the "*Six Month Air Toxics Study*" that were used by the USEPA to guide air toxic policies in the 1980s. I also directed the emissions assessment, dispersion modelling, and ambient monitoring associated with urban-scale air toxics studies for the US EPA in Philadelphia, Baltimore, Denver, and the Silicon Valley.

5. After the Bhopal tragedy in India, the US EPA selected my technical proposal to evaluate the exposures and risks associated with the high concentration of the chemical industry in the Kanawha Valley of West Virginia, which included the same process as in Bhopal. I managed this project for over four years, which included a cancer risk assessment and the evaluation of short-term non-cancer risks. Through the latter phase of this project, I developed the prototype code for the Toxic Modeling System Short-Term (**TOXST**) model. TOXST was developed as a complementary program to the Industrial Source Complex Short Term, Version 3 model (and there is a TOXST switch available in AERMOD) to provide Monte Carlo analysis of intermittent releases include batch operations. TOXST was adopted later as an EPA model.

6. Over the past 22 years, I have been heavily involved in evaluating air quality exposures from fumigants. I have managed the implementation of over 50 field studies (flux studies) to evaluate airborne emissions as a function of time.

This work has included all of the existing fumigants and others in the process of seeking registration for a wide range of application methods. More recently this field work included a flux study of timber fumigation at a research station in California.

7. Since 1980, I have served as an air quality expert for many major air quality litigation matters covering a wide range of industrial facilities, pesticide exposures, and other matters.

8. I serve as the President of Sullivan Environmental Consulting, Inc. (SEC). In this capacity I manage company projects, which includes designing the modeling or monitoring approaches and overseeing the quality of work products. My staff includes Certified Consulting Meteorologist Dennis Hlinka (43 years of experience), Meteorologist Ryan Sullivan (16 years of experience), and Environmental Engineer Mark Holdsworth (21 years of experience). Our firm has conducted a large fraction of the U.S. flux studies for agricultural fumigants and have developed the Fumigant Emissions Modeling System (FEMS) which was approved in 2004 by the US EPA's Science Advisory Panel to provide Monte Carlo modeling methods for air quality analysis of agricultural fumigants.

My Involvement in this Application

9. Sullivan Environmental Consulting Ltd (**SEC**) was engaged by the Stakeholders in Methyl Bromide Reduction Inc (**STIMBR**) to simulate expected airborne methyl bromide concentrations at the Port of Tauranga. The results of this work are reported in two reports — *Air Concentration Dispersion Modelling Assessment of Methyl Bromide Concentrations in Tauranga Port, New Zealand* (10 July 2018), and *Addendum to — Air Concentration Dispersion Modelling Assessment of Methyl Bromide Concentrations in Tauranga Port, New Zealand* (20 March 2019) — which I understand were included as Appendices 7A and 7B to STIMBR's application for modified reassessment.

10. I have considered the following documents:

(a) A submission filed by Bay of Plenty Regional Council (**BOPRC**) including *Review of an Air Concentration Dispersion Modelling*

Assessment of Methyl Bromide Concentrations in Tauranga Port, New Zealand (Atmospheric Science Global (**ASG**), August 2019);

(b) *Air Quality Review Dispersion Modelling Assessment of Methyl Bromide* (Todoroski Air Sciences (**TAS**), 16 September 2019);

(c) *Air Dispersion Modelling Methyl Bromide* (TAS, 4 November 2019);

(d) *Review of TAS Air Sciences Air Modelling Assessment of Methyl Bromide at Port of Tauranga* (ASG, November 2019);

(e) *Review of Air Dispersion Modelling of Methyl Bromide Fumigation Events* (Pattle Delamore Partners (**PDP**), 14 November 2019);

(f) *Technical Air Quality Assessment, Genera Limited* (Golder Associates (NZ) Limited (**Golder**), October 2019);

(g) *Methyl Bromide Modelling Study – Port of Tauranga* (PDP, 11 February 2020) (in draft);

(h) *Review of (Beca, latest Golder modelling (Oct19) and ESR) Genera Air Assessment for Fumigant Release at the Port of Tauranga* (ASG, December 2019).

11. At the direction of the Decision-making Committee (**DMC**) I attended a conference with Jennifer Barclay, Aleks Todoroski and Cathy Nieuwenhuijsen (I refer to us collectively as the "*expert panel*" for the purposes of this evidence) on 30 January 2020, and agreed on a joint statement of the same date.

12. At the DMC's further direction, the expert panel had a second conference and agreed an additional joint statement on 19 March 2020.

13. Broadly speaking, the purpose of these two conferences was to attempt to reach a consensus on the most appropriate approach for modeling the air dispersion of methyl bromide fumigations of logs at the Port of Tauranga.

14. At the DMC's direction, and in accordance with the expert panel's consensus recommendations, SEC undertook further air dispersion modeling, and reported the results of that modeling in a report dated 25 June 2020: *Modelling Report for Methyl Bromide Exposures for Timber Fumigation at the*

Port of Tauranga, New Zealand.

15. I was instructed to include in that report minimal interpretation of the output data, as the purpose of the report was to provide the results of the modeling, not to provide my interpretation of those results. My interpretation of those results is set out in this statement.

Code of Conduct

16. I understand this reassessment is to be determined by a Decision-making Committee of the Environmental Protection Authority. However, I have read the Code of Conduct for expert witnesses in the Environment Court Practice Note 2014 and I have complied with it when preparing this evidence. Other than when I state that I am relying on the advice of another person, this evidence is within my area of expertise. I have not omitted from consideration any material facts known to me that might alter or detract from the opinions that I express.

Scope of Evidence

17. The three modeling reports prepared by SEC form part of my evidence. However, I believe it is appropriate for the most recent report to be relied on to a greater extent than the earlier reports, as it represents the expert panel's consensus on the approach for modeling air dispersion and reliance on more specific port operational data.

18. In addition to the contents of that report, I cover in this statement:

    (a) Information on the limitations of the paired TVOC / methyl bromide monitoring data.

    (b) Interpretation of available monitoring data relative to dispersion modeling results.

    (c) Further clarification on the limitations of relying on the extreme upper tail of modeled air quality concentrations.

    (d) Further perspective on the extent of time applicators spend in near-field exposures during a work day.

(e) Information on the challenges of comparing model performance when the model is constrained to represent results paired in time and space with measured concentrations.

EXECUTIVE SUMMARY

19. I followed the recommendations of the expert panel in producing the probabilistic modeling assessment and the deterministic modeling of worker exposure. For the areas not specifically addressed in the expert statements I acted to conservatively address model inputs.

20. The modeling results generally show that the Workplace Exposure Standard (**WES**) and the Tolerable Exposure Limits (**TEL**s) are being met. I make two points of clarification:

(a) The 8-hour deterministic modeling mathematically shows the need for relatively large buffer zones, but as described in this statement, these modeled values substantially overstate actual expected exposures.

(b) The annual TEL is exceeded at the portions of the port with relatively small distances to the port boundary but these locations are non-residential, commercial areas where individuals would not be reasonably expected to be continuously exposed on an annual basis. All residential areas where annual exposures would apply are well below the annual TEL.

21. The modeling and measured data were reasonably consistent. However, there are three samples that disclose methyl bromide concentrations above the 1-Hour TEL. Two, in the Golder data set, disclose methyl bromide concentrations substantially higher than the paired TVOC data. The remaining sample, from the Worksafe data set shows methyl bromide approximately 20 percent higher than the paired TVOC data. While some differences in accuracy between the two methods would be expected, there is no explanation at this time why the methyl bromide subset of TVOC is more than double the TVOC for two of these samples. On this basis, the upper-bound methyl bromide data should be viewed with the understanding that there is no established explanation for this degree of inconsistency between these upper-end paired values. The more extensive data set of paired TVOC and methyl bromide shows much lower concentrations and

with typical ratios of TVOC / methyl bromide that are more in line with expected dilution ratios from the venting sources to the site boundary involving 100 m or more downwind travel.

22. In my judgment there are more effective and efficient ways to reduce airborne concentrations, if that is deemed necessary, than reliance solely on evolving recapture technology:

(a) as feasible, fumigating large log stacks exclusively at the more distant location from the port boundary, e.g. Location 1, or

(b) if acceptable to the export nations, a lower maximum application rate would present a viable option to further reduce exposures.

I would expect either (or both) of these methods to produce more immediate reductions in emissions and exposures than the evolving recapture technology.

CHOICE OF SOFTWARE FOR AIR DISPERSION MODELING

23. The most recent modeling undertaken by SEC (reported on 25 June 2020) does not follow my normal methodology.

24. For example, my preference would have been to use the AERMOD model, which in my opinion would likely have produced equivalent results, but in a much more streamlined manner. CALPUFF Version 7 as used in this assessment is not viewed as an appropriate model for most of the modeling I undertake because this version of CALPUFF is not approved for use in the U.S.

25. I agreed in the first conference of the expert panel to use CALPUFF for the further modeling work, because the version of CALPUFF agreed to (Version 7) has many of the updates of the AERMOD model. In addition, the model has features that can address the land/sea interactions that are useful for this application. I agree that CALPUFF Version 7 is an appropriate modeling approach for this application.

26. SEC has relied on CALPUFF modeling for many model applications, including multiple regional assessments in the U.S., on an international study in Indonesia, and in major litigation matters in the U.S. and in South America that have involved regional scales of analysis or cases with complex

mountain wind flow. We have shown good model performance when using CALPUFF in these matters.

LIMITATIONS OF JOINT WITNESS STATEMENTS

27. Throughout the modeling I was guided by the two joint witness statements agreed by the expert panel, with the objective of following the panel's prescription as closely as possible.

