ATTACHMENT C
Indiana Department of Environmental Management
Office of Air Quality
Study of AERMOD Accuracy

Indiana Department of Environmental Management
Office of Air Quality
www.idem.IN.gov

An Assessment of the American Meteorological Society/U.S. EPA Regulatory Model's (AERMOD's) Accuracy: A Case Study

Keith Baugues
Assistant Commissioner, Office of Air Quality
Indiana Department of Environmental Management
May 29, 2015

TABLE OF CONTENTS

SECTION PAGE

LIST OF FIGURES

FIGURE PAGE

LIST OF TABLES

TABLE PAGE

EXECUTIVE SUMMARY

This analysis compares predicted and observed SO2 levels at the Gibson power plant in southwestern Indiana. Actual hourly SO2 emission rates for 2010 were modeled in AERMOD and compared to SO2 levels measured at four monitors near the plant. Modeling was conducted using Evansville meteorological data (Scenario 2) and on-site meteorological data (Scenario 3).

Using Evansville meteorological data, AERMOD predicted 450 hours of exceedances of the 1-hour standard. The monitors measured 11 hours of exceedances in 2010.

Direct comparisons of predicted and observed SO2 levels indicate that AERMOD significantly over-predicts by more than a factor of two. If comparisons are made using EPA's preferred approach, the analyses still show that AERMOD over-predicts by more than a factor of two.

Using on-site meteorological data, AERMOD predicted 610 hours of exceedances of the 1-hour standard. The monitors measured 11 hours of exceedances during this period.

Direct comparisons of predicted and observed SO2 levels indicate that AERMOD significantly over-predicts by more than a factor of two. If comparisons are made using EPA's preferred approach, the analyses still show that AERMOD over-predicts by more than a factor of two.

This analysis discovered that AERMOD often "blows up" when modeling low wind speeds (less than one meter per second). Under these conditions the model predicts high concentrations at all receptors regardless of wind direction.

We believe that this analysis demonstrates concerns with the use of AERMOD without making modifications to improve agreement between predicted and observed values and to reduce the amount of over-prediction.

ACKNOWLEDGEMENTS

I would like to thank several persons for their assistance in getting this project accomplished. First, I would like to thank Brian Callahan, Mark Neyman and Eric Bailey of my staff who put together the files and made the modeling runs. Also thanks to Kali Frost, a former staff member, who oversaw much of the preliminary analytical work.

Thanks to Randy Robinson of U.S. EPA Region V for his review and comments during this analysis. Special thanks to Chet Wayland, Roger Brode and Tyler Fox of the U.S. EPA's Office of Air Quality, Planning and Standards (OAQPS).

A final thanks to my Administrative Assistant, Agripina Sturgis, who put this report together.

BACKGROUND

In December of 2010 Indiana was faced with modeling over a hundred industrial sources to establish sulfur dioxide (SO2) limits necessary to comply with the one-hour standard. Prior to beginning this effort, I called Chet Wayland, Division Director at the U.S. EPA's Office of Air Quality, Planning and Standards (OAQPS) and asked how accurate the AERMOD model was. Instead of referring me to other studies, Chet asked us to conduct an analysis to demonstrate the relationship between AERMOD predictions and ambient measurements. This report documents the work carried out to answer this question.

It should be noted that IDEM's interest in doing this study was:

1) **To demonstrate that AERMOD worked very well.**
2) **To demonstrate that AERMOD did not work well and to work with the U.S. EPA to make corrections to improve performance.**

This analysis has taken a long time to reach this stage. During this review the version of AERMOD has changed, thoughts on how to carry out the comparisons or make the model estimates have changed and staff working on this project have left to take other jobs.

This analysis describes the methodology used for testing the model; the data used and provides several different analyses of the data.

In the end we want to be able to answer the question of how well does AERMOD predict 1-hour sulfur dioxide concentrations and if it does poorly are there refinements that can be made to improve model performance.

FACILITY

The Indiana Department of Environmental Management (IDEM) decided to test the performance of AERMOD by comparing model predictions with measured sulfur dioxide values near the Duke – Gibson power plant in southwestern Indiana. This facility was selected for several reasons:

1) **It is located such that it is not impacted by other nearby SO2 sources.**
2) **It has continuous emission monitors (CEMs) on each of its stacks so that hourly SO2 emission rates are known.**
3) **It has four SO2 monitors surrounding the facility.**
4) **It has a three level meteorological tower on-site taking numerous meteorological parameters.**

The year of 2010 was selected for analysis. Model predictions were made at the four monitoring sites under three meteorological scenarios. The first was to use on-site meteorological data prepared in the standard way. The second was to model using data from the nearest National Weather Service (NWS) station (Evansville) which is located approximately 40 kilometers south of the plant. The third scenario was to use on-site meteorological data, but to process it from the top down. Only results from the final two scenarios are included in this report. The U.S. EPA believes that the on-site data processed in the typical fashion is influenced by a nearby cooling pond. By processing the data from the top down, this problem should be minimized.

Modeling was based on actual hourly emission rates for each stack. This is an important point. Since emission rates vary by hour it is not appropriate to compare the data unless it is paired in time. You cannot compare the highest modeled and highest monitored hourly values for a site.

They may be based on very different emission totals or distributions of emissions by stack. This will be discussed in greater detail later.
Figure 1 shows the locations of the five stacks versus the four sulfur dioxide monitors. Winds from the following directions blow directly from the stacks to the four monitors:

Site	Wind Direction Range (degrees)
Mt. Carmel	**169 – 172**
Coal Road	**214 – 219**
East	**297 – 300**
Schrodt	**87 – 90**

All modeled values contain a background SO2 value. This background level is determined for each hour and is based on the lowest of the four monitored values for each hour.

SCENARIO 2 RESULTS

Scenario 2 involves modeling using National Weather Service data from Evansville which is approximately 40 kilometers south of the Gibson facility.

All Data

The first set of results included all data where the hour has both a modeled and a monitored concentration. Those hours where monitored values were missing were excluded from the analysis.

Mt. Carmel Site

Figure 2 shows a comparison of modeled and monitored concentrations compared in time for the Mt. Carmel site. The line from the lower left corner to the upper right corner shows where the model and monitor would perfectly agree. The dashed lines show the factor of 2 areas. The dashed line above the continuous line is the area where the model under-predicts but is within a factor of 2 of the monitored value. If values are above this line, the values under-predict the monitored value by more than a factor of 2. The dashed line at the bottom of the chart is the line of over-prediction. Values above this line are within a factor of two, but are over-predicted by AERMOD. Values that are below this line are over-predicted by more than a factor of two. Of the 8196 hours of data, 82.0 percent are within a factor of 2, 4.0 percent are under-predicted and 14.0 percent are over-predicted.

Figure 1

Gibson Generating Station

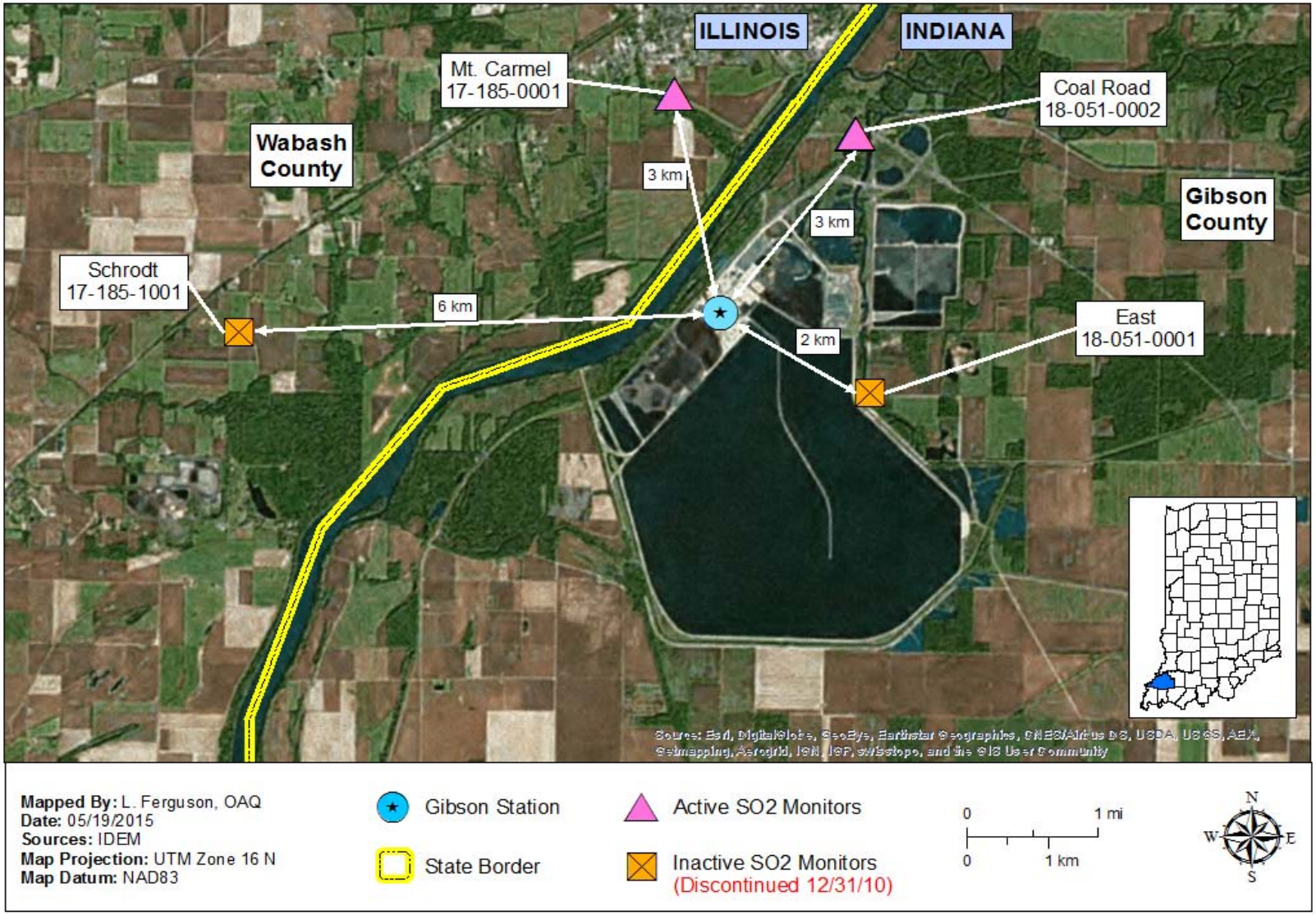
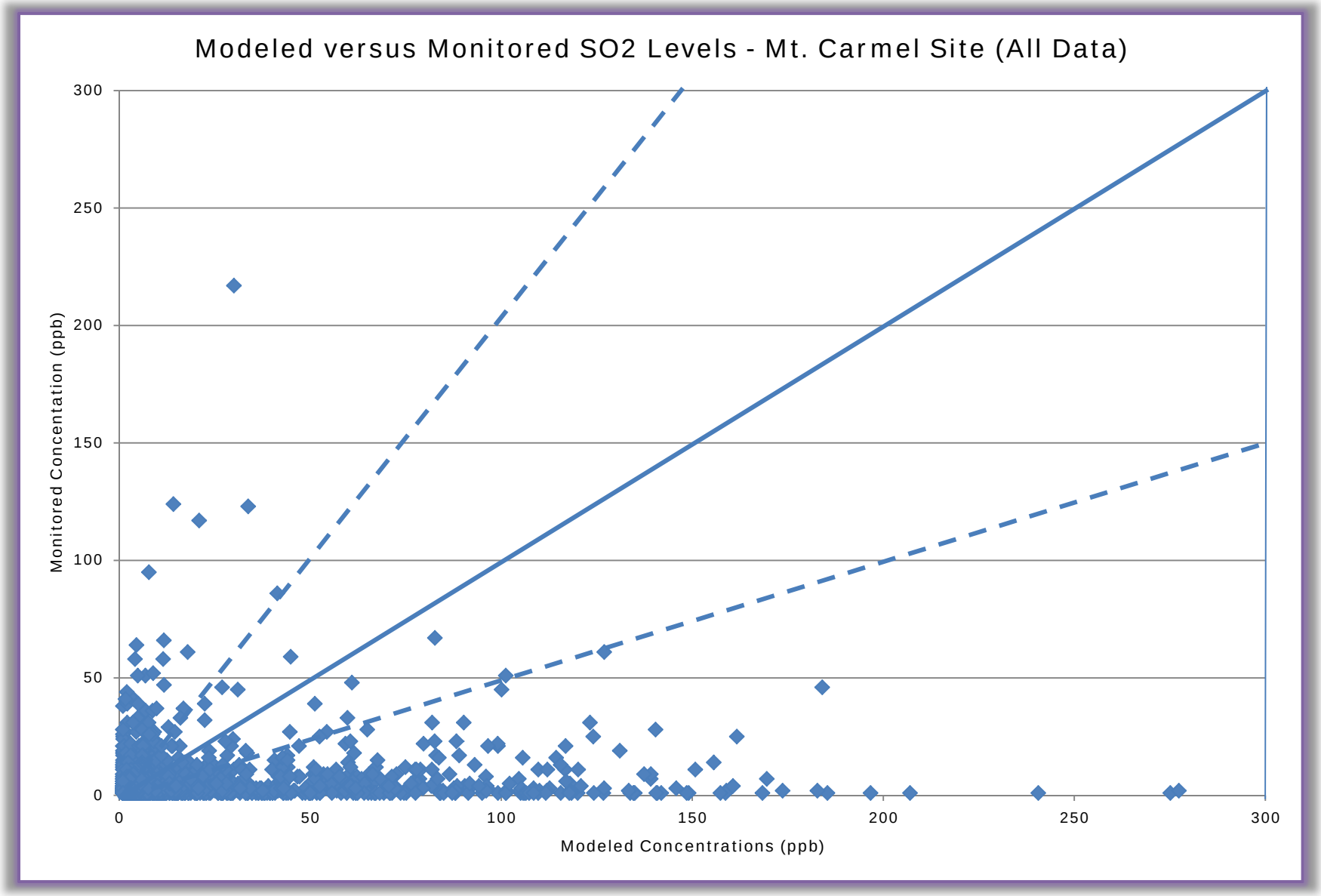


Figure 2


Modeled versus Monitored SO2 Levels - Mt. Carmel Site (All Data)
Monitored Concentation (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250
300

East Site

Figure 3 shows a comparison of modeled and monitored concentrations compared in time for the East site. Of the 8,344 hours, 77.6 percent are within a factor of 2, 8.7 percent are under-predicted and 13.7 percent are over-predicted.

Coal Road Site

Figure 4 shows a comparison of modeled and monitored concentrations compared in time for the Coal Road site. Of the 8333 hours, 72.2 percent are predicted within a factor of 2, 14.9 percent are under-predicted and 12.9 percent are over-predicted.

Schrodt Site

Figure 5 shows a comparison of modeled and monitored concentrations compared in time for the Schrodt site. Of the 8302 hours, 75.9 percent are predicted within a factor of 2, 18.8 percent are under-predicted and 5.3 percent are over-predicted.

SUMMARY

Table 1 summarizes the results for all four sites. Overall 76.9 percent of the predictions are within a factor of 2 of the measured values, 11.6 percent are under-predicted and 11.5 percent are over-predicted. On a first glance it would appear that AERMOD is working well. The majority of the predictions are within a factor of two and the amount of over-predictions is nearly equal to the number of under-predictions. Later results will explain why this is not the case.

Table 1

Results of Scenario 2 Analyses – All Data

	Mt. Carmel		East		Coal Road		Schrodt		Total	
Range	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent
<0.5	327	4.0	725	8.7	1245	14.9	1560	18.8	3857	11.6
0.5 – 2.0	6722	82.0	6473	77.6	6014	42.2	6300	75.9	25509	76.9
➢ **2.0**	1147	14.0	1146	13.7	1074	12.9	442	5.3	3809	11.5
Total	8196		8344		8333		8302		33175	

Figure 3

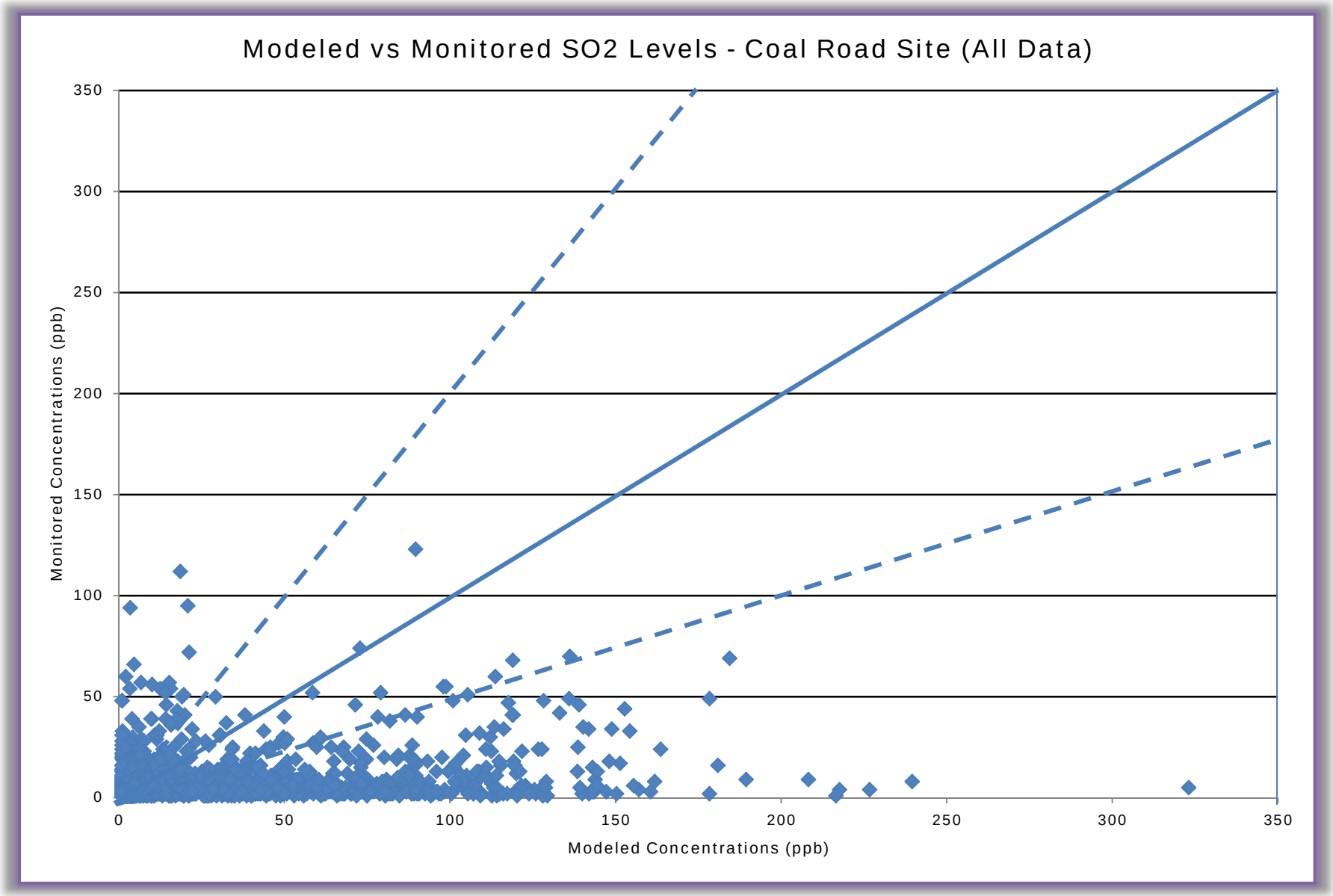
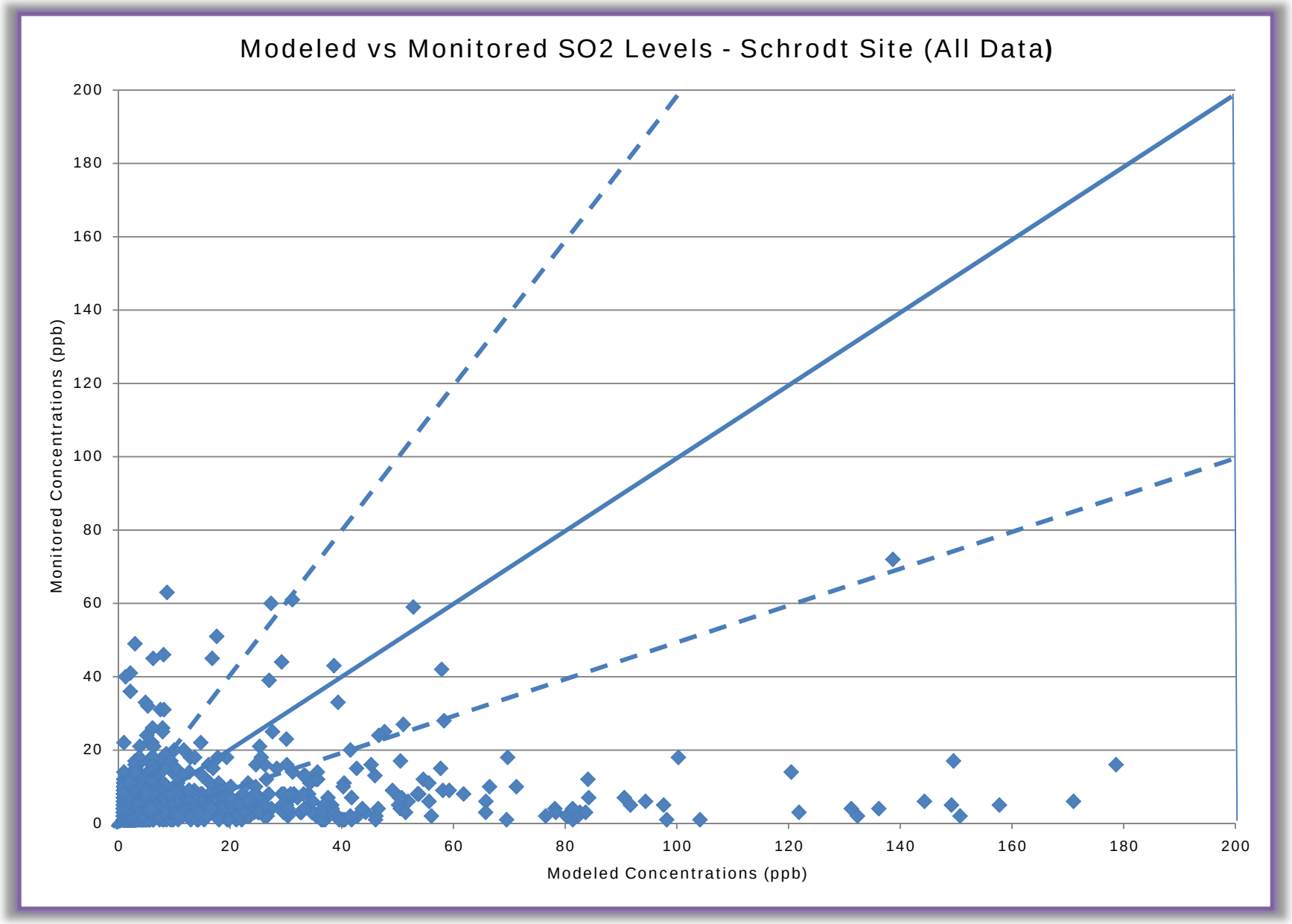

Modeled vs Monitored SO2 Levels - Coal Road Site (All Data)
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250
300
350

Figure 4


Modeled vs Monitored SO2 Levels - Schrodt Site (All Data)
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
20
40
60
80
100
120
140
160
180
200

Wind Speed Analysis

Table 2 shows the average ratio of modeled divided by monitored concentrations versus wind speed. Three of the sites, Mt. Carmel, East and Schrodt, show that the ratio peaks at 2 to 3 meters per second and drops off with increasing wind speeds. The Coal Road site does not show this trend. Ratios appear to increase as wind speed increases. It should be noted that not all wind speed categories have the same number of readings. The greater than 10 meters per second category has very few readings. Any conclusions based on this category may be questionable.

Table 2

Comparison of Average Modeled/Monitored Ratios vs. Wind Speed

Wind Speed Range	Mt. Carmel	East	Coal Road	Schrodt
0 -1 m/s	1.53	1.35	0.88	0.84
1.01 – 2	2.47	2.47	2.16	1.44
2.01 – 3	3.96	2.85	1.79	1.43
3.01 – 4	3.54	2.68	2.07	1.09
4.01 – 5	2.71	1.74	2.94	0.91
5.01 – 6	2.72	1.95	2.63	0.87
6.01 – 7	2.64	1.7	3.34	0.92
7.01 – 8	1.51	1.33	2.82	0.83
8.01 – 9	1.06	1.10	4.12	0.77
9.01 – 10	0.98	0.99	3.67	0.86
➢ 10	1.03	0.88	6.01	0.96

Some persons would argue that using average values is inappropriate. Because the sample size of some categories may be small, one high ratio can overly impact the average. Table 3 shows the median ratios versus wind speed. In most cases this shows that the ratios are between 0.5 and 1, within the factor of two range.

Table 3

Comparison of Median Modeled/Monitored Ratios vs. Wind Speed

Wind Speed Range	Mt. Carmel	East	Coal Road	Schrodt
0 -1 m/s	1.00	1.00	0.50	0.50
1.01 – 2	1.00	1.00	0.50	0.67
2.01 – 3	1.00	1.00	0.75	0.86
3.01 – 4	1.00	1.00	0.72	0.80
4.01 – 5	1.01	1.00	0.67	0.77
5.01 – 6	1.02	1.00	0.67	1.00
6.01 – 7	1.08	1.00	0.70	1.00
7.01 – 8	1.06	1.00	0.73	1.00
8.01 – 9	1.05	1.05	1.00	0.78
9.01 – 10	1.01	1.01	0.99	1.00
➢ 10	1.01	1.00	1.00	1.02

Wind Direction Analysis

Table 4 compares average modeled to monitored ratios versus wind direction. The directions which are directly from the stacks to the monitors are highlighted in the table.

Table 4

Comparison of Average Modeled to Monitored Ratios versus Wind Direction

WD Range	Mt. Carmel	East	Coal Road	Schrodt
0 – 10	1.22	1.15	0.82	0.85
11 – 20	1.17	1.18	0.83	0.86
21 – 30	1.21	1.27	0.82	0.77
31 – 40	1.28	1.14	0.84	0.73
41 – 50	1.19	1.21	0.90	0.68
51 – 60	1.01	0.95	0.70	0.69
61 – 70	1.14	1.12	0.80	1.31
71 – 80	1.32	1.28	0.92	1.51
81 – 90	1.40	1.48	0.94	**6.58**
91 – 100	1.25	1.43	0.94	4.38
101 – 110	1.20	1.38	0.87	2.74
111 – 120	1.28	1.56	1.02	2.03
121 – 130	1.27	1.69	1.05	1.11
131 – 140	1.16	1.15	0.80	0.91
141 – 150	3.04	1.27	0.86	0.84
151 – 160	6.78	2.28	1.28	0.93
161 – 170	**16.63**	1.55	0.87	0.84
171 – 180	**28.36**	1.40	1.08	0.86
181 – 190	7.16	1.24	1.15	0.87
191 – 200	3.53	1.45	2.25	0.91
201 – 210	1.73	1.27	4.88	0.87
211 – 220	1.63	1.62	**10.83**	0.86
221 – 230	1.52	1.58	9.20	0.87
231 – 240	1.56	1.65	5.72	0.84
241 – 250	1.85	2.03	2.83	1.01
251 – 260	1.32	1.58	1.15	0.81
261 – 270	1.47	2.55	0.84	0.93
271 – 280	1.36	2.96	0.86	0.89
281 – 290	1.45	6.83	0.97	0.89
291 – 300	1.34	**7.65**	0.79	0.88
301 – 310	1.24	**6.16**	0.89	0.85
311 – 320	1.17	5.39	0.76	0.83
321 – 330	1.40	5.21	0.87	0.87
331 – 340	1.59	2.24	1.02	1.02
341 – 350	1.58	1.53	0.97	0.92
351 – 360	1.15	1.04	0.77	0.91

For the key wind directions the average ratios are much higher than two. This would indicate that in the directions where the wind is blowing from the stacks to the monitors, the disagreement between the model and the monitor is greatest.

Table 5
Comparison of Median Modeled to Monitored Ratios versus Wind Direction

WD Range	Mt. Carmel	East	Coal Road	Schrodt
0 – 10	1.00	1.00	0.67	0.80
11 – 20	1.00	1.00	0.65	0.82
21 – 30	1.00	1.00	0.67	0.67
31 – 40	1.00	1.00	0.67	0.56
41 – 50	1.00	1.00	0.50	0.50
51 – 60	1.00	1.00	0.50	0.50
61 – 70	1.00	1.00	0.50	0.50
71 – 80	1.00	1.00	0.67	0.67
81 – 90	1.00	1.00	0.67	1.00
91 – 100	1.00	1.00	0.75	1.00
101 – 110	1.00	1.00	0.67	1.00
111 – 120	1.00	1.00	0.67	0.72
121 – 130	1.00	1.00	0.67	0.73
131 – 140	1.00	1.00	0.67	0.83
141 – 150	1.00	1.00	0.67	0.82
151 – 160	1.00	1.00	0.68	1.00
161 – 170	3.99	1.00	0.67	1.00
171 – 180	6.71	1.00	0.59	1.00
181 – 190	1.00	1.00	0.57	0.78
191 – 200	1.00	1.00	0.62	0.97
201 – 210	1.00	1.00	1.04	1.00
211 – 220	1.00	1.00	3.48	0.69
221 – 230	1.00	1.00	1.56	1.00
231 – 240	1.00	1.00	0.99	0.90
241 – 250	1.00	1.00	0.75	1.00
251 – 260	1.00	1.00	0.58	0.67
261 – 270	1.00	1.00	0.63	0.72
271 – 280	1.00	1.00	0.66	0.75
281 – 290	1.00	1.00	0.58	0.76
291 – 300	1.00	1.00	0.62	0.74
301 – 310	1.00	1.00	0.67	0.76
311 – 320	1.00	1.00	0.60	1.00
321 – 330	1.00	1.00	0.67	1.00
331 – 340	1.00	1.00	0.60	1.00
341 – 350	1.00	1.00	0.58	1.00
351 – 360	1.00	1.00	0.67	1.00

Table 5 shows the median ratios of modeled to monitored concentrations versus wind direction. Once again the key wind directions show the largest discrepancies between the modeled and monitored concentrations.

Comparisons Not in Time

The U.S. EPA does not believe that these values should be paired in time. While we do not agree we wish to show the results of such an analysis. In this case the modeled and monitored values are ranked from lowest to highest and then paired. Figures 6 through 9 show the results. For the Mt. Carmel site (Figure 6) AERMOD over-predicts throughout the entire range with the exception of three points, which while still over-predicted, are within the factor of two. The East

site (Figure 7) shows an AERMOD over-prediction throughout the entire range of data, in all cases outside the factor of two ranges. The Coal Road site (Figure 8) shows over-prediction outside the factor of two ranges for the entire range of data. The Schrodt site (Figure 9) shows over-prediction outside the factor of two ranges for the entire range of data.

IDEM believes that it is not appropriate to compare the data in this fashion. Since each hour has a different emission rate, comparison of different hours is comparing apples and oranges. Without making corrections for emission rates an accurate assessment of a comparison of this type is not appropriate.

However, it may be possible to compare the data without actually comparing individual hours at all. Table 6 looks at the frequency at which modeled and monitored concentrations occur within certain concentration ranges. Of particular interest are the number of hours that exceed the standard of 75 parts per billion (ppb). For the Mt. Carmel site AERMOD predicts 132 hours above the standard, while the monitor only measured 6. For the East site AERMOD predicts 78 hours above the standard, while the monitor measured none. For the Coal Road site AERMOD predicts 209 hours above the standard while the monitor measured 5. For the Schrodt site AERMOD predicts 31 hours above the standard while the monitor measured none. This seems to indicate that AERMOD predicts many more exceedances than the monitors are measuring.

