



AERMOD/BLP Development and Testing

AERMOD/BLP Development and Testing

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Air Quality Assessment Division
Air Quality Modeling Group
Research Triangle Park, North Carolina

Preface

This document provides the modification and evaluation procedures used to incorporate the Buoyant Line and Point Source (BLP) model into AERMOD.

Acknowledgements

The incorporation of BLP into AERMOD was performed by Jim Paumier of AMEC Foster/Wheeler Environment & Infrastructure Inc., Part 4, Task Order No. EP-G15-D-00208, contract No. GS-35F-0851R with Chris Owen as Part 4 Task Order Project Officer.

Contents

Preface.....	ii
Acknowledgements.....	iii
Figures.....	v
Tables.....	vi
1. Introduction.....	1
2. Source Code Modifications.....	1
3. Testing.....	2
3.1 Initial Tests.....	2
3.2 Further Testing of AERMOD	17
4. Differences between AERMOD/BLP and BLP.....	24
5. Additional Changes to AERMOD/BLP	24
5.1 Background Concentration.....	24
5.2 Event Processing	24
5.3 BLP Source Group	24
6. Recommendations.....	24
APPENDIX.....	26
1. AERMOD Keywords for Buoyant Line Sources.....	26

Figures

Figure 1. Buoyant Line Source and Receptor Locations	3
--	---

Tables

Table 1. Beginning and Ending Coordinates of the Buoyant Lines	2
Table 2. Bouyant Line Source Average Parameters	2
Table 3. Top 50 1-hour Concentration Estimates ($\mu\text{g}/\text{m}^3$): 1-day Scenario	4
Table 4. Top 50 3-hour Concentration Estimates ($\mu\text{g}/\text{m}^3$): 1-day Scenario	5
Table 5. Top 50 24-hour Concentration Estimates ($\mu\text{g}/\text{m}^3$): 1-day Scenario	6
Table 6. Top 50 1-hour Concentration Estimates ($\mu\text{g}/\text{m}^3$): 4-day Scenario	7
Table 7. Top 50 3-hour Concentration Estimates ($\mu\text{g}/\text{m}^3$): 4-day Scenario	8
Table 8. Top 50 24-hour Concentration Estimates ($\mu\text{g}/\text{m}^3$): 4-day Scenario	9
Table 9. Top 50 1-hour Concentration Estimates ($\mu\text{g}/\text{m}^3$): 1-month Scenario	10
Table 10. Top 50 3-hour Concentration Estimates ($\mu\text{g}/\text{m}^3$): 1-month Scenario	11
Table 11. Top 50 24-hour Concentration Estimates ($\mu\text{g}/\text{m}^3$): 1-month Scenario	12
Table 12. Top 50 1-hour Concentration Estimates ($\mu\text{g}/\text{m}^3$): 1-year Scenario	13
Table 13. Top 50 3-hour Concentration Estimates ($\mu\text{g}/\text{m}^3$): 1-year Scenario	15
Table 14. Top 50 24-hour Concentration Estimates ($\mu\text{g}/\text{m}^3$): 1-year Scenario	16
Table 15. Additional Tests - 1-year Scenarios.....	17
Table 16. Top 5 Concentration Estimates ($\mu\text{g}/\text{m}^3$), Test A (Gridded Network).....	18
Table 17. Top 5 Concentration Estimates ($\mu\text{g}/\text{m}^3$), Test B (Includes Two Point Sources).....	18
Table 18. Concentration Estimates ($\mu\text{g}/\text{m}^3$), Test C	18
Table 19. Concentration Estimates ($\mu\text{g}/\text{m}^3$), Test C	19
Table 20. Concentration Estimates ($\mu\text{g}/\text{m}^3$) for Test D	19
Table 21. Concentration Estimates ($\mu\text{g}/\text{m}^3$) for Test E	20
Table 22. Concentration Estimates ($\mu\text{g}/\text{m}^3$) for Test F (24-hr PM-2.5).....	21
Table 23. Concentration Estimates ($\mu\text{g}/\text{m}^3$) for Test G (1-hr SO_2).....	22
Table 24. Concentration Estimates ($\mu\text{g}/\text{m}^3$) for Test H -	23
Table 25. Concentration Estimates ($\mu\text{g}/\text{m}^3$) for Test I -	23
Table 26. Concentration Estimates ($\mu\text{g}/\text{m}^3$) for Test J -	23

1. Introduction

The AERMOD dispersion model was modified to incorporate the buoyant line algorithms of the Buoyant Line and Point source (BLP) dispersion model. For purposes of this discussion, we will refer to this draft of AERMOD as AERMOD/BLP.

2. Source Code Modifications

The buoyant line algorithms in BLP (version 99176) were first incorporated into AERMOD version 14134 and later into version 15181. For this phase of development, the buoyant line algorithms were ported unchanged from BLP to AERMOD. To keep the routines easily identifiable in AERMOD/BLP, "BL_" was added to the beginning of the subroutine and function names. Within those subroutines and functions, variable names were added as needed or changed to match the AERMOD variable names, such as the reference height wind speed. BLP was written decades ago and used GOTO statements and other obsolescent structures to control conditional programming. Those structures were replaced with IF..THEN..ELSE..ENDIF and SELECT..CASE structures. Other parts of the original BLP code were updated to reflect more recent versions of the Fortran language such as named DO loop structures, double precision, and allocatable arrays. Some of the GOTO statements were retained since deconstructing those structures would require a much greater effort. A new module, buoyant_line, was added to centralize the global variables associated with BLP. Variables and constants in the module and routines were defined as double precision.