28. However, modeling of this sort requires considerable detail to set up. While the panel agreed on all of the fundamental methods and parameters (as recorded in the two joint witness statements), this inevitably did not cover every matter of detail necessary to set up and run the model. The details that needed to be added by SEC under my direction and supervision were designed in every instance to:

(a) achieve consistency with the intent of the joint witness statements of the expert panel, and

(b) seek conservative simplifications, where necessary, that generally acted to overstate modeled concentrations.

The next section provides greater detail on conservative simplifications.

29. In addition, the number of simulated years for the Monte Carlo Analysis was set to 24 to strike a balance between processing more years of analysis to promote stability of the distributions and to maintain manageable computer run times. In other words, each modeling scenario was run eight times for the three-year meteorological data set and then the results were merged to create distributions based on 24 years of simulated port operation.

30. As a simplification to keep the run times and number of runs manageable, some scenarios that were very similar to others were not run, i.e. Scenarios 2, 4, and 5 as specified in the second joint witness statement. Scenario 1 is not considered representative because currently available data show a minimum of approximately 30 percent control rather than zero, but this scenario is included in Appendix B of this expert statement for completeness.

31. In the modeling report submitted in June 2020 the far-field results for Scenarios

3a through 3d[1] and the low rate scenario (Scenario 7)[2] had estimated percent differences relative to the base modeling scenario, provided in Table 1-2. During my review of the modeling results I noted that the volume of the ship venting was determined based upon the 1st joint statement's depth of the ship holds that did not take into account the total depth of the ship holds below the water line. The actual volume of the holds was therefore understated and a larger amount of methyl bromide was available for emissions during the ship hold venting periods. The base scenario (Scenario 6) and the base scenario with 1-hour emissions only (6a) were corrected and the results displayed in Table 1-2, with approximate percent differences for the alternative scenarios (3a, 3b, 3c, 3d, and 7). For completeness, SEC has since re-run the modeling for all the alternative scenarios to improve the accuracy of the results, and the updated results are reported, and compared with the previous approximations, in Appendix A to this statement. As Appendix A shows, the difference between projected benefits and computed benefits is relatively small, as ship venting is very infrequent with a total of only six ships venting in 2019 (5 holds in five ships India bound and 2 holds in one ship China bound).

CONSERVATISM

32. A number of steps were taken to promote conservatism in the modeling analysis, including the following:

(a) Log stacks were apportioned into five groupings from the smallest to the largest for each location area at the port. The largest volume at the upper-end of each group's range was conservatively used for all log stacks in the group, thereby biasing the volume high.

(b) Recapture in the base scenario was set to the lower end of the tested range, i.e. 30 percent recapture efficiency. The average was approximately 40 percent, with a range from approximately 30 to 80 percent. The use of 30 percent acted to understate expected control benefits and thereby produce more conservative model estimates.

---

[1] 3a (70% with recapture / 30% efficiency), 3b (70% with recapture / 45% efficiency), 3c (70% with recapture / 60% efficiency), and 3d (70% with recapture / 80% efficiency),

[2] Low rate scenario limited the application rate for all venting to 40 g/m^3.

(c) Distributions were based on hours with active ventilation at the port with equivalent percentiles identified to represent distributions based only on hours associated with the first hour of ventilation activity at the port. Actual distributions to which individuals are exposures would be based on all hours during the work day and all hours for residential areas. This approach results in a conservative basis for the distributions.

(d) It was conservatively assumed the applicators removing the tarps were stationary at the identified downwind distances for their entire 8-hour shift and directly downwind of log stack. This assumption substantially overstates their actual exposures because: (a) the actual time in close proximity to venting tarps is a small fraction of the work day, and (b) workers in close proximity are protected by fitted respirators.

(e) Deterministic near-field model runs were based on constant maximum (first hour) emission rates for the entire work day at the port, i.e. simplified to 7:00 A.M. to 7:00 P.M. This approach assumed that a fresh application started each hour and that the first hour of highest emission rates occurred during each 12 hours of port operations. This simplification substantially overstates actual expected concentrations but was provided as a bounding analysis.

33. Conservative assumptions viewed individually can seem reasonable, but when combined can produce an unrealistic analysis. I refer to this as "cascading conservatism". As an example, consider near-field worker exposure. Putting aside the other conservative assumptions in the modeling that are listed above, the following multiplicative factors would combine to produce an extremely high level of conservatism on a collective basis:

(a) Assuming for eight hours a worker is stationary directly downwind is at least a factor of eight-fold conservative based on available data. [3]

[3] Sullivan Environmental Consulting, Inc., Documenting Worker Movements Associated with Timber Fumigation of a Surface-Based Log set, a Tarped Container, and Untarped Container (Without Product Applied), March 2019, submitted to U.S. Environmental Protection Agency in 2020.

(b) Then assuming zero respirator benefit adds an additional factor of 50 fold safety margin (98 percent efficiency for fitted respirator)

(c) The margin of exposure for the WES is 60 fold. [4]

Multiplying all of the above leads to an overstatement of 24,000-fold beyond the conservatism in the modeling, which for the deterministic approach adds at least another 10-fold increase. Each step along the way seems reasonable enough but when the cascading conservatism is fully expressed the results can be unrealistically high as shown in this example.

APPROPRIATE PERCENTILES FOR REGULATORY DECISIONS

34. The modeling includes all of the percentiles agreed by the expert panel, ranging from the 90th to the 100th percentile. The results shown in the report have emphasized the upper values in the range from the 98th to the 100th percentiles, which conservatively represents the distributions by focussing on the upper values. This approach is consistent with the Ministry for the Environment *Good Practice Guide for Atmospheric Dispersion Modelling* which says the 99.9th percentile should be reported as the maximum likely to occur, but also recommends providing an indication of the representativeness of the 99.9th percentile by also presenting a number of other percentiles, such as maximum, 99.5th and 99th.[5] I have followed this procedure.

35. The accuracy of the model, however, becomes questionable at the extreme upper end of the distributions. At the extreme upper end, the modeling may simulate concentrations that are in practice unlikely to occur. It is well known that at the extreme tail of modeled distributions model artifacts often occur, i.e. unusual events that may or may not occur in the atmosphere. A more appropriate approach is to use modeling to produce full distributions of concentrations showing concentrations and the probability for the range of concentrations, which can provide sufficient context to better inform health experts and regulatory decision makers. This approach avoids limiting the review of exposure to only worst-case events and enables such worst-case

[4] Appendix D.2 Acute RELs and toxicity summaries using the previous version of the Hot Spots Risk Assessment guidelines (OEHHA 1999).

[5] Recommendation 53 on page 104.

events to be considered in the context relative to the more typical exposures. In other words full distributions enable regulators to move beyond the question *"what is the worst-case event that could occur,"* to consider what are the ranges of events that could occur and what is the expected frequency especially as the extreme upper tail of the distribution is approached?

36. Reliance on distributions of exposure rather than worst-case highest or second-highest modeled concentrations is well accepted within the scientific community. For example, the American Meteorological Society sponsored a workshop on dispersion model performance, where the participant's findings indicated the following:[6]

> Workshop participants agreed that the accuracy of the highest or second highest estimates is expected to be poor and difficult to evaluate statistically. Statistical evaluations have greater meaning when applied to a relatively larger number of values than to one or two extremes. Generally, statistical evaluations applied to an upper percentile (2% or 5%) of the predicted values are more informative than those applied to only the highest or second highest predictions. Estimates applied to mean performance will supply more information about overall model performance than will evaluations applied to extremes only. The workshop participants, therefore, recommended that the statistical form of standards and increments be changed to consider the upper 2% - 5% of concentrations (95th to 98th percentiles) rather than one or two extreme values.

37. Short-term (≤ 24-hour averaging) National Ambient Air Quality Standards in the U.S. were subsequently changed from reliance on the second-highest short-term concentrations to probabilistic approaches based on the 98th or 99th percentiles.

38. The benefit of evaluating realistic distributions of exposure, as compared to only evaluating worst-case exposures is that sound and objective risk assessment can consider the health-based significance of entering the margin of exposure.[7] Health-based standards such as TELs and the WES are based on toxicological-based studies that include a composite (safety) margin of exposure. In addition to the safety margin in the health standards,

---

[6] (Fox, 1981; Page 601)

[7] Such assessments are beyond the expertise of air dispersion modellers – they are matters that fall within the expertise of toxicologists and other health professionals.

there are additional safety margins incorporated into the modeling analysis of exposure based on further reliance on conservative assumptions.

39. As an example, in SEC's latest modeling report, we have evaluated 24 simulated years of port operation based on detailed Monte Carlo-based sampling of port operation records for the calendar year 2019. The highest 1-hour modeled concentration along the port boundary (worst-case exposure) in the Base Scenario (status quo) occurs statistically once every 24 years. This value is approximate seven times higher than the 99.99th percentile and an obvious outlier value. This peak occurred with the coincidence of a large log stack venting coupled with a ship venting at the same time and further alignment of worst-case conditions, which will not occur from 2020 onward since the ships are vented at night and log stack during the daytime.

40. I note the expert panel for the ethane dinitrile (**EDN**) approval agreed that the 98th percentile was a suitable basis for regulatory decisions.[8]

41. I recommend that the 98th percentile of the modeled concentrations also be used as the basis for this matter. Although the distributions could properly be based on all hours in a year, to be conservative, it would be reasonable to use the equivalent of the 98th percentile basing distributions on those hours with the first hour of ventilation occurring at any location within the port. As shown in SEC's June 2020 report, the 99.5th percentile of the modeling based on all hours with active venting at the port is equivalent to the 98th percentile based on first hour (maximum) emissions, and the 99th percentile of the modeling based on all hours with active ventilation at the port is equivalent to the 98th percentile of the first hour of active venting distributions for 8-hour averaging. For 24-hour averaging, the two distributions become similar and the 98th percentile of the modeled distributions would be appropriate for both the all-hour and first-hour distributions.