Figure 6

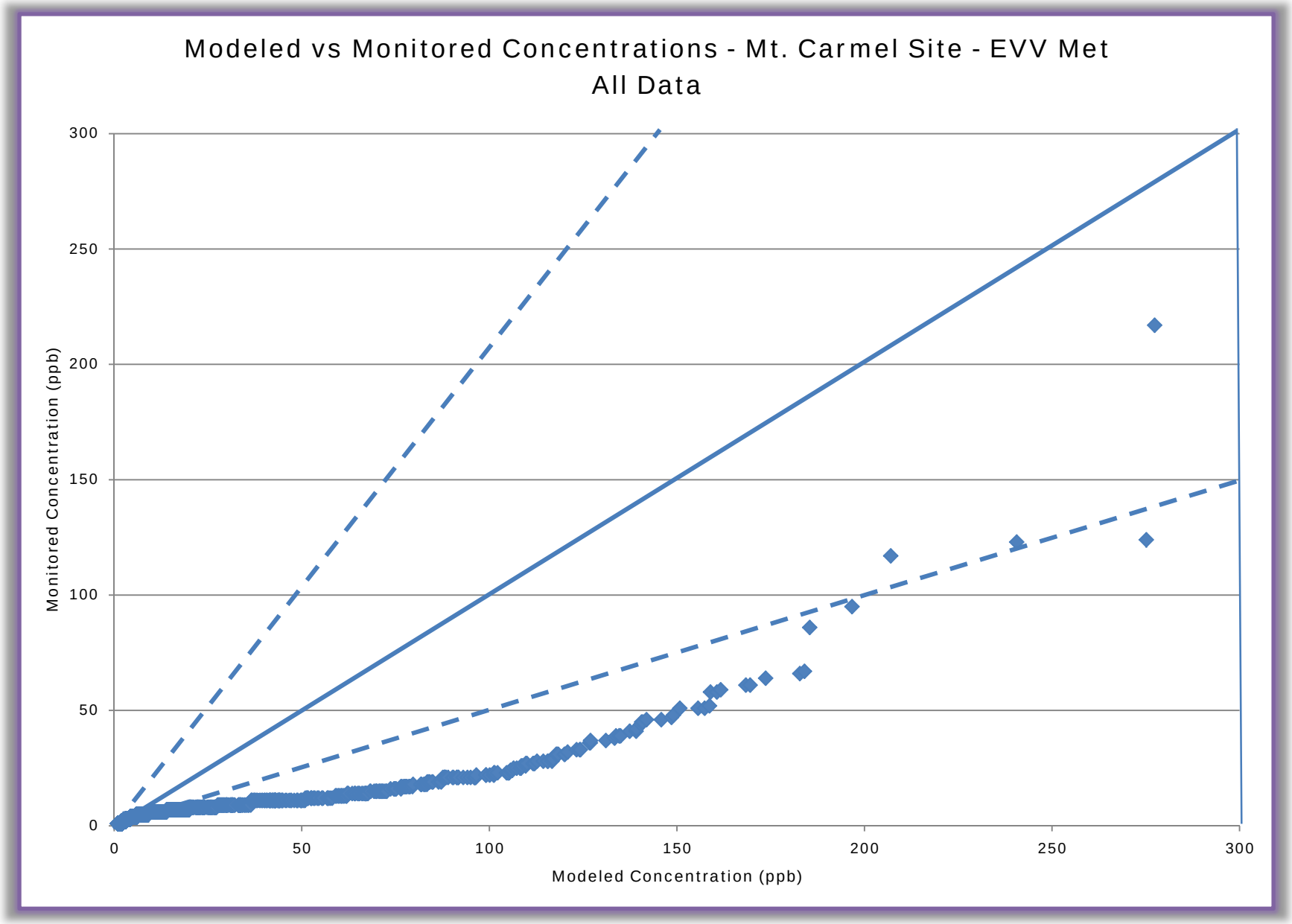

Modeled vs Monitored Concentrations - Mt. Carmel Site - EVV Met
All Data
Monitored Concentration (ppb)
Modeled Concentration (ppb)
0
50
100
150
200
250
300

Figure 7

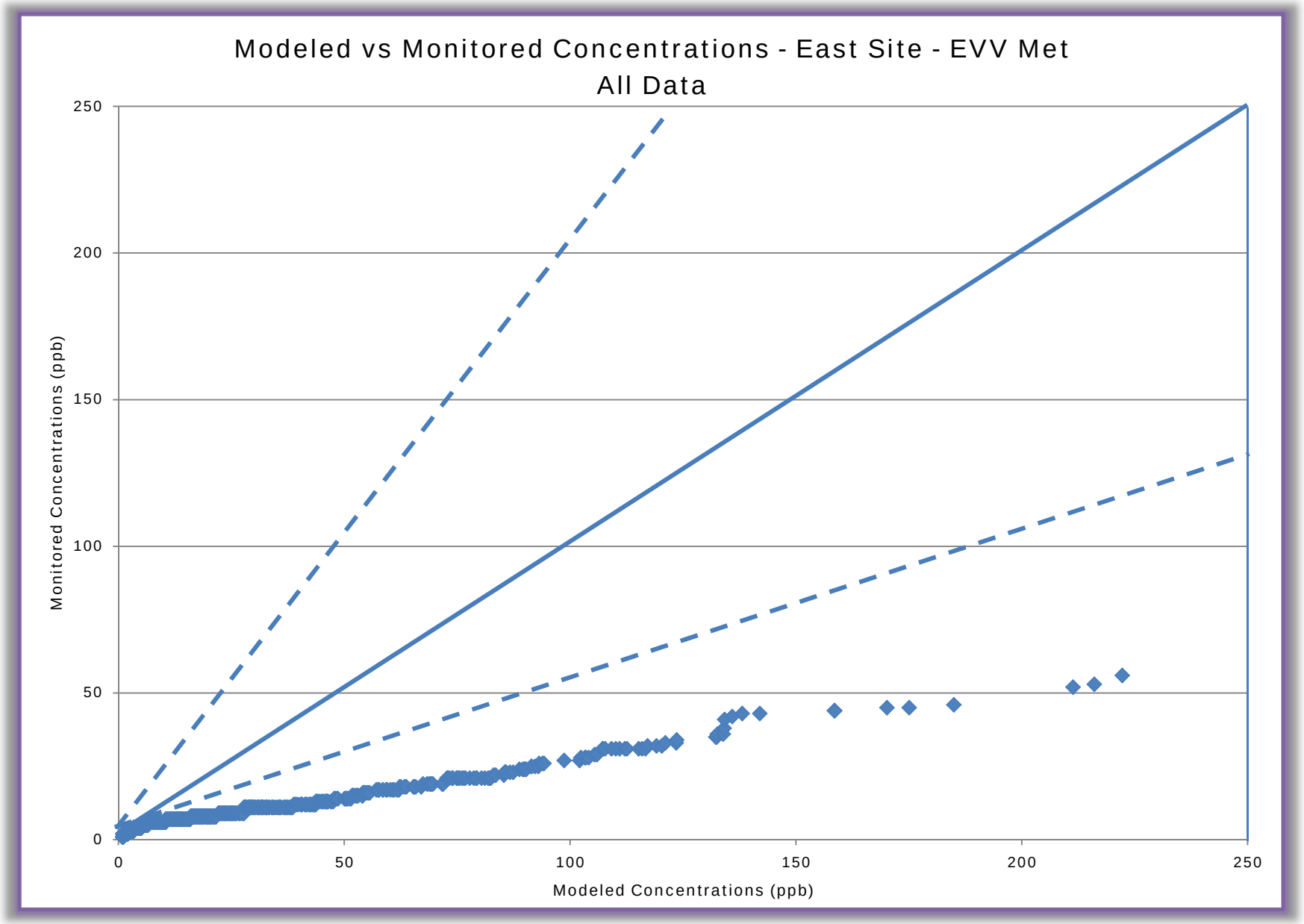

Modeled vs Monitored Concentrations - East Site - EVV Met
All Data
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250

Figure 8

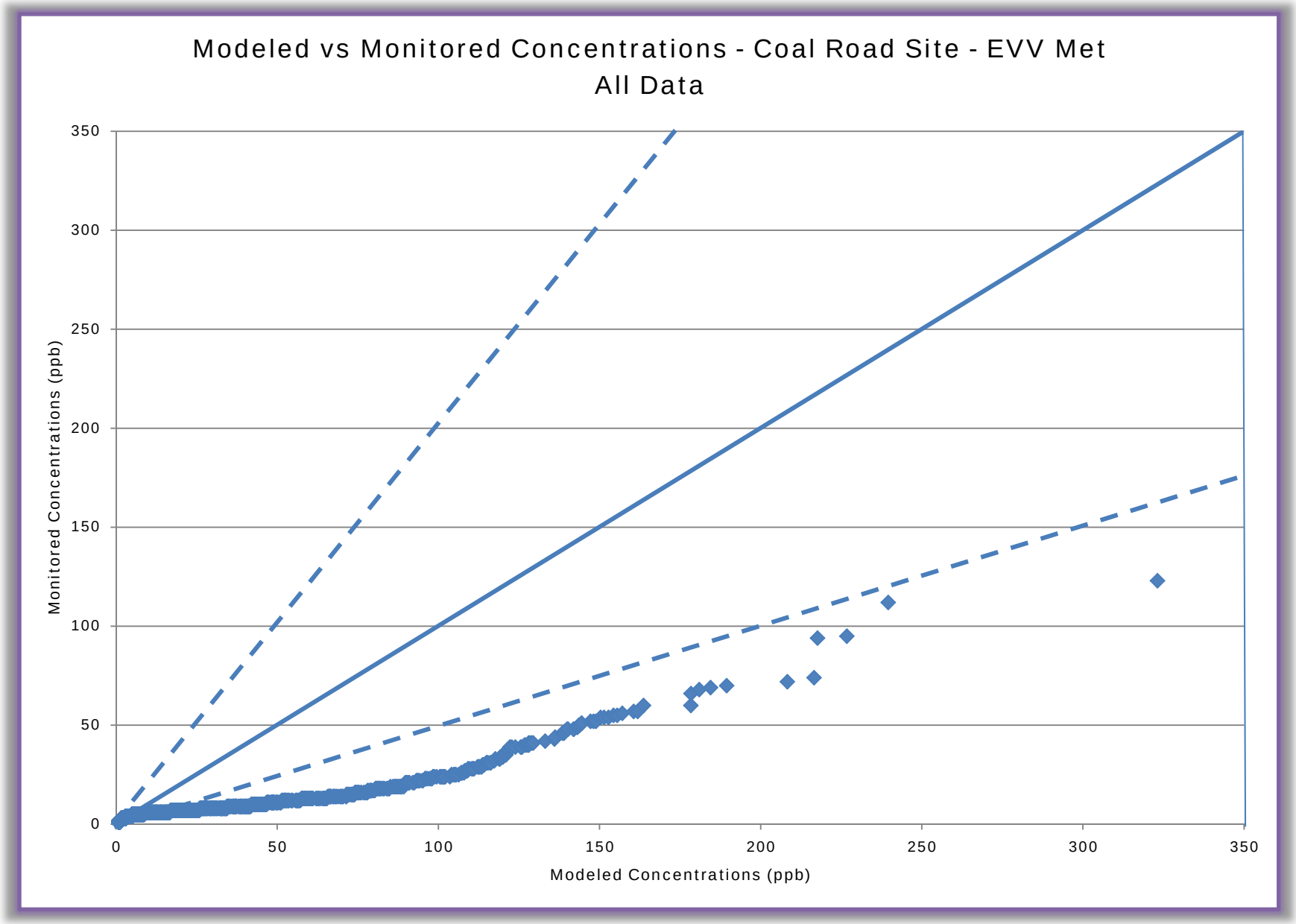

Modeled vs Monitored Concentrations - Coal Road Site - EVV Met
All Data
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250
300
350

Figure 9

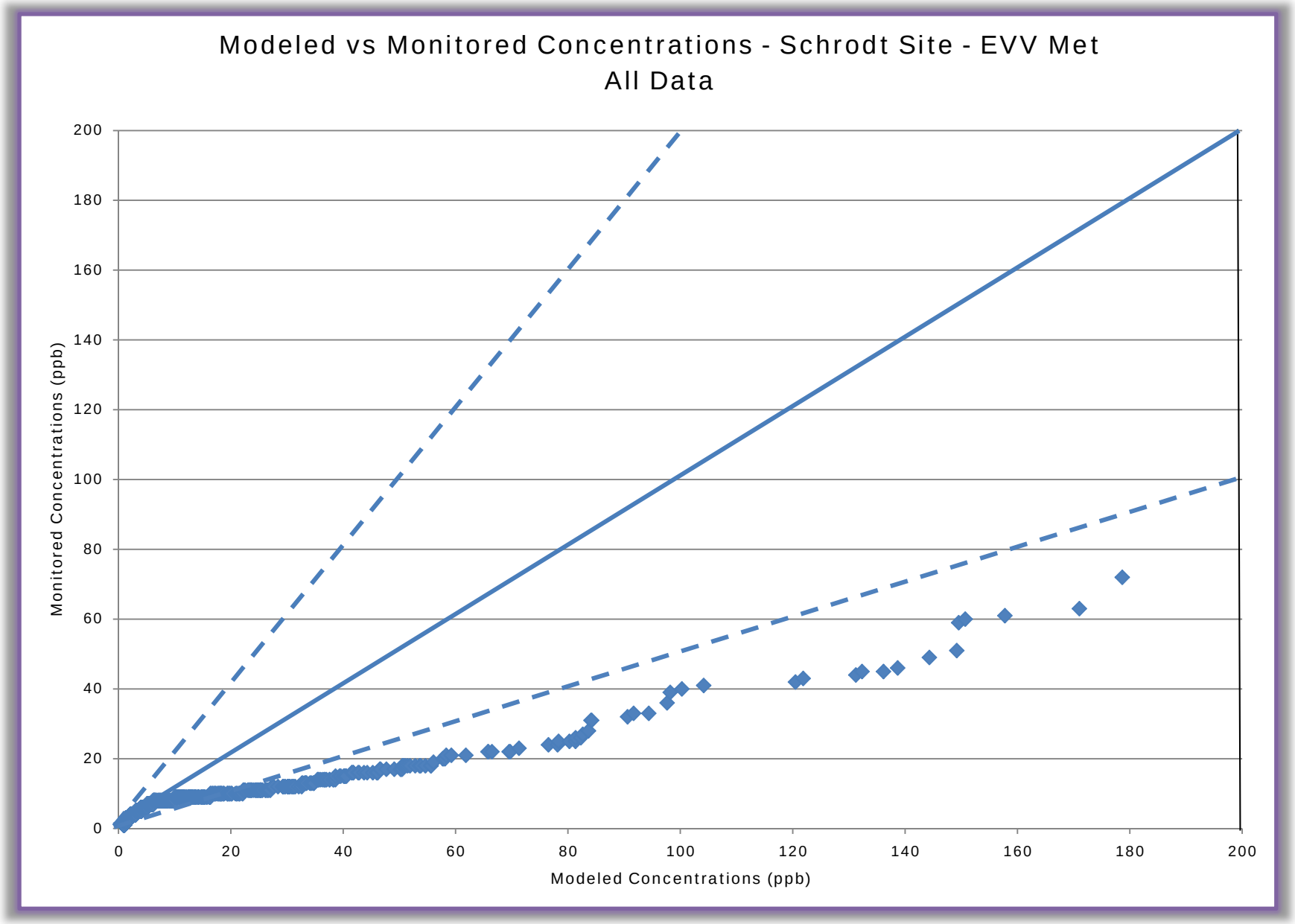

Modeled vs Monitored Concentrations - Schrodt Site - EVV Met
All Data
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
20
40
60
80
100
120
140
160
180
200

Table 6
Hours within Selected Ranges – Scenario 2 – All Data

	Mt. Carmel		East		Coal Road		Schrodt	
Range	Model	Monitor	Model	Monitor	Model	Monitor	Model	Monitor
1 – 25	7822	8134	8049	8298	7735	8234	8153	8276
26 – 50	154	44	146	43	259	73	91	20
51 – 75	88	12	71	3	130	21	27	6
76 – 100	53	2	36	0	90	3	16	0
101 – 125	42	3	25	0	68	2	4	0
126 – 150	19	0	9	0	31	0	7	0
151 – 175	10	0	3	0	9	0	3	0
176 – 200	4	0	2	0	5	0	1	0
201 – 225	1	1	3	0	3	0	0	0
226 – 250	1	0	0	0	2	0	0	0
251 – 275	0	0	0	0	0	0	0	0
276 – 300	2	0	0	0	0	0	0	0
301 – 325	0	0	0	0	1	0	0	0
Total	8196	8196	8344	8344	8333	8333	8302	8302
Above 75	132	6	78	0	209	5	31	0

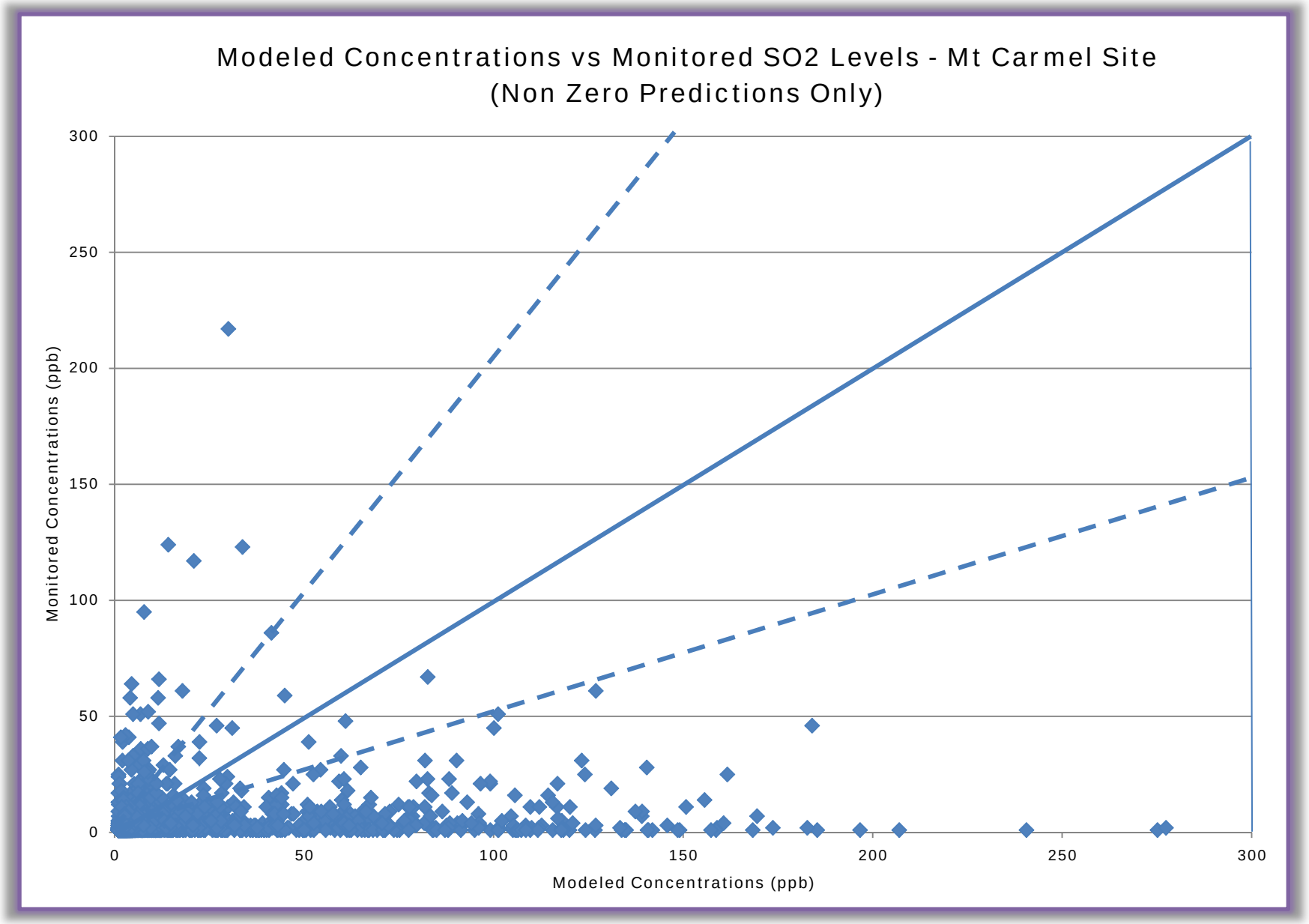
Non-Zero Predictions Only

The analyses presented so far have used all data where both the predicted and the monitored values are available for an hour. However the majority of these readings are non-meaningful. In most cases AERMOD predicts a zero value which then has a background value added and then is compared to the monitored value. This is not a true measure of how the model is working. Model predictions of zero are of little interest except for computing an annual average value. This set of analyses removes all hours where the AERMOD predicted value was zero.

Mt. Carmel Site

Figure 10 shows a comparison of predicted and measured SO2 levels compared in time for the Mt. Carmel site. Of the 3395 hours of data, 62.1 percent are predicted within a factor of two, while 4.7 percent are under-predicted by more than a factor of two and 33.2 percent are over-predicted by more than a factor of two.

Figure 10


Modeled Concentrations vs Monitored SO2 Levels - Mt Carmel Site
(Non Zero Predictions Only)
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250
300

East Site

Figure 11 shows a comparison of predicted and measured SO2 levels compared in time for the East site. Of the 3240 hours of data, 59.3 percent are predicted within a factor of two, while 5.8 percent are under-predicted by more than a factor of two and 34.9 percent are over-predicted by more than a factor of two.

Coal Road Site

Figure 12 shows a comparison of predicted and measured SO2 levels compared in time for the Coal Rd. site. Of the 3469 hours of data, 59.2 percent are predicted within a factor of two, while 9.8 percent are under-predicted by more than a factor of two and 31.0 percent are over-predicted by more than a factor of two.

Schrodt Site

Figure 13 shows a comparison of predicted and measured SO2 levels compared in time for the Schrodt site. Of the 3404 hours of data, 75.6 percent are predicted within a factor of two, while 11.8 percent are under-predicted by more than a factor of two and 12.6 percent are over-predicted by more than a factor of two.

SUMMARY

Table 7 summarizes the results for all four sites. Overall 64.1 percent of the predictions are within a factor of two of the measured values, 8.1 percent are under-predicted by more than a factor of two and 27.8 percent are over-predicted by more than a factor of two. The performance of AERMOD is not as good as shown earlier. Fewer predictions are within the factor of two and more than three times as many over-predictions are occurring as under-predictions.

Table 7
Results of Scenario 2 Analyses – Non-Zero Predictions Only

	Mt. Carmel		East		Coal Road		Schrodt		Total	
Range	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent
<0.5	158	4.7	187	5.8	341	9.8	402	11.8	1088	8.1
0.5 – 2.0	2109	62.1	1920	59.3	2055	59.2	2573	75.6	8657	64.1
➢ **2.0**	1128	33.2	1133	34.9	1073	31.0	429	12.6	3763	27.8
Total	3395		3240		3469		3404		13508	

Figure 11

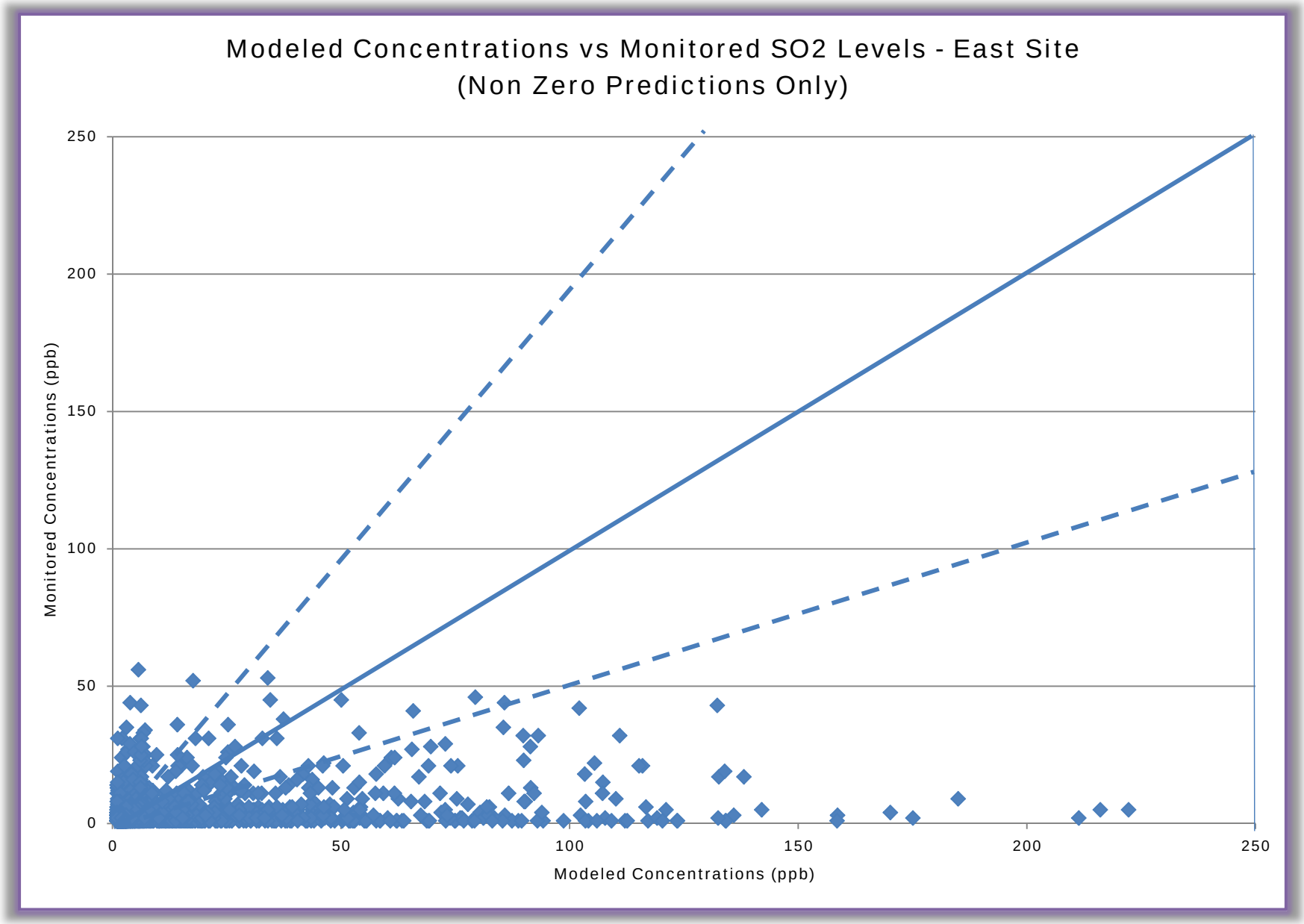

Modeled Concentrations vs Monitored SO2 Levels - East Site
(Non Zero Predictions Only)
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250

Figure 12

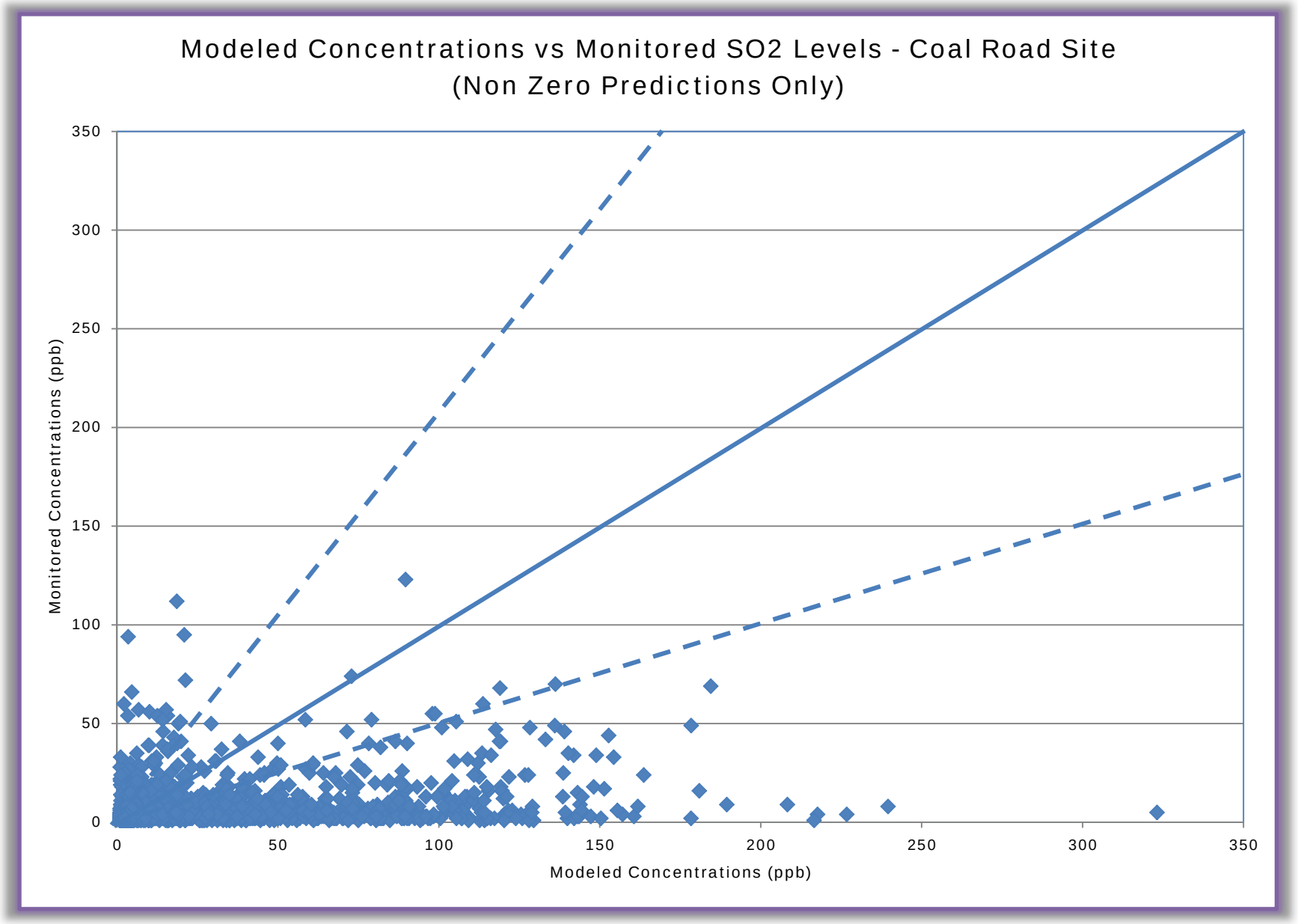
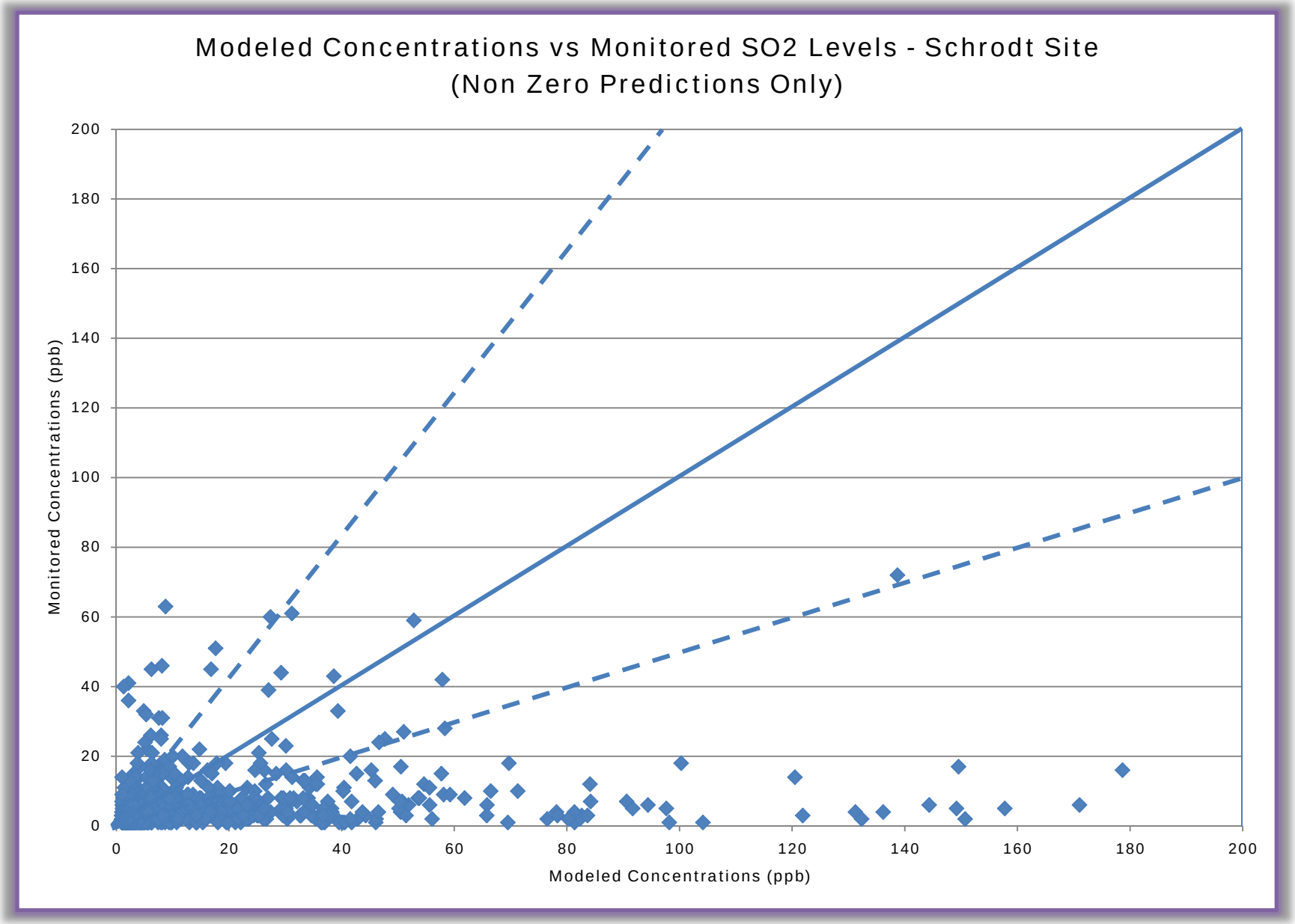

Modeled Concentrations vs Monitored SO2 Levels - Coal Road Site
(Non Zero Predictions Only)
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250
300
350

Figure 13


Modeled Concentrations vs Monitored SO2 Levels - Schrodt Site
(Non Zero Predictions Only)
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
20
40
60
80
100
120
140
160
180
200

Wind Speed Analysis

Table 8 shows the average ratio of modeled divided by monitored concentrations versus wind speed. Three of the four sites, Mt. Carmel, East and Schrodt, show that ratios drop off with speed. The Coal Road shows this trend, but then shows ratios increase as wind speeds increase from about 8 meters per second and above. Remembering that not all wind speed categories may help to explain this difference.