BLP version 99176 is very limited in the number of sources (up to 10 lines in a single buoyant line source and 51 point sources) and receptors (up to 100) that can be processed in a single model run. As part of the porting process, array size limitations imposed by BLP were changed to allocatable arrays in AERMOD/BLP.

Additional keywords and parameters were added to process buoyant lines. These additions can be found in the appendix attached to this memo.

The following files were modified in the process of incorporating BLP into AERMOD: aermod.f, calc1.f, soset.f, reset.f, setup.f, modules.f, metext.f, and evcalc.f (minimal changes; not all necessary changes were made for event processing). For testing AERMOD/BLP, 64-bit executables were generated.

3. Testing

3.1 Initial Tests

Modifications to BLP version 99176 were required to compare concentration estimates between BLP and AERMOD/BLP. These included reading and processing command line arguments (complying with the Intel Fortran requirements) and increasing the number of receptors. Since BLP was originally limited to 100 receptors, the BLP code was modified to allow up to 1000 receptors.

During the initial development and debugging process, one-day and four-day meteorological data sets were used to evaluate whether or not BLP and AERMOD/BLP were giving the same results. A buoyant line source consisting of three lines parallel to each other was defined, with the lines oriented northwest-to-southeast at a 45-degree angle as shown in Figure 1. The endpoints of the three lines that make up the line source are in Table 1.

Table 1. Beginning and Ending Coordinates of the Buoyant Lines

Source ID	Xbegin	Ybegin	Xend	Yend
BLINE1	300	800	900	200
BLINE2	300	1000	900	400
BLINE3	300	1200	900	600

BLP requires the average value for several parameters in its calculations. These values are defined in the BLP User's Manual. The average parameters associated with the buoyant line source used in this testing are taken from one of the example cases packaged with BLP version 99176 and are presented in Table 2.

Table 2. Bouyant Line Source Average Parameters

Bldg Length (m)	Bldg Hgt (m)	Bldg Width (m)	Line Width (m)	Bldg Separation (m)	Buoyancy Param. (m ⁴ /s ³)
848.0	20.0	100.0	2.0	37.5	300.0

The release height for the lines was 20.0 meters (m) and the elevation for the lines was 0.0 m.

A 31-by-31 discrete receptor grid, with the origin at (0,0), and 50-meter node spacing was defined for the analyses, for a total of 961 receptors. The receptors are shown in Figure 1 as light grey dots.

For these initial tests, each buoyant line was modeled with an emission rate of 1.0 grams/second/square meter (g/s/m^2). The averaging times modeled were 1-, 3-, and 24-hr. Some test scenarios were modeled with 8-hr averaging periods, but the results are not reported here. Flat terrain was assumed for all model runs.