42. Todoroski Air Sciences (TAS) has provided an alternative modeling report that shows potential exposures that could occur. The TAS report shows worst-case exposures based on a deterministic approach that is not based on a

[8] https://www.epa.govt.nz/assets/FileAPI/hsno-ar/APP202804/8e6d1c54fd/APP202804-Joint-Expert-Statement-Tolerable-Exposure-Limit.pdf

distributional analysis. This type of analysis also is useful and provides a contrast with the use of probabilistic approaches.

43. For example, the modeling includes considering of ventilation all hours of the day. During night-time conditions from 7:00 P.M. through 7:00 A.M., for example, substantially higher modeled concentrations were shown than the daytime conditions when fumigation and venting operations actually occur. In this sense, the TAS report shows the benefits of the daytime venting constraints that are operational practice at the Port of Tauranga.

44. TAS has employed deterministic modeling assuming worst-case emission rates throughout the day, which provides a representation of upper-bound exposures, but this approach does not include an assessment of frequency versus exposure that is the end result of Monte Carlo assessment. I agree there is value in evaluating upper-bound concentrations and that the TAS analysis can complement the analyses as shown in the SEC report.   In my judgment, however, regulatory actions are best supported by the full assessment of expected exposures in terms of concentration and frequency of exposure. For example, if a modeled 100^{th} percentile concentration only would be expected to occur once every 25 years, this would be important input to an informed judgment as compared to modeled concentrations occurring with much greater frequency. Air quality standards already have a margin of safety incorporated, which for this example could lead to the conclusion that entering the safety margin once every 25 years is reasonable. Without perspective on concentration and frequency, however, a much different conclusion could be reached.

45. On average there are 1,535 hours per year when there is active ventilation at the Port of Tauranga, i.e. 17.5 percent of the time. As an example, the 99.9^{th} percentile of 1,535 hours would be 1.5 hours per year. Over the course of 24 simulated years this would total to 37 hours. The 99.99^{th} percentile, on the other hand, would only occur 4 hours over a 24-year period. Obviously the 100^{th} percentile event would only occur with a 24-year recurrence interval.

SUB-HOURLY MODELING BY PDP

46. The Pattle Delamore Partners Draft Report[9] focused on two short-term (1 hour) periods, one on 11 December 2019 and another on 9 January 2020, which was the highest measurement in the Worksafe data set. PDP ran CALPUFF on a minute-by-minute and hourly basis for these two selected periods. This does not conform to the expert panel's agreements on modeling methodology.

47. The correspondence between the measured and modeled methyl bromide was not close in the PDP draft report, which in my opinion is not surprising as it is due to the limitation of the model rather than the skills of the modeler. The differences between the measured and modeled peak concentrations were as much as 22-fold for the minute-by-minute analysis and 7-fold for hourly analysis, with the model biased low in both cases. As recommended in Fox, 1981: "*Statistical evaluations have greater meaning when applied to a relatively larger number of values than to one or two extremes*." During conditions with lighter and more variable winds, the differences between modeled and measured concentrations could be even greater.[10]

48. The differences between the measured and modeled data are due to the inherent limitations of any air quality model when constrained to estimate concentrations for specific locations and for specific hours.

49. Model performance is best reviewed when models are not constrained to estimate concentrations at a specific location and at a specific time, i.e. generally referred to as "*model performance paired in time and space*." It is widely accepted within the scientific community that air quality models are more useful in a distributional sense than when constrained to estimate concentrations at specific locations and at a specific times.[11]

50. Models such as CALPUFF and AERMOD, or any air quality model for that matter, have minimal skill when constrained on this basis. While at a specific

---

[9] Above, at paragraph 10(g).

[10] Fox, Douglas, Judging Air Quality Model Performance: A Summary of the AMS Workshop on Model Performance, 8-11, September 1980, Bulletin of the American Meteorological Society, Vol. 62, No. 5, May 1981, 599-615,

[11] U.S. Environmental Protection Agency, Guideline on Air Quality Models, 40 CFR Part 51, Federal Register, Vol. 82, No. 10 / Tuesday, January 17, 2017 / Rules and Regulations.

time, a model may show good performance for identifying the maximum concentration that occurs somewhere in the modeling domain, models generally do not perform well in pinpointing the specific location for the maximum impacts for a specific hour, i.e. there is no basis to expect reliable model performance for a specific location and specific hour.[12]

51. As the averaging time is decreased, this limitation becomes more severe. Small differences in wind direction, emission variability, and many other factors can, and usually do, adversely affect the performance.

52. When using a model such as CALPUFF to estimate concentrations at the extreme of a minute-by-minute basis, for example, the model limitations become severe to the extent that in the U.S. sub-hourly CALPUFF modeling is not accepted for regulatory matters (CALPUFF 5 is the current accepted model in the U.S. for regulatory purposes, which does not have sub-hourly capability).

53. A further weakness that applies to sub-hourly modeling for log fumigation is that flux data are not available to quantify emission rates with a sub-hourly, minute-by-minute resolution. In other words, even if the model were assumed to be accurate for estimating concentrations at specific locations to a minute-by-minute resolution, minute-by-minute emissions data ("*flux data*") are not available to input to the model.

54. Modeling longer duration periods would be expected to improve performance for most sources, but for highly episodic releases, such as is found with fumigations of this nature, transient emissions are the norm, and I would generally expect poor model performance when constrained in time and space.

55. Modeling on a minute-by-minute basis is an option for special case reviews such as conducted by PDP, i.e. review of a few hours of data, but is not feasible when modeling multiple years as needed to reliably estimate the expected distribution (full range) of exposures over a long period of time. Individual model run times would require multiple months to complete. It is not practical to perform sub-hourly model runs in CALPUFF without having

[12] Fox, 1981 above n 10; US EPA, 2017 above n 11.

sub-hourly emission rates on a minute by minute basis; and sub-hourly modeling is of little benefit when the goal is to develop 1, 8, 24, and annual averaged methyl bromide concentrations (being the time frames set by current NZ regulations). Rather, using the standard approach of hourly analysis is the only practical option to estimate full range distributions.

NEAR-FIELD RESULTS

56. The results for near-field modeling are represented in Tables 1-3 and 1-4 in SEC's latest modeling report. As described in that report[13] the modeling incorporates many elements of conservatism.

57. A Good Laboratory Practice (GLP) pilot-scale study of time in the zone for worker exposure in the U.S. for log fumigation as conducted by SEC showed that at the pilot-scale, the maximum amount of time an applicator is within close proximity to the venting log stack was approximately 5 minutes.

58. This finding is similar to reports in ASG, 2020 that two tarps were removed on 11 December 2019 in 4 minutes;[14] tarps on 11 log stacks were removed in 62 minutes on 9 January 2020,[15] i.e. ~6 minutes per tarp. Even if this removal process were repeated 10 times in a shift, for example, and it was assumed that the crew was always directly downwind, this would constitute less than 1 hour of potential near-field exposure to the venting tarps.

59. Considering time in zone and the fact that fitted respirator use is required, the actual 8-hour weighted exposures would be substantially lower than the modeling as a function of set distances from the log stacks that assumes eight continuous hours of exposure. These issues apply to both the probabilistic and deterministic modeling analyses. Furthermore, the results tables for the deterministic analysis more conservatively assume that the highest 1-hour emission rate occurs for every hour from 7:00 A.M. to 7:00 P.M., which produces extreme conservatism when computing the highest and second-highest modeled concentration over the three-year periods evaluated in the deterministic modeling. For this reason, a more realistic

[13] For example, at pages 6-7 and 22.

[14] At page 13.

[15] Pages 26-27.

assessment is shown in the bottom half of near-field deterministic tables, i.e. Table 1-3 and Table 1-4 of the SEC report, where the impacts are divided by eight, i.e. assuming that an application crew member was fixed at the specified downwind distance more realistically for one hour per day.

MEASURED DATA / MONITORING RESULTS

60. Measured air quality data provide a means to evaluate the modeled data in a limited fashion. The goal of the expert panel is to seek modeling scenarios that are reasonably consistent with measured data, i.e. "*Use monitoring data to inform performance of model*."[16]

61. Measured air quality data have been collected by Genera as part of its resource consent, by Golder as part of their 2019 modeling report, and by Worksafe. The most extensive data are for total volatile organic compounds (TVOC), which includes methyl bromide.

Genera and Golder Data

62. Genera performs routine data collection using PID monitors to meet the conditions of its resource consent. These measured data are representative of the port boundary, or near-port boundary locations. Genera calibrates the PID monitors following the recommended process every two weeks and the sensitivity factor for methyl bromide of 1.9 is incorporated into the readings.

63. Typically three monitors are placed downwind of the ventilating source near the boundary (directly downwind, 45 degrees to the left of direct downwind, and 45 degrees to the right of direct downwind).

64. On more limited occasions, paired TVOC and canister methyl bromide data are available at common sites including locations at or near the port boundary and more near-field exposures. Also, on a limited basis, gas chromatographs have been used in the Golder study to obtain short-term sampling and variability of methyl bromide concentrations within the hourly averages typically measured for TVOC and methyl bromide canister sampling.