Table 8
Comparison of Average Modeled/Monitored Ratios vs. Wind Speed

Wind Speed Range	Mt. Carmel	East	Coal Road	Schrodt
0 -1 m/s	19.75	18.55	10.21	7.84
1.01 – 2	7.91	9.02	7.57	4.17
2.01 – 3	8.14	6.22	3.45	2.45
3.01 – 4	5.93	4.72	3.33	1.45
4.01 – 5	3.80	2.45	4.48	1.03
5.01 – 6	3.57	2.61	3.64	0.90
6.01 – 7	3.28	2.12	4.41	0.96
7.01 – 8	1.72	1.52	3.65	0.88
8.01 – 9	1.08	1.17	5.09	0.77
9.01 – 10	1.01	1.09	5.62	0.85
➢ 10	1.05	0.89	10.32	0.95

Some persons would argue that using average values is inappropriate. Because the sample size of some categories may be small, one high ratio can overly impact the average. Table 9 shows the median ratios versus wind speed. The trends seen in the average ratios appear to be duplicated in the median data.

Table 9
Comparison of Median Modeled/Monitored Ratios versus Wind Speed

Wind Speed Range	Mt. Carmel	East	Coal Road	Schrodt
0 -1 m/s	7.80	11.55	8.15	4.54
1.01 – 2	3.48	4.47	2.47	1.97
2.01 – 3	1.94	1.99	1.35	1.08
3.01 – 4	1.44	1.38	0.99	0.87
4.01 – 5	1.23	1.12	0.83	0.77
5.01 – 6	1.17	1.11	0.74	1.01
6.01 – 7	1.17	1.11	0.76	1.04
7.01 – 8	1.11	1.11	1.10	1.04
8.01 – 9	1.09	1.09	1.13	0.78
9.01 – 10	1.07	1.14	2.35	1.01
➢ 10	1.06	1.06	6.12	1.02

Wind Direction Analysis

Table 10 compares average modeled to monitored ratios versus wind direction. The directions which are directly from the stacks to the monitors are highlighted in the table.

Table 10
Comparison of Average Modeled to Monitored Ratios versus Wind Direction

WD Range	Mt. Carmel	East	Coal Road	Schrodt
0 – 10	1.53	1.59	1.02	1.04
11 – 20	1.56	1.70	1.15	1.15
21 – 30	1.63	2.04	1.07	1.02
31 – 40	2.05	1.91	1.34	1.05
41 – 50	2.73	3.69	2.70	1.24
51 – 60	1.46	1.79	1.09	1.40
61 – 70	1.97	2.34	1.55	4.31
71 – 80	2.39	2.61	1.62	3.73
81 – 90	2.40	2.86	1.58	**11.08**
91 – 100	1.98	2.95	1.64	8.57
101 – 110	1.75	2.50	1.36	5.88
111 – 120	1.79	2.76	1.55	3.80
121 – 130	1.87	2.86	1.77	1.78
131 – 140	1.73	1.80	1.05	1.21
141 – 150	6.46	2.06	1.24	1.01
151 – 160	8.62	4.34	2.17	1.09
161 – 170	**19.23**	2.58	1.20	0.97
171 – 180	**32.32**	2.14	1.72	1.04
181 – 190	12.64	1.77	1.93	1.03
191 – 200	6.10	2.10	3.92	1.13
201 – 210	2.34	1.66	6.47	1.01
211 – 220	2.34	2.53	**13.96**	1.10
221 – 230	2.17	2.53	13.56	1.08
231 – 240	2.19	2.65	11.15	1.01
241 – 250	2.79	3.45	5.31	1.32
251 – 260	1.69	2.67	1.85	1.01
261 – 270	1.86	4.64	1.11	1.11
271 – 280	2.03	7.90	1.38	1.11
281 – 290	2.07	13.13	1.32	1.05
291 – 300	2.06	**11.71**	1.12	1.19
301 – 310	1.77	**11.89**	1.33	1.09
311 – 320	1.54	12.66	1.02	0.92
321 – 330	1.90	10.25	1.16	0.99
331 – 340	2.41	4.23	1.55	1.26
341 – 350	2.25	2.34	1.39	1.11
351 – 360	1.46	1.35	0.96	1.12

For the key wind directions the average ratios are much higher than two. This indicates that when the wind is blowing from the stacks to the monitors the disagreement between the model and the monitor is greater.

Table 11

Comparison of Median Modeled to Monitored Ratios versus Wind Direction

WD Range	Mt. Carmel	East	Coal Road	Schrodt
0 – 10	1.21	1.10	0.78	1.01
11 – 20	1.19	1.05	0.77	1.03
21 – 30	1.35	1.19	0.89	0.95
31 – 40	1.40	1.25	1.03	0.74
41 – 50	1.15	1.26	1.02	0.71
51 – 60	1.00	1.05	0.63	0.78
61 – 70	1.15	1.08	0.99	1.29
71 – 80	1.16	1.04	1.01	1.90
81 – 90	1.36	1.60	1.05	**4.67**
91 – 100	1.50	1.63	1.08	3.75
101 – 110	1.27	1.50	1.08	2.89
111 – 120	1.08	1.15	0.87	1.02
121 – 130	1.17	1.18	0.93	0.82
131 – 140	1.18	1.20	0.88	1.03
141 – 150	3.31	1.48	1.01	0.98
151 – 160	3.43	1.46	1.03	1.01
161 – 170	**5.58**	1.32	0.98	0.95
171 – 180	**10.19**	1.34	0.72	1.02
181 – 190	3.97	1.24	0.81	1.01
191 – 200	1.77	1.16	1.57	1.03
201 – 210	1.15	1.15	2.46	1.04
211 – 220	1.38	1.44	**5.58**	1.04
221 – 230	1.40	1.45	6.17	1.04
231 – 240	1.61	1.65	5.44	0.83
241 – 250	1.50	1.57	1.34	1.06
251 – 260	1.32	1.27	0.82	1.02
261 – 270	1.28	1.11	0.76	0.83
271 – 280	1.24	1.63	0.80	0.79
281 – 290	1.21	2.25	0.73	1.02
291 – 300	1.19	**1.84**	0.76	1.01
301 – 310	1.08	**3.00**	0.76	0.95
311 – 320	1.12	2.61	0.72	1.01
321 – 330	1.36	2.35	0.78	1.02
331 – 340	1.40	1.58	0.84	1.04
341 – 350	1.26	1.21	0.70	1.05
351 – 360	1.17	1.04	0.77	1.04

Table 11 shows the median ratios of modeled to monitored concentrations versus wind direction. Once again the key wind directions show the largest discrepancies between the modeled and monitored concentrations. One question that will be addressed later is why are there predicted non-zero concentrations in directions where the winds are not blowing from the stack to the monitors?

A good example of this occurs on January 31, hour 13. The wind direction for this hour is 196 which should take the plume between the Mt. Carmel and Coal Road monitors. However, the following concentrations are predicted for the four monitors.

Monitoring Site	Predicted Concentration (ppb)
Mt. Carmel	87.60
East	103.5
Coal Road	87.16
Schrodt	50.49

It is impossible for AERMOD to accurately be predicting concentrations at each of these four monitors given the wind direction of 196. The wind speed for this hour is 0.62 meters per second. As shown later with on-site meteorology, AERMOD seems to be "blowing up" for many cases where the wind speed is less than 1 meter per second and predicting concentrations at all receptors regardless of wind direction. This is an area that U.S. EPA should investigate further.

Comparisons Not in Time

Figures 14 – 17 show predicted concentrations versus monitored concentrations where the values have independently been ranked from lowest to highest. Figure 14 (Mt. Carmel) shows an over-prediction by AERMOD except at very low or very high concentrations. Figure 15 (East) shows an over-prediction by AERMOD except at very low concentrations. Figure 16 (Coal Road) shows an over-prediction by AERMOD except at very low concentrations. Figure 17 (Schrodt) shows over-prediction of AERMOD except at very low concentrations.

When compared in this fashion, the following overall statistics (ratios of modeled to monitored concentrations) are found:

Ratio	Mt. Carmel		East		Coal Road		Schrodt		Total	
Range	Hours	Percent	Hours	Percent	Hours	Percent	Hours	Percent	Hours	Percent
< 0.5	0	0	0	0	0	0	0	0	0	0
0.5 – 2	1869	55.1	2205	68.1	2480	71.5	3177	93.3	9731	72.0
➢ 2.0	1526	44.9	1035	31.9	989	28.5	227	6.7	3777	28.0
Total	3395		3240		3469		3404		13508	

This appears to show significant over-prediction with no under-prediction.

Figure 14

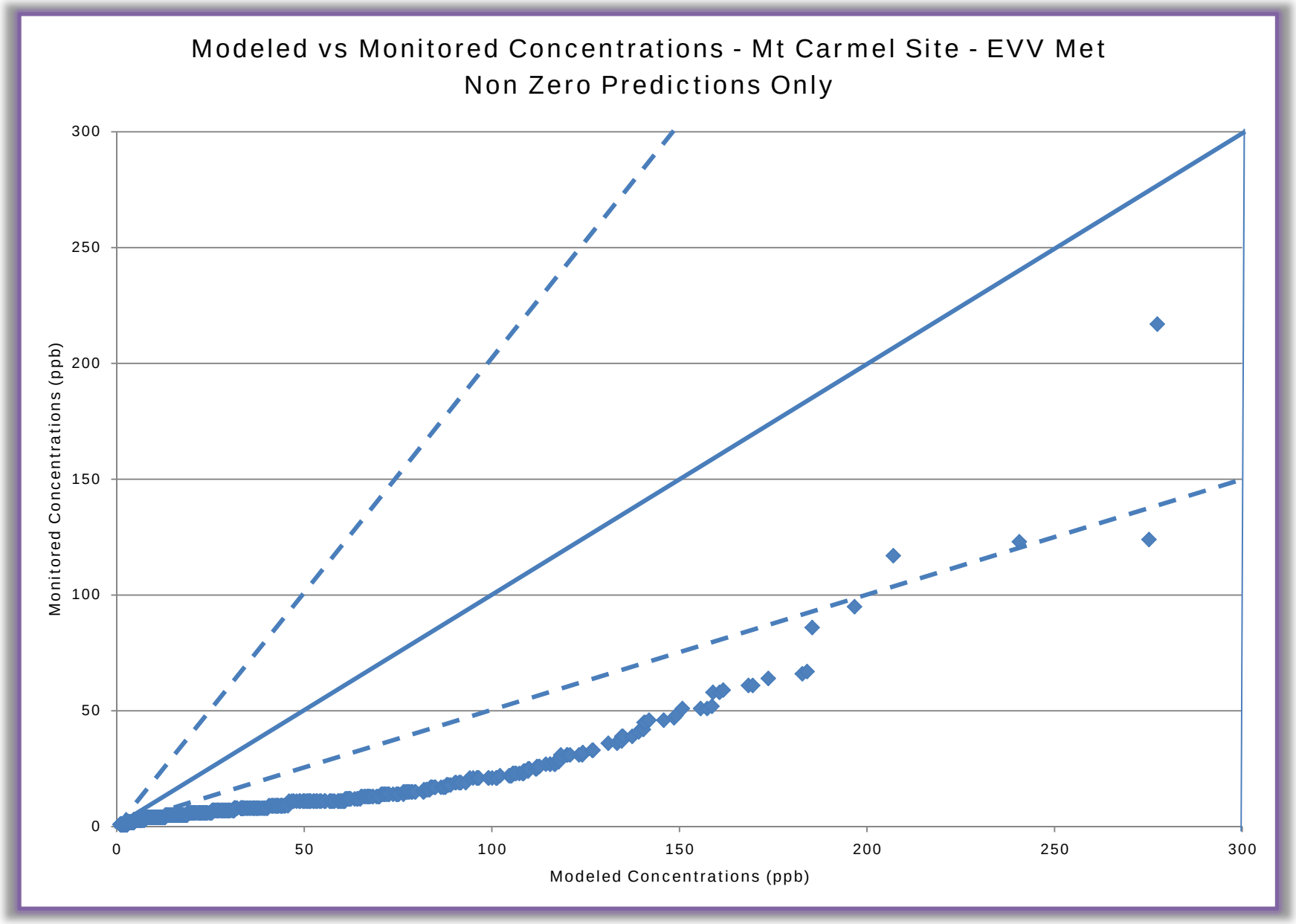

Modeled vs Monitored Concentrations - Mt Carmel Site - EVV Met
Non Zero Predictions Only
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250
300

Figure 15

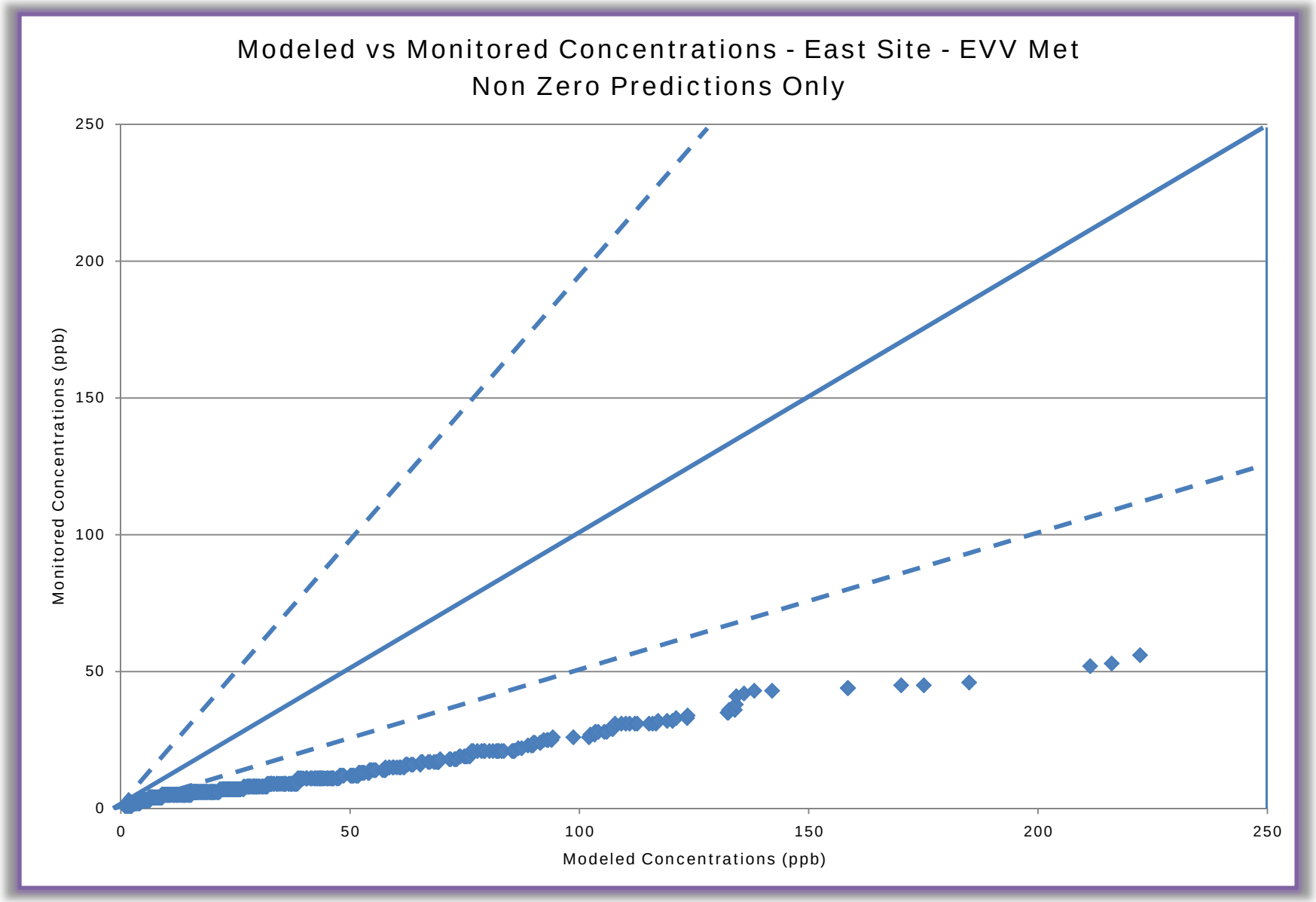

Modeled vs Monitored Concentrations - East Site - EVV Met
Non Zero Predictions Only
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250

Figure 16

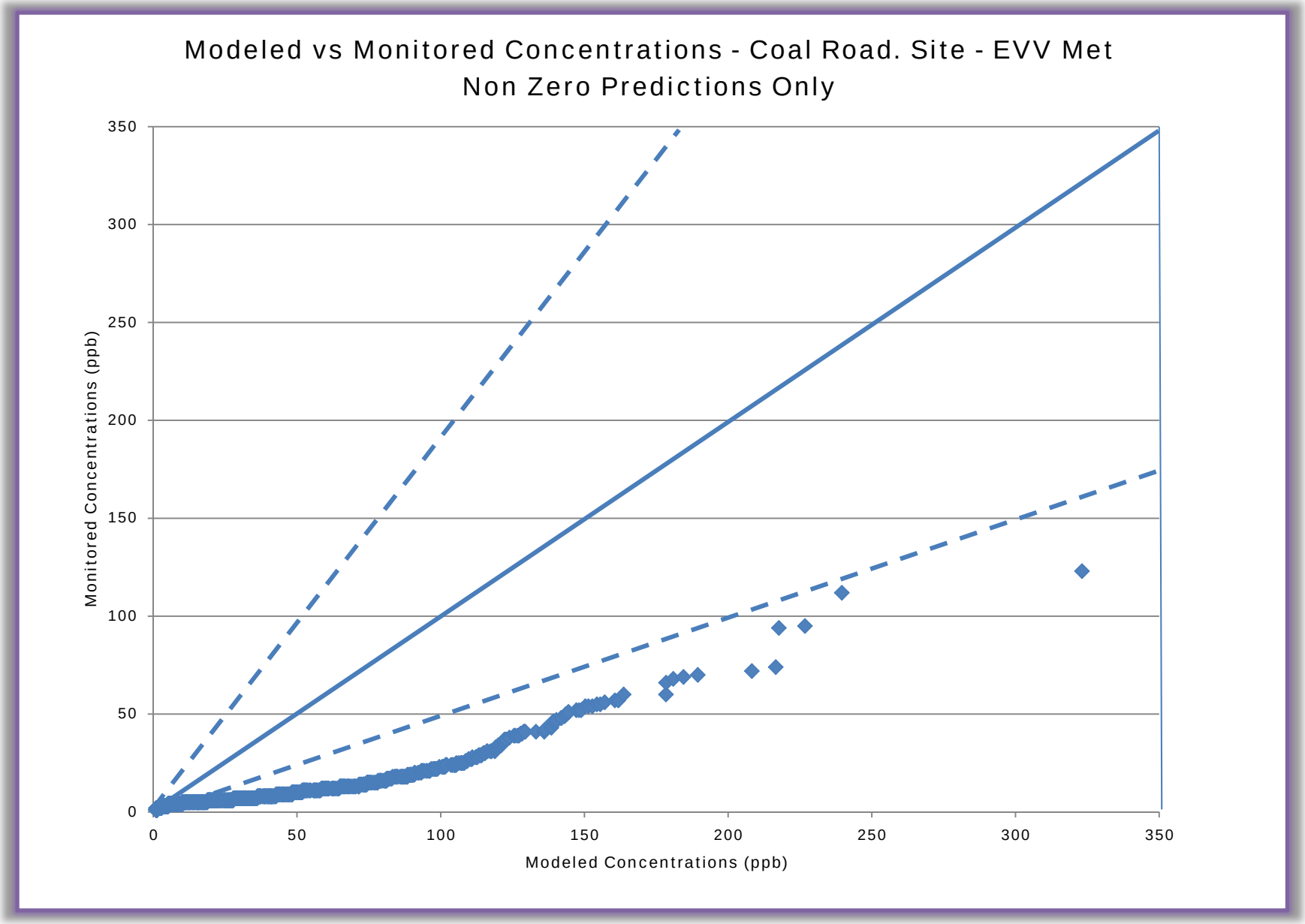

Modeled vs Monitored Concentrations - Coal Road. Site - EVV Met
Non Zero Predictions Only
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250
300
350

Figure 17

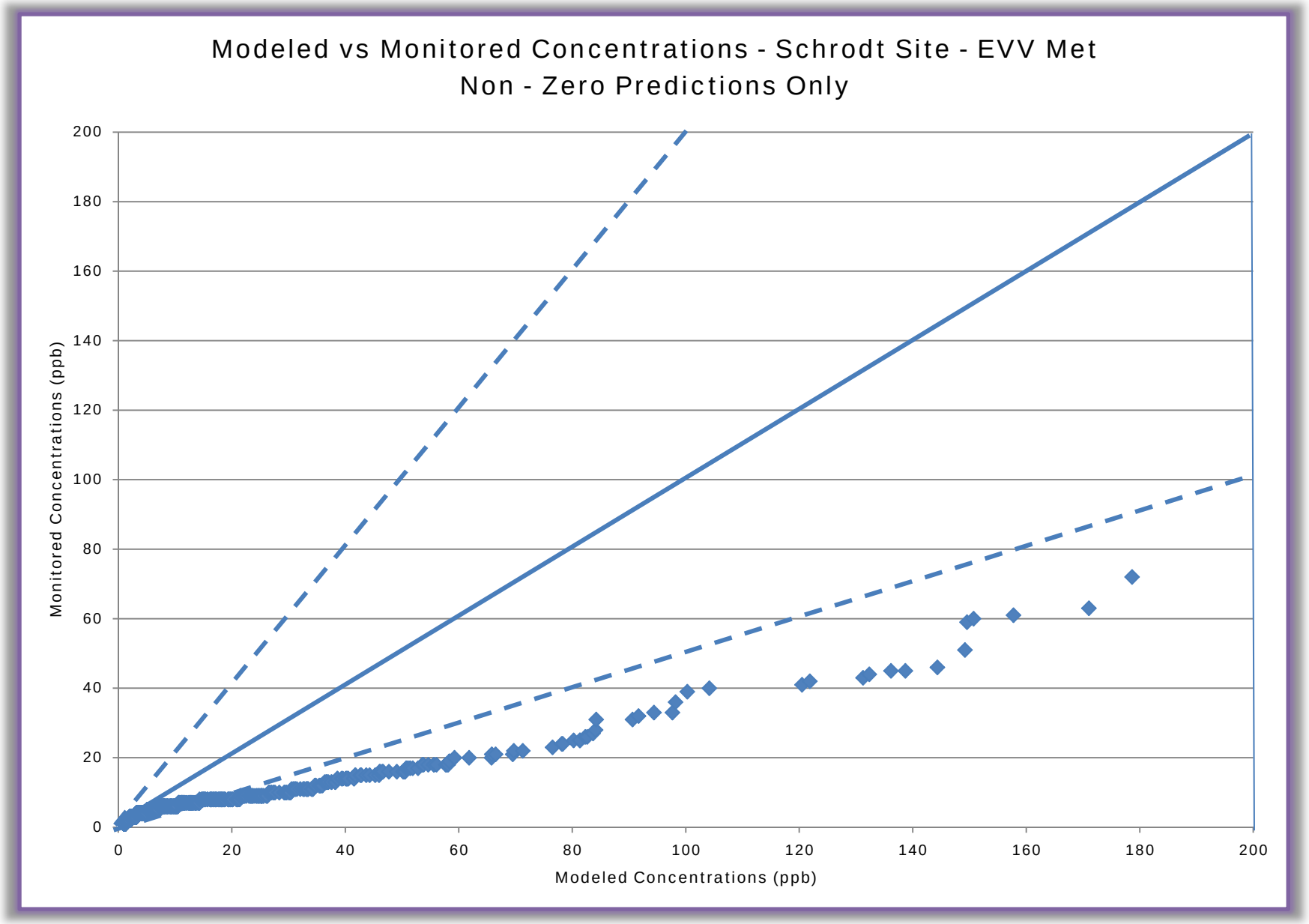

Modeled vs Monitored Concentrations - Schrodt Site - EVV Met
Non - Zero Predictions Only
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
20
40
60
80
100
120
140
160
180
200

Table 12 looks at the frequency at which modeled and monitored concentrations occur within certain concentration ranges. Of particular interest are the numbers of hours that exceed the standard of 75 ppb. Overall AERMOD predicts 450 hours above the standard while the monitors measured 11.

Table 12
Hours within Selected Ranges – Scenario 2 – Non-Zero Predictions Only

	Mt. Carmel		East		Coal Road		Schrodt	
Range	Model	Monitor	Model	Monitor	Model	Monitor	Model	Monitor
1 – 25	3021	3340	2945	3196	2871	3374	3255	3379
26 – 50	154	37	146	41	259	70	91	19
51 – 75	88	12	71	3	130	21	27	6
76 – 100	53	2	36	0	90	3	16	0
101 – 125	42	3	25	0	68	2	4	0
126 – 150	19	0	9	0	31	0	7	0
151 – 175	10	0	3	0	9	0	3	0
176 – 200	4	0	2	0	5	0	1	0
201 – 225	1	1	3	0	3	0	0	0
226 – 250	1	0	0	0	2	0	0	0
251 – 275	0	0	0	0	0	0	0	0
276 – 300	2	0	0	0	0	0	0	0
301 – 325	0	0	0	0	1	0	0	0
Total	3395	3395	3240	3240	3469	3469	3404	3404
Above 75	132	6	78	0	209	5	31	0

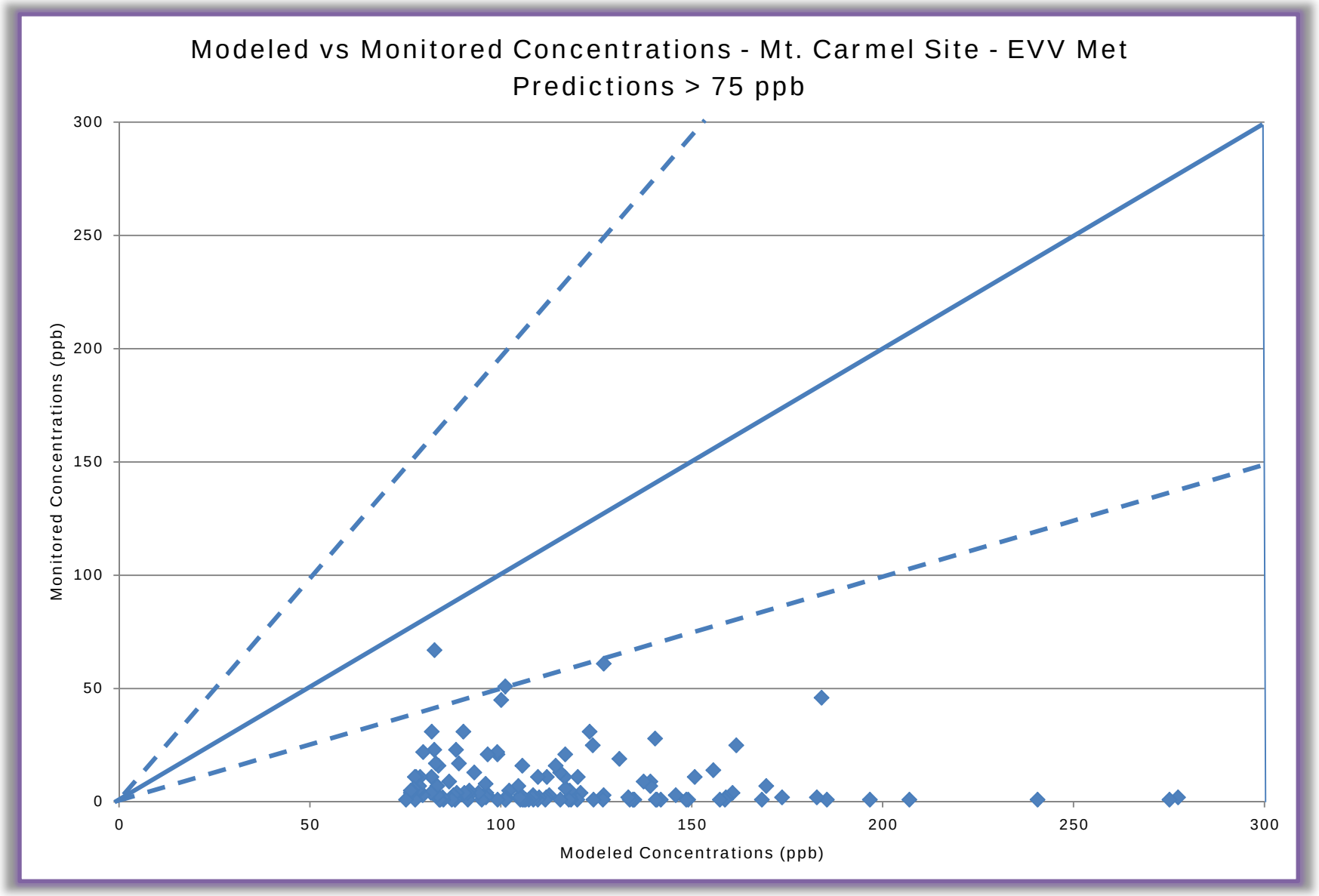
Predictions Greater Than 75 ppb

Even when looking at non-zero predicted hours, the majority of the concentrations are in the range of 1 to 10 ppb. This range is of little interest in the regulatory scheme. When the model predicts concentrations at or above 75 ppb, the level of the national ambient air quality standard for SO2, model performance is much more of an issue. This section focuses on predicted SO2 concentrations that are 75 ppb or greater.