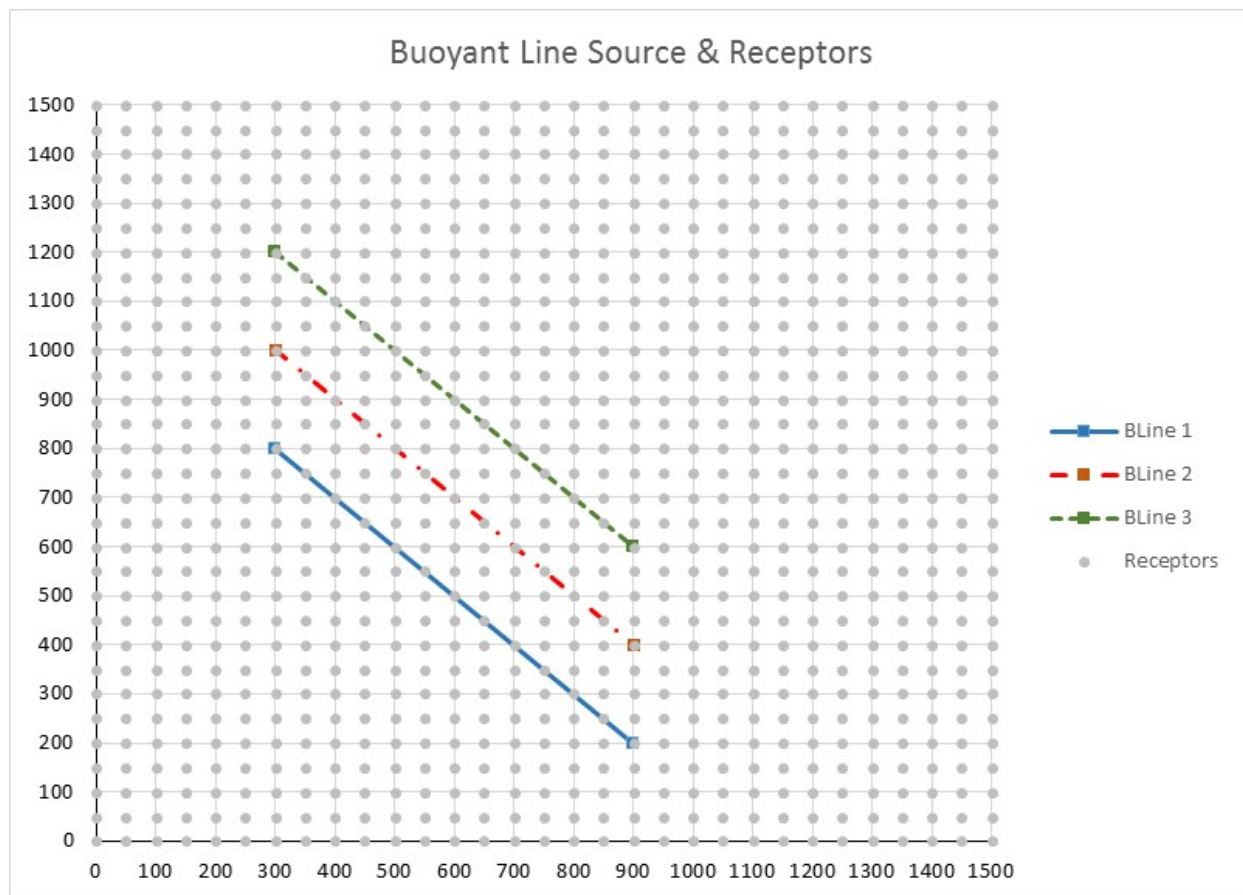


Figure 1. Buoyant Line Source and Receptor Locations

To run the AERMOD meteorology (or as near as possible) in BLP, which requires PCRAMMET-like format, AERMOD/BLP was modified to output the necessary parameters for BLP to read. The parameters are: wind speed (meters/second, m/s), flow vector (although it is referred to as wind direction in the BLP manuals) (degrees), ambient temperature (kelvin), Pasquill-Gifford (P-G) stability class, and rural and urban mixing heights (m). The wind direction, an input to AERMOD, was converted to flow vector for BLP. Since the P-G stability class is not an input to AERMOD, the subroutine LTOPG found in AERMOD was used to generate and output the appropriate stability class for the hour. The rural and urban mixing heights were set to the same value and are the larger of the convective and mechanical mixing heights that are input to AERMOD. For the one-day and four-day periods, all meteorological parameters were present (i.e., no missing data).

The results from BLP and AERMOD/BLP were compared and significant differences were noted with the one- and four-day runs. The code was reviewed and a few bugs were corrected, but differences remained. The difference was traced to the use of double precision in AERMOD/BLP (real variables are declared double precision). BLP was recompiled with the real-size:64 option (the default is real-size:32) and the results from both models (AERMOD/BLP and BLP) for the two short meteorological data sets were nearly identical. Table 1 shows the top 50 1-hour concentration impacts for the one-day scenario with the discrete receptor grid. Table 2 shows the 3-hour impacts, and Table 3 shows the 24-hour impacts. The 'NaN' in Table 3 for BLP indicates 'not a number'; the cause of this is unclear or why it would appear in the top 50.

Table 3. Top 50 1-hour Concentration Estimates ($\mu\text{g}/\text{m}^3$): 1-day Scenario

Rank	BLP	AERMOD	Rank	BLP	AERMOD
1	1493.2	1345.38	26	87.7	87.39
2	843.5	843.51	27	87.4	87.01
3	517.9	517.93	28	87.0	86.94
4	211.7	211.68	29	86.9	86.40
5	193.0	181.35	30	86.4	86.20
6	175.2	175.19	31	86.2	86.10
7	108.1	108.07	32	86.1	85.90
8	97.9	97.87	33	85.9	85.45
9	97.5	97.50	34	85.5	85.31
10	96.6	96.57	35	85.3	85.18
11	95.0	95.03	36	85.2	84.70
12	94.1	93.87	37	84.7	84.48
13	91.7	91.72	38	84.5	84.41
14	91.0	91.02	39	84.4	84.21
15	90.3	90.85	40	84.2	83.78
16	90.3	90.31	41	83.8	83.62
17	90.0	90.31	42	83.6	83.14
18	89.8	89.98	43	83.1	83.03
19	89.6	89.07	44	83.0	82.24
20	89.1	88.42	45	82.2	82.15
21	88.4	88.31	46	82.2	81.66
22	88.3	88.18	47	81.7	81.34
23	88.2	88.14	48	81.3	81.30
24	88.1	87.94	49	81.3	81.14
25	87.9	87.68	50	81.1	81.07

Table 4. Top 50 3-hour Concentration Estimates ($\mu\text{g}/\text{m}^3$): 1-day Scenario

Rank	BLP	AERMOD	Rank	BLP	AERMOD
1	498.0	448.63	26	39.4	39.41
2	281.3	281.34	27	39.0	39.01
3	203.0	199.91	28	37.6	38.06
4	93.3	75.40	29	37.6	37.59
5	89.6	75.33	30	37.3	37.26
6	71.5	71.53	31	37.2	37.20
7	55.2	54.35	32	37.0	37.18
8	54.4	53.97	33	36.4	37.04
9	54.0	52.64	34	36.3	36.30
10	53.3	51.33	35	36.3	36.30
11	52.6	51.31	36	35.4	35.75
12	51.3	50.93	37	35.1	35.05
13	51.1	46.15	38	35.0	33.66
14	50.9	45.53	39	33.7	33.56
15	46.2	45.01	40	33.6	33.00
16	45.5	44.31	41	33.2	32.98
17	44.3	43.21	42	33.0	32.71
18	43.0	42.97	43	33.0	32.71
19	42.8	42.82	44	32.7	32.17
20	42.2	42.20	45	32.2	32.16
21	40.2	40.52	46	31.9	31.75
22	40.1	40.22	47	31.8	31.59
23	39.8	40.07	48	31.7	31.50
24	39.8	39.79	49	31.2	31.24
25	39.5	39.52	50	31.2	31.23

Table 5. Top 50 24-hour Concentration Estimates ($\mu\text{g}/\text{m}^3$): 1-day Scenario