[16] Joint Statement Of Experts In The Field Of Air Dispersion Modelling 30 January 2020.

65. Figure 1 shows the measured 2019 TVOC data collected by PID through Genera's response to the resource consent requirement. As shown, it is very rare for the total VOCs to exceed 1 ppm. Figure 2 shows the maximum concentrations by month. Figure 3 presents the distribution of the 2019 TVOC measured data at the port boundary. Table 1 shows the expected dilution with ambient air of a methyl bromide plume emitted from a log stack (3,750 m^3 volume source) based on the SCREEN3 model. Figure 4 shows the ratios of paired TVOC/methyl bromide ratios for the Golder data.

66. The Golder measured data shows:

(a) TVOC rarely exceeds 1 ppm at the port boundary based on 1 hour averaging directly downwind of the venting log stack;

(b) the highest concentrations tend to be associated with the closer distances to the boundary;

(c) by 100 m of downwind travel or more the plume including the methyl bromide component during daytime venting procedures would be expected to comprise only 10-20 percent of the plume as compared to a reference distance of 25 m from the venting log stack (refer to Table 1). This finding is consistent with the observation based on the Genera paired data set of TVOC and methyl bromide over the past full three years, i.e. on a typical day the methyl bromide concentrations are 17 percent of the total VOCs even though in close proximity to the log stacks methyl bromide would be expected to dominate. As the plume grows via entrainment of ambient air, the mixture of VOCs becomes more and more dilute in terms of the methyl bromide component.

Golder Measured Data May through August 2019

67. In addition to the routine data collection by Genera, special data collection was performed for a report issued by Golder in October 2019. On two days in 2019 (30 May and 8 August) there were high methyl bromide measurements where the ratios of TVOCs / methyl bromide showed more than two times higher methyl bromide concentration as compared to TVOC at the site boundary. Table 2 shows comparative paired TVOC and methyl bromide paired data collected by Genera and Golder. Figure 5 shows the ratio of

TVOCs / methyl bromide for Genera and Golder data. As shown, the special study by Golder at the bottom of Table 2 show ratios that are inconsistent with the earlier three years of paired data.

68. In my judgment, there are unresolved questions in the Golder data set that would need to be resolved prior to relying on these limited samples. Attempts have been made to get answers on these unresolved questions, but to date, I have not received any information that would lead me to rely on these anomalous data. The ratios at the boundary of TVOCs / methyl bromide on these two days are greatly different than the long-term data set. In particular, these boundary samples taken 130 m and 330 m from the venting operations would have had a great degree of dilution from entraining ambient air during unstable daytime conditions. Such dilution would have rendered the importance of general VOCs to become more significant than at closer distances. I would expect the ratio of TVOC/methyl bromide to increase with distance. In this respect the data are anomalous.

69. Further, over the course of a full year (2019) only three boundary samples had concentrations of TVOC greater than 1 ppm, with a maximum of 1.6 ppm. On this basis, it would be highly unlikely that the methyl bromide fraction of TVOC would exceed 2 ppm for two out of three boundary samples with associated TVOC values in the range with values of 0.9 to 1.1 ppm.

Worksafe Data

70. Worksafe commissioned monitoring at the port based on methyl bromide specific canister sampling and total PID monitoring of total VOCs. The results are shown in Table 3. As shown, there was one sample greater than 1 ppm, which was measured on 9 January 2020 at 1.2 ppm (1,220 ppb). The remaining 22 paired samples showed measured methyl bromide concentrations of 0.6 ppm or less.

71. The relevant fumigation activities at the port at the time of the sampling on 9 January 2020 were:

(a) A total of 11 rows were vented from 16:01 to 17:02, which would be expected to have generally favourable dispersion conditions (although atmospheric stability conditions during venting are not documented in the report).

(b) The total applied amount applied was 559 kg, with an estimated release of 122 kg estimated.

This canister sample showing 1.2 ppm methyl bromide was marginally higher than the TVOCs (0.98 ppm) as measured by the associated PID. Therefore, taking these paired samples on face value it would be expected that all of the VOCs in the plume after 200 m of dilution was comprised of MB. Considering the travel distance of 200 m, however, it would be expected that the core plume at 200 m would be diluted to 10 percent of the original plume concentration (refer to Table 1). On this basis, similar to the Golder samples, although with a more marginal exceedance, the discrepancy between the TVOC and canister sampling should be resolved prior to relying on this paired sample.

CONCLUSIONS: MONITORING RESULTS

72. My conclusions regarding measured concentrations can be summed as follows.

73. Typical TVOC concentrations at the site boundary and directly downwind of active ventilation have a median of approximately 0.06 ppm. There are 47 paired TVOC and methyl bromide samples collected by Genera, the Golder study, and the Worksafe study that I have reviewed. Three out of the 47 samples showed exceedances of the 1 ppm level at or near the boundary, i.e. 1.2 ppm for Worksafe and 2.2 ppm and 2.3 ppm for Golder. These exceedances shared the following common factor: the measured methyl bromide concentrations were greater than the TVOC.

74. The PID instruments used by Genera and Golder data provide an indication of TVOC with the instruments calibrated for the sensitivity for the air pollutant of interest, which in this case is methyl bromide. For Genera, for example, the PID units are calibrated every two weeks (the manufacturer's recommendation is at least once annually). In addition, the methyl bromide specific sensitivity factor of 1.9 is applied as recommended by the manufacturer. It would be expected that these instruments would provide reasonably accurate results, but not necessarily as accurate as methyl bromide-specific canister sampling. The manufacturer's stated accuracy for

the PID Cub used by Genera is +/- 5 percent.[17] The actual accuracy, however, could be affected by the specific mixture of VOCs. While some variability between the PID and canister sampling is expected, it is not likely that the differences should show the methyl bromide specific component of TVOC to be double TVOC hundreds of meters downwind of the source.

75. There simply is insufficient information at this time to explain these differences. On this basis, and for the reasons stated in the previous section, I do not support any reliance being placed on the 3 boundary samples with measured methyl bromide specific concentrations above 1 ppm.

CONCLUSIONS: MODELED CONCENTRATIONS

76. The modeling results of the base scenario that are representative of 2019 POT operations show concentrations that are generally within the existing TELs and WES for the 1-hour, 8-hour, and 24-hour averages. This assessment is based on using the equivalent percentiles to the 98th percentile when distributions are conservatively based on the first (maximum) hour of venting at the port, i.e. using the 99.5th percentile for 1-hour averaging, the 99th percentile for 8-hour averaging, and the 98th percentile for 24-hour averaging for the distributions in this the SEC modeling report based on all hours with active ventilation.

77. Within the port for worker exposures, nominal buffer zones can be established based on the conservative modeling analysis performed on a Monte Carlo basis. All results are less than the 5 ppm WES. Based on the upper-bound deterministic modeling for near-field exposures, on the other hand, the results are higher than the 5 ppm 8-hour WES. These exposures, however, are unrealistic for two reasons:

(a) the modeling assumes that every hour from 7:00 A.M. to 7:00 P.M. the log stacks of various sizes are offgassing at the maximum 1-hour rate applicable to the first hour of ventilation; and

[17] https://www.ionscience.com/products/cub-personal-voc-detector/.

(b) as with the probabilistic analysis, it is artificially assumed that the applicator is stationary at the downwind distance specified for the entire 8-hour shift.

Collectively these two factors inflate the modeled concentrations by well over a factor of 10-fold.

78. The annual chronic TEL value is exceeded in a relatively small commercial area along the southern portion of the port where the distance from the fumigation areas to the boundary is compressed. I note there are no residential areas where these exceedances are shown and annual chronic thresholds are typically for the protection of residents exposed over durations far longer than workers. At all residential locations, the annual TEL is not exceeded by a wide margin.

79. The probabilistic modeling that is based on 24 simulated years of operation based on practices applicable to 2019 at the Port of Tauranga provides reasonable stable distributions of exposure for percentiles other than the extreme upper tail of the distribution. Consistent with the nature of Monte Carlo modeling methods, there will be some variability in the results for repeated runs. This variability tends to be more significant at the extreme upper tail of the distribution, such as the 99.99th and 100th percentile. If the goal was to create a stable distribution up to the 100th percentile, a much longer simulation period would be needed than 24 years. The selected 24-year period provides reasonable stability for the distributions for the range of the 98th through 99th percentiles, which are the primary focus of this analysis. If a single scenario were to be isolated, a longer duration simulation could be run to create more stability in the upper extreme of the distribution if this is deemed necessary in the future.

MODEL PERFORMANCE REVIEW

80. There are inherent limitations when comparing measured and modeled data.

81. First, the available measured data at the port were not designed to support standard model performance review because the emissions data are not measured values but have had to be estimated in the absence of dedicated flux studies.

82. Second, comparing measured and modeled data for 1-hour concentrations paired in time and space exceeds the skill level of dispersion models such as CALPUFF and other alternatives. On this basis, the most appropriate point of comparison is to compare distributions of measured and modeled concentrations.

83. Figure 6 shows the modeled methyl bromide concentrations in comparison to the modeled concentrations based on the Base Scenario, with the first hour of venting as the basis for the distributions to be consistent with the basis for the measured PID data. As shown, at the upper percentiles, the correspondence between TVOC and the modeled methyl bromide is most closely represented by the 98th-99th percentiles. At lower percentiles, the general TVOCs beyond methyl bromide are dominating.

84. CALPUFF is a useful modeling tool, but like all air quality dispersion models, it is well recognized that model output is not accurate when paired in time and space. In other words, CALPUFF would be expected to provide reasonable estimates of average or upper percentile concentrations that would occur sometime during a year or season but not necessarily on a specific day and hour at a specific place.