Mt. Carmel Site

Figure 18 shows a comparison of modeled and monitored SO2 concentrations for the Mt. Carmel site for those hours where AERMOD predicts a maximum concentration of 75 ppb or greater. Of the 132 hours of ratios (modeled to monitored) shown, two are within the factor of two range (1.5 percent) while 130 hours are above a factor of two (98.5 percent).

Figure 18


Modeled vs Monitored Concentrations - Mt. Carmel Site - EVV Met
Predictions > 75 ppb
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250
300

East Site

Figure 19 shows a comparison of modeled and monitored SO2 concentrations for the East site for those hours where AERMOD predicts a maximum concentration of 75 ppb or greater. Of the 79 hours of ratios (modeled to monitored) shown, two are within the factor of two range (2.5 percent) while 77 hours are above a factor of two (97.5 percent).

Coal Road Site

Figure 20 shows a comparison of modeled and monitored SO2 concentrations for the Coal Rd. site for those hours where AERMOD predicts a maximum concentration of 75 ppb or greater. Of the 209 hours of ratios (modeled to monitored) shown, eight are within the factor of two range (3.8 percent) while 201 hours are above a factor of two (96.2 percent).

Schrodt Site

Figure 21 shows a comparison of modeled and monitored SO2 concentrations for the Schrodt site for those hours where AERMOD predicts a maximum concentration of 75 ppb or greater. Of the 31 hours of ratios (modeled to monitored) shown, 1 is within the factor of two range (3.2 percent) while 30 hours are above a factor of two (96.8 percent).

Overall this indicates that AERMOD is over-predicting 97 percent of the predicted concentrations that are 75 ppb or greater. In no case is it under-predicting these concentrations. In only 3 percent of the cases are the predictions within a factor of two. This would indicate serious problems with the model, both in accuracy and over-prediction.

Adjustment to Emission Rates

In comparing hours without comparing them in time, there is a problem that the predicted concentrations are based on different emission rates than those seen on the monitored days. In an attempt to correct for this, the emission rate on the highest monitored hour was determined as well as the emission rate on the highest predicted hour. The predicted concentration was then adjusted by a ratio of the monitored emission rate divided by the predicted emission rate. This set of corrections was made for all hours where the predicted concentration was greater than 75 ppb. The results for each site as discussed below.

Mt. Carmel Site

Figure 22 shows a comparison of adjusted predicted concentrations versus monitored concentrations for the Mt. Carmel Site. Of the 132 hours included, 12 are within a factor of two of the monitored values, while 120 are over-predicted by more than a factor of two. None of the values are under-predicted.

Figure 19

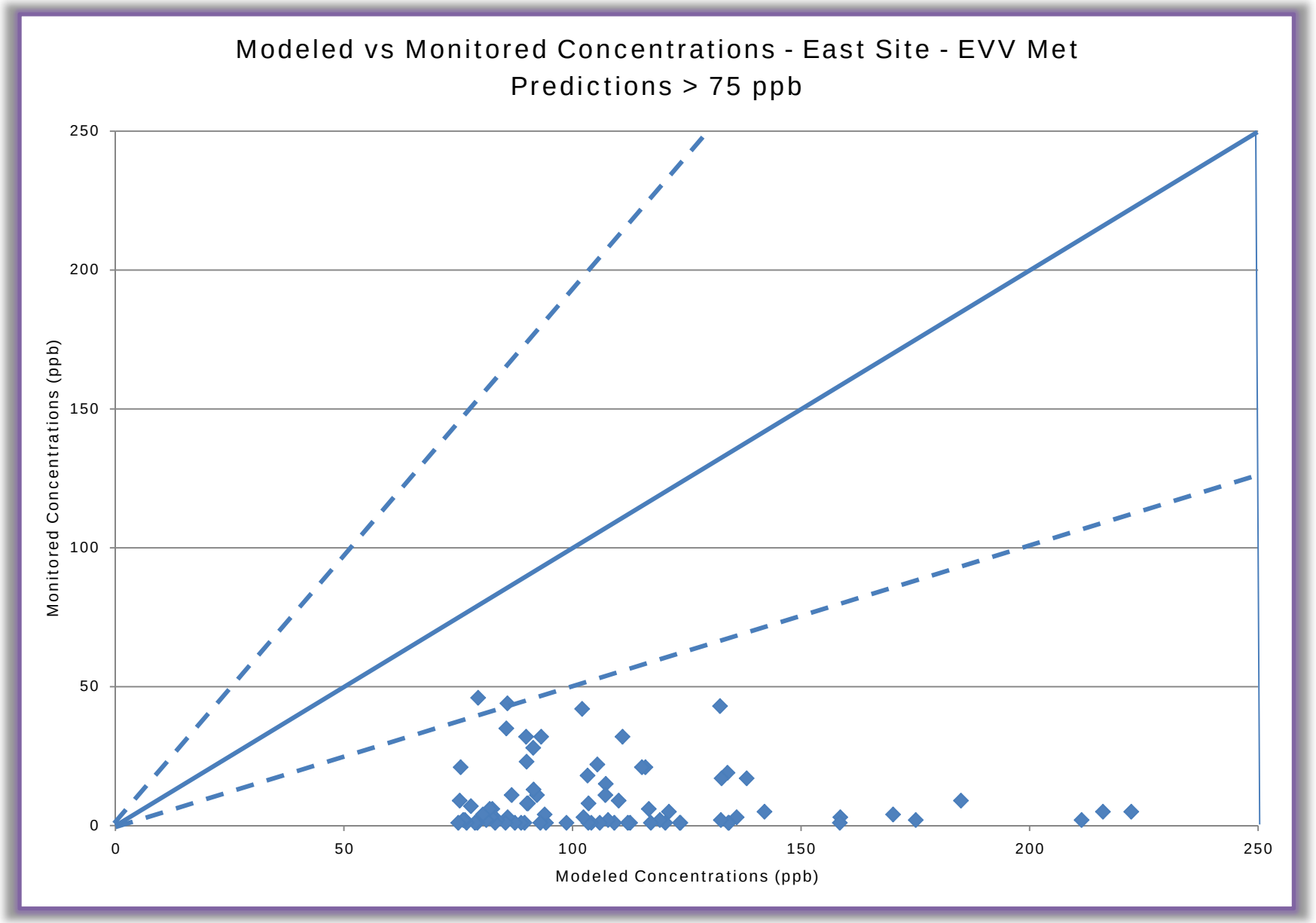

Modeled vs Monitored Concentrations - East Site - EVV Met
Predictions > 75 ppb
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250

Figure 20

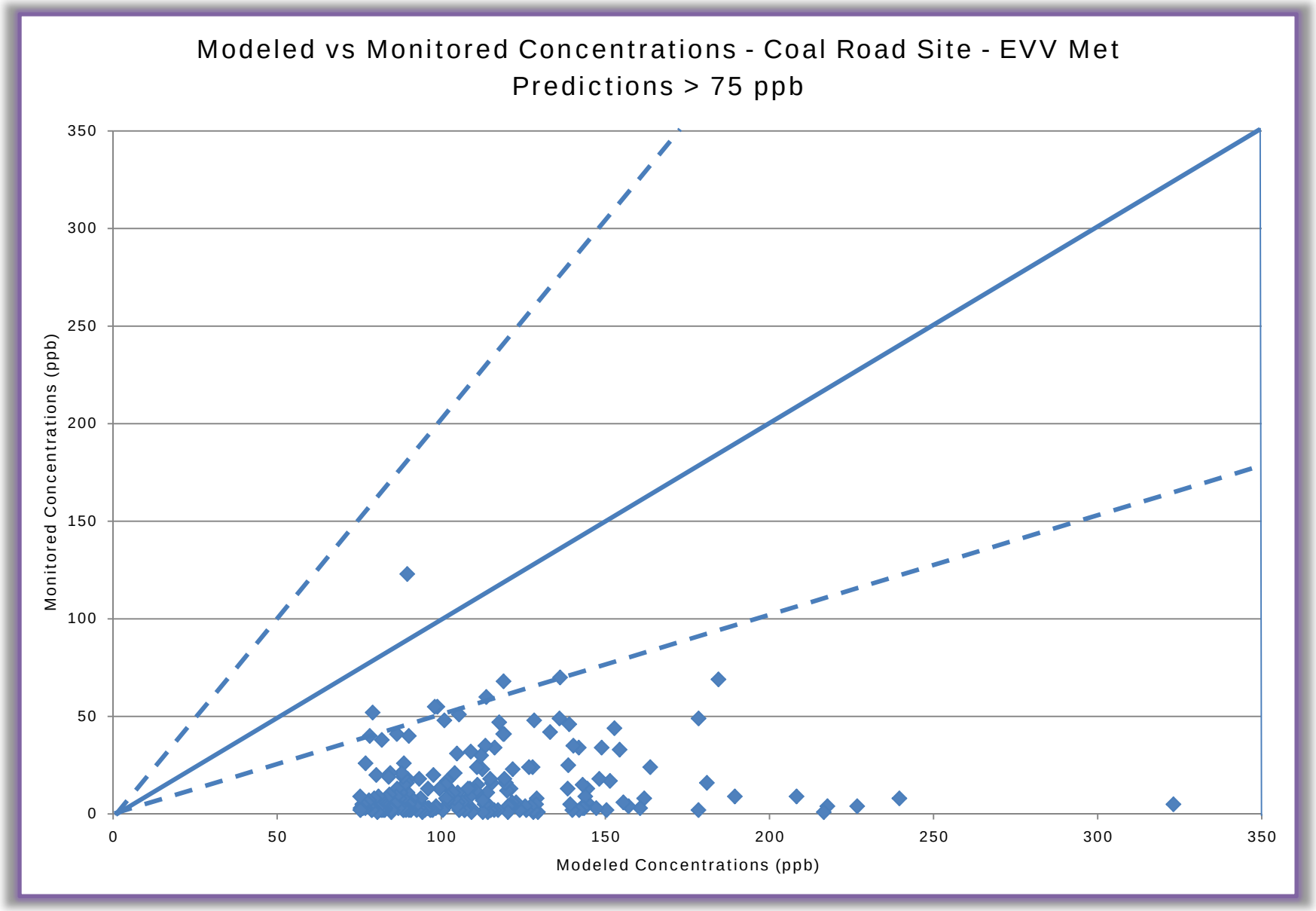

Modeled vs Monitored Concentrations - Coal Road Site - EVV Met
Predictions > 75 ppb
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250
300
350

Figure 21

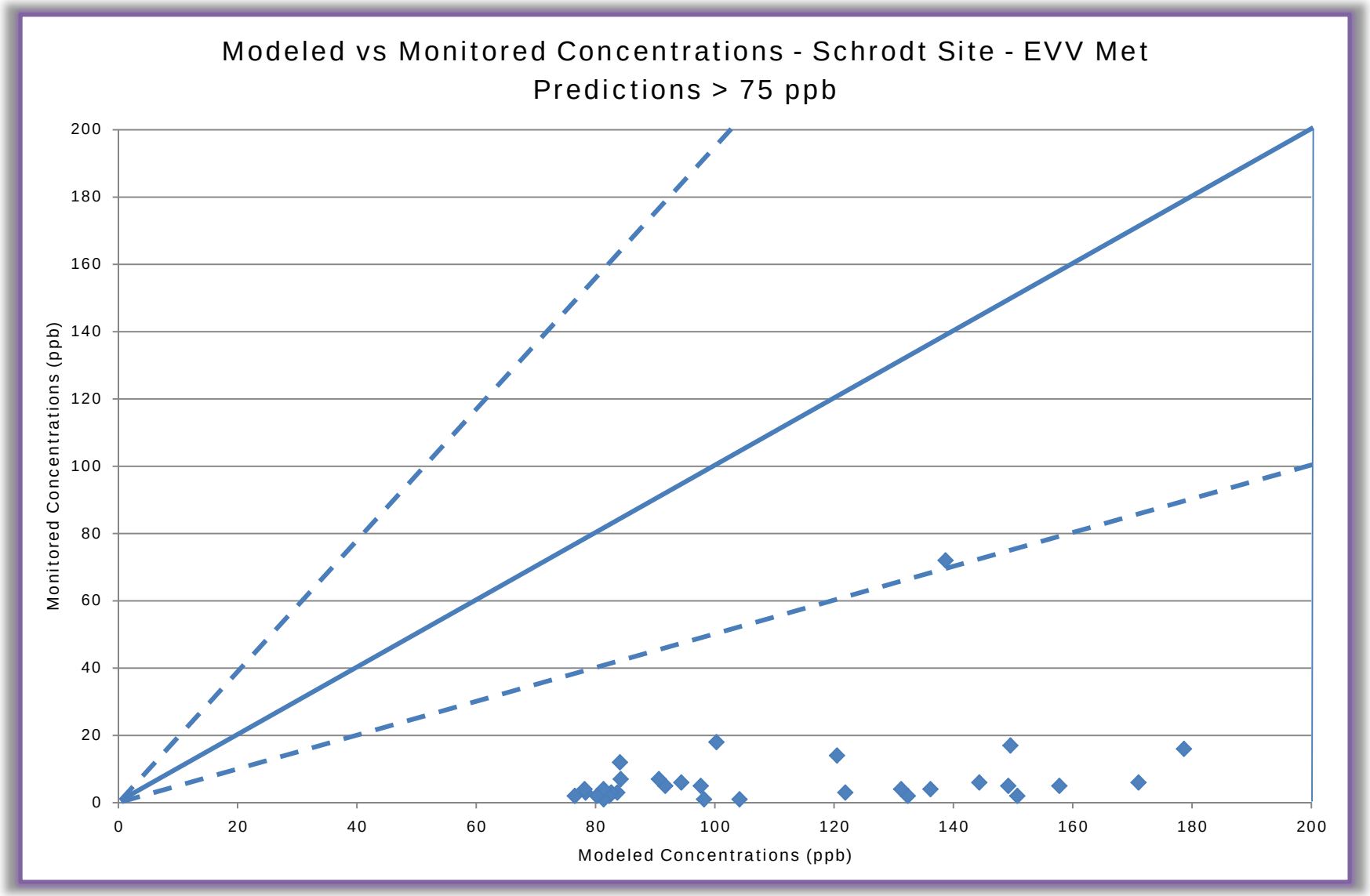

Modeled vs Monitored Concentrations - Schrodt Site - EVV Met
Predictions > 75 ppb
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
20
40
60
80
100
120
140
160
180
200

Figure 22

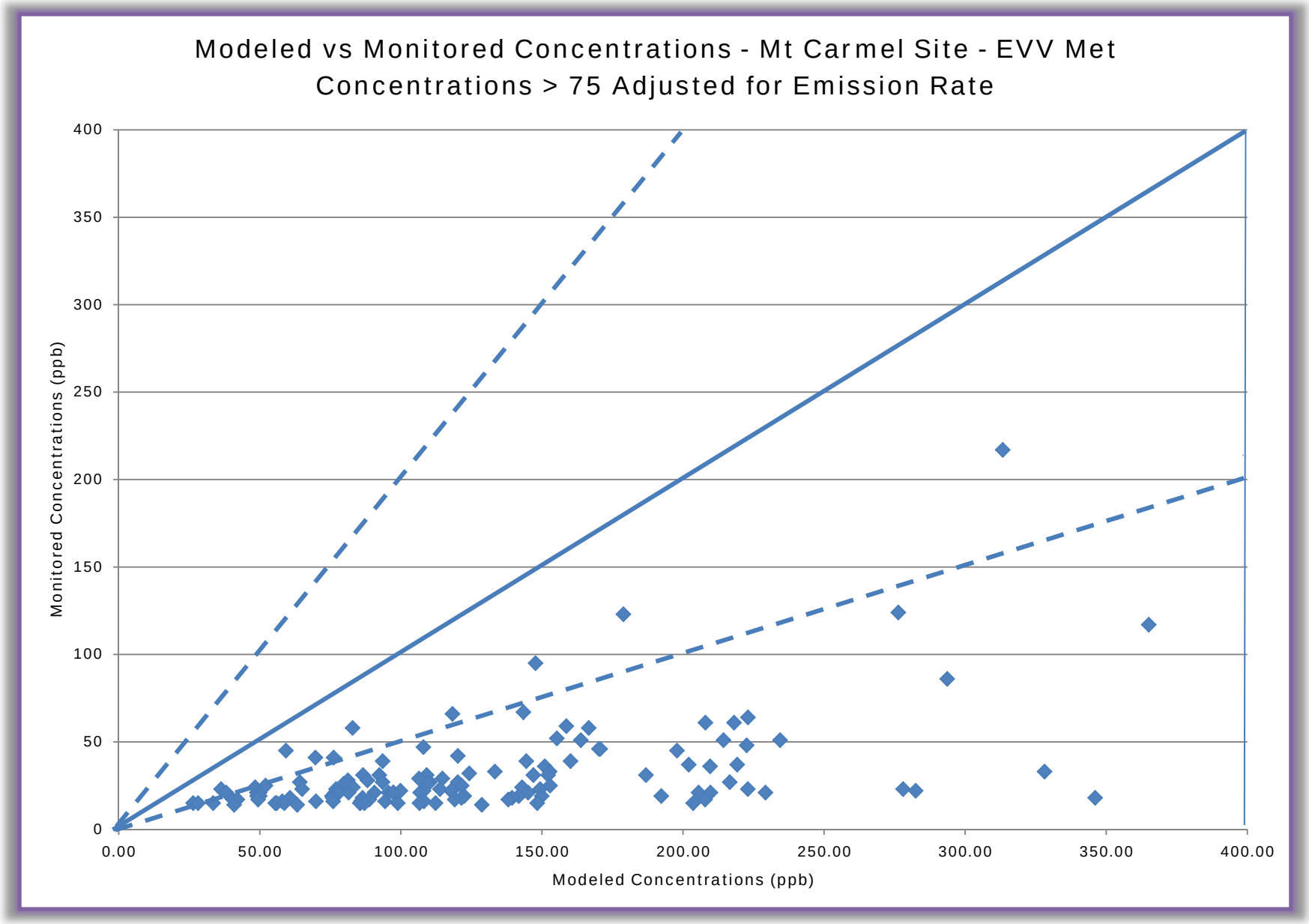
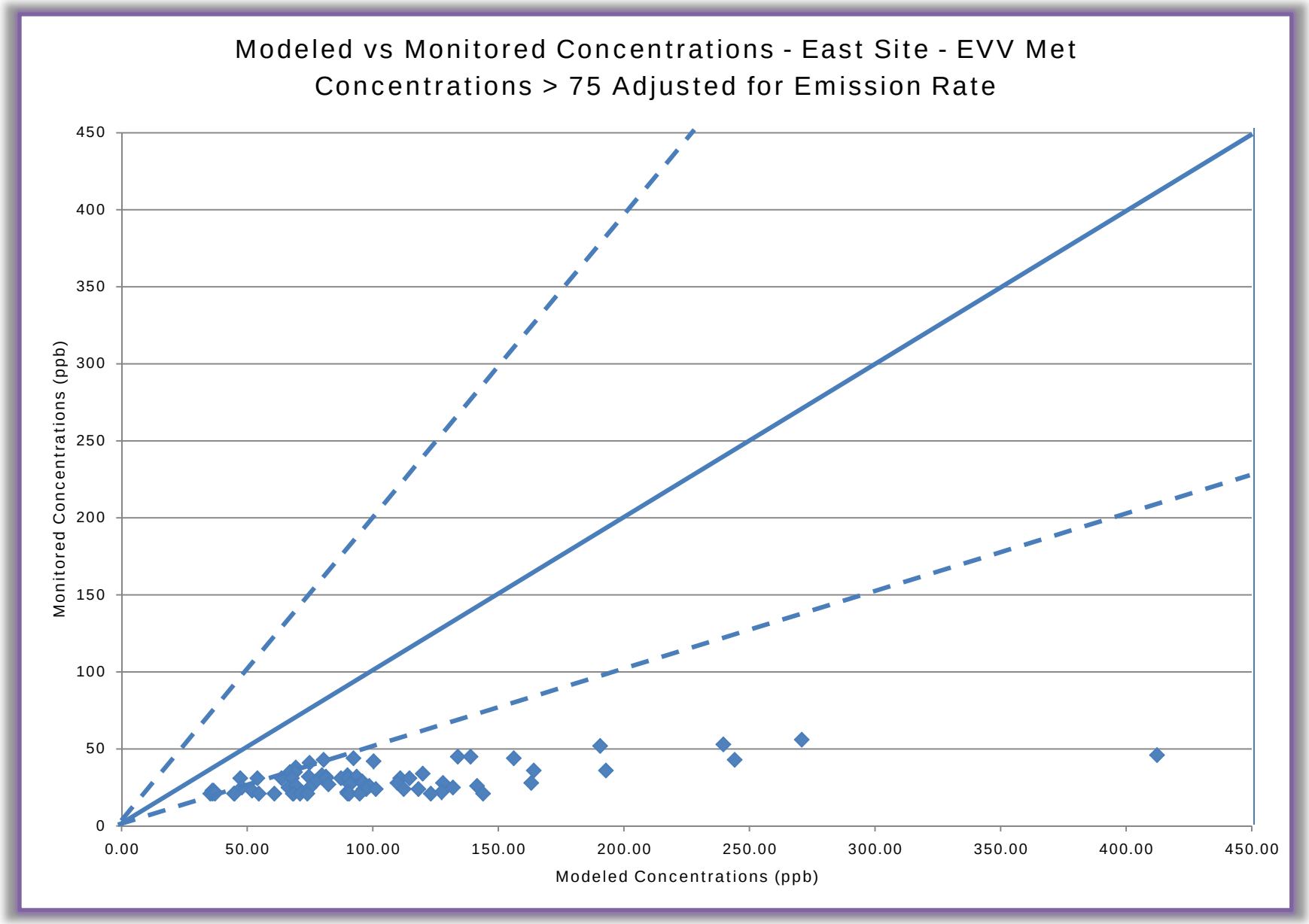

Modeled vs Monitored Concentrations - Mt Carmel Site - EVV Met
Concentrations > 75 Adjusted for Emission Rate
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250
300
350
400
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00

Figure 23


Modeled vs Monitored Concentrations - East Site - EVV Met
Concentrations > 75 Adjusted for Emission Rate
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250
300
350
400
450
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00

East Site

Figure 23 shows a comparison of adjusted predicted concentrations versus monitored concentrations for the East Site. Of the 74 hours included, 13 are within a factor of two of the monitored values, while 61 are over-predicted by more than a factor of two. None of the values are under-predicted.

Coal Road Site

Figure 24 shows a comparison of adjusted predicted concentrations versus monitored concentrations for the Coal Road Site. Of the 208 hours included, 26 are within a factor of two of the monitored values, while 182 are over-predicted by more than a factor of two. None of the values are under-predicted.

Schrodt Site

Figure 25 shows a comparison of adjusted predicted concentrations versus monitored concentrations for the Schrodt Site. Of the 31 hours included, 2 are within a factor of two of the monitored values, while 29 are over-predicted by more than a factor of two. None of the values are under-predicted.

SUMMARY

While the emission rate correction improves the agreement between predicted and monitored values, the majority of the predictions are still over-predicted by more than a factor of two.

The U.S. EPA argues that it is inappropriate to compare the values at the monitor sites (predicted and measured) due to the fact that the meteorological data from the National Weather Service station in Evansville may not be correct for the Gibson site. By the time the winds get there they may have different directions, perhaps plus or minus 10 degrees. The wind speeds may be different. While not included in this report, the U.S. EPA suggests looking at other receptor locations surrounding the monitor sites and using the highest predicted values within this box. Using higher predicted values will not improve the agreement between the monitored values and predicted values. It will result in worse model performance. Instead of pursuing this we have looked at the predicted concentrations at the monitor sites using on-site meteorology. This is addressed in the next section.

SCENARIO 3 RESULTS

Scenario 3 involves modeling using on-site data. The on-site meteorological data has been processed in a non-standard way. Typical processing begins with the lowest level of data and then proceeds to fill in missing data with higher levels. In this case to minimize the impact of an on-site cooling pond and due to the fact that the stacks are fairly tall, the data has been processed from the top down. This should provide a better set of meteorological data for the modeling analysis.

Figure 24

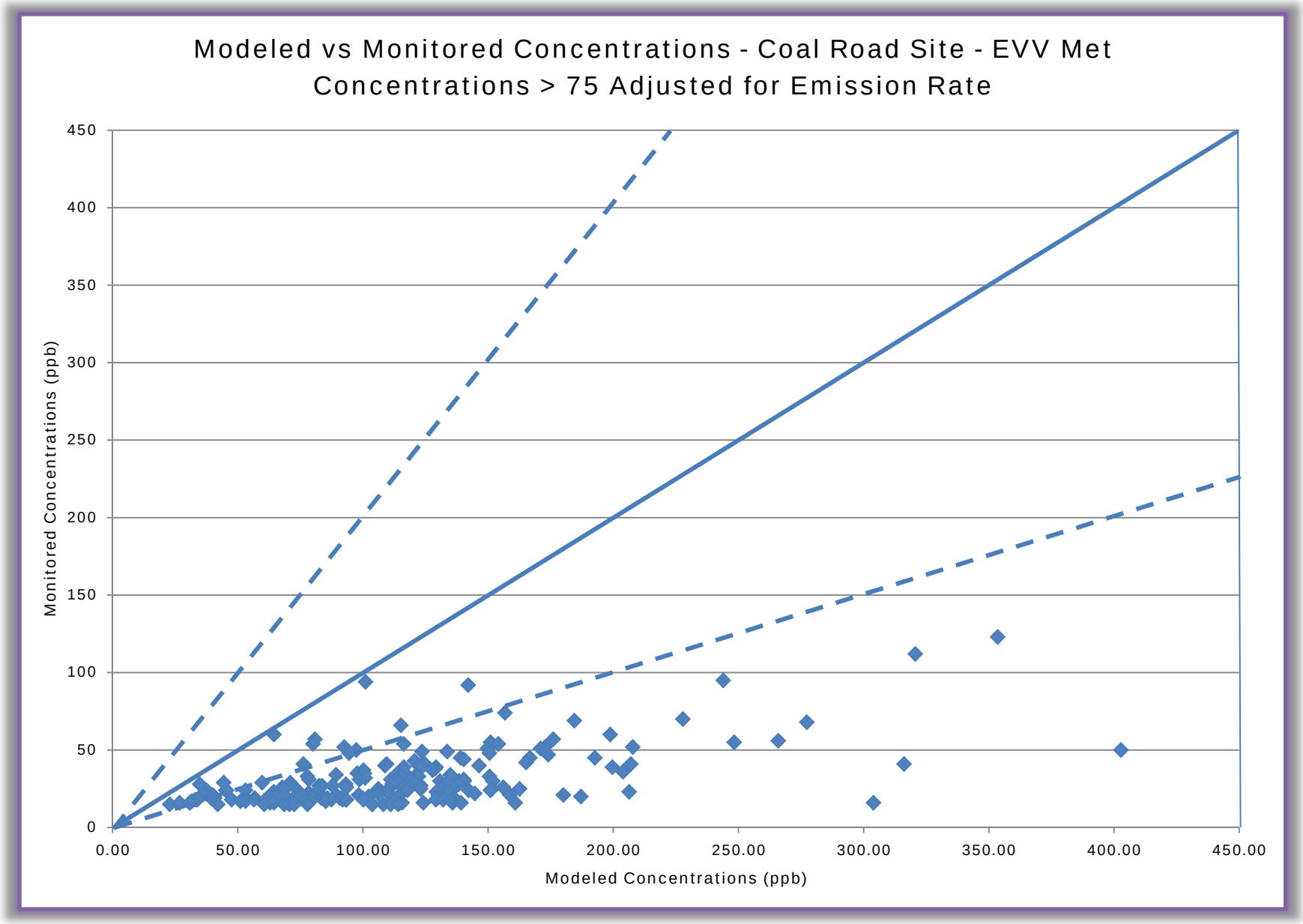
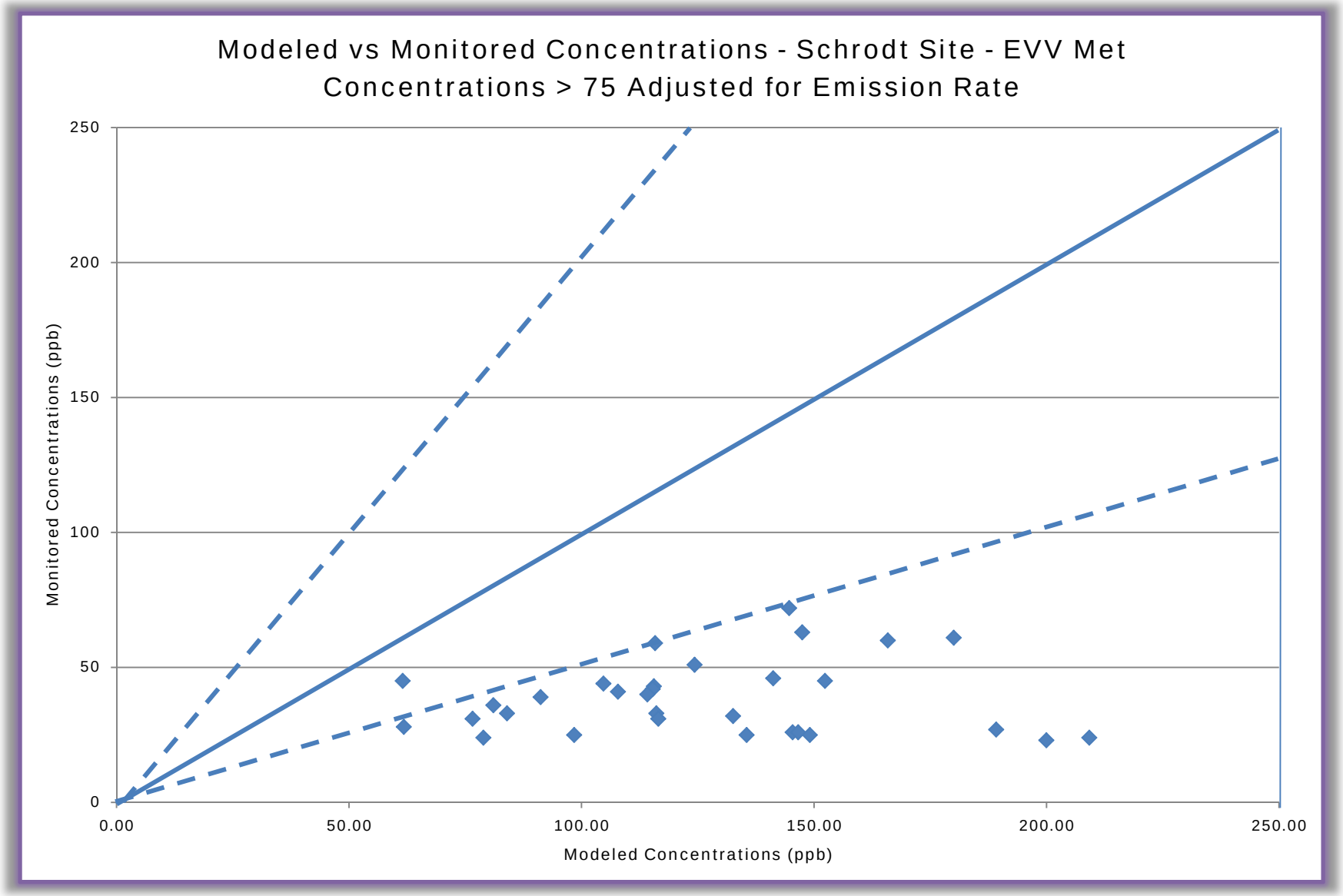

Modeled vs Monitored Concentrations - Coal Road Site - EVV Met
Concentrations > 75 Adjusted for Emission Rate
Monitored Concentrations (ppb)
0
50
100
150
200
250
300
350
400
450
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00
Modeled Concentrations (ppb)

Figure 25


Modeled vs Monitored Concentrations - Schrodt Site - EVV Met
Concentrations > 75 Adjusted for Emission Rate
Monitored Concentrations (ppb)
0
50
100
150
200
250
0.00
50.00
100.00
150.00
200.00
250.00
Modeled Concentrations (ppb)

All Data

The first set of results included all data where the hour has both a modeled and a monitored concentration. Those hours where monitored values were missing were excluded from the analysis.