Rank	BLP	AERMOD	Rank	BLP	AERMOD
1	110.0	102.23	26	11.1	11.58
2	54.5	52.89	27	11.1	11.49
3	26.9	25.14	28	11.1	11.38
4	21.7	22.32	29	10.9	11.38
5	20.5	20.76	30	10.6	11.28
6	19.6	20.64	31	10.6	11.27
7	18.0	18.60	32	10.5	11.23
8	17.0	17.07	33	10.2	11.19
9	15.7	16.66	34	10.2	11.14
10	14.1	15.79	35	10.2	11.00
11	13.8	14.87	36	10.2	10.97
12	12.8	14.53	37	10.1	10.96
13	12.7	13.51	38	10.1	10.91
14	12.7	13.20	39	10.1	10.68
15	12.3	13.19	40	10.0	10.67
16	12.3	12.81	41	10.0	10.60
17	11.9	12.59	42	10.0	10.59
18	11.7	12.59	43	9.9	10.58
19	11.7	12.56	44	9.9	10.49
20	11.7	12.40	45	9.8	10.42
21	11.6	11.96	46	NaN	10.40
22	11.4	11.95	47	9.8	10.30
23	11.3	11.80	48	9.7	10.18
24	11.1	11.73	49	9.7	10.16
25	11.1	11.61	50	9.6	10.02

For the 4-day scenario with the discrete receptor network, Table 4 shows the top 50 1-hour concentration impacts for the one-day scenario with a discrete receptor grid. Table 5 shows the 3-hour impacts, and Table 6 shows the 24-hour impacts.

Table 6. Top 50 1-hour Concentration Estimates ($\mu\text{g}/\text{m}^3$): 4-day Scenario

Rank	BLP	AERMOD	Rank	BLP	AERMOD
1	1493.2	1345.38	26	157.9	157.92
2	843.5	843.51	27	157.6	157.55
3	517.9	517.93	28	156.0	156.02
4	265.5	265.46	29	155.5	155.47
5	244.3	226.88	30	154.8	154.76
6	211.7	211.68	31	154.6	154.63
7	206.5	191.17	32	154.2	154.19
8	193.0	189.72	33	152.7	152.70
9	191.2	189.16	34	150.7	150.71
10	189.2	188.66	35	149.1	149.13
11	188.7	184.32	36	148.7	148.66
12	184.3	181.35	37	146.7	146.67
13	180.2	180.25	38	146.5	146.53
14	178.8	178.78	39	145.8	145.80
15	178.4	178.39	40	145.2	145.19
16	176.2	176.16	41	142.0	142.44
17	175.2	175.19	42	141.9	141.87
18	171.5	171.54	43	140.3	140.26
19	170.5	170.48	44	138.1	138.07
20	169.9	169.94	45	137.7	137.66
21	168.3	168.32	46	135.5	135.50
22	167.8	167.82	47	135.2	135.17
23	166.3	166.27	48	134.6	134.64
24	163.9	163.86	49	133.8	133.81
25	163.5	163.47	50	133.8	133.76

Table 7. Top 50 3-hour Concentration Estimates ($\mu\text{g}/\text{m}^3$): 4-day Scenario

Rank	BLP	AERMOD	Rank	BLP	AERMOD
1	498.0	448.63	26	72.2	72.23
2	281.3	281.34	27	71.5	71.53
3	202.5	199.91	28	69.4	69.39
4	145.9	145.88	29	68.8	68.81
5	145.4	145.43	30	68.2	68.18
6	129.2	129.17	31	68.0	67.02
7	100.1	100.05	32	67.0	66.63
8	97.7	97.69	33	66.6	64.45
9	97.2	91.92	34	63.7	63.72
10	95.1	89.95	35	63.3	63.26
11	91.9	89.37	36	63.1	63.09
12	89.4	88.21	37	63.1	63.05
13	88.8	80.40	38	62.8	62.78
14	88.2	79.88	39	62.5	62.50
15	80.3	78.80	40	62.3	62.32
16	78.8	77.46	41	62.2	62.17
17	77.5	77.28	42	62.1	62.13
18	77.3	77.18	43	62.0	62.04
19	77.2	76.10	44	62.0	62.01
20	75.4	75.40	45	61.9	61.86
21	75.1	75.33	46	61.7	61.73
22	75.0	75.03	47	61.5	61.51
23	73.8	73.83	48	61.4	61.39
24	73.8	73.75	49	61.1	61.14
25	73.5	73.52	50	61.1	61.07

Table 8. Top 50 24-hour Concentration Estimates ($\mu\text{g}/\text{m}^3$): 4-day Scenario

Rank	BLP	AERMOD	Rank	BLP	AERMOD
1	109.6	102.23	26	25.8	25.34
2	52.9	52.89	27	25.3	25.32
3	38.6	38.60	28	25.2	25.14
4	33.0	32.99	29	25.2	25.00
5	32.9	32.87	30	24.9	24.92
6	32.6	32.63	31	24.7	24.83
7	31.6	31.39	32	24.6	24.62
8	30.6	30.60	33	24.5	24.61
9	30.3	30.40	34	24.5	24.50
10	30.2	30.30	35	24.3	24.26
11	29.8	30.16	36	23.8	23.87
12	29.4	29.65	37	23.4	23.60
13	29.4	29.48	38	23.1	23.09
14	28.5	29.37	39	23.0	23.04
15	28.1	28.19	40	22.7	22.73
16	28.0	28.10	41	22.7	22.66
17	28.0	27.92	42	22.4	22.56
18	27.9	27.88	43	22.4	22.43
19	27.7	27.82	44	22.4	22.32
20	27.7	27.77	45	22.3	22.28
21	27.7	27.68	46	22.1	22.05
22	26.7	26.95	47	22.0	22.03
23	26.7	26.06	48	21.9	22.00
24	26.1	26.01	49	21.7	21.70
25	26.0	25.83	50	21.7	21.68

A 1-month scenario (January) was run using meteorological data processed for the Lovett evaluation. To get AERMOD to accept the data, the version number in the header of the .SFC file was changed to 14134. For the discrete receptor network, Table 7 shows the top 50 1-hour concentration impacts for the one-day scenario with a discrete receptor grid. Table 8 shows the 3-hour impacts, and Table 9 shows the 24-hour impacts. For the 1-hour estimates, differences are apparent immediately after the highest value, but are more in line with each other further down.