85. For example, the U.S. Environmental Protection Agency's Guideline on Air Quality models states:[18]

> We (EPA) acknowledge the issues and potential challenges associated with conducting field studies for use in model performance evaluations, especially during stable light wind conditions, given the potentially high degree of variability that may exist across the modeling domain and the increased potential for microscale influences on plume transport and dilution. This variability is one of the reasons that we discourage placing too much weight on modeled versus predicted concentrations paired in time and space in model performance evaluations.)….Because of the uncertainty in paired modeled and observed concentrations, any attempts at calibration of models based on these comparisons is of questionable benefit and shall not be done.

86. Other organizations and peer-reviewed literature support the same position:[19]

[18] EPA Guideline on Air Quality Models Federal Register January 17, 2017 Page 5209.
[19] Frost, K.D. (2014) AERMOD performance evaluation for three coalfired electrical generating units in Southwest Indiana, Journal of the Air & Waste Management Association, 64:3, 280-290, DOI: 10.1080/10962247.2013.858651.

> Hourly paired comparisons represent an extremely stringent measure of model performance, as even small instrumentation errors or shifts in wind direction can cause a spatial displacement between model predictions and observations.

87. These limitations are not eliminated by using CALPUFF in an hourly or minute-by-minute fashion.

88. Similarly, the European Environmental Agency notes:[20]

> The models have difficulty predicting the maxima at the right time and place, although the predicated peaks are in the correct general areas and the offsets in time are random within 2h limits. Thus, is rather difficult to predict the peaks in the same location as a monitoring network.

89. Rather than emphasizing how well CALPUFF replicated specific monitoring site locations at specific hours, my focus is using measured data to show how effectively CALPUFF replicated the upper percentile concentrations not constrained in time and space.

90. Measured concentrations collected by WorkSafe and Genera also have been included in this review. There is some limited coverage in 2019 and 2020 where there are both PID data and canister data that provide specific methyl bromide coverage. Measured concentrations applicable to 2019 have been emphasized since these are representative of the port operation records of 2019 that are the basis to assign venting operations.

91. The most appropriate form of comparison of measured and modeled concentrations is on a distributional basis, comparing maximum boundary concentrations based on modeling and measured concentrations. Detailed statistics (such as correlation analysis, bias, root mean error analysis, etc.) that would be appropriate for research purposes generally involve situations where the emissions are known (measured) on an ongoing basis (or a tracer is used) and the monitoring network was designed for model performance purposes. Neither of those conditions applies here.

92. While formatted meteorological data for 2019 was not available to allow me to compare it with the operational data directly I am satisfied that there is no need to undertake a detailed statistical analysis as the percentile approach

[20] European Environmental Agency, Modeling, 20 April 2016 Section 5.4 (Uncertainty of Modeling Results)

over 24 years of modeling that I have used is sufficient to cover the expected concentrations. In my view it is appropriate to compare the distribution of measured and modeled maximum eastern port boundary concentrations as shown in Figure 6 for the Base Scenario that represents port operations in 2019. For further perspective, the special study methyl bromide specific data at the boundary showed maximum measured concentrations in the range of 2.0 to 2.2 ppm, which is of similar magnitude to the 99.99th percentile based on the distribution of hours associated with active venting at the port.

93. The emphasis of the modeling in my expert report was on representing the 2019 port operations. This was referred to as the base scenario in my report. Due to time constraints, it was not feasible to model every alternative recapture rate scenario, but in my judgment a sufficient number of scenarios were run to describe the expected benefits of alternative recapture goals. In the interest of time, each of the alternative modeled scenarios was corrected for the relatively minor issue associated with the far-field modeled runs and the corrected runs are in Appendix A. Minor differences are shown between the results in the SEC June 2020 report and the updates in Appendix A.

94. While I agree that it would have been desirable to have an additional two years of CALMET ready data to further document meteorological variability, I do not expect that the modeled distributions would have been substantially different if the additional two years were included in the data set. While it is possible that the upper extreme of the distributions could have been increased, three years of meteorological data with 24 simulated years of Monte Carlo based port operations provides a sufficient range of conditions for the analysis, especially for reasonable upper-end percentiles sufficiently below the 100th percentile.

MITIGATION MEASURES

95. If deemed necessary, there are several options available to further reduce exposure to methyl bromide concentrations. These options include:

(a) reduced maximum application rate (if agreed by trading partners),

(b) enhanced recapture to more consistently achieve the higher end of the range of recapture efficiency that is possible with current technology, and

(c) conducting fumigation of the largest category log stacks in Location 1, which has the greatest distance to the property boundary.

I defer to other experts as to which measure(s) would be the most efficient way to reduce emissions in the event that this is deemed necessary. From a modeling perspective, however, option (c) above provides a practical means of reducing impacts at the port boundary for all averaging times. The greater atmospheric dilution associated with the greater distance to boundary, especially during daytime conditions, may provide a more timely option than the preceding two alternatives.

DAVID A. SULLIVAN
Certified Consulting Meteorologist

27 July 2020

REFERENCES

California Office of Environmental Health and Hazard Assessment, Appendix D.2 Acute RELs and toxicity summaries using the previous version of the Hot Spots Risk Assessment guidelines (OEHHA 1999).

European Environmental Agency, modelling, 20 April 2016 Section 5.4 (Uncertainty of modelling Results).

Fox, Douglas, Judging Air Quality Model Performance: A Summary of the AMS Workshop on Model Performance, 8-11, September 1980, Bulletin of the American Meteorological Society, Vol. 62, No. 5, May 1981, 599-615.

Frost, K.D. (2014) AERMOD performance evaluation for three coalfired electrical generating units in Southwest Indiana, Journal of the Air & Waste Management Association, 64:3, 280-290, DOI: 10.1080/10962247.2013.858651.

Ion, Cub PID monitor specifications: https://www.ionscience.com/products/cub-personal-voc-detector/.

Joint Statement Of Experts In The Field Of Air Dispersion Modelling 30 January 2020.

Joint Statement Of Experts In The Field Of Air Dispersion Modelling 19 March 2020,

Personal communication with Dr. Julien Huteau 30 January 2020.

Sullivan Environmental Consulting, Inc., Documenting Worker Movements Associated with Timber Fumigation of a Surface-Based Log set, a Tarped Container, and Untarped Container (Without Product Applied), March 2019, submitted to U.S. Environmental Protection Agency in 2020.

U.S. Environmental Protection Agency, Guideline on Air Quality Models, 40 CFR Part 51, Federal Register, Vol. 82, No. 10 / Tuesday, January 17, 2017 / Rules and Regulations

Figure 1: 2019 PID Measurement of TVOC Data by Genera as Required by the Resource Consent as a Function of Distance from Venting Source