Mt. Carmel Site

Figure 26 shows a comparison of modeled and monitored concentrations compared in time for the Mt. Carmel site. The line from the lower left corner to the upper right corner shows where the model and the monitor would perfectly agree. The other two lines show the factor of 2 areas. Values above the corner to corner line are under-predicted. Values below the corner to corner line are over-predicted. Those contained within the lines are within a factor of 2 of the monitored values. Of the 8214 hours of data, 83.9 percent are within a factor of 2, 3.7 percent are under-predicted and 12.5 percent are over-predicted.

East Site

Figure 27 shows a comparison of modeled and monitored concentrations compared in time for the East site. Of the 8360 hours of data, 80.2 percent are predicted within a factor of 2, 9.2 percent are under-predicted and 10.6 percent are over-predicted.

Coal Road Site

Figure 28 shows a comparison of modeled and monitored concentrations compared in time for the Coal Road site. Of the 8,349 hours of data, 72.3 percent are predicted within a factor of 2, 16.4 percent are under-predicted and 11.3 percent are over-predicted.

Schrodt Site

Figure 29 shows a comparison of modeled and monitored concentrations compared in time for the Schrodt site. Of the 8,319 hours of data, 75.5 percent are predicted within a factor of 2, 18.4 percent are under-predicted and 6.1 percent are over-predicted.

SUMMARY

Table 13 summarizes the results for all four sites. Overall 77.9 percent of the predictions are within a factor of 2 of the measured values, 12.0 percent are under-predicted and 10.1 percent are over-predicted. While this appears to be a reasonable performance later sections will explain why it is not.

Figure 26

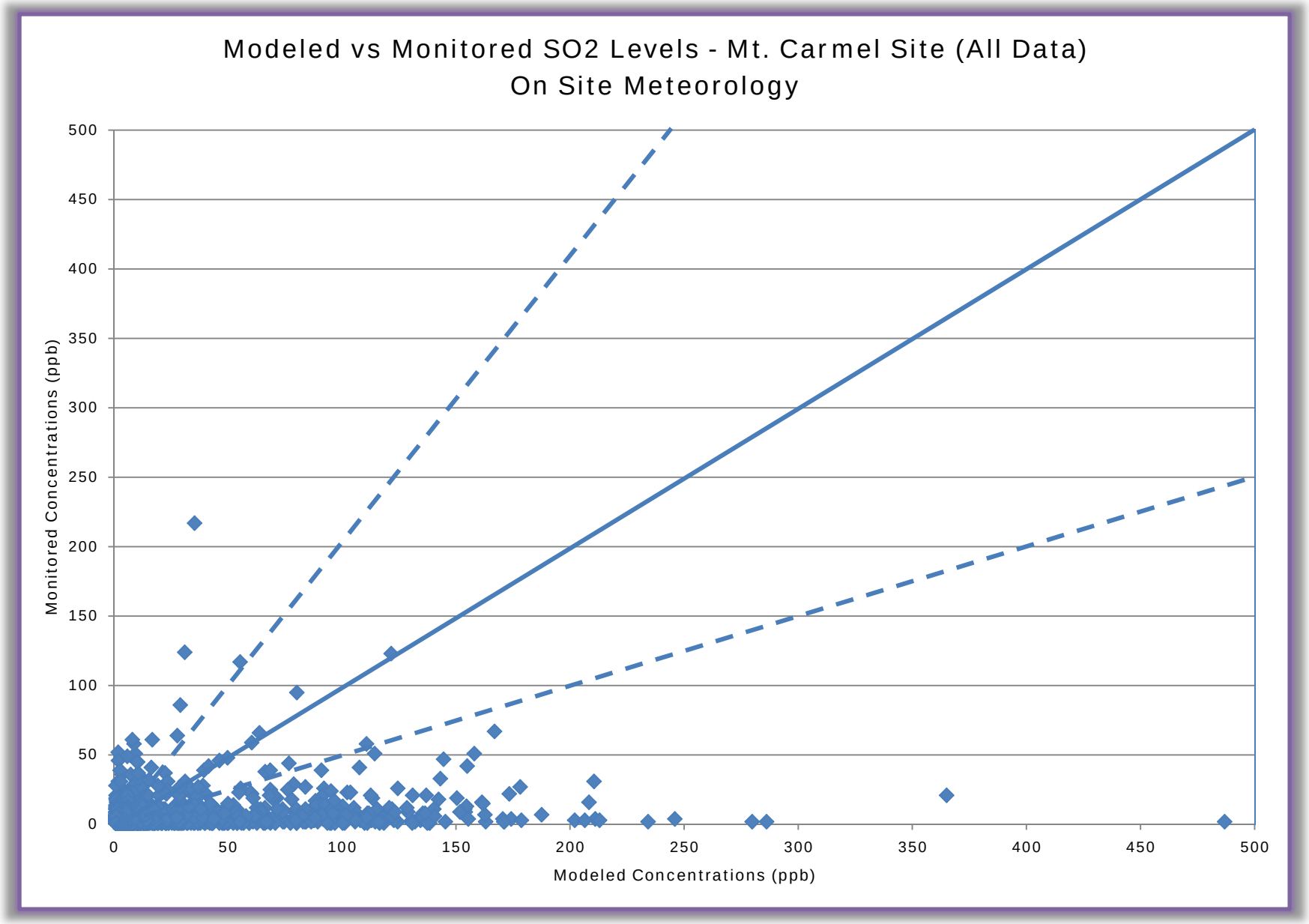

Modeled vs Monitored SO2 Levels - Mt. Carmel Site (All Data)
On Site Meteorology
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250
300
350
400
450
500

Figure 27

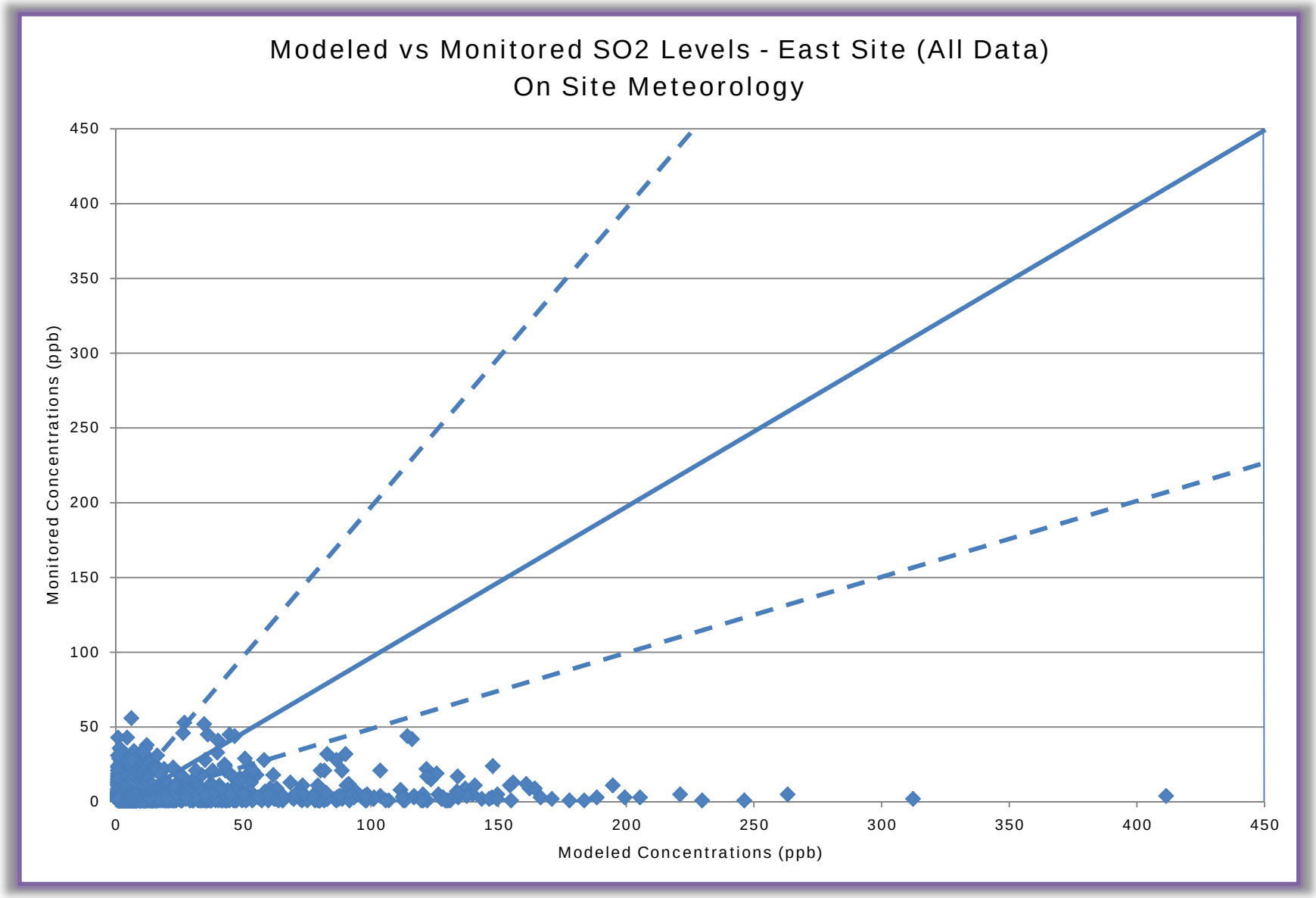

Modeled vs Monitored SO2 Levels - East Site (All Data)
On Site Meteorology
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250
300
350
400
450

Figure 28

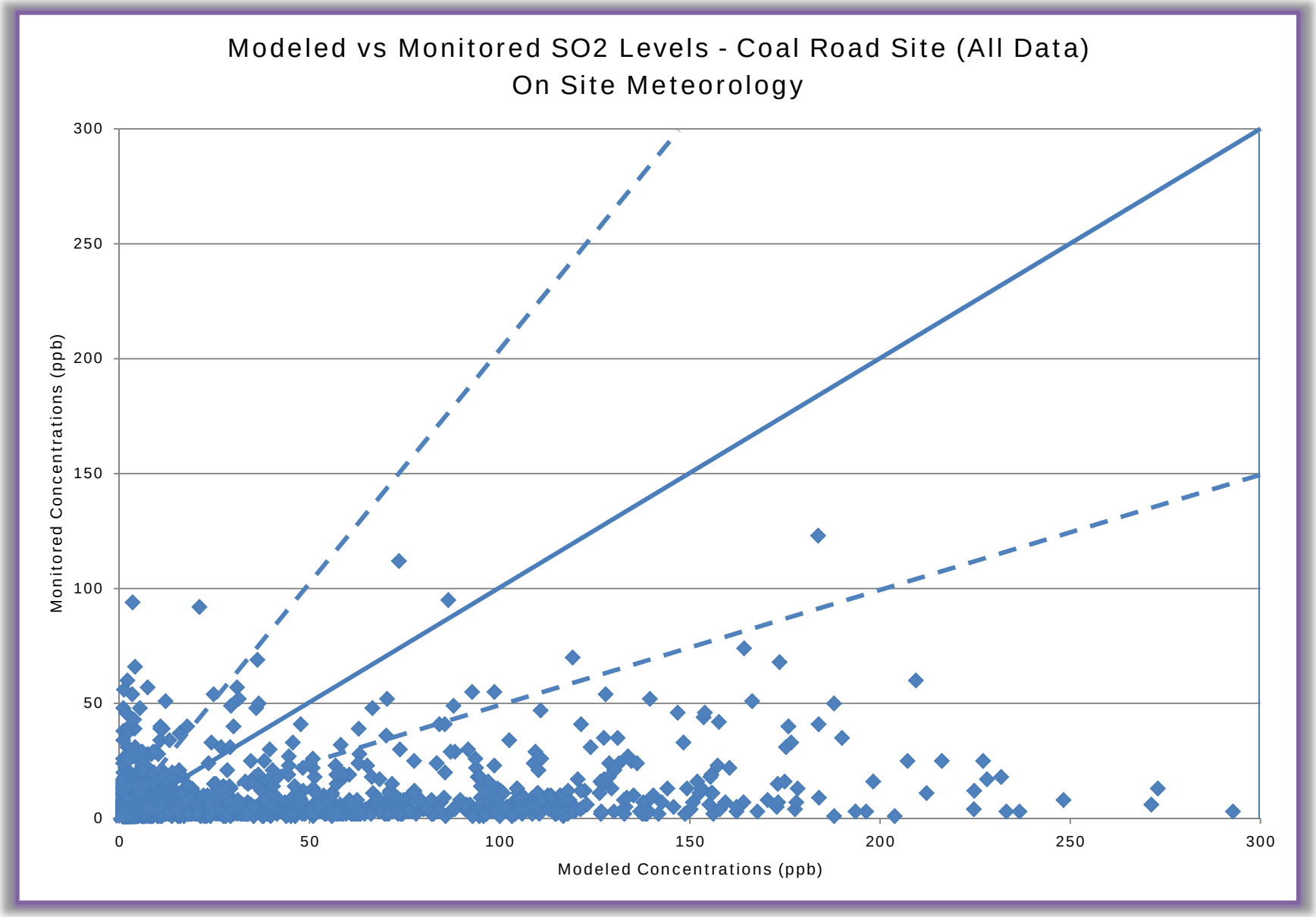

Modeled vs Monitored SO2 Levels - Coal Road Site (All Data)
On Site Meteorology
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250
300

Figure 29

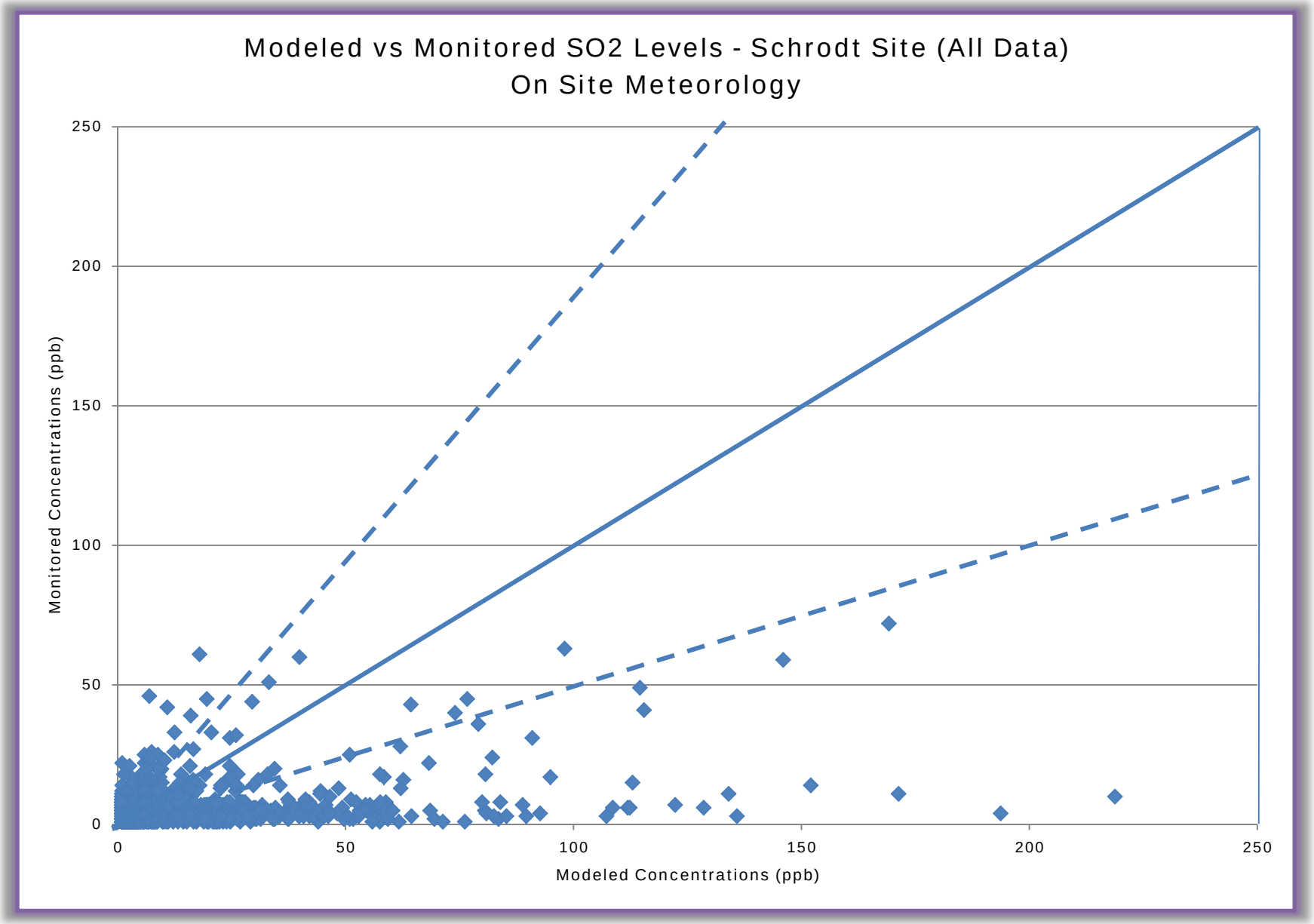

Modeled vs Monitored SO2 Levels - Schrodt Site (All Data)
On Site Meteorology
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250

Table 13
Results of Scenario 3 Analyses – All Data

	Mt. Carmel		East		Coal Road		Schrodt		Total	
Range	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent
<0.5	307	3.7	772	9.2	1367	16.4	1531	18.4	3977	12.0
0.5 – 2.0	6889	83.9	6704	80.2	6036	72.3	6283	75.5	25912	77.9
➢ **2.0**	1018	12.4	884	10.6	946	11.3	505	6.1	3353	10.1
Total	8214		8360		8349		8319		33242	

Wind Speed Analysis

Table 14 shows the average ratio of modeled divided by monitored concentrations versus wind speed. All four sites show that ratios drop off with wind speed. Ratios for higher wind speeds may not contain nearly as many data points as those for lower wind speeds.

Table 14
Comparison of Average Modeled/Monitored Ratios versus Wind Speed

Wind Speed Range	Mt. Carmel	East	Coal Road	Schrodt
0 -1 m/s	9.19	11.36	5.99	4.29
1.01 – 2	4.09	4.67	2.87	2.11
2.01 – 3	2.66	2.58	2.07	1.12
3.01 – 4	2.04	1.74	1.53	0.88
4.01 – 5	1.43	1.14	1.27	0.77
5.01 – 6	1.44	1.04	1.60	0.74
6.01 – 7	1.65	1.05	1.49	0.78
7.01 – 8	2.09	1.14	2.12	0.90
8.01 – 9	1.25	1.03	1.65	0.91
9.01 – 10	1.53	0.95	2.35	0.87
➢ **10**	1.96	1.03	2.73	0.83

Some persons would argue that using average values is inappropriate. Because the sample size of some categories may be small, one high ratio can overly impact the average. Table 15 shows the median ratios versus wind speed. In all cases the ratios are between 0.5 and 2.

Table 15
Comparison of Median Modeled/Monitored Ratios versus Wind Speed

Wind Speed Range	Mt. Carmel	East	Coal Road	Schrodt
0 -1 m/s	1.00	1.00	0.86	1.00
1.01 – 2	1.00	1.00	0.80	1.00
2.01 – 3	1.00	1.00	0.68	0.80
3.01 – 4	1.00	1.00	0.64	0.67
4.01 – 5	1.00	1.00	0.51	0.67
5.01 – 6	1.00	1.00	0.54	0.67
6.01 – 7	1.00	1.00	0.53	1.00
7.01 – 8	1.00	1.00	0.58	1.00
8.01 – 9	1.00	1.00	0.54	1.00
9.01 – 10	1.01	1.00	0.55	1.00
➢ **10**	1.02	1.01	0.54	1.00

Wind Direction Analysis

Table 16 compares modeled to monitored ratios versus wind direction. The directions which are directly from the stacks to the monitors are highlighted in the table.

Table 16
Comparison of Average Modeled to Monitored Ratios versus Wind Direction

WD Range	Mt. Carmel	East	Coal Road	Schrodt
0 – 10	1.49	1.31	1.04	0.97
11 – 20	1.67	1.57	1.22	0.90
21 – 30	1.70	1.85	1.21	0.93
31 – 40	1.85	1.51	1.16	0.89
41 – 50	1.18	1.23	0.83	0.75
51 – 60	1.81	2.15	1.28	0.91
61 – 70	1.75	1.98	1.46	1.50
71 – 80	2.25	1.61	1.23	2.68
81 – 90	1.91	2.79	1.28	**3.57**
91 – 100	2.31	2.44	1.39	3.43
101 – 110	1.47	1.32	0.87	1.79
111 – 120	1.30	1.33	0.91	0.94
121 – 130	1.49	1.44	0.84	0.94
131 – 140	1.28	1.48	1.02	0.93
141 – 150	3.18	1.73	1.18	1.00
151 – 160	2.93	1.45	0.84	0.90
161 – 170	**6.68**	1.72	1.24	0.93
171 – 180	**9.61**	1.72	1.03	0.99
181 – 190	4.28	3.19	1.94	1.04
191 – 200	2.31	2.03	1.34	1.03
201 – 210	1.93	2.25	4.62	1.32
211 – 220	2.24	2.84	**9.73**	1.09
221 – 230	2.12	2.80	6.67	1.22
231 – 240	1.95	1.76	3.00	1.16
241 – 250	2.45	2.51	2.08	1.21
251 – 260	1.73	2.08	1.37	0.97
261 – 270	1.88	2.87	1.01	0.75
271 – 280	2.20	4.94	1.20	0.79
281 – 290	1.71	8.37	1.04	0.98
291 – 300	1.55	**5.62**	1.08	0.73
301 – 310	1.38	**4.16**	0.95	0.76
311 – 320	1.87	2.81	1.16	0.75
321 – 330	1.36	1.64	0.86	1.00
331 – 340	1.38	1.68	0.88	1.00
341 – 350	1.30	1.32	0.85	1.00
351 – 360	1.34	1.00	0.84	1.00

For the key wind directions the average ratios are much higher than two. This would indicate that in the directions where the wind is blowing from the stacks to the monitors, the disagreement between model and the monitor is greatest.

Table 17

Comparison of Median Modeled to Monitored Ratios versus Wind Direction

WD Range	Mt. Carmel	East	Coal Road	Schrodt
0 – 10	1.00	1.00	0.59	1.00
11 – 20	1.00	1.00	0.67	0.80
21 – 30	1.00	1.00	0.67	0.71
31 – 40	1.00	1.00	0.56	0.67
41 – 50	1.00	1.00	0.55	0.60
51 – 60	1.00	1.00	0.67	0.63
61 – 70	1.00	1.00	0.67	0.75
71 – 80	1.00	1.00	0.76	0.63
81 – 90	1.00	1.00	0.67	1.00
91 – 100	1.00	1.00	0.67	0.75
101 – 110	1.00	1.00	0.67	0.67
111 – 120	1.00	1.00	0.52	0.67
121 – 130	1.00	1.00	0.57	0.75
131 – 140	1.00	1.00	0.67	0.67
141 – 150	1.00	1.00	0.67	0.70
151 – 160	1.00	1.00	0.51	0.67
161 – 170	1.00	1.00	0.67	0.67
171 – 180	1.25	1.00	0.67	1.00
181 – 190	1.00	1.00	0.50	0.80
191 – 200	1.00	1.00	0.50	0.67
201 – 210	1.00	1.00	0.67	0.93
211 – 220	1.00	1.00	1.32	0.75
221 – 230	1.00	1.00	1.00	0.75
231 – 240	1.01	1.00	0.57	0.67
241 – 250	1.00	1.00	0.68	1.00
251 – 260	1.00	1.00	0.67	0.99
261 – 270	1.00	1.00	0.50	1.21
271 – 280	1.00	1.00	0.52	1.14
281 – 290	1.00	1.00	0.51	1.10
291 – 300	1.00	1.00	0.67	0.99
301 – 310	1.00	0.75	0.67	0.87
311 – 320	1.00	0.50	0.67	1.25
321 – 330	1.00	0.67	0.52	0.99
331 – 340	1.00	0.71	0.55	0.96
341 – 350	1.00	1.00	0.51	0.96
351 – 360	1.00	1.14	0.50	1.04

Table 17 shows the median ratios of modeled to monitored concentrations versus wind direction. Once again the key wind directions show the largest discrepancies between the modeled and the monitored concentrations.

Comparisons Not in Time

U.S. EPA does not believe that these values should be paired in time. While we do not agree we wish to show the results of such an analysis. In this case the modeled and monitored values are ranked from lowest to highest and then paired. Figures 30 through 33 show the results. For the Mt. Carmel Site (figure 30) AERMOD over-predicts throughout the entire range except for where concentrations are below about 25 ppb. The East Site (Figure 31) shows an AERMOD over-prediction outside the factor of two for the entire range except for concentrations below 25 ppb. The Coal Road Site (Figure 32) shows an AERMOD over-prediction of more than a factor of two except for concentrations below about 20 ppb. The Schrodt Site (Figure 33) shows an AERMOD over-prediction by more than a factor of two except for concentrations below 20 ppb.

IDEM believes that it is not appropriate to compare the data in this fashion. Since each hour has a different emission rate, comparison of different hours is comparing apples and oranges. Without making corrections for emission rates, an accurate assessment of a comparison of this type is not appropriate.

However, it is possible to compare the data without actually comparing individual hours at all. Table 18 looks at the frequency at which modeled and monitored concentrations occur within certain concentration ranges. Of particular interest are the number of hours that exceed the standard of 75 parts per billion (ppb). For the Mt. Carmel site AERMOD predicts 256 hours above the standard, while the monitor only measured 6. For the East site AERMOD predicts 140 hours above the standard, while the monitor measured none. For the Coal Road site AERMOD predicts 244 hours above the standard, while the monitor measured 5. For the Schrodt site AERMOD predicts 35 hours above the standard, while the monitor measured none. This seems to indicate that AERMOD predicts many more exceedances than the monitors are measuring.