Table 9. Top 50 1-hour Concentration Estimates ($\mu\text{g}/\text{m}^3$): 1-month Scenario

Rank	BLP	AERMOD	AERMOD (UREF=50)	Rank	BLP	AERMOD	AERMOD (UREF=50)
1	1208.3	1208.26	1208.26	26	454.2	447.49	465.48
2	841.6	1098.06	1098.06	27	454.1	447.39	461.54
3	787.3	1038.66	1038.66	28	453.5	443.00	454.19
4	763.2	841.62	841.62	29	451.4	429.36	454.09
5	755.3	787.32	787.32	30	451.0	425.40	453.48
6	676.9	763.23	763.23	31	447.5	421.43	451.39
7	674.6	755.30	755.30	32	447.4	418.98	450.96
8	654.5	676.90	676.90	33	445.0	411.38	447.49
9	604.5	674.59	674.59	34	443.0	404.82	447.39
10	548.5	654.49	654.49	35	441.7	403.88	444.99
11	545.8	604.45	604.45	36	432.8	402.95	443.00
12	521.7	548.53	548.53	37	429.4	400.58	441.69
13	508.1	545.84	545.84	38	425.4	399.16	432.77
14	500.0	521.73	521.73	39	421.4	399.02	429.36
15	499.9	499.99	508.09	40	419.0	398.14	425.40
16	497.1	499.93	499.99	41	411.4	397.58	421.43
17	494.1	497.10	499.93	42	410.7	397.13	418.98
18	494.1	494.11	497.10	43	407.2	386.52	411.38
19	485.1	494.07	494.11	44	404.8	384.66	410.67
20	484.7	471.74	494.07	45	403.9	383.36	407.23
21	475.8	461.54	485.13	46	403.0	383.24	404.82
22	475.1	454.19	484.74	47	401.0	378.09	403.88
23	471.7	454.09	475.76	48	400.6	374.51	402.95
24	465.5	453.48	475.14	49	399.2	371.74	401.00
25	461.5	451.39	471.74	50	399.0	371.59	400.58

Table 10. Top 50 3-hour Concentration Estimates ($\mu\text{g}/\text{m}^3$): 1-month Scenario

Rank	BLP	AERMOD	AERMOD (UREF=50)	Rank	BLP	AERMOD	AERMOD (UREF=50)
1	440.4	440.37	440.37	26	195.8	195.75	196.06
2	420.8	420.79	420.79	27	194.9	194.91	195.88
3	402.8	402.75	402.75	28	193.4	193.38	195.75
4	390.3	390.34	390.34	29	192.8	192.80	194.91
5	378.3	378.27	378.27	30	192.8	192.77	193.38
6	370.5	370.46	370.46	31	191.1	191.09	192.80
7	350.1	367.97	367.97	32	189.9	189.92	192.77
8	331.4	366.02	366.02	33	189.9	188.48	191.09
9	327.1	350.14	350.14	34	188.5	186.66	189.92
10	326.7	331.44	331.44	35	186.7	185.98	189.90
11	323.3	327.06	327.06	36	186.0	184.15	188.48
12	280.4	326.73	326.73	37	184.2	183.70	186.66
13	275.0	323.27	323.27	38	183.7	183.34	185.98
14	247.8	280.36	280.36	39	183.3	180.25	184.15
15	237.4	275.02	275.02	40	180.3	179.92	183.70
16	234.2	247.83	247.83	41	179.9	179.24	183.34
17	233.6	237.36	237.36	42	179.6	178.04	180.25
18	229.0	234.17	234.17	43	179.2	177.52	179.92
19	219.6	229.00	233.61	44	178.0	174.03	179.56
20	218.8	219.57	229.00	45	177.5	171.62	179.24
21	217.9	218.82	219.57	46	174.0	171.37	178.04
22	213.0	217.91	218.82	47	171.4	170.34	177.52
23	199.0	212.95	217.91	48	171.2	170.33	174.03
24	196.1	196.06	212.95	49	171.0	169.57	171.37
25	195.9	195.88	199.03	50	170.3	168.73	171.22

Table 11. Top 50 24-hour Concentration Estimates ($\mu\text{g}/\text{m}^3$): 1-month Scenario

Rank	BLP	AERMOD	AERMOD (UREF=50)	Rank	BLP	AERMOD	AERMOD (UREF=50)
1	84.7	84.53	84.67	26	62.3	52.66	62.36
2	79.9	76.75	79.74	27	61.9	52.62	62.33
3	76.3	72.75	76.30	28	61.7	52.62	61.86
4	73.6	70.79	73.63	29	61.6	52.56	61.70
5	70.8	63.65	70.90	30	61.5	52.26	61.64
6	70.5	61.60	70.81	31	61.3	52.25	61.34
7	70.1	61.02	70.54	32	61.3	52.14	61.29
8	68.9	61.02	70.08	33	61.2	51.53	61.15
9	68.3	60.73	68.93	34	60.9	51.49	60.91
10	67.2	60.60	68.33	35	60.8	51.48	60.76
11	67.1	60.39	68.01	36	60.3	51.30	60.25
12	66.4	59.07	67.19	37	60.1	50.99	60.14
13	65.9	58.64	66.39	38	60.0	50.91	60.06
14	65.9	58.53	65.92	39	59.9	50.60	59.97
15	65.8	58.12	65.86	40	58.9	50.39	59.91
16	65.8	57.45	65.78	41	58.7	50.30	58.91
17	64.7	57.44	65.75	42	58.3	50.24	58.71
18	64.7	56.31	64.71	43	57.0	50.22	58.64
19	64.2	56.13	64.68	44	56.9	50.16	58.31
20	63.7	55.63	64.18	45	56.7	50.01	57.04
21	63.6	55.03	63.65	46	56.7	49.90	56.86
22	63.2	54.95	63.54	47	56.5	49.54	56.67
23	62.9	54.56	63.16	48	56.4	49.25	56.66
24	62.9	54.05	62.94	49	56.3	49.20	56.47
25	62.5	53.26	62.48	50	56.1	48.42	56.41