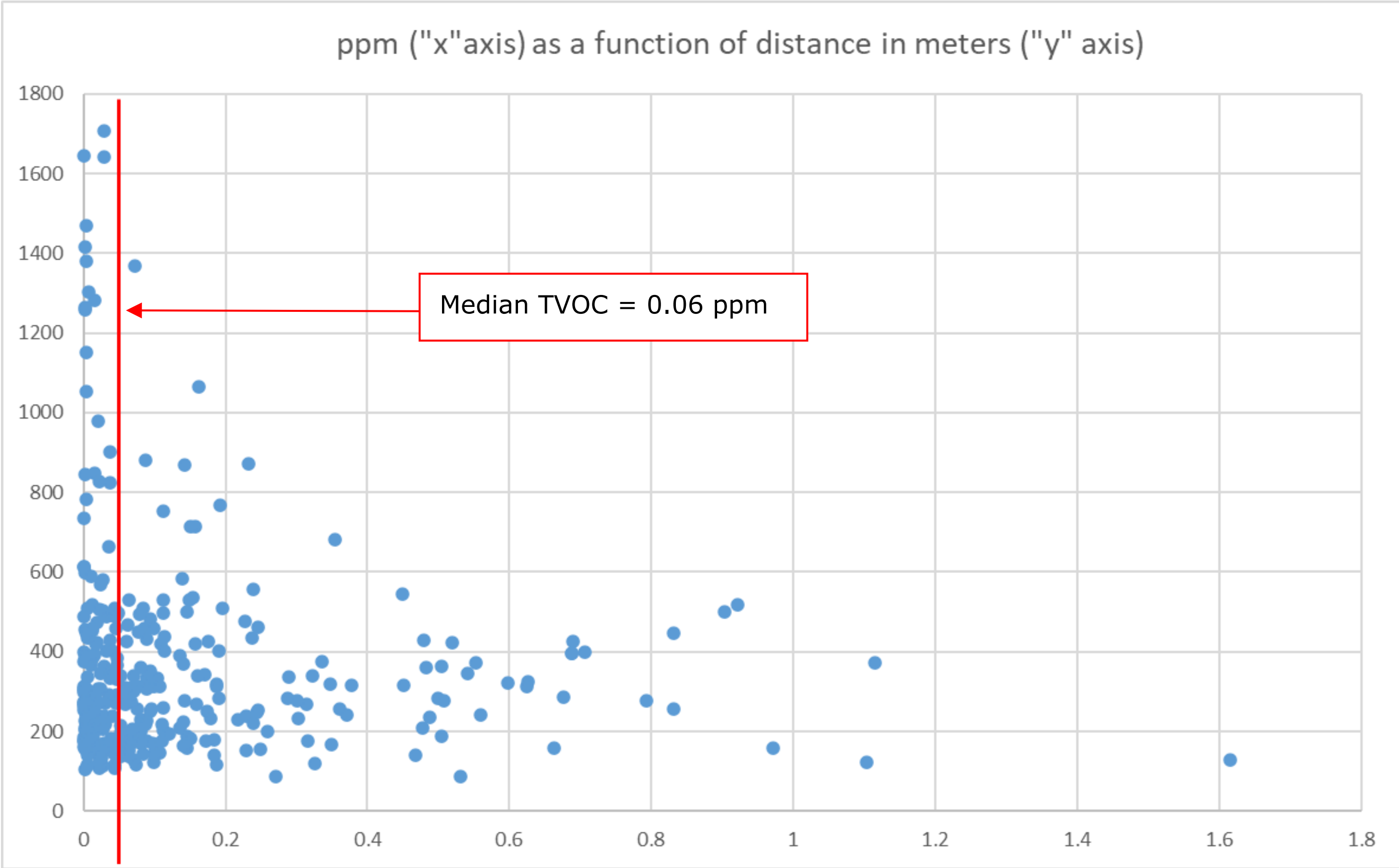


Figure 2: Maximum Monthly TVOC Concentrations (ppm) at the Port Boundary

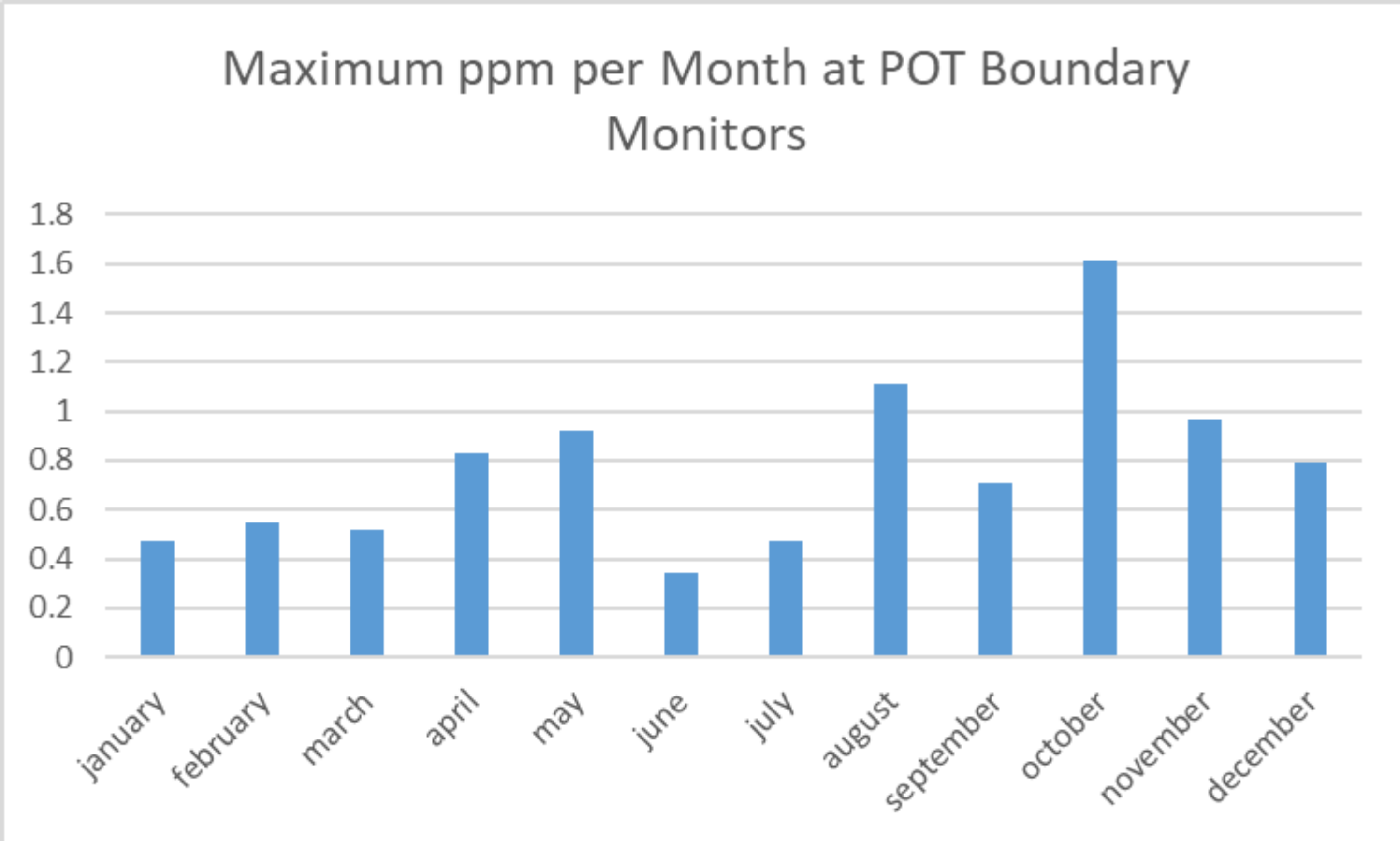


Figure 3: Annual Distribution of Measured TVOCs at the Port Boundary

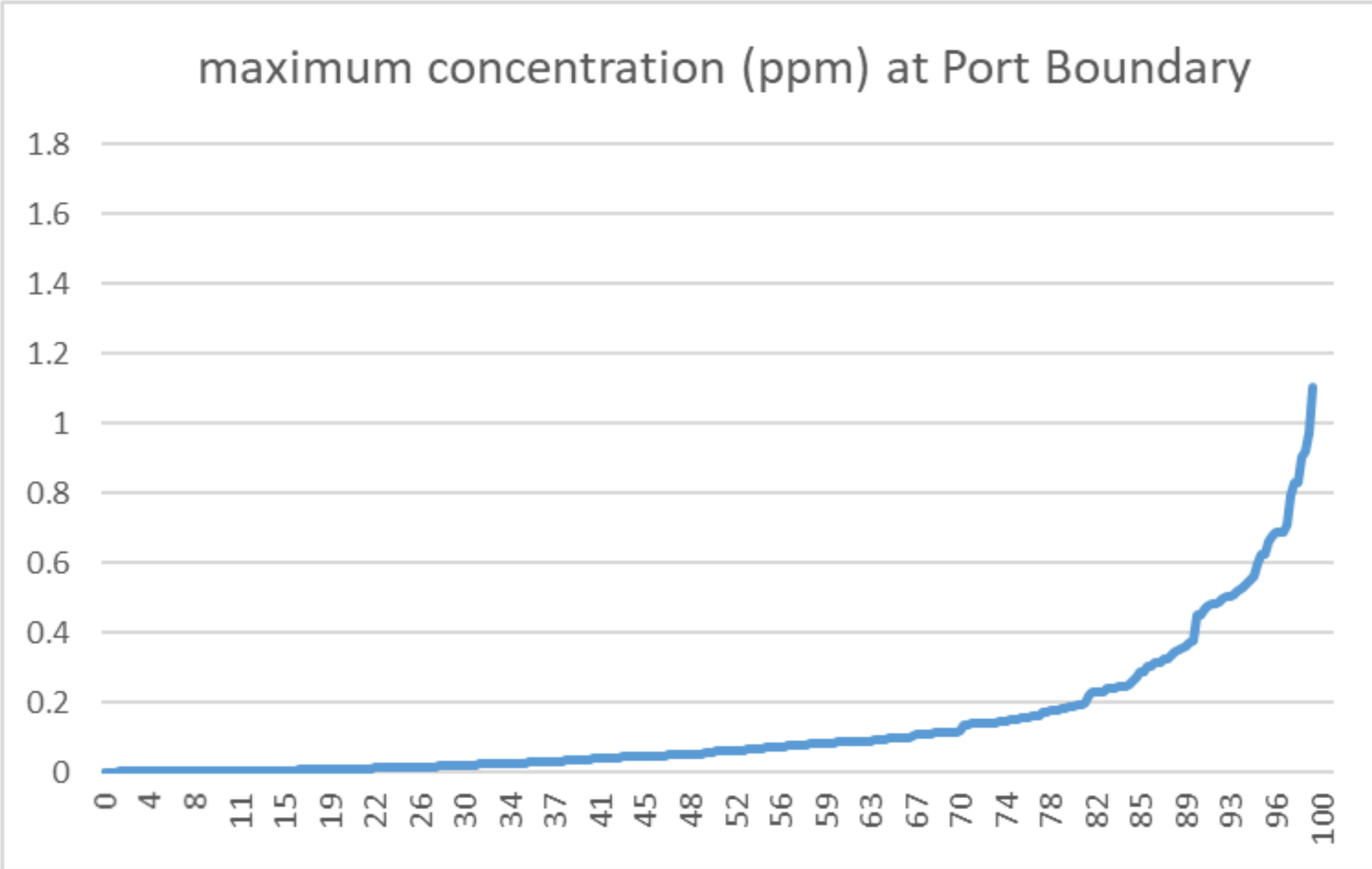


Figure 4: Ratio of TVOCs / MB Based on Data Collected by Genera (2017-2019)