Figure 30

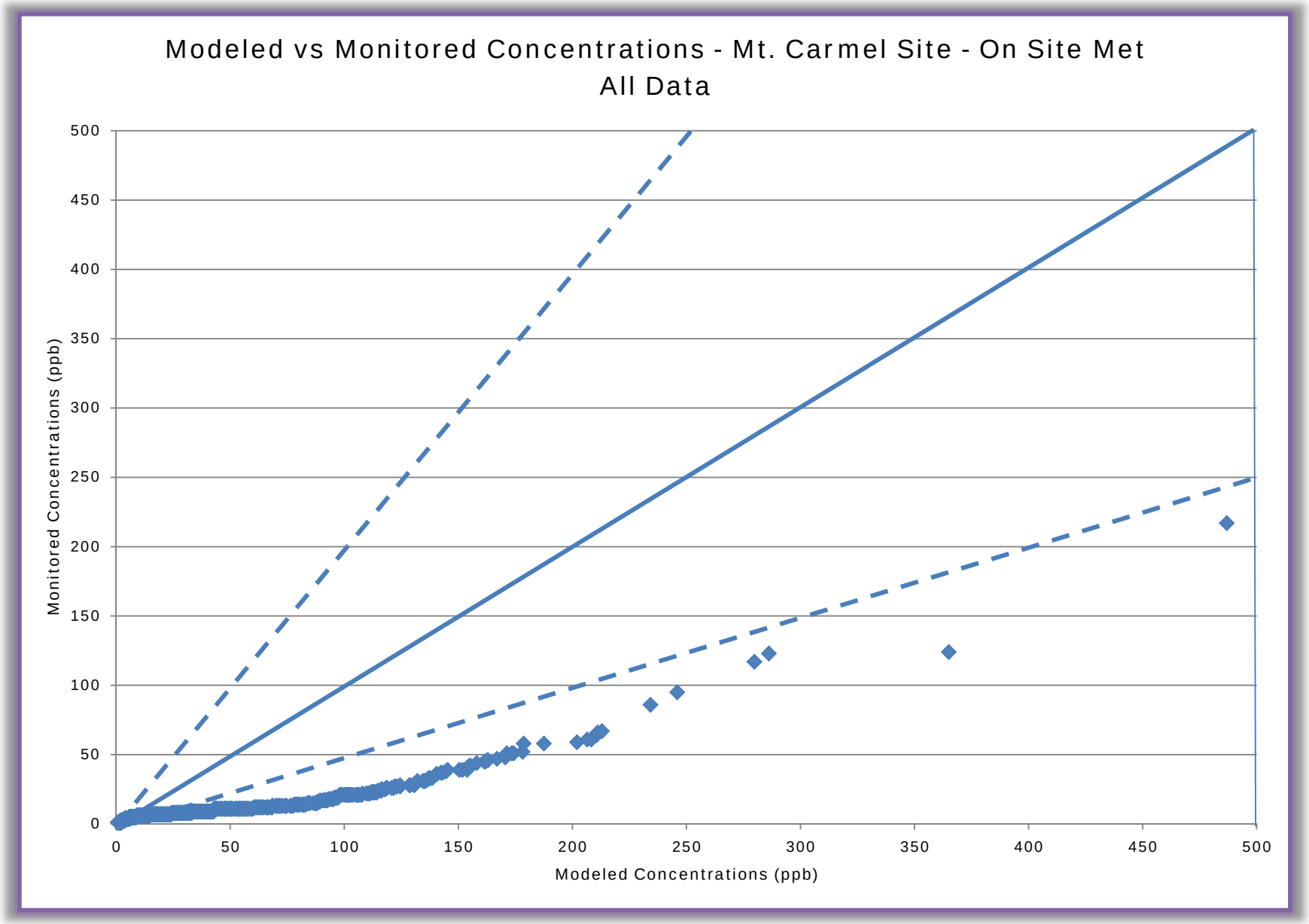

Modeled vs Monitored Concentrations - Mt. Carmel Site - On Site Met
All Data
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250
300
350
400
450
500

Figure 31

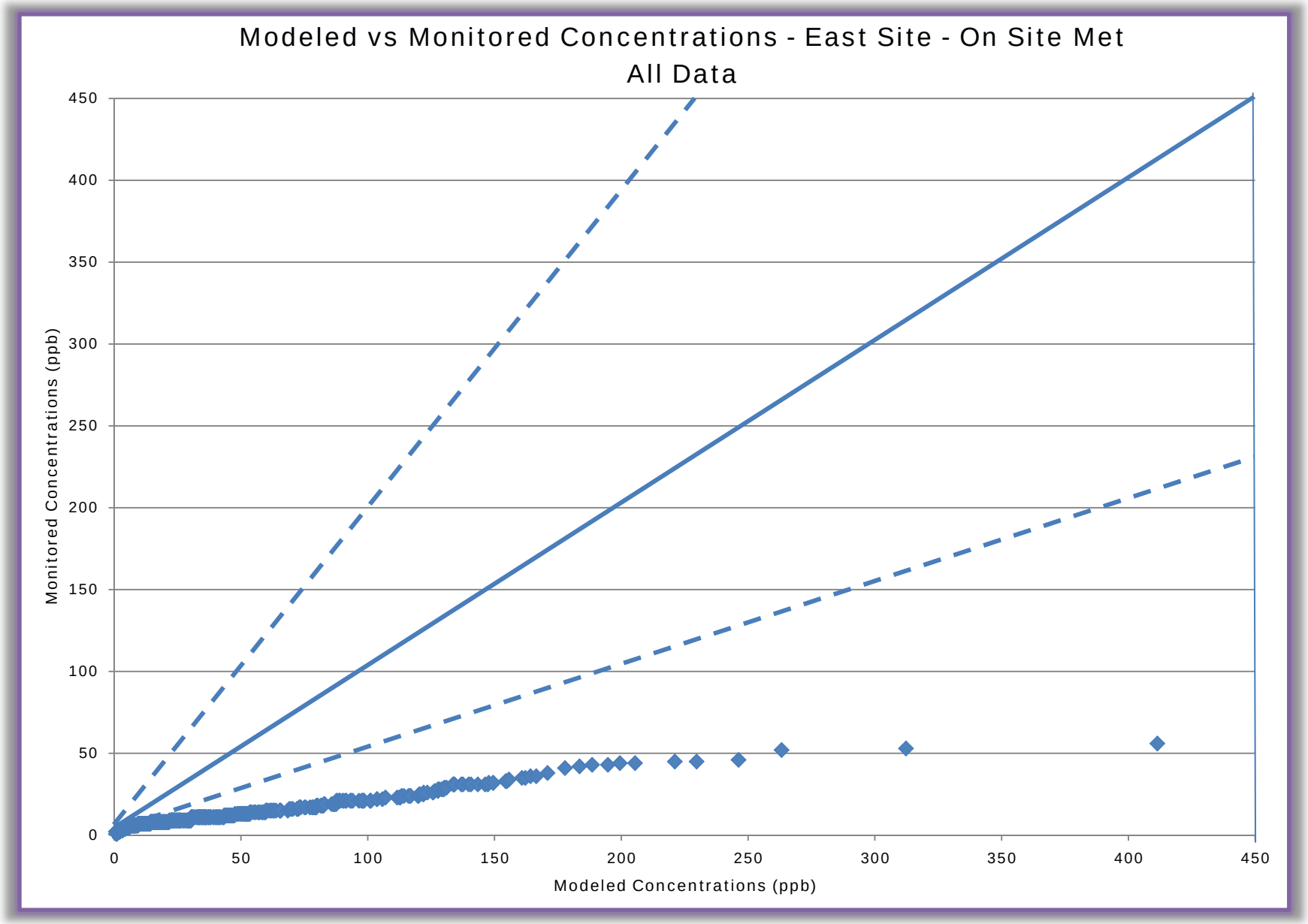

Modeled vs Monitored Concentrations - East Site - On Site Met
All Data
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250
300
350
400
450

Figure 32

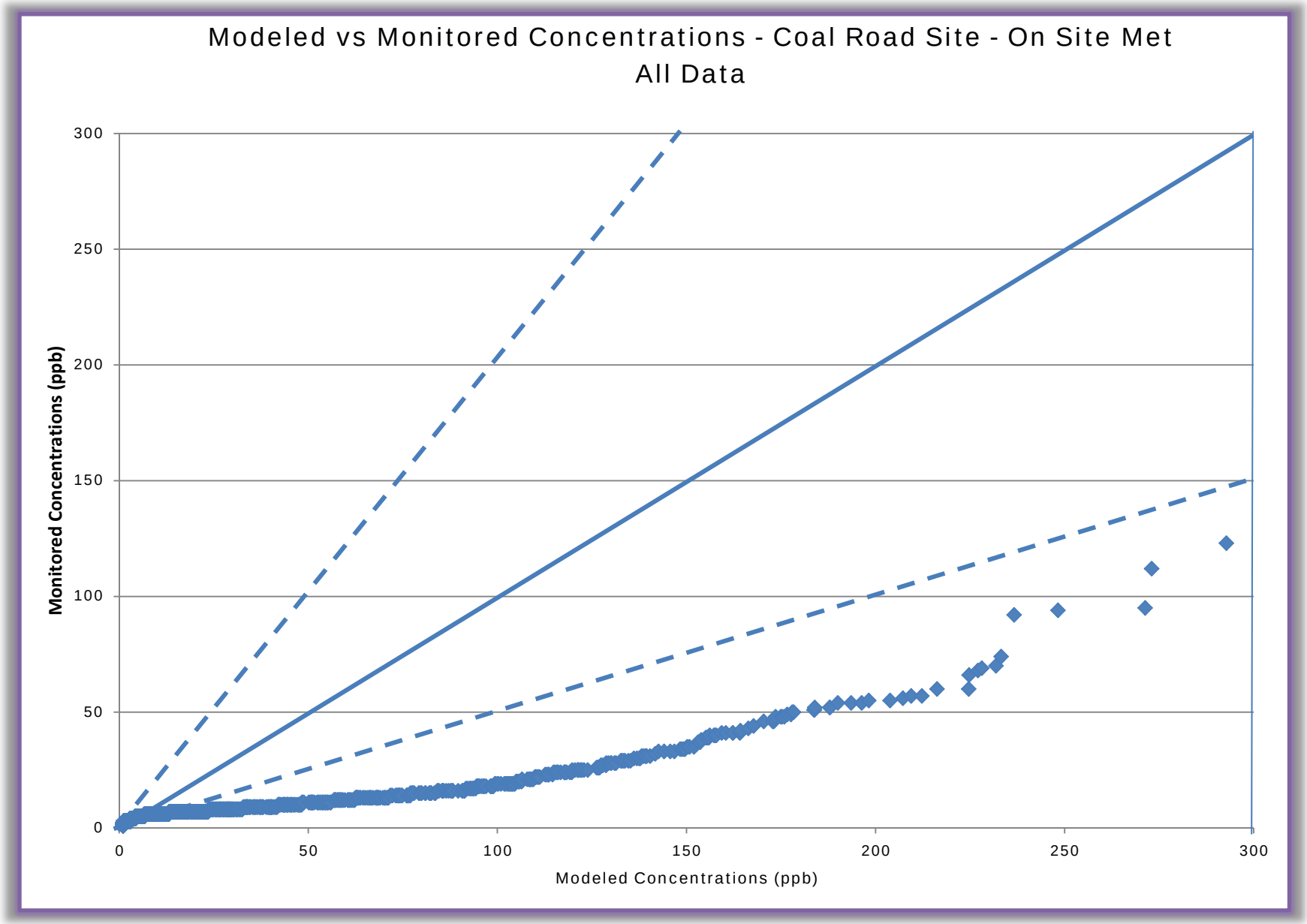

Modeled vs Monitored Concentrations - Coal Road Site - On Site Met
All Data
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250
300

Figure 33

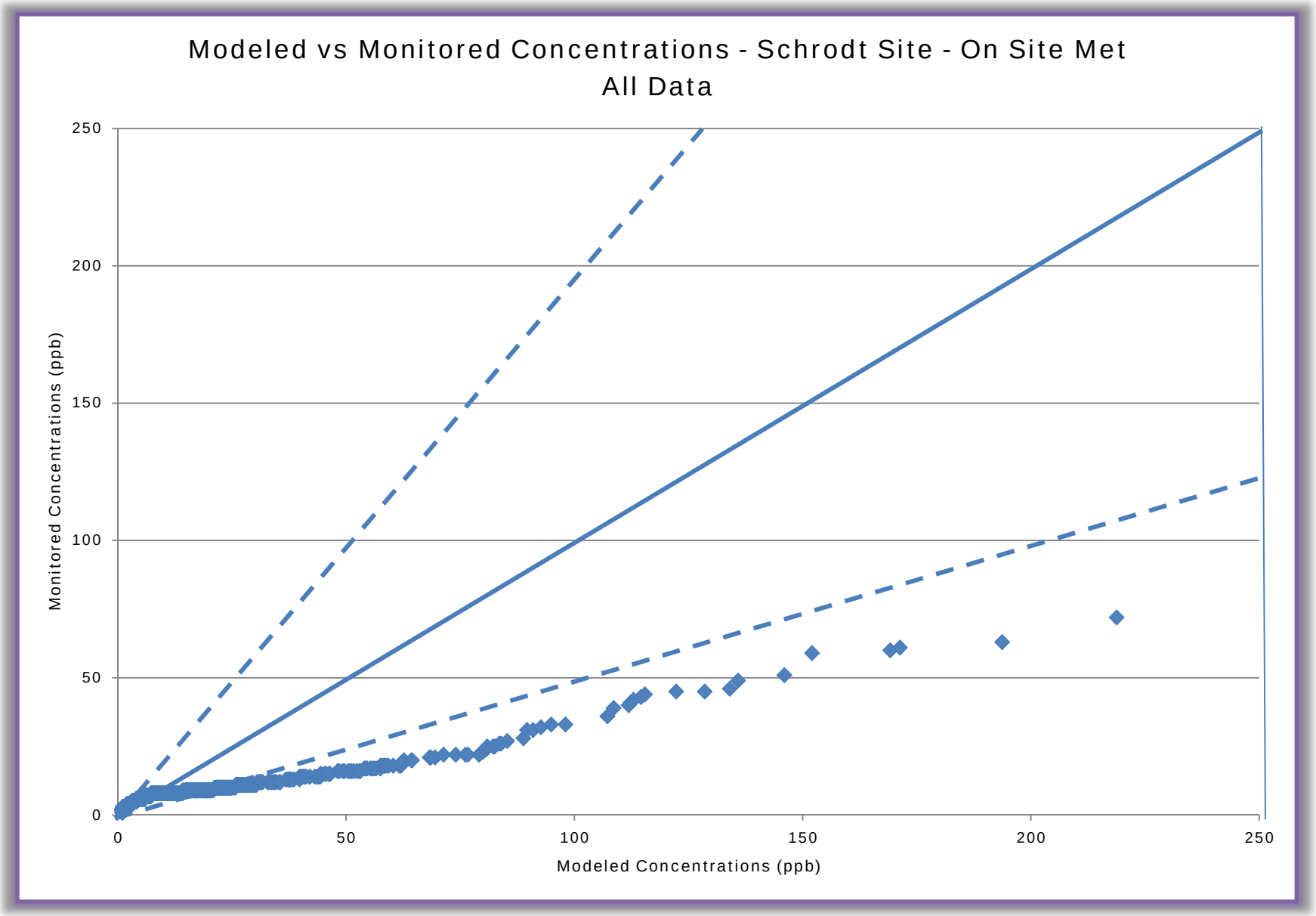

Modeled vs Monitored Concentrations - Schrodt Site - On Site Met
All Data
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250

Table 18
Hours within Selected Ranges – Scenario 3 – All Data

	Mt. Carmel		East		Coal Road		Schrodt	
Range	Model	Monitor	Model	Monitor	Model	Monitor	Model	Monitor
1 – 25	7791	8150	8052	8314	7773	8247	8146	8293
26 – 50	167	46	138	43	207	77	102	20
51 – 75	82	12	54	3	125	20	36	6
76 – 100	154	2	48	0	77	3	18	0
101 – 125	48	3	24	0	65	2	8	0
126 – 150	21	0	24	0	41	0	4	0
151 – 175	18	0	32	0	30	0	3	0
176 – 200	3	0	5	0	15	0	1	0
201 – 225	6	1	2	0	7	0	1	0
226 – 250	2	0	2	0	6	0	0	0
251 – 275	0	0	1	0	2	0	0	0
276 – 300	2	0	0	0	1	0	0	0
301 – 325	0	0	1	0	0	0	0	0
326 – 350	0	0	0	0	0	0	0	0
351 – 375	1	0	0	0	0	0	0	0
376 – 400	0	0	0	0	0	0	0	0
401 – 425	0	0	1	0	0	0	0	0
426 – 450	0	0	0	0	0	0	0	0
451 – 475	0	0	0	0	0	0	0	0
476 - 500	1	0	0	0	0	0	0	0
Total	8214	8214	8360	8360	8349	8349	8319	8319
Above 75	256	6	40	0	244	5	35	0

Non-Zero Predictions Only

The analyses presented so far have used all data where both the predicted and the monitored values are available for an hour. However, the majority of these readings are non-meaningful. In most cases AERMOD predicts a zero value which then has a background value added and then is compared to the monitored value. This is not a true measure of how the model is working. Model predictions of zero are of little interest except for computing an annual average value. This set of analyses removes all hours where the AERMOD predicted value was zero.

Mt. Carmel Site

Figure 34 shows a comparison of predicted and measured SO2 levels compared in time for the Mt. Carmel site. Of the 3150 hours of data, 63.0 percent are predicted within a factor of two, while 5.5 percent are under-predicted by more than a factor of two and 31.5 percent are over-predicted by more than a factor of two.

East Site

Figure 35 shows a comparison of predicted and measured SO2 levels compared in time for the East site. Of the 2825 hours of data, 62.3 percent are predicted within a factor of two, while 6.7 percent are under-predicted by more than a factor of two and 31.0 percent are over-predicted by more than a factor of two.

Coal Road Site

Figure 36 shows a comparison of predicted and measured SO2 levels compared in time for the Coal Road site. Of the 3213 hours of data, 57.3 percent are predicted within a factor of two, while 13.3 percent are under-predicted by more than a factor of two and 29.4 percent are over-predicted by more than a factor of two.

Schrodt Site

Figure 37 shows a comparison of predicted and measured SO2 levels compared in time for the Schrodt site. Of the 3402 hours of data, 73.9 percent are predicted within a factor of two, while 11.8 percent are under-predicted by more than a factor of two and 14.3 percent are over-predicted by more than a factor of two.

SUMMARY

Table 19 summarizes the results for all four sites. Overall 64.3 percent of the predictions are within a factor of two of the measured values, 9.5 percent are under-predicted by more than a factor of two and 26.2 percent are over-predicted by more than a factor of two. The performance of AERMOD is not as good as shown earlier. Fewer predictions are within the factor of two and there are nearly three times as many over-predictions as under-predictions.

Table 19
Results of Scenario 3 Analyses – Non-Zero Predictions Only

	Mt. Carmel		East		Coal Road		Schrodt		Total	
Range	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent
<0.5	172	5.5	190	6.7	429	13.3	403	11.8	1194	9.5
0.5 – 2.0	1983	63.0	1761	62.3	1840	57.3	2513	73.9	8097	64.3
➢ **2.0**	995	31.5	874	31.0	944	29.4	486	14.3	3299	26.2
Total	3150		2825		3213		3402		12590	

Figure 34

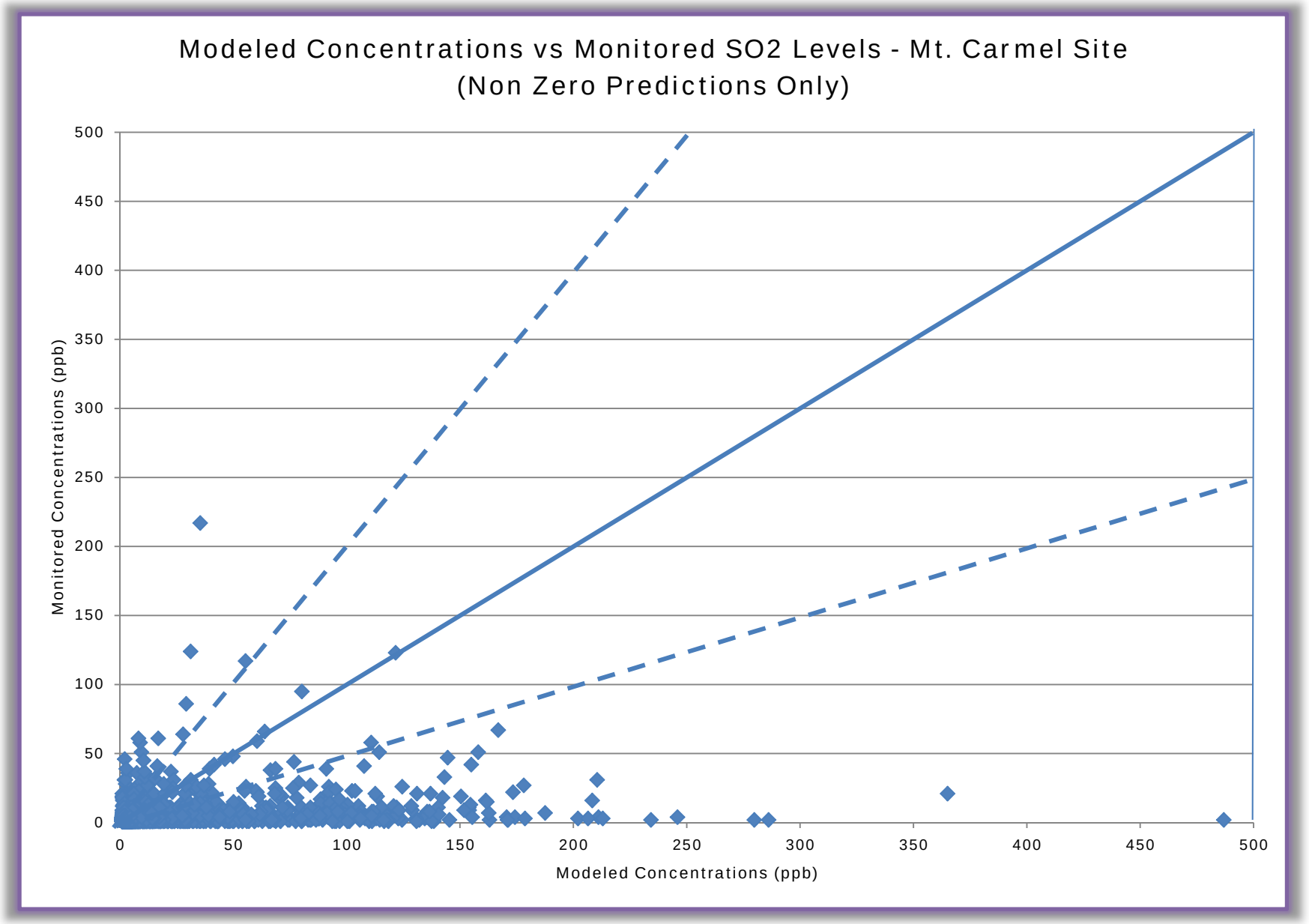

Modeled Concentrations vs Monitored SO2 Levels - Mt. Carmel Site
(Non Zero Predictions Only)
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250
300
350
400
450
500

Figure 35

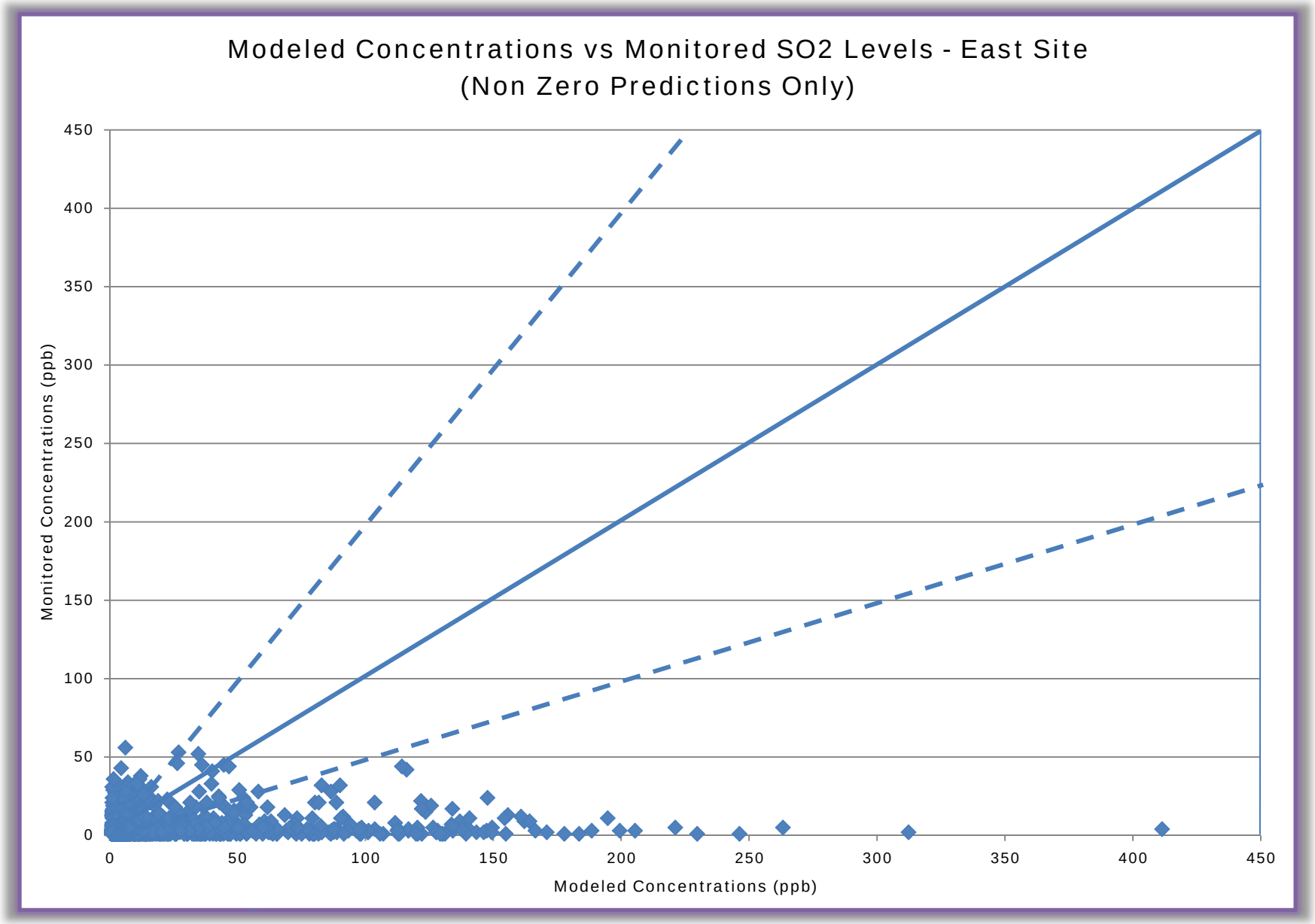

Modeled Concentrations vs Monitored SO2 Levels - East Site
(Non Zero Predictions Only)
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250
300
350
400
450

Figure 36

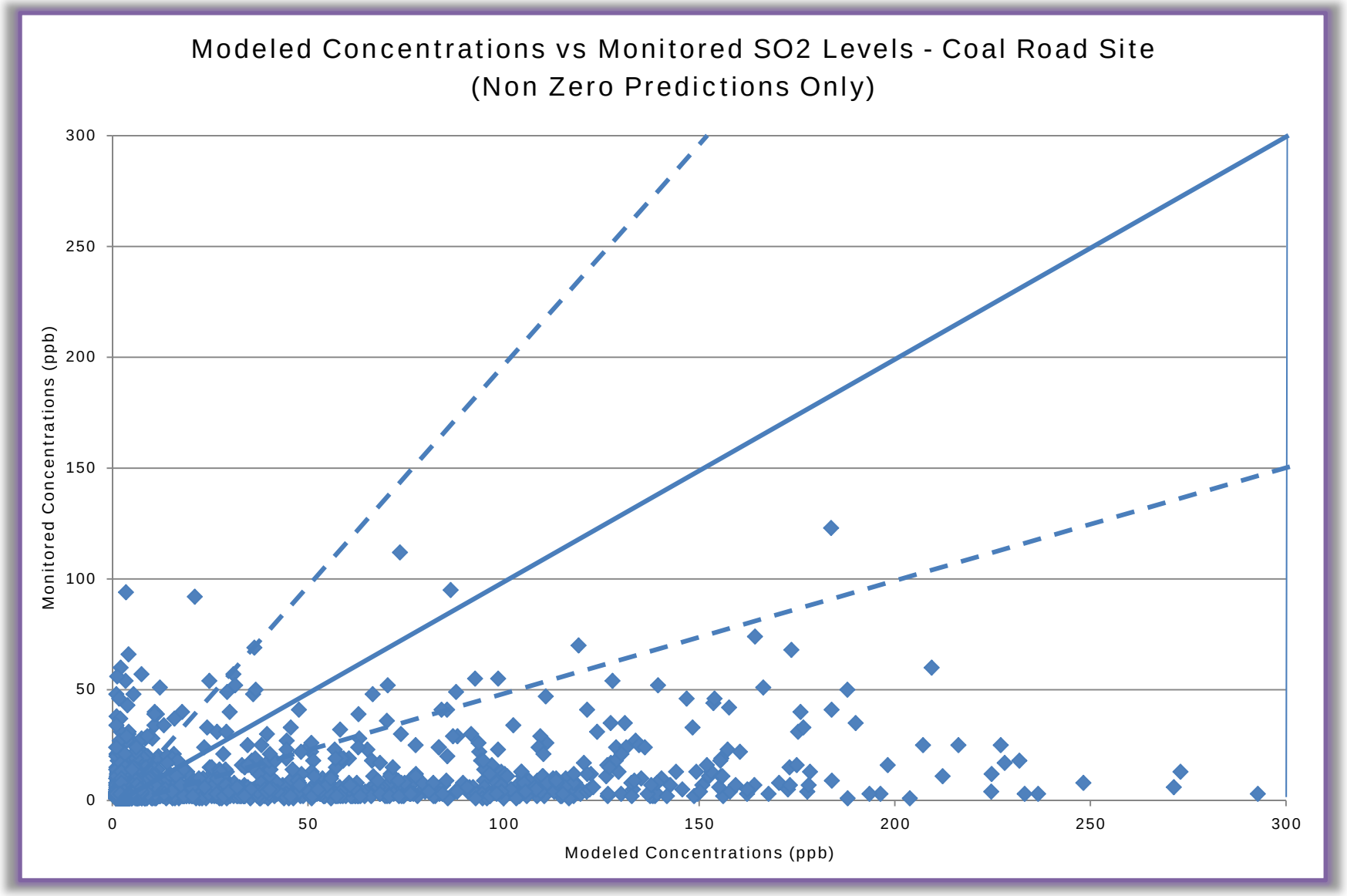
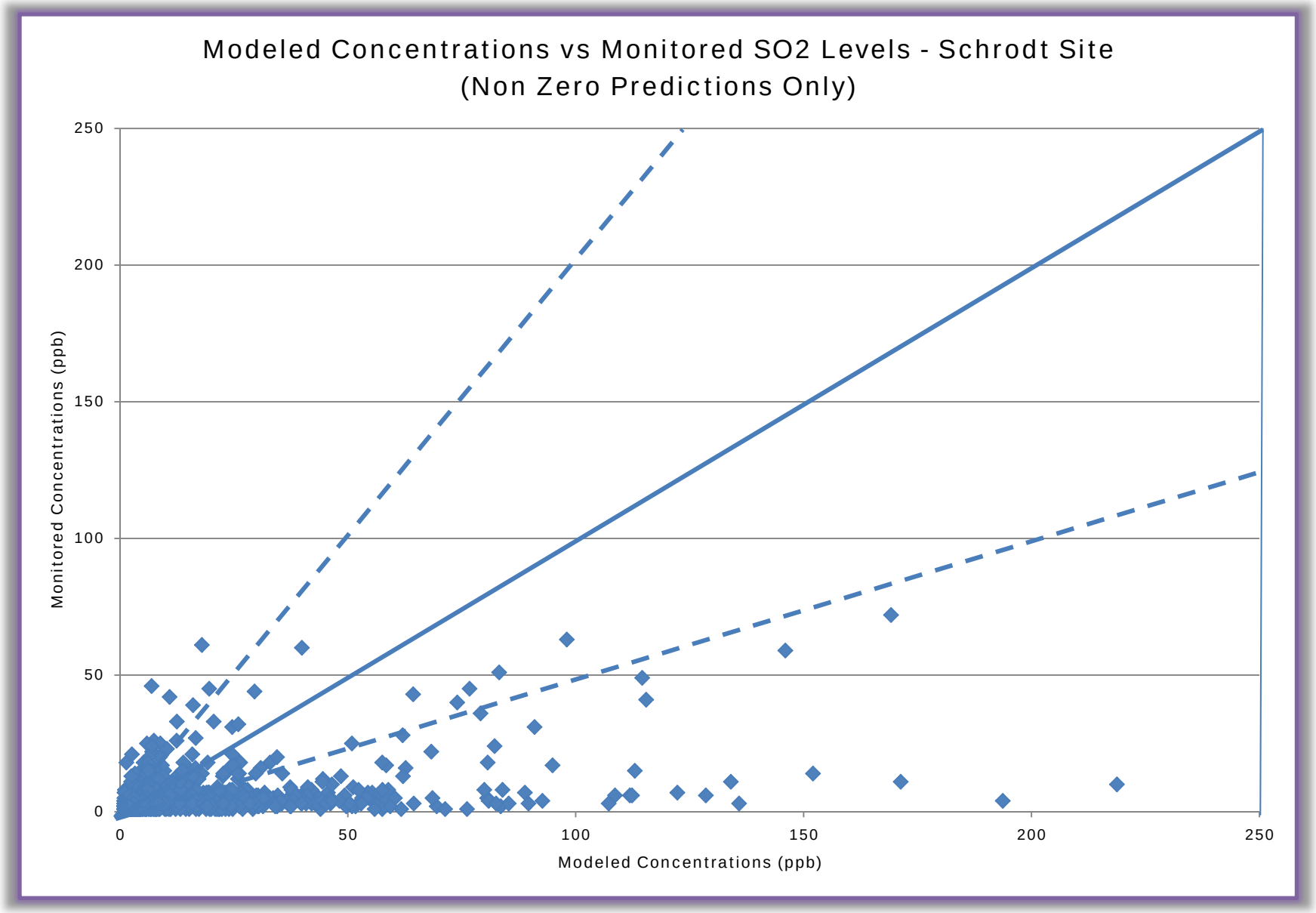

Modeled Concentrations vs Monitored SO2 Levels - Coal Road Site
(Non Zero Predictions Only)
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250
300

Figure 37


Modeled Concentrations vs Monitored SO2 Levels - Schrodt Site
(Non Zero Predictions Only)
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250

Wind Speed Analysis

Table 20 shows the average ratio of modeled divided by monitored concentrations versus wind speed. In general each of the sites shows that the ratios drop off with wind speed. In some cases the higher wind speeds have higher ratios, but this is likely due to smaller sample size.

Table 20

Comparison of Average Modeled/Monitored Ratios versus Wind Speed

Wind Speed Range	Mt. Carmel	East	Coal Road	Schrodt
0 -1 m/s	23.27	29.26	15.52	10.45
1.01 – 2	9.12	10.94	6.50	4.18
2.01 – 3	5.63	6.03	4.70	1.84
3.01 – 4	4.10	3.80	3.32	1.24
4.01 – 5	2.48	2.03	2.71	0.97
5.01 – 6	2.33	1.75	3.24	0.84
6.01 – 7	2.63	1.61	2.60	0.86
7.01 – 8	2.69	1.63	3.72	0.92
8.01 – 9	1.49	1.28	2.59	0.97
9.01 – 10	1.98	1.03	3.90	0.83
➢ 10	2.37	1.13	3.65	0.87

Some persons would argue that using average values is inappropriate. Because the sample size of some categories may be small, one high ratio can overly impact the average. Table 21 shows the median ratios versus wind speed. The trends seen in the average data appear to be duplicated in the median data.