It is important to note that the reference measurement height for winds in the Lovett-based meteorology can vary from 10 m to 50m and even as high as 100 m, whereas the 'measurement height' in BLP is a user-defined static value. For these tests it was set at 50 m. To eliminate this height as a source of possible differences, the reference height in AERMOD/BLP (UREFHT) was set to 50 m for all hours. As seen in Table 11, it makes some difference, ranging from 1-2% to as much as 15%.

Once most of the 'bugs' had been worked out using the short meteorological data sets, testing was extended to using a full year of meteorological data. The Lovett evaluation database profile and surface files were used: LOVETT.PFL and LOVETT.SFC. As with the one- and four-day cases, AERMOD/BLP was run to output the year of meteorological data for BLP.

BLP requires a complete period of meteorological record but AERMOD will skip the hour if critical parameters are missing. There were approximately 250 hours skipped in the output meteorological file generated by AERMOD/BLP for the year of meteorological data. Periods

ranged from one hour to several consecutive hours. The resulting output file for BLP was edited manually to fill those hours. Interpolation, persistence, and professional judgment were used to fill the parameters, depending on the variable and, in part, on the length of the missing data period.

A single case was developed to test AERMOD/BLP initially and identify any further bugs with the three lines and receptors shown in the figure above. Tables 12-14 show the top 50 1-hr, 3-hr, and 24-hr impacts, respectively.

Table 12. Top 50 1-hour Concentration Estimates ($\mu\text{g}/\text{m}^3$): 1-year Scenario

Rank	BLP	AERMOD	BLP (real-size:32)	Rank	BLP	AERMOD	BLP (real-size:32)
1	2528.8	146052.19	146002.9	26	966.4	1078.10	1208.3
2	2525.6	2528.82	6802.1	27	940.5	1071.29	1185.6
3	2364.9	2525.60	3010.3	28	919.8	1066.18	1183.6
4	2220.2	2434.01	3006.0	29	895.3	1065.83	1174.5
5	1825.4	2364.93	2713.6	30	793.3	1054.35	1149.7
6	1821.3	2220.21	2517.8	31	766.7	1046.85	1113.7
7	1602.4	2208.78	2472.9	32	751.6	1038.66	1112.6
8	1501.9	1825.36	2434.0	33	730.2	1013.93	1098.1
9	1488.1	1821.31	2208.8	34	718.8	1012.96	1071.3
10	1332.6	1761.65	1827.7	35	696.3	966.38	1066.2
11	1330.8	1602.43	1825.4	36	691.3	940.46	1065.8
12	1291.5	1548.45	1821.3	37	674.2	939.13	1054.3
13	1208.3	1501.89	1761.6	38	671.0	919.75	1038.7
14	1171.8	1488.07	1626.7	39	668.4	895.25	1012.2
15	1167.5	1332.55	1548.4	40	663.0	874.41	999.8
16	1153.9	1330.77	1501.9	41	662.8	841.62	999.8
17	1133.0	1291.44	1488.1	42	660.9	831.39	982.7
18	1131.1	1208.26	1332.6	43	660.1	793.28	966.3
19	1082.2	1171.84	1330.8	44	650.8	791.68	819.5
20	1079.9	1167.48	1291.4	45	650.1	790.26	1.3
21	1078.1	1153.89	1282.3	46	648.0	787.32	NaN
22	1066.2	1132.99	1275.1	47	644.3	766.66	919.8
23	1046.9	1131.08	1264.0	48	637.3	763.23	874.4
24	1013.9	1098.06	1242.3	49	637.3	761.52	847.5
25	1013.0	1079.88	1240.1	50	636.4	755.30	838.8

With the full year of data the 1-hour concentration estimates were found to be vastly different: $146,052 \mu\text{g}/\text{m}^3$ for AERMOD/BLP and $2,528 \mu\text{g}/\text{m}^3$ for BLP. The remaining impacts were two orders of magnitude smaller, with the concentration estimates between AERMOD/BLP and BLP

somewhat similar, although there are ranks where the AERMOD/BLP is 30-40 percent (%) greater than BLP. The large hourly value also affects the maximum 3-hour and 24-hour results.

AERMOD/BLP also was run with the wind reference height set a constant 50 meters (as is the case in BLP). There is little difference between the two AERMOD/BLP model runs, with most differences 2% or less. These results are not shown here.

On further investigation, the highest AERMOD/BLP impact was at receptor at x=450, y=1050. That receptor is on one of the lines (#3, the uppermost line in Figure 1) and the wind direction associated with the date of the highest value is 315° or long the line. This may partly explain the extreme value (a receptor right on the line). However, several other receptors appear to fall directly on the lines and there are nearly 40 cases where the winds direction is 315° as well, yet the impacts are much smaller. Why this single hour stands out has not been investigated.

Why this single hour at one receptor yielded such a large impact while similar receptors (i.e., on a line) and wind directions did not has not been investigated in detail. However, BLP was recompiled with real-case:32 (32-bit precision) and, unexpectedly, the 32-bit version of BLP yielded an estimate of the same magnitude as AERMOD/BLP (Table 12). The remaining BLP maximum values are all greater than the corresponding AERMOD/BLP values to the 44th maximum value. The 45th (1.3) and 46th (NaN) values cannot be explained at this time, and is similar to the NaN seen in Table 5. Nor is it clear why the 47th-50th values are about the same magnitude as the 44th value. This issue may require further exploration, although since it is an issue with BLP, it may not be important for AERMOD/BLP.