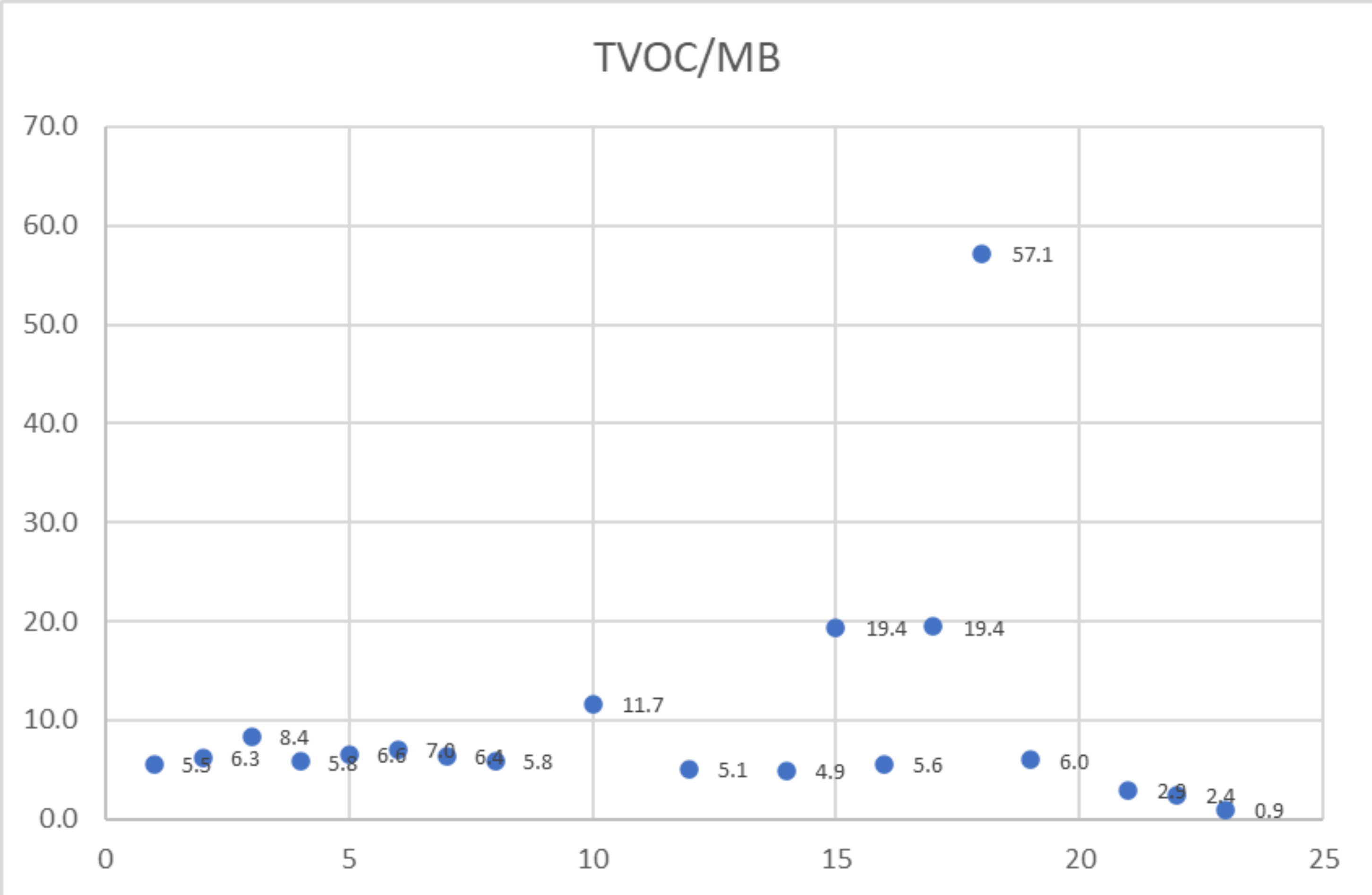


Figure 5: Comparison of Ratios of TVOC Genera with Golder Special Study (ratio on “y” axis; observation along “x” axis)

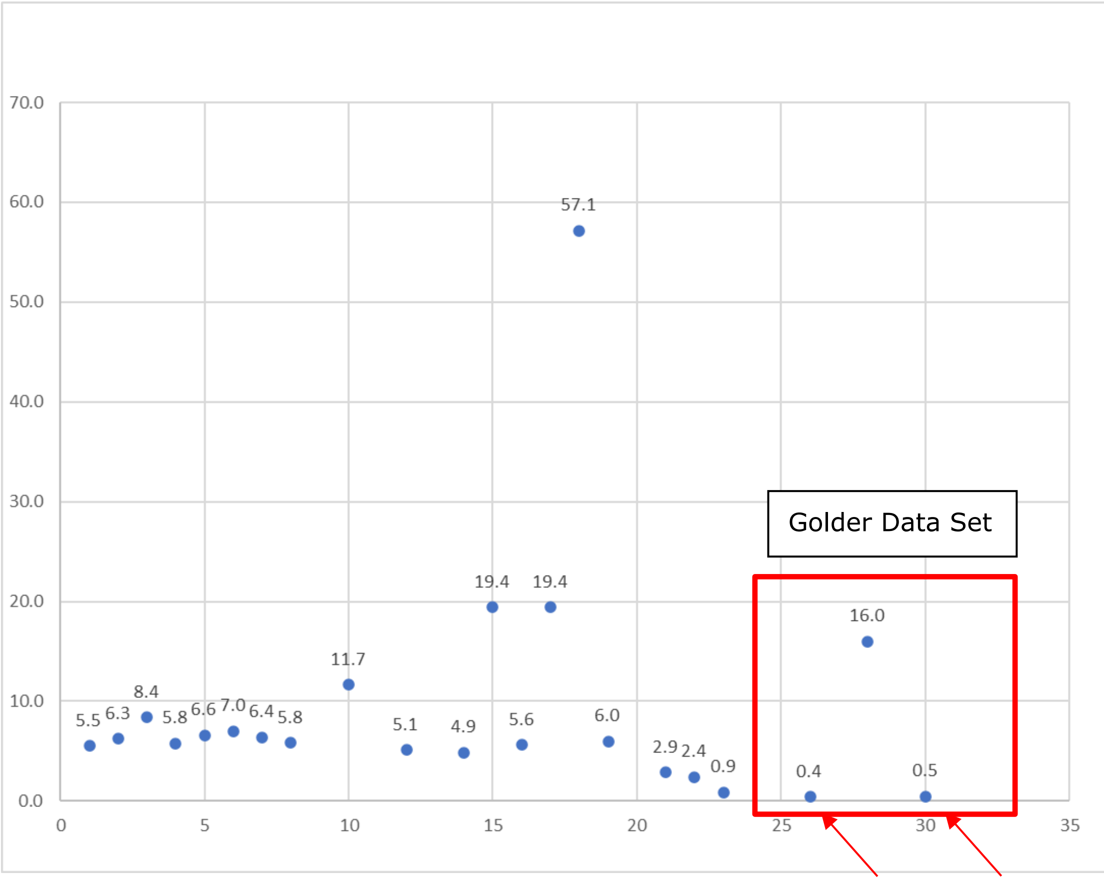
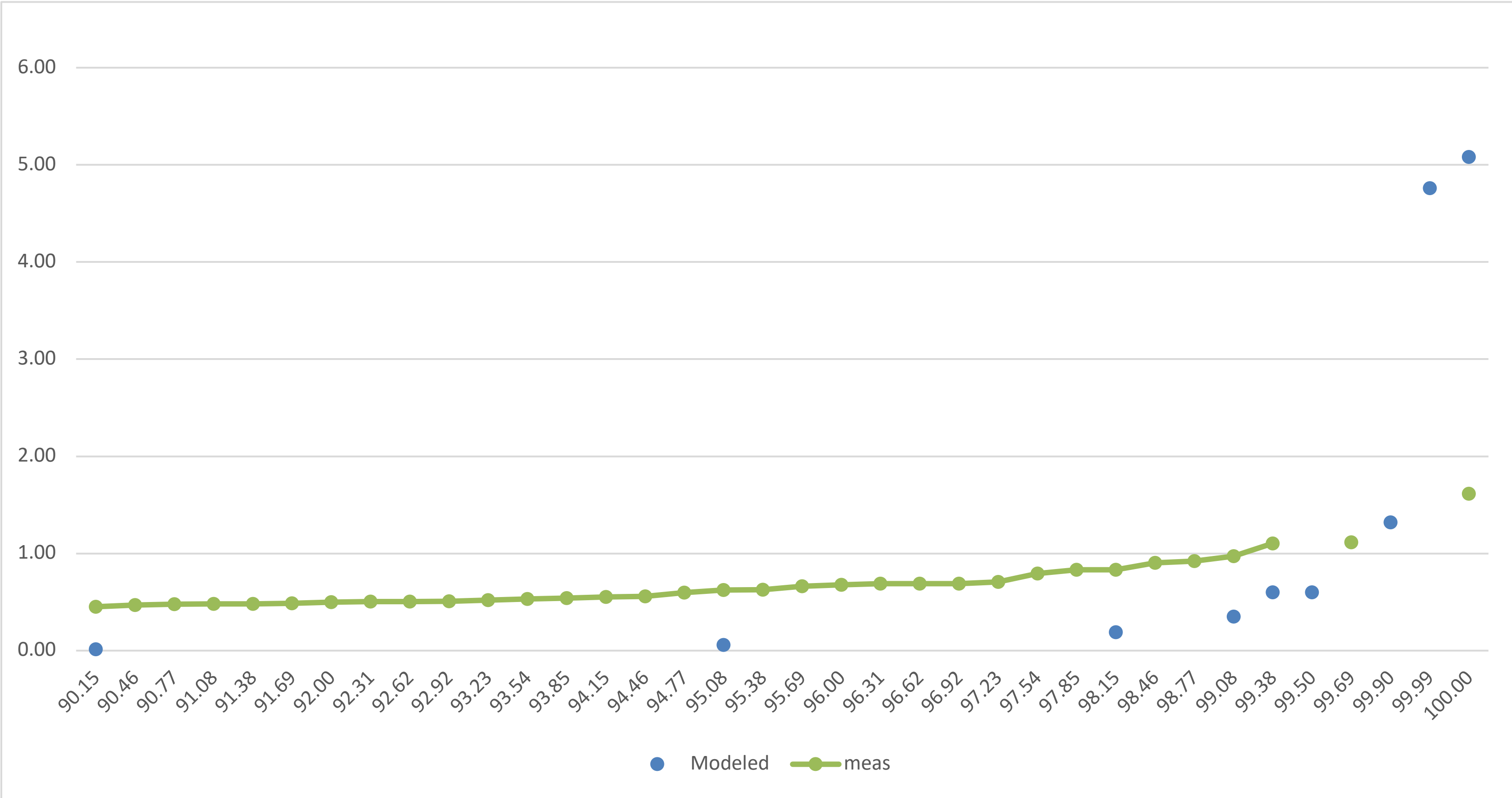


Figure 6: Comparison of Measured Maximum PID Concentration Distribution with Base Scenario Modeled Distribution[21] of Comparable First Hour Venting Concentrations (ppm)



[21] The modeled distribution represents the maximum concentration along the port boundary while the measured distributions are the highest of the three downwind monitors established based on wind direction at the start of the venting period. These differences should be considered with interpreting these data.