Table 21

Comparison of Median Modeled/Monitored Ratios versus Wind Speed

Wind Speed Range	Mt. Carmel	East	Coal Road	Schrodt
0 -1 m/s	11.80	18.03	9.52	7.53
1.01 – 2	4.48	4.35	3.15	2.45
2.01 – 3	2.19	2.07	1.44	1.12
3.01 – 4	1.39	1.38	1.00	0.85
4.01 – 5	1.11	1.06	0.75	0.75
5.01 – 6	1.15	1.06	0.67	0.76
6.01 – 7	1.12	1.03	0.67	1.01
7.01 – 8	1.08	1.02	0.70	1.01
8.01 – 9	1.06	1.04	0.64	1.02
9.01 – 10	1.10	1.06	0.60	1.02
➢ 10	1.05	1.02	0.57	1.02

Wind Direction Analysis

Table 22 compares average modeled to monitored ratios versus wind direction. The directions which are directly from the stacks to the monitors are highlighted in the table.

Table 22

Comparison of Average Modeled to Monitored Ratios versus Wind Direction

WD Range	Mt. Carmel	East	Coal Road	Schrodt
0 – 10	2.43	2.23	1.83	1.27
11 – 20	2.74	2.82	2.09	1.13
21 – 30	3.60	3.95	2.26	1.38
31 – 40	3.74	3.13	2.27	1.39
41 – 50	1.84	2.29	1.28	1.06
51 – 60	3.62	5.29	2.61	1.47
61 – 70	3.28	4.35	2.98	2.85
71 – 80	4.56	3.52	2.31	5.89
81 – 90	4.32	4.83	2.97	**6.20**
91 – 100	5.98	7.60	3.44	7.13
101 – 110	3.03	3.02	1.44	4.48
111 – 120	2.12	2.46	1.51	1.41
121 – 130	2.63	2.65	1.29	1.39
131 – 140	1.99	2.82	1.70	1.41
141 – 150	8.50	3.91	2.42	1.45
151 – 160	9.50	5.00	2.04	1.62
161 – 170	**9.58**	4.37	2.61	1.40
171 – 180	**13.66**	4.02	1.82	1.44
181 – 190	9.32	9.21	4.88	1.70
191 – 200	4.98	4.68	2.86	1.63
201 – 210	3.92	4.81	7.78	2.09
211 – 220	3.91	4.59	**12.55**	1.57
221 – 230	3.32	4.98	9.20	1.68
231 – 240	2.76	2.59	4.96	1.54
241 – 250	3.89	4.31	3.56	1.69
251 – 260	2.80	4.06	2.48	1.33
261 – 270	3.53	7.55	1.85	1.94
271 – 280	4.45	14.05	2.35	1.74
281 – 290	2.80	18.31	1.79	1.58
291 – 300	2.75	**10.24**	2.11	1.41
301 – 310	2.42	**8.95**	1.71	1.05
311 – 320	3.42	6.58	2.03	2.02
321 – 330	2.28	4.49	1.48	1.24
331 – 340	2.32	3.94	1.46	1.36
341 – 350	2.01	2.41	1.36	1.18
351 – 360	2.22	1.93	1.44	1.50

For the key wind directions the average ratios are much higher than two. This indicates that when the wind is blowing from the stacks to the monitors the disagreement between the model and the monitor is greater.

Table 23
Comparison of Median Modeled to Monitored Ratios versus Wind Direction

WD Range	Mt. Carmel	East	Coal Road	Schrodt
0 – 10	1.39	1.42	1.00	1.02
11 – 20	1.21	1.15	0.90	0.98
21 – 30	1.13	1.06	0.81	0.89
31 – 40	1.14	1.11	0.75	1.03
41 – 50	1.14	1.01	0.63	0.73
51 – 60	1.08	1.01	0.85	0.91
61 – 70	1.26	1.74	1.11	1.46
71 – 80	1.43	1.20	1.02	2.40
81 – 90	1.32	1.41	1.01	**3.20**
91 – 100	1.08	1.08	1.01	2.65
101 – 110	1.08	0.80	0.81	1.06
111 – 120	1.02	1.01	0.71	0.69
121 – 130	1.04	1.02	0.74	1.01
131 – 140	1.02	1.01	0.81	0.82
141 – 150	1.23	1.09	0.96	0.92
151 – 160	1.41	1.43	1.05	1.00
161 – 170	**2.79**	1.16	1.02	0.75
171 – 180	**4.53**	1.38	0.87	1.01
181 – 190	1.75	1.07	0.67	1.03
191 – 200	1.08	1.07	0.82	1.00
201 – 210	1.09	1.06	1.66	1.01
211 – 220	1.23	1.26	**5.17**	1.02
221 – 230	1.44	1.37	3.27	1.02
231 – 240	1.27	1.34	1.54	1.01
241 – 250	1.46	1.31	1.33	1.13
251 – 260	1.48	1.34	1.05	1.07
261 – 270	1.25	1.62	0.76	1.03
271 – 280	1.22	4.70	0.78	0.99
281 – 290	1.27	4.31	0.69	1.05
291 – 300	1.22	**2.28**	0.81	1.01
301 – 310	1.14	**1.71**	1.01	1.01
311 – 320	1.13	0.73	0.75	0.92
321 – 330	1.11	0.62	0.67	1.02
331 – 340	1.08	1.02	0.69	1.02
341 – 350	1.20	1.06	0.67	1.03
351 – 360	1.28	1.31	0.85	1.05

Table 23 shows the median ratios of modeled to monitored concentrations versus wind direction. Once again the key wind directions show the largest discrepancies between the modeled and monitored concentrations. One question that will be addressed later is why are there predicted non-zero concentrations in directions where the winds are not blowing from the stack to the monitors?

A good example of this occurs on July 26, hour 11. The wind direction for this hour is 25 which do not blow toward any of the four monitors. However, as shown below, AERMOD predicts exceedances at all four monitors:

Monitoring Site	Predicted Concentration (ppb)
Mt. Carmel	234.22
East	312.31
Coal Road	233.21
Schrodt	112.96

It is impossible for AERMOD to accurately be predicting concentrations at each of these four monitors given the wind direction of 25. The wind speed for this hour is 0.31 meters per second.

Table 24 shows cases where the model is predicting concentrations that do not appear to be accurate given the wind direction. In each case the wind speed is less than one meter per second. It would appear that AERMOD has some flaw that leads to erroneous predictions under low wind speeds.

Table 24

Outlier Predictions

Site	Month	Day	Hour	WS	WD	Model	Monitor
Mt. Carmel	7	26	11	0.31	25	234.22	2
Mt. Carmel	7	26	10	0.36	67	178.66	3
Mt. Carmel	4	19	10	0.31	315	174.24	4
Mt. Carmel	4	12	9	0.36	90	163.04	2
Mt. Carmel	3	8	13	0.41	240	153.90	11
Mt. Carmel	5	19	16	0.31	92	138.47	1
Mt. Carmel	9	12	10	0.31	319	116.31	2
Mt. Carmel	3	8	15	0.41	244	113.45	19
Mt. Carmel	11	3	14	0.31	260	111.17	8
Mt. Carmel	4	19	9	0.46	17	102.99	5
Mt. Carmel	8	9	11	0.82	232	101.44	4
East	7	26	11	0.31	25	312.31	2
East	8	13	10	0.41	197	229.71	1
East	7	26	10	0.36	67	205.42	3
East	3	8	14	0.41	240	194.72	11
East	6	21	12	0.51	187	183.54	1
East	5	19	16	0.31	92	177.78	1
East	4	13	13	0.31	196	166.45	3
East	7	12	13	0.67	153	162.16	9
East	8	15	10	0.41	186	154.91	1
East	8	9	13	0.36	228	146.30	4
East	4	12	9	0.36	90	143.41	2
East	3	8	15	0.41	244	136.94	9
East	8	10	11	0.62	188	131.07	1
East	8	12	13	0.41	190	129.24	1
East	8	9	11	0.82	242	127.73	2
East	4	11	11	0.51	207	127.72	2
East	7	16	16	0.36	125	126.47	5
East	5	26	11	0.62	233	122.03	7
East	8	2	13	0.51	214	120.37	5
East	7	26	16	0.41	57	106.99	1
East	9	9	14	0.51	160	101.24	3
East	7	14	10	0.36	176	100.99	2
Coal Road	7	26	11	0.31	25	233.21	3
Coal Road	7	26	10	0.36	67	177.63	4
Coal Road	4	19	10	0.31	315	172.63	5
Coal Road	4	12	9	0.36	90	162.25	3
Coal Road	5	19	16	0.31	92	138.16	2
Coal Road	7	12	13	0.67	153	126.52	16
Coal Road	9	12	10	0.31	319	115.21	3
Coal Road	4	19	9	0.46	17	102.05	5
Schrodt	7	26	11	0.31	25	112.96	15

The only outliers that were investigated in this analysis were those that exceeded the standard. There may be many other hours where this same behavior is occurring.

Comparisons Not in Time

Figures 38 – 41 show predicted concentrations versus monitored concentrations where the values have independently been ranked from lowest to highest. Figure 38 (Mt. Carmel) shows an over-prediction by more than a factor of two by AERMOD except at very low concentrations. Figure 39 (East) shows an over-prediction of more than a factor of two except at very low concentrations. Figure 40 (Coal Road) shows an over-prediction of more than a factor of two except at very low concentrations. Figure 41 (Schrodt) shows over-prediction of more than a factor of two except at very low concentrations.

Figure 38


Modeled vs Monitored Concentrations - Mt. Carmel Site - On Site Met
Non Zero Predictions Only
500
450
400
350
300
250
200
150
100
50
0
0
50
100
150
200
250
300
350
400
450
500
Modeled Concentrations (ppb)

Figure 39

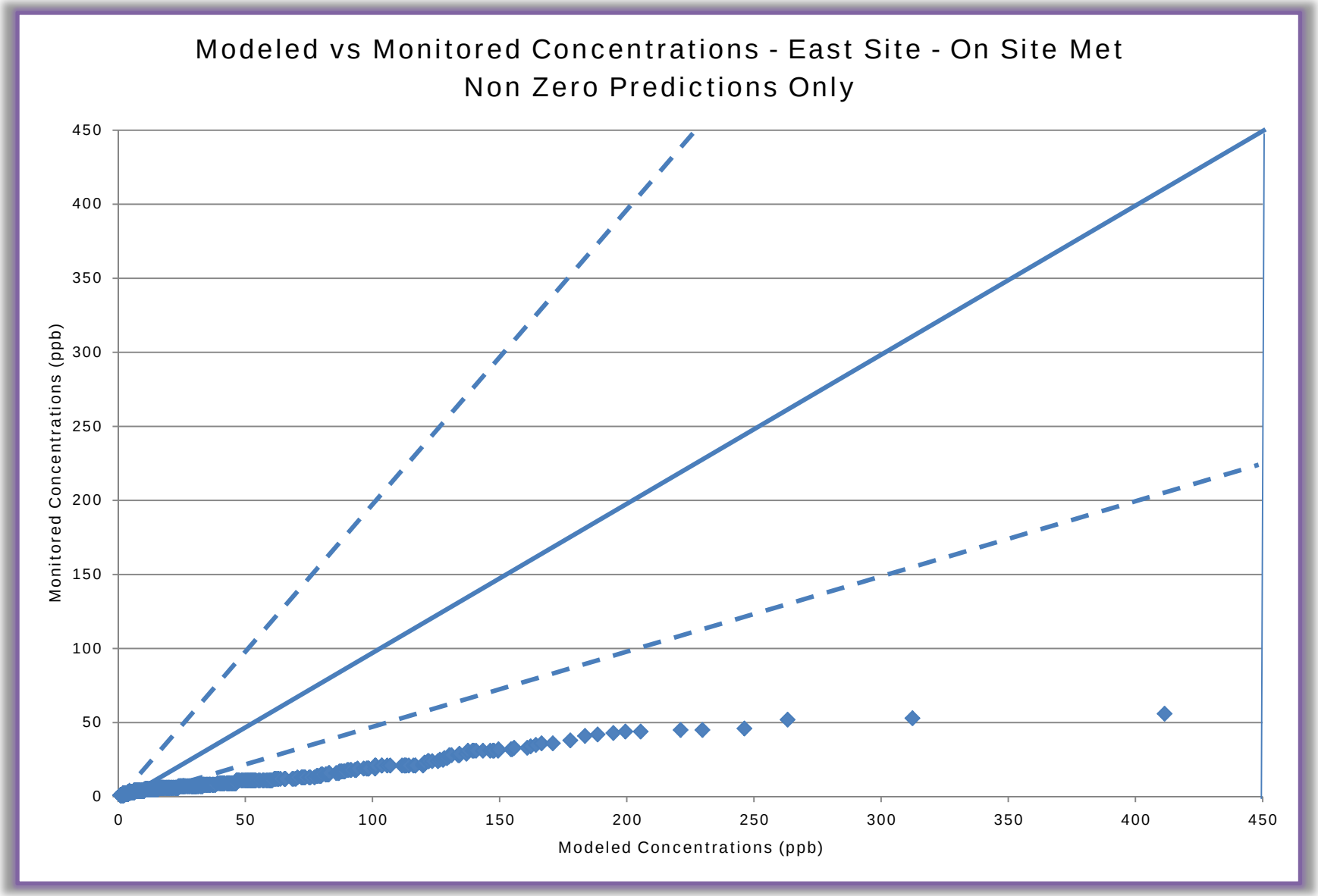

Modeled vs Monitored Concentrations - East Site - On Site Met
Non Zero Predictions Only
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250
300
350
400
450

Figure 40

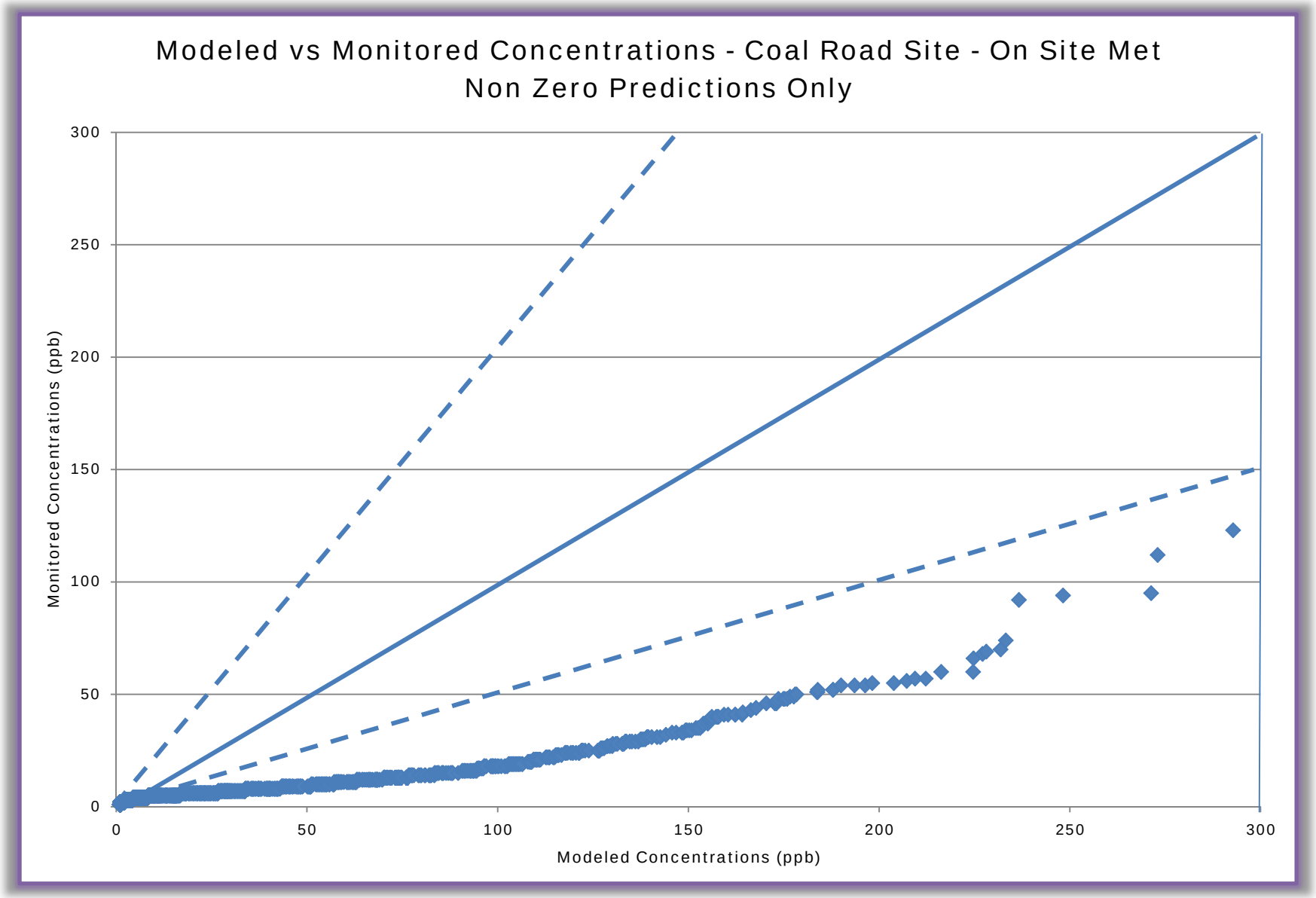
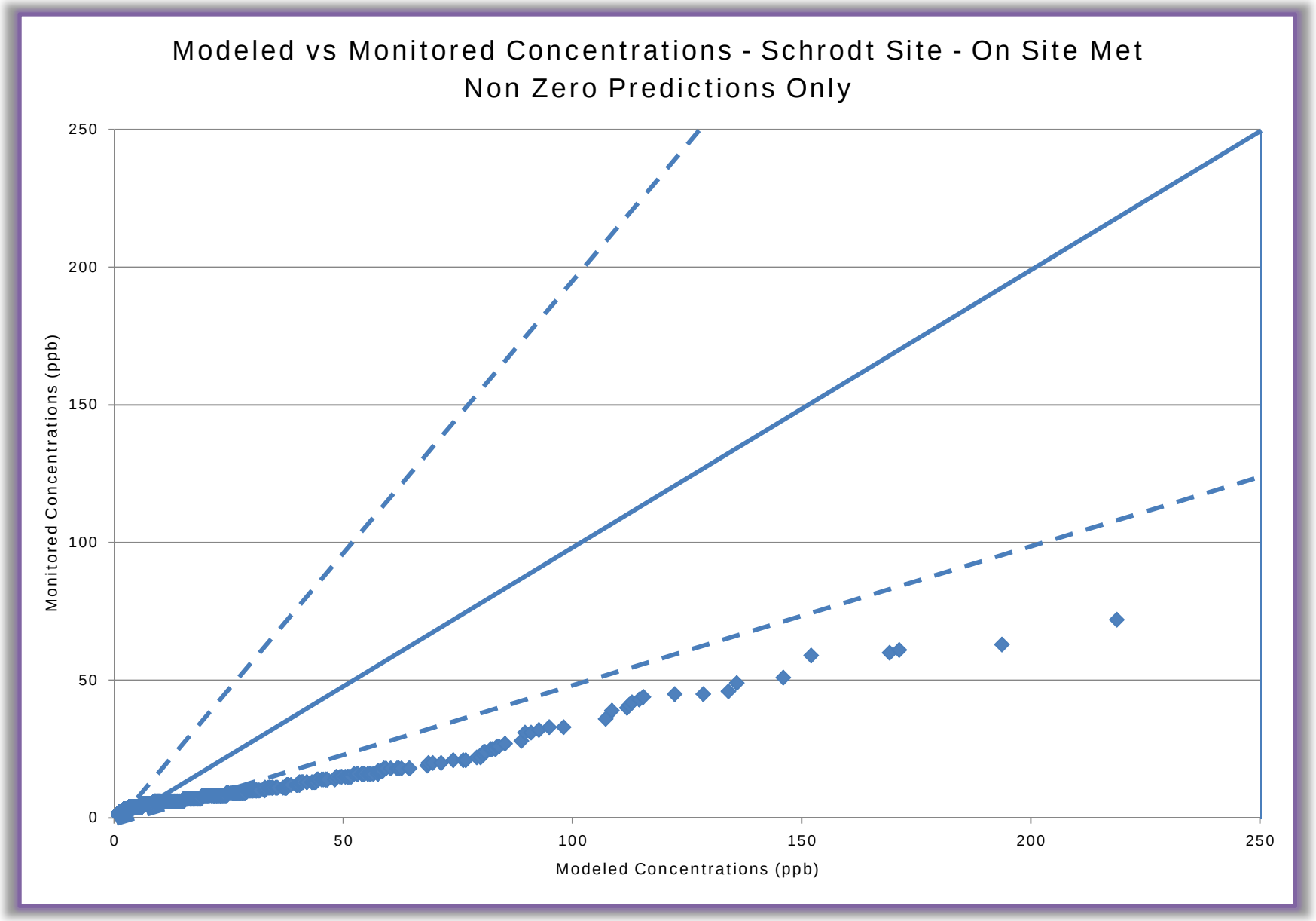

Modeled vs Monitored Concentrations - Coal Road Site - On Site Met
Non Zero Predictions Only
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250
300

Figure 41


Modeled vs Monitored Concentrations - Schrodt Site - On Site Met
Non Zero Predictions Only
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250

When compared in this fashion, the following overall statistics (ratios of modeled to monitored concentrations) are found:

Ratio	Mt. Carmel		East		Coal Road		Schrodt		Total	
Range	Hours	Percent	Hours	Percent	Hours	Percent	Hours	Percent	Hours	Percent
< 0.5	0	0	0	0	0	0	0	0	0	0
0.5 – 2	2008	63.7	2075	73.5	2397	74.6	3064	90.1	9544	75.8
➢ **2.0**	1142	36.3	750	26.5	816	25.4	338	9.9	3046	24.2
Total	3150		2825		3213		3402		12590	

This appears to show significant over-prediction with no under-prediction.

Table 25 looks at the frequency at which modeled and monitored concentrations occur within certain concentration ranges. Of particular interest are the number of hours that exceed the standard of 75 ppb. Overall AERMOD predicts 610 hours above the standard while the monitors measured 11.

Table 25

Hours within Selected Ranges – Scenario 3 – Non-Zero Predictions Only

	Mt. Carmel		East		Coal Road		Schrodt	
Range	Model	Monitor	Model	Monitor	Model	Monitor	Model	Monitor
1–25	2727	3089	2518	2785	2637	3115	3229	3376
26–50	167	44	138	37	207	73	101	20
51–75	82	11	54	3	125	20	36	6
76–100	72	2	47	0	77	3	19	0
101–125	48	3	24	0	65	2	8	0
126-150	21	0	24	0	41	0	4	0
151-175	18	0	8	0	71	0	3	0
176-200	3	0	5	0	15	0	1	0
201-225	6	1	2	0	7	0	1	0
226-250	2	0	2	0	6	0	0	0
251-275	0	0	1	0	2	0	0	0
276-300	2	0	0	0	1	0	0	0
301-325	0	0	1	0	0	0	0	0
326-350	0	0	0	0	0	0	0	0
351-375	1	0	0	0	0	0	0	0
376-400	0	0	0	0	0	0	0	0
401-425	0	0	1	0	0	0	0	0
426-450	0	0	0	0	0	0	0	0
451-475	0	0	0	0	0	0	0	0
476-500	1	0	0	0	0	0	0	0
Total	3150	3150	2825	2825	3213	3213	3402	3402
Above 75	174	6	115	0	285	5	36	0

Predictions Greater Than 75 ppb

Even when looking at non-zero predicted hours, the majority of the concentrations are in the range of 1 to 10 ppb. This range is of little interest in the regulatory scheme. When the model predicts concentrations at or above 75 ppb, the level of the national ambient air quality standard for SO2, model performance is much more of an issue. This section focuses on predicted SO2 concentrations that are 75 ppb or greater.

Mt. Carmel Site

Figure 42 shows a comparison of modeled and monitored SO2 concentrations for the Mt. Carmel site for those hours where AERMOD predicts a maximum concentration of 75 ppb or greater. Of the 173 hours of ratios (modeled to monitored) shown, four are within a factor of two range (2.3 percent) while 169 hours are above a factor of two (97.7percent).

East Site

Figure 43 shows a comparison of modeled and monitored SO2 concentrations for the East site for those hours where AERMOD predicts a maximum concentration of 75 ppb or greater. Of the 116 hours of ratios (modeled to monitored) shown, none are within a factor of two range, while all 116 hours are above the factor of two.

Coal Road Site

Figure 44 shows a comparison of modeled and monitored SO2 concentrations for the Coal Rd. site for those hours where AERMOD predicts a maximum concentration of 75 ppb or greater. Of the 245 hours of ratios (modeled to monitored) shown, six are within a factor of two (2.4 percent) while 239 hours are above the factor of two (97.6 percent).

Schrodt Site

Figure 45 shows a comparison of modeled and monitored SO2 concentrations for the Schrodt site for those hours where AERMOD predicts a maximum concentration of 75 ppb or greater. Of the 35 hours of ratios (modeled to monitored) shown, two are within a factor of two (5.7 percent) while 33 hours are above the factor of two (94.3 percent).

Overall this indicates that AERMOD is over-predicting 97 percent of the predicted concentrations that are 75 ppb or greater. In no case is it under-predicting these concentrations. In only 3 percent of the cases are the predictions within a factor of two. This would indicate serious problems with the model, both in accuracy and over-prediction.

Figure 42

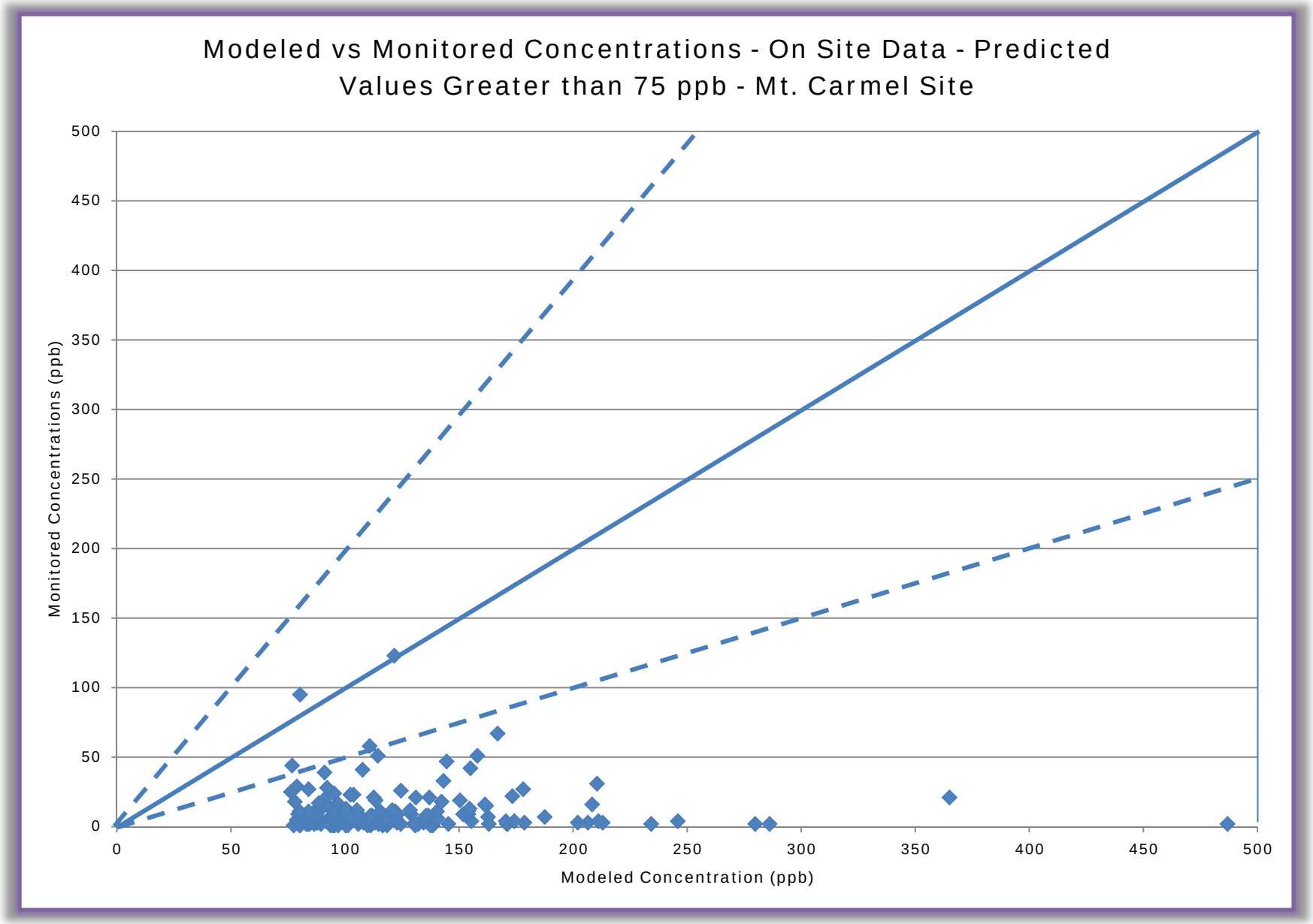

Modeled vs Monitored Concentrations - On Site Data - Predicted Values Greater than 75 ppb - Mt. Carmel Site
Monitored Concentrations (ppb)
Modeled Concentration (ppb)
0
50
100
150
200
250
300
350
400
450
500

Figure 43

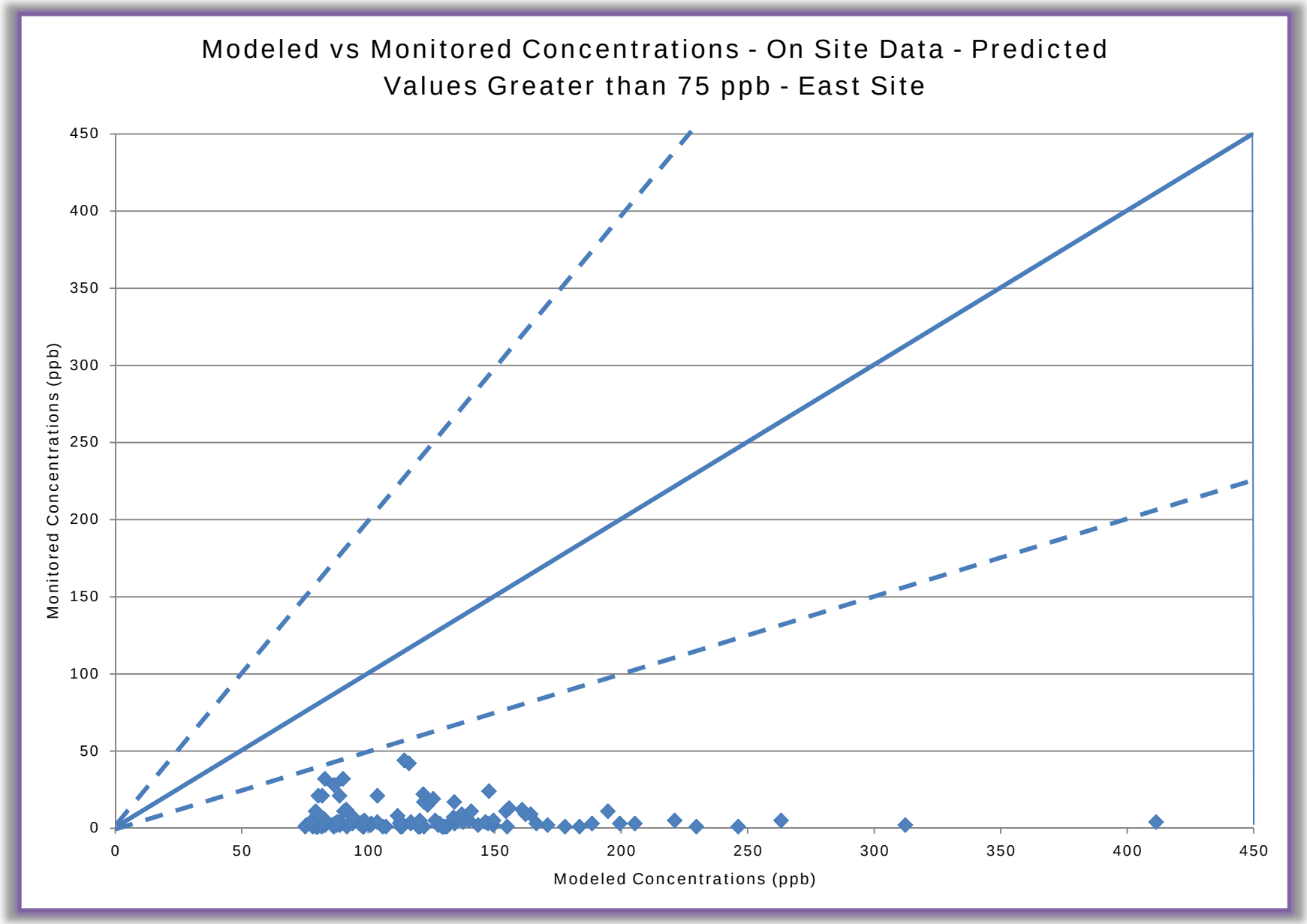

Modeled vs Monitored Concentrations - On Site Data - Predicted Values Greater than 75 ppb - East Site
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250
300
350
400
450