Table 13. Top 50 3-hour Concentration Estimates ($\mu\text{g}/\text{m}^3$): 1-year Scenario

Rank	BLP	AERMOD	Rank	BLP	AERMOD
1	917.8	48710.30	26	340.7	390.34
2	848.8	917.78	27	315.2	389.85
3	763.7	849.38	28	313.9	384.60
4	652.8	815.06	29	289.9	380.06
5	614.4	807.64	30	282.1	378.27
6	545.4	781.35	31	281.3	372.41
7	543.1	763.73	32	280.4	370.46
8	507.0	652.83	33	266.3	369.49
9	472.2	632.31	34	264.2	369.30
10	455.0	614.38	35	264.2	368.99
11	440.4	578.72	36	252.6	367.97
12	435.5	543.10	37	251.8	366.02
13	434.8	507.04	38	248.5	362.82
14	427.5	504.81	39	245.1	357.25
15	425.2	472.22	40	243.4	355.91
16	400.9	454.98	41	242.6	350.39
17	389.9	440.37	42	236.6	350.14
18	384.6	440.29	43	235.5	347.01
19	380.1	435.54	44	231.6	342.61
20	369.3	434.75	45	229.9	340.66
21	369.0	425.18	46	227.1	334.85
22	362.8	420.79	47	222.7	333.33
23	352.6	402.75	48	222.4	331.44
24	350.4	400.92	49	217.0	328.37
25	342.6	390.61	50	216.2	327.06

Table 14. Top 50 24-hour Concentration Estimates ($\mu\text{g}/\text{m}^3$): 1-year Scenario

Rank	BLP	AERMOD	Rank	BLP	AERMOD
1	138.7	6094.37	26	69.5	84.53
2	131.0	142.76	27	69.3	84.14
3	126.2	131.84*	28	64.7	83.88
4	103.6	131.19	29	64.2	82.44
5	101.3	129.66	30	63.2	82.14
6	100.8	125.95	31	63.2	80.33
7	93.3	122.70	32	63.1	80.10
8	90.8	121.06	33	62.3	78.89
9	90.1	119.73	34	61.5	78.86
10	88.6	109.95*	35	61.3	78.22*
11	88.3	109.74	36	61.2	78.06
12	83.2	106.66	37	59.8	77.90
13	82.9	104.74	38	59.1	77.52
14	82.3	103.60*	39	58.4	77.27
15	79.1	98.31	40	56.3	76.75
16	78.2	97.62	41	56.3	76.68
17	76.6	95.75	42	55.7	76.45
18	74.9	95.56	43	54.1	75.68
19	74.4	93.79	44	53.9	74.64
20	74.4	93.34	45	53.5	74.14
21	74.3	92.73	46	52.2	73.92
22	71.6	89.54	47	52.2	73.78
23	71.4	89.09	48	51.9	73.54
24	70.9	88.60	49	51.8	72.90
25	69.7	86.93	50	51.6	72.75

* missing data processing

At this juncture, it is important to note that the original BLP model removes receptors that are within the rectangle defined by the maximum extents that enclose the multiple lines that define a buoyant line source (the three lines in this case). In Figure 1 this would result in about 275 receptors being removed. To be able to compare AERMOD/BLP to BLP, that part of the BLP code (only about 3 lines) was commented out, otherwise it would be impossible to compare and debug AERMOD/BLP with BLP. This removal of receptors likely would result in the elimination of the large AERMOD/BLP impact since it is exactly on the line. Recall that it is up to the user to eliminate receptors inside a facility boundary in AERMOD; as such, the receptors within the rectangle defined by the buoyant line source would likely be removed during this process and this large discrepancy never an issue.

3.2 Further Testing of AERMOD

Several additional one-year test cases were created. The buoyant line source always consisted of three lines. In those test cases that indicate two point sources, the sources were located slightly south of the center of the buoyant line source. These additional cases are described here.

Table 15. Additional Tests - 1-year Scenarios

Test	Scenario
A	Buoyant line source and gridded receptor network
B	Buoyant line source and two point sources
C	Buoyant line source, using an hourly emissions file: two scenarios - hourly emissions for a single line and hourly emissions for all three lines
D	Buoyant line source and two point sources, using HROFDY emission factors for the lines
E	Buoyant line source and two point sources, using three different emission factors for each of the lines (SEASON, HROFDY, MONTH)
F	Buoyant line source and two point sources modeling 24-hr PM2.5 and using MAXDCONT
G	Buoyant line source and two point sources modeling 1-hr SO2 and using MAXDCONT
H	Buoyant line source and two point sources with the lines oriented ENE to WSW
I	Buoyant line source and two point sources with the lines oriented vertically
J	Buoyant line source and two point sources with the lines oriented horizontally

Since most of the testing was to exercise AERMOD options, and similar options are not available in BLP, model-to-model comparisons are not possible, except for Tests A and B. For a few of the tests, variations on input parameters were modeled to see if the results were as expected. For example, the emission rate in the hourly emission file was doubled or tripled to see if the resulting impacts doubled or tripled. All results appear to be in line with what is expected.

With the exception of the highest value, the remaining impacts in Tables 16 and 17 are comparable between AERMOD/BLP and BLP for all three averaging periods.