Table 1: Model-Based Computations of Ratio of Modeled Concentrations at Various Distances Downwind over the Modeled Concentration at 25 m (showing the dilution ratio of the methyl bromide plume during daytime dispersion conditions as a function of downwind distance (m))

	Dilution Ratios Relative to Concentration @ 25 M				
	Stability	25 m	50 m	100 m	200 m
URBAN	A	1.00	0.22	0.08	0.01
RURAL	A	1.00	0.30	0.10	0.03
URBAN	B	1.00	0.24	0.09	0.03
RURAL	B	1.00	0.39	0.17	0.06
URBAN	C	1.00	0.28	0.10	0.03
RURAL	C	1.00	0.45	0.23	0.09
URBAN	D	1.00	0.36	0.14	0.06
RURAL	D	1.00	0.60	0.32	0.14

Note that B stability / rural conditions shows a dilution ratio of 0.17 at 100 m, which is comparable to the typical ratio of methyl bromide / TVOC based on the composite paired data set.

Table 2: Paired Total VOCs and Methyl Bromide Data Collected by Genera and Golder

Report	ID	TVOC (ppm)	MB (ppm)	Location	Distance (m)	Ratio TVOC/MB
Tauranga 2017	1	0.132	0.024	Boundary		5.5
Tauranga 2017	2	0.058	0.009	Boundary		6.3
Tauranga 2017	3	0.233	0.028	Boundary		8.4
Tauranga 2017	4	1.573	0.271	Boundary		5.8
Tauranga 2017	5	0.527	0.080	Boundary		6.6
Tauranga 2017	6	0.120	0.017	Boundary		7.0
Tauranga 2017	7	0.118	0.018	Boundary		6.4
Tauranga 2017	8	0.083	0.014	Boundary		5.8
Tauranga 2017	9	0.001	0.000	Boundary		
Tauranga 2017	10	0.186	0.016	Boundary		11.7
Tauranga 2017	11	0.036	0.000	Boundary		
Tauranga 2017	12	0.157	0.031	Boundary		5.1
Tauranga 2018	1	0.581	0.120	Boundary		4.9
Tauranga 2018	2	0.308	0.016	Boundary		19.4
Tauranga 2018	3	0.515	0.091	Boundary		5.6
Tauranga 2018	4	0.047	0.002	Boundary		19.4
Tauranga 2018	5	0.147	0.003	Boundary		57.1
Tauranga 2018	6	0.066	0.011	Boundary		6.0
Tauranga 2019	1	0.704	0.244	Boundary		2.9
Tauranga 2019	2	0.023	0.009	Boundary		2.4
Tauranga 2019	3	0.128	0.143	Boundary		0.9
Golder 2019	1	11	35.9	onsite	60	0.3
Golder 2019	2	0.92	2.2	Boundary	330	0.4
Golder 2019	3	0.49	0.19	onsite	60	2.6
Golder 2019	4	0.16	0.01	Boundary	230	16.0
Golder 2019	5	2.9	6.4	onsite	80	0.5
Golder 2019	6	1.1	2.3	Boundary	130	0.5
			median			5.8

Table 3: Paired Total VOCs and Methyl Bromide Data Collected by Worksafe

date	applicatior	Site	ppb PID	ppb Canister	PID/Canister	Distance
20-Nov-19	log stacks	1	450	180	2.50	160
20-Nov-19	log stacks	2	862	259	3.33	130
20-Nov-19	log stacks	3	926	409	2.26	150
27-Nov-19	ship	5	44	21	2.10	630
27-Nov-19	ship	6	515	180	2.86	760
27-Nov-19	ship	7	264	37	7.14	780
27-Nov-19	ship	8	1	0.25	4.00	770
11-Dec-19	log stacks	6	188	20	9.40	1260
11-Dec-19	log stacks	9	389	162	2.40	210
11-Dec-19	log stacks	10	293	243	1.21	260
11-Dec-19	log stacks	11	180	8	22.50	630
9-Jan-20	log stacks	2	116	0.25	464.00	360
9-Jan-20	log stacks	14	1	13.5	0.07	420
9-Jan-20	log stacks	15	311	274	1.14	300
9-Jan-20	log stacks	16	983	1220	0.81	200
25-Jan-20	log stacks	3	1339	720	1.86	150
25-Jan-20	log stacks	9	464	201	2.31	200
25-Jan-20	log stacks	18	475	11	43.18	160
25-Jan-20	log stacks	19	64	266	0.24	260
25-Jan-20	log stacks	5	31	12	2.58	570
25-Jan-20	log stacks	11	709	603	1.18	210
25-Jan-20	log stacks	20	1	4.3	0.23	160
25-Jan-20	log stacks	21	56	5	11.20	320
				median	2.40	

Appendix A: Final Modeling Results for the Far-Field Analysis with Minor Corrections to the Alternative Recapture Scenarios with Corrections Made to the Ship Hold Depth for the Ship Contributions to the Distributions

This appendix is provided to correct a minor error in the ship contributions to the total distributions in the SEC report of June 2020. The ship depth component of the volume calculation was understated. The SEC report provided approximate percent benefits of the alternative recapture scenarios. This appendix provides the updated values, which generally show minor differences from those in the report, i.e. generally less than 10-20 percent.

The following page provides three tables: (a) the top table shows the far field results with the approximated percent reduction benefits relate to the base scenario, (b) the middle table show the updated results based on the corrected analysis, and (c) the bottom table shows the percent difference between the original and corrected results.

TABLE FROM REPORT ON PERCENTAGE DIFFERENCES

Scenario	1-Hour				24-Hour				Annual Average (Across 3-year Period)
	98th	99.5th	99.99th	100th	98th	99.5th	99.99th	100th	
Base 2019 70% / 30% Limited to First Hour Emissions	0.199	0.574	3.944	12.131	0.028	0.058	0.341	0.519	0.0010
Base 2019 70% / 30%	0.045	0.212	2.176	15.424	0.027	0.058	0.252	0.652	0.0015
70% / 30%	80%	95%	110%	155%	95%	110%	90%	155%	150%
70% / 45%	80%	95%	100%	70%	95%	110%	90%	70%	120%
70% / 60 %	60%	80%	85%	60%	80%	90%	50%	60%	105%
70% / 80%	50%	50%	80%	120%	55%	80%	50%	120%	105%
Low Rate 40 g/m^3 70% / 30%	40%	45%	30%	30%	40%	45%	30%	25%	50%

New Percentages

	1-Hour				24-Hour				
	98th	99.5th	99.99th	100th	98th	99.5th	99.99th	100th	Annual
70% / 30%	119%	113%	115%	180%	109%	113%	129%	179%	109.7%
70% / 45%	111%	110%	106%	61%	110%	98%	142%	61%	100.1%
70% / 60 %	98%	88%	87%	60%	91%	87%	82%	69%	96.3%
70% / 80%	69%	64%	89%	73%	73%	77%	142%	79%	94.1%
Low Rate 40 g/m^3 70% / 30%	59%	51%	62%	63%	47%	56%	73%	63%	60.0%

Comparison of Estimates from Original Report to Actual Modeling Results for Alternative Scenarios

	1-Hour				24-Hour				
Alternative Scenario	98th	99.5th	99.99th	100th	98th	99.5th	99.99th	100th	Annual
70% / 30%	33%	16%	4%	14%	13%	3%	30%	13%	-36.8%
70% / 45%	28%	13%	5%	-15%	13%	-12%	37%	-15%	-19.9%
70% / 60 %	39%	9%	2%	-1%	12%	-3%	39%	13%	-9.0%
70% / 80%	27%	22%	10%	-65%	25%	-3%	65%	-51%	-11.6%
Low Rate 40 g/m^3 70% / 30%	32%	11%	52%	52%	14%	20%	59%	60%	16.7%

Appendix B: Worst-Case Scenario Results

The special worst-case scenario was run using 0% capture efficiency to provide additional perspective to the modeling of the alternative scenarios. Without any controls employed at the Port of Tauranga, the concentrations are expected to be larger by a significant margin as is being shown here across the various averaging periods.

Scenario	1-Hour				24-Hour				Annual Average (Across 3-year Period)
	98th	99.5th	99.99th	100th	98th	99.5th	99.99th	100th	
Worst Case 0%/0%	0.061	0.308	3.455	33.191	0.037	0.077	0.544	1.414	0.0030