Figure 44

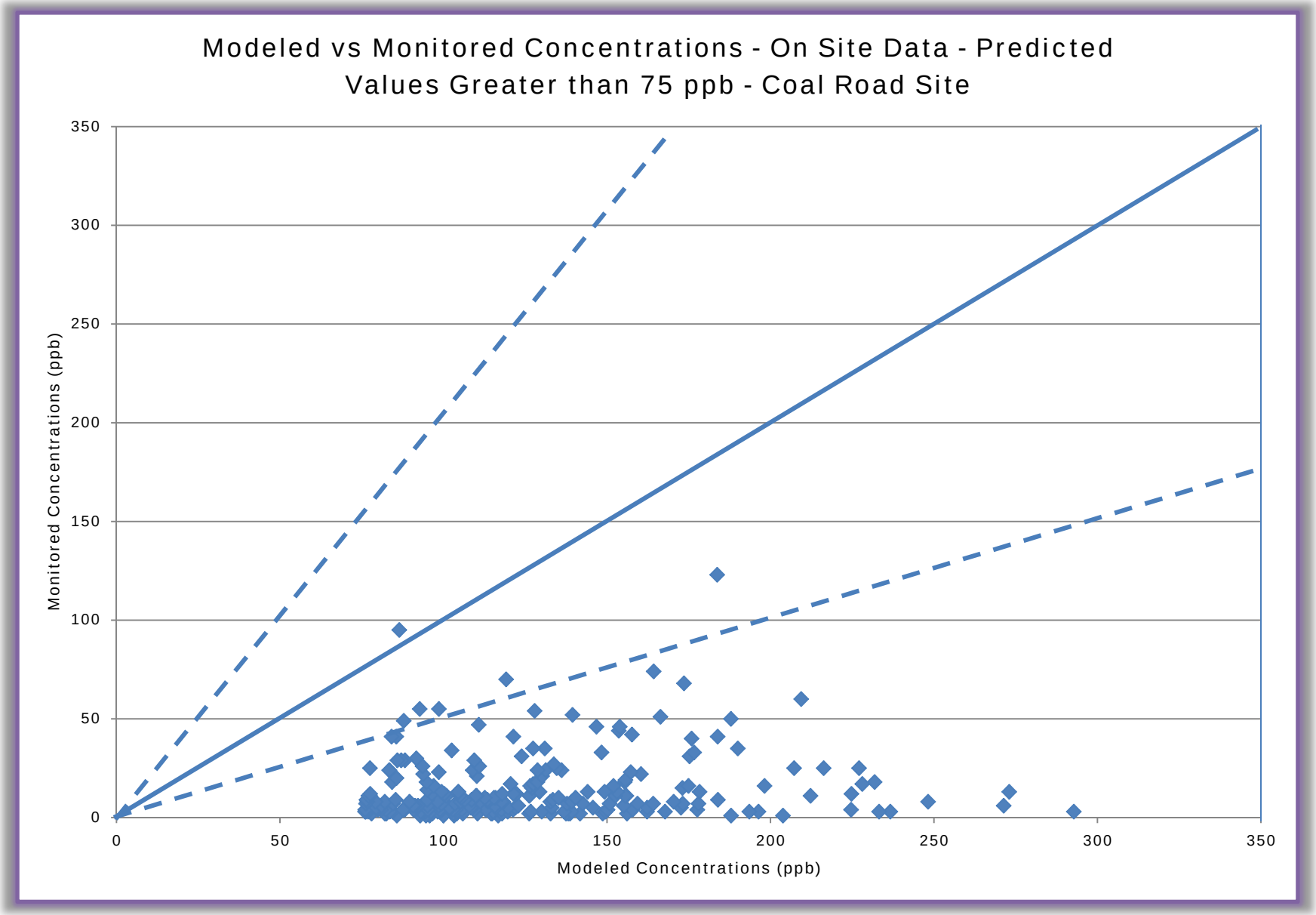
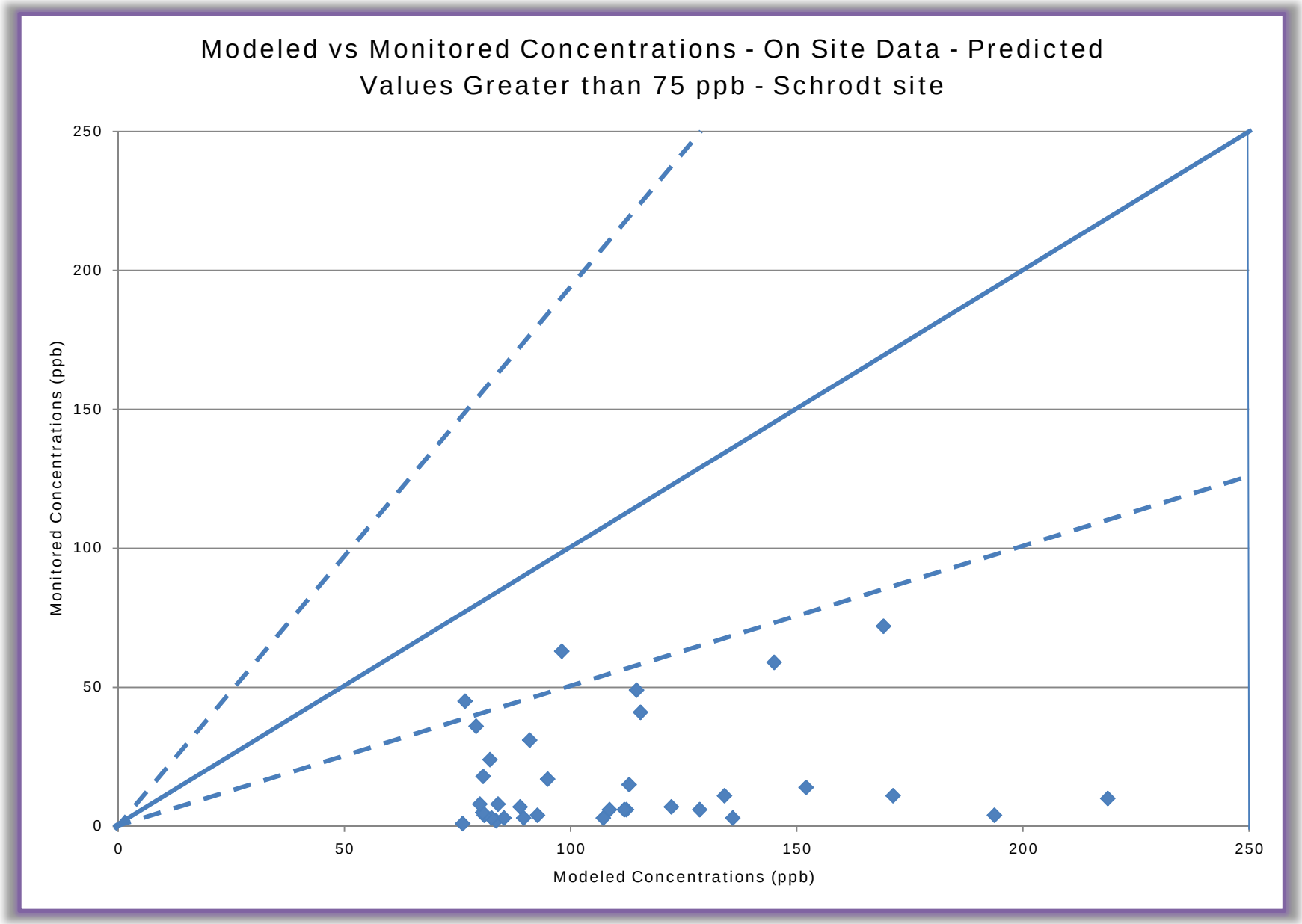

Modeled vs Monitored Concentrations - On Site Data - Predicted Values Greater than 75 ppb - Coal Road Site
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250
300
350

Figure 45


Modeled vs Monitored Concentrations - On Site Data - Predicted Values Greater than 75 ppb - Schrodt site
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250

Adjustment to Emission Rates

In comparing hours without comparing them in time, there is a problem that the predicted concentrations are based on different emission rates than those seen on the monitored days. In an attempt to correct for this, the emission rate on the highest monitored hour was determined as well as the emission rate on the highest predicted hour. The predicted concentration was then adjusted by a ratio of the monitored emission rate divided by the predicted emission rate. This set of corrections was made for all hours with predicted concentrations greater than 75 ppb. The results for each site are discussed below.

Mt. Carmel Site

Figure 46 shows a comparison of adjusted predicted concentrations versus monitored concentrations for the Mt. Carmel Site. Of the 173 hours included, 10 are within a factor of two of the monitored values, while 163 are over-predicted by more than a factor of two. None of the values are under-predicted.

East Site

Figure 47 shows a comparison of adjusted predicted concentrations versus monitored concentrations for the East Site. Of the 115 hours included, only one is within a factor of two of the monitored values, while 114 are over-predicted by more than a factor of two. None of the values are under-predicted.

Coal Road Site

Figure 48 shows a comparison of adjusted predicted concentrations versus monitored concentrations for the Coal Road site. Of the 243 hours included, twenty are within a factor of two of the monitored values, while 223 are over-predicted by more than a factor of two. None of the values are under-predicted.

Schrodt Site

Figure 49 shows a comparison of adjusted predicted concentrations versus monitored concentrations for the Schrodt site. Of the 35 hours included, five are within a factor of two of the monitored values, while thirty are over-predicted by more than a factor of two. None are under-predicted.

SUMMARY

While the emission rate correction improves the agreement between predicted and monitored values, the majority of the predictions are still over-predicted by more than a factor of two.

Figure 46

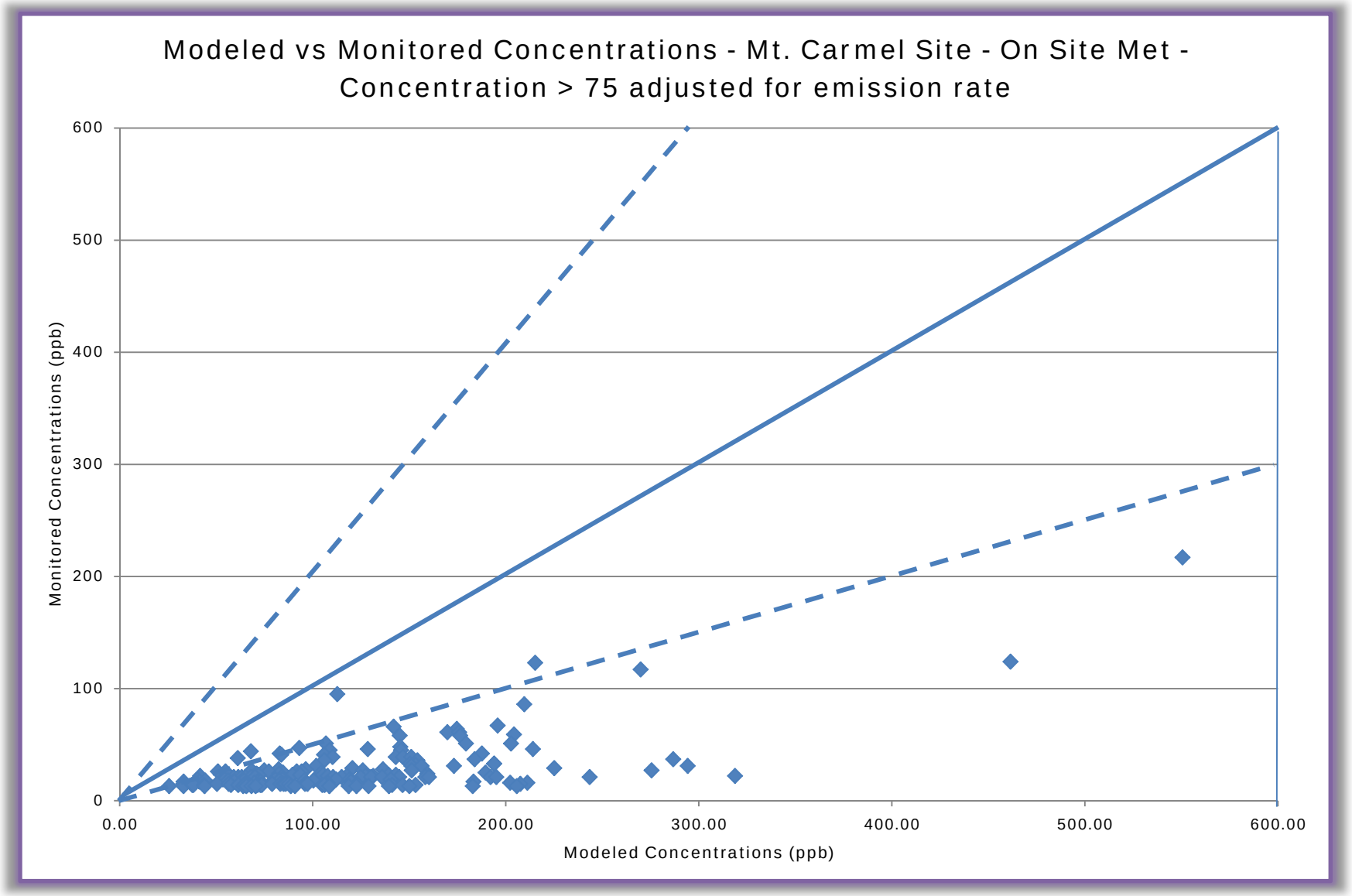

Modeled vs Monitored Concentrations - Mt. Carmel Site - On Site Met - Concentration > 75 adjusted for emission rate
Monitored Concentrations (ppb)
600
500
400
300
200
100
0
0.00
100.00
200.00
300.00
400.00
500.00
600.00
Modeled Concentrations (ppb)

Figure 47

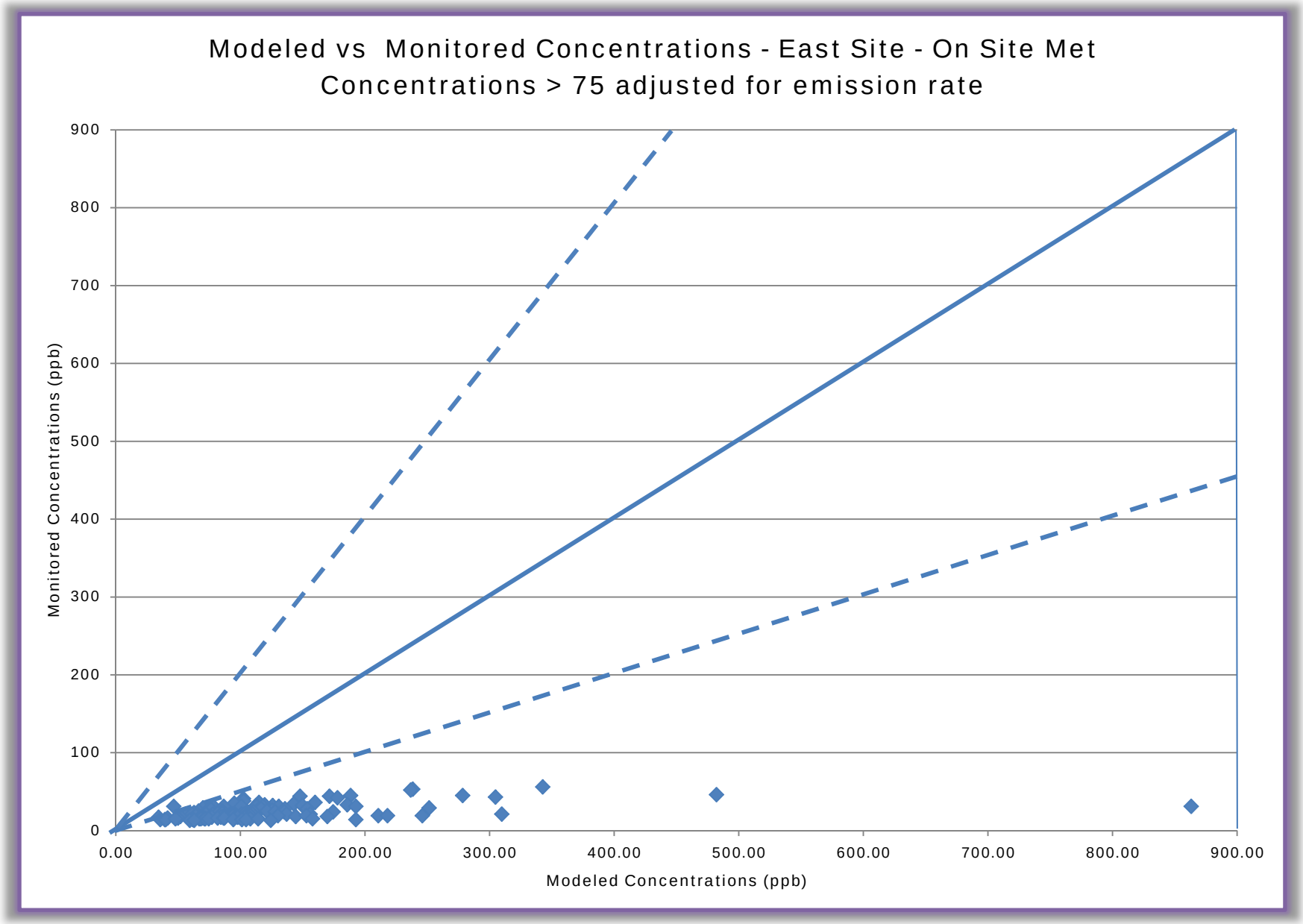

Modeled vs Monitored Concentrations - East Site - On Site Met
Concentrations > 75 adjusted for emission rate
Monitored Concentrations (ppb)
900
800
700
600
500
400
300
200
100
0
0.00
100.00
200.00
300.00
400.00
500.00
600.00
700.00
800.00
900.00
Modeled Concentrations (ppb)

Figure 48

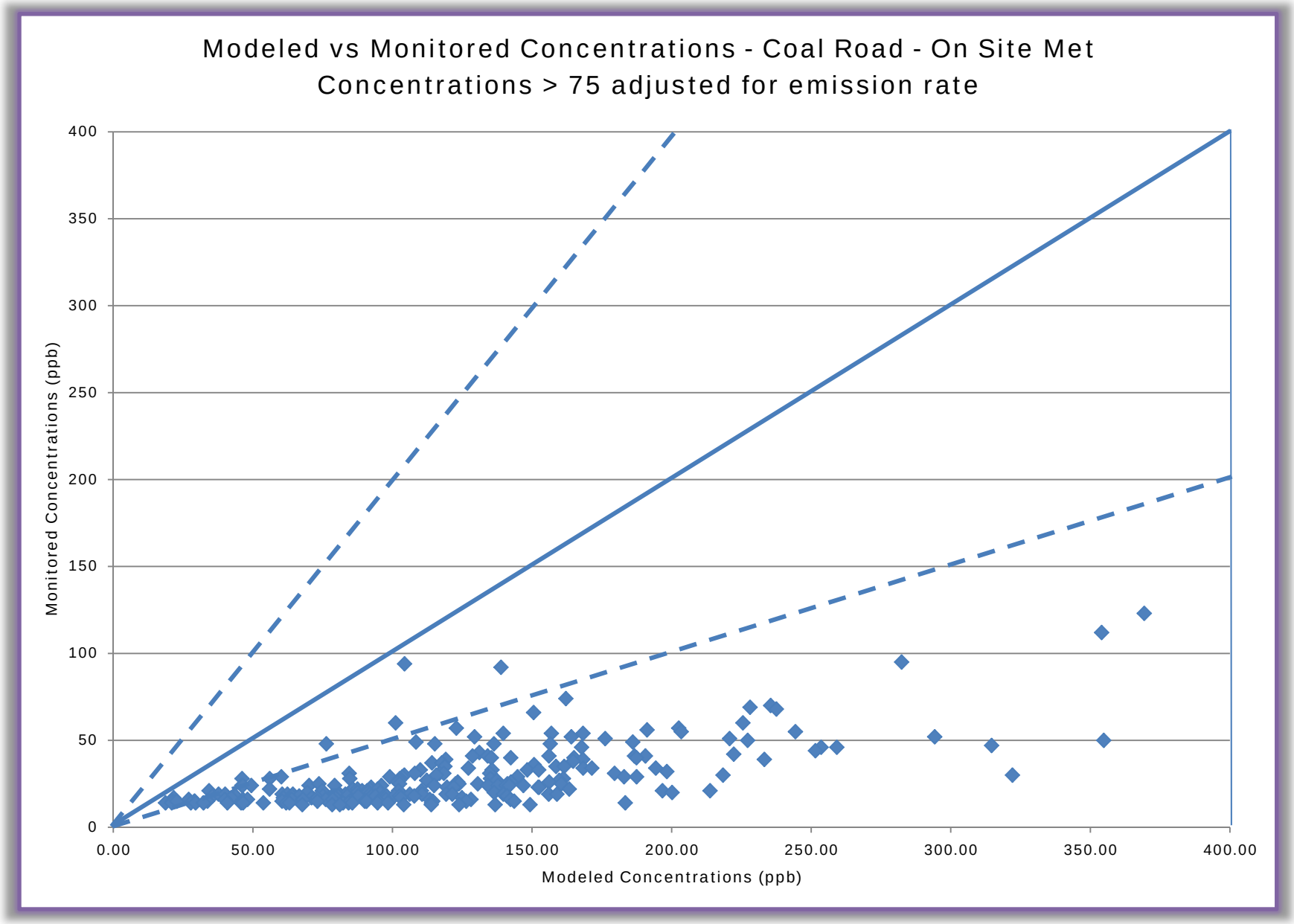
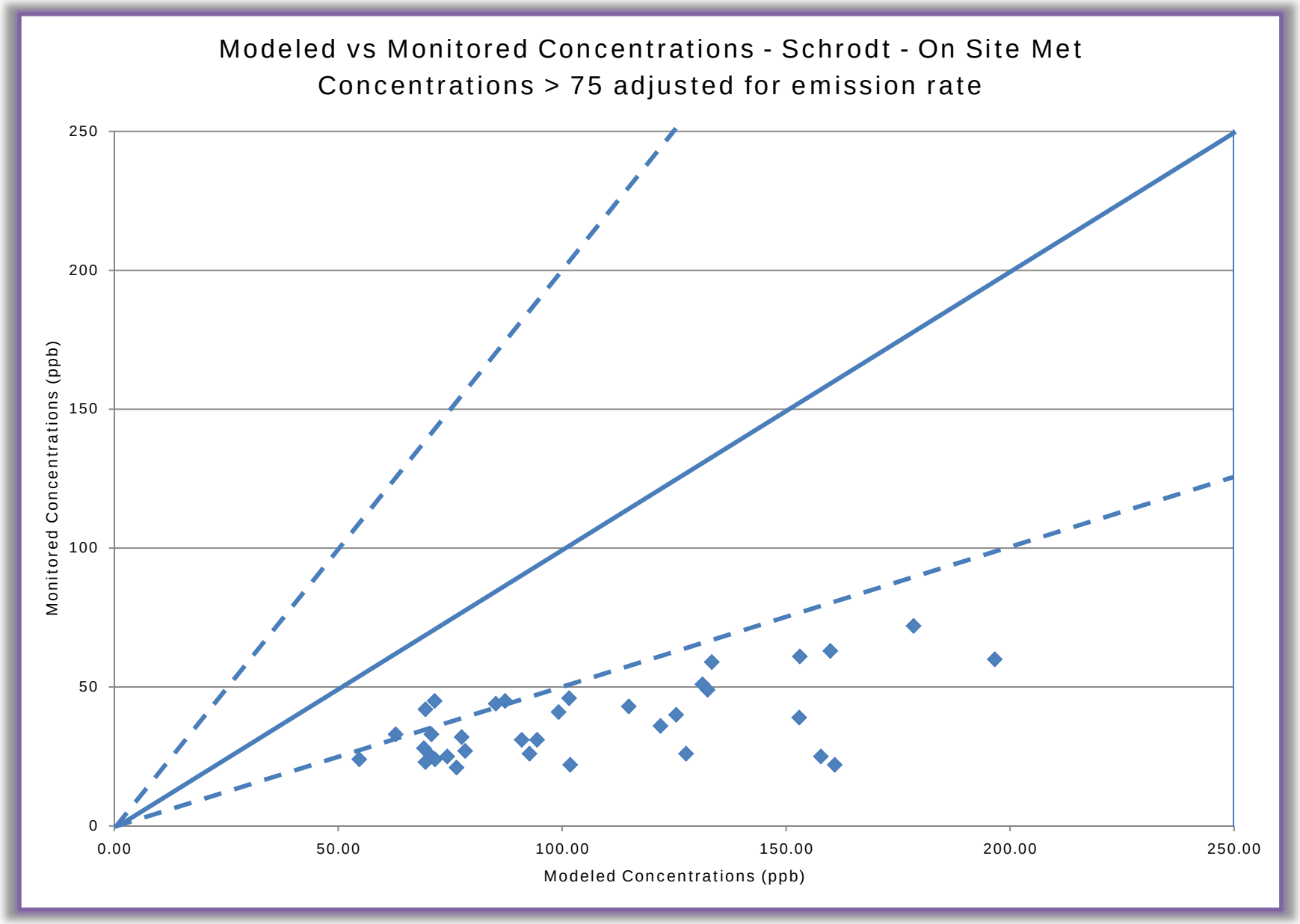

Modeled vs Monitored Concentrations - Coal Road - On Site Met
Concentrations > 75 adjusted for emission rate
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250
300
350
400
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00

Figure 49


Modeled vs Monitored Concentrations - Schrodt - On Site Met
Concentrations > 75 adjusted for emission rate
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250
0.00
50.00
100.00
150.00
200.00
250.00

OVERALL SUMMARY

Two attributes of a good refined model are:

1) **That predictions match observations as closely as possible (EPA has defined an acceptable limit as a factor of two) and**
2) **The model should not be biased; the number of under-predictions should be approximately the same as the number of over-predictions.**

This analysis has looked at observations and predictions in several different ways to determine whether AERMOD meets these two criteria. The following sums up our analysis.

Based on Evansville Meteorology

When looking at predicted values of 75 ppb or greater and comparing the predictions and observations in time, AERMOD grossly over-predicts. Only 2.9 percent of the 455 predictions are within a factor of two, while 8.8 percent are within a factor of 2 – 4. Another 19.3 percent are within a factor of 4 – 10, while another 41.3 percent are over-predicted by a factor of 10 – 50. Another 4.5 percent are over-predicted by a factor of 50 -100. A final 13.2 percent are over-predicted by a factor of more than 100.

The U.S. EPA argues that is inappropriate to compare predictions at exact locations because the wind speed/direction seen at the Gibson power plant may be different that those conditions measured at the Evansville airport. However, their solution is to expand the area of prediction to account for a variation in both wind speed and direction. They then suggest using the highest predicted value within this "box" to compare to the monitored value. This approach would only lead to higher predictions and therefore worse model performance. We have not followed this approach in this analysis.

When looking at predictions of 75 ppb or greater and not comparing data in time, AERMOD shows that only 0.7 percent of the predicted values are within a factor of two, while another 51.0 percent are over-predicted by a factor of 2 – 4 and another 48.3 percent are over-predicted by a factor of 4 – 6. Thus using the U.S. EPA's methodology, AERMOD fails to meet the factor of two criteria.

IDEM disagrees that this approach, not comparing in time, is appropriate. Since each hour has a different emission rate, comparing different hours without accounting for the difference in emission rates is inappropriate. In an attempt to correct for this difference, we have multiplied the predicted value by a ratio of the emission rate for the monitored hour divided by the emission rate for the predicted hour. While this is not an exact correction, it is the best that can be done with this information.

After the emission rate correction has been made, 11.9 percent of the predictions are now within a factor of two of the measured values. However, the amount of over-prediction has increased. A total of 46.1 percent are over-predicted by a factor of 2 – 4, while another 27.9 percent is over-predicted by a factor of 4 – 6. The remainder, 14.1 percent, is over-predicted between a factor of 6 and 20.

With the emission rate correction and using the U.S. EPA's procedure of not comparing values in time, the best AERMOD can achieve is 12 percent of the values predicted within a factor of two. The remainder is all over-predicted at ratios between 2 and 20. This is not acceptable performance.

Based Upon On Site Meteorology

When looking at predicted values of 75 ppb or greater and comparing the predictions and observations in time, AERMOD shows gross over-prediction. Only 2.1 percent of the 570 observations are within a factor of two, while 9.5 percent are over-predicted by a factor of 2 – 4. Another 17.0 percent are over-predicted by a factor of 4 – 10. Another 51.2 percent are over-predicted by a factor of 10 – 50. Another 13.7 percent are over-predicted by a factor of 50 – 100. A final 6.5 percent are over-predicted by more than a factor of 100.

When looking at predicted values of 75 ppb or greater and not comparing the data in time, AERMOD shows that none of the predictions are within a factor of two. Twenty one and nine tenths (21.9 percent) are over-predicted by a factor of 2 – 4, while another 73.9 percent are over-predicted by a factor of 4 – 6. The final 4.2 percent are over-predicted by a factor of 6 – 8.

After emission rate corrections have been made, AERMOD shows that 6.4 percent of the predictions are within a factor of two. Another 37.5percent are over-predicted by a factor of 2 – 4, while another 34.8 percent are over-predicted by a factor of 4 – 6. The remainder, 21.5 percent, is over-predicted by a factor of 6 – 30.

With the emission rate correction and using EPA's procedure of not comparing values in time, the best that AERMOD can do is 6.4 percent within a factor of two. The remainder is over-predicted by a factor of up to 30. This is not acceptable model performance.

RECOMMENDATIONS

Some of the work carried out shows that AERMOD "blows up" when the wind speed is less than one meter per second. In these cases the model predicts high values at all receptors regardless of wind direction. This is an area that the U.S. EPA should investigate and correct.

Another suggestion also involves wind speed. The U.S. EPA assumes instantaneous transport in AERMOD. In other words if emissions leave the stack they are instantly at the monitor regardless of the wind speed and the distance between the stack and monitor. In reality it takes time for the emissions to reach the monitor. The U.S. EPA should give some consideration to reducing the predicted concentrations by a factor based on the time it takes to get to the monitor. For example, if it takes 30 minutes to get from the stack to the monitor, given the wind speed and distance, the predicted hourly concentration should be cut in half. If it takes more than an hour to get from the stack to the monitor, the predicted concentration should be set to zero.

In the absence of making such a revision to AERMOD, the U.S. EPA should consider using some type of PUFF model which would account for this effect directly.

Based upon these results, AERMOD needs some serious testing to determine the reasons for over-prediction. IDEM is willing to work with the U.S. EPA to begin this process. However, we have no more test cases to recommend similar to the Gibson facility.