Table 16. Top 5 Concentration Estimates ($\mu\text{g}/\text{m}^3$), Test A (Gridded Network)

	1-hour		3-hour		24-hour	
Rank	BLP	AERMOD	BLP	AERMOD	BLP	AERMOD
1	3010.3	146052.19	1083.3	48710.30	157.2	6094.37
2	3006.0	2528.82	1010.3	917.78	154.2	142.76
3	2713.6	2525.60	865.8	849.38	148.7	131.84
4	2517.8	2434.01	652.8	815.06	105.2	131.19
5	1827.7	2364.93	619.4	807.64	103.6	129.66

Table 17. Top 5 Concentration Estimates ($\mu\text{g}/\text{m}^3$), Test B (Includes Two Point Sources)

	1-hour		3-hour		24-hour	
Rank	BLP	AERMOD	BLP	AERMOD	BLP	AERMOD
1	2528.8	146052.19	917.8	48710.30	138.7	6094.38
2	2525.6	2528.82	848.8	917.78	131.0	142.81
3	2364.9	2525.60	763.7	849.39	126.2	132.32
4	2220.2	2434.01	652.8	815.06	103.6	131.27
5	1825.4	2364.93	614.4	807.67	101.3	129.76

The remaining tests were only performed with AERMOD/BLP since BLP does not have all the processing options that AERMOD employs. Tables 18-25 correspond to Test C-J. The maximum 5 values are shown for the 1-hour, 3-hour, and 24-hour impacts. For the annual average, the high-first-high through high-fifth-high are shown.

Table 18 represents hourly emissions for all three of the buoyant lines, whereas Table 19 show the results when Line 3 is the only contributor to the estimates (lines 1 and 2 are not included in the hourly emission file and the emission rate is set to 0.0 g/s in the control file). The only effect is seen mostly for the annual averaging period and somewhat in the 24-hr averaging period.

Table 18. Concentration Estimates ($\mu\text{g}/\text{m}^3$), Test C
(Hourly Emissions File with All Three Lines Contributing)

Rank	1-hour	3-hour	24-hour	Annual
1	146052.19	48710.30	6094.37	47.58
2	2528.82	917.78	142.76	27.84
3	2525.60	849.38	131.84	26.99
4	2434.01	815.06	131.19	24.88
5	2364.93	807.64	129.66	22.45

Table 19. Concentration Estimates ($\mu\text{g}/\text{m}^3$), Test C
(Hourly Emissions File with Only Line 3 Contributing)

Rank	1-hour	3-hour	24-hour	Annual
1	146052.19	48710.30	6094.37	42.39
2	2528.82	917.78	131.83	15.47
3	2525.60	848.13	130.61	15.24
4	2434.01	815.06	130.43	14.42
5	2364.93	800.67	129.34	13.50

Table 20 shows the impacts when the HROFDY keyword is used to control the emissions. The following factors were used.

```
EMISFACT BLINE1 HROFDY 5*0.0 0.0 18*0.0
EMISFACT BLINE2 HROFDY 5*0.0 0.0 18*0.0
EMISFACT BLINE3 HROFDY 5*0.0 0.5 18*0.0
```

The only contributor to the concentration estimates is BLINE3 and only for 0600. This hour corresponds to the hour when the extremely large impacts were seen on October 3. Since the emission factor is 0.5, the resulting hourly rate should be half of the largest value seen in the tables above. This is in fact the case: $146052/2 = 73026$. One would expect slight differences in the 3-hour and 24-hour values since there are no contributions from the other hours to these averaging periods.

Table 20. Concentration Estimates ($\mu\text{g}/\text{m}^3$) for Test D

Rank	1-hour	3-hour	24-hour	Annual
1	73026.09	24342.03	3042.76	9.41
2	523.42	297.76	72.29	5.26
3	468.59	294.39	72.22	5.16
4	465.44	294.32	71.55	5.08
5	465.26	292.62	71.44	5.00

Table 21 shows the impacts when the three different emission factor keywords are used to control the emissions. The following factors were used. In this scenario, the SEASON emission factor was used for line 3 (BLINE3) and was set to 0.0 for the fall (October-December). The highest impacts seen in the tables above (e.g., Table 18) are the result of the extreme concentration estimate on October 3 at 0600. With the emission factor set to 0.0, this hour's impact does not factor in to the results in Table 21.

```
EMISFACT BLINE3 SEASON 1.0 1.0 1.0 0.0
EMISFACT BLINE2 HROFDY 5*0.0 1.0 18*0.0
EMISFACT BLINE1 MONTH 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
```

Table 21. Concentration Estimates ($\mu\text{g}/\text{m}^3$) for Test E

Rank	1-hour	3-hour	24-hour	Annual
1	2528.82	917.78	3042.76	9.41
2	2525.60	848.14	72.29	5.26
3	2434.01	815.06	72.22	5.16
4	2220.21	763.73	71.55	5.08
5	1761.65	632.31	71.44	5.00

Table 22 shows the results for the 24-hr PM-2.5 impacts with the three buoyant lines and the two point sources modeled and the MAXDCONT output option specified for source groups ALL, STACKS (both stacks), and BLINES (three lines). The emission rate was 1.0 g/s/m^2 for all three lines, i.e. no emission factors were applied.

Table 22. Concentration Estimates ($\mu\text{g}/\text{m}^3$) for Test F (24-hr PM-2.5)

Group	Rank	Average Concentration	Contribution ALL	Contribution STACKS	Contribution BLINES
ALL	1	6094.38	6094.38	0.01	6094.37
	2	126.54	126.54	0.58	125.95
	3	110.07			
	4	104.95			
	5	103.66			
	6	98.67			
	7	97.67			
	8	93.06			
	9	90.05			
	10	87.16			
STACKS	1	72.29	79.67	72.29	7.37
	2	72.22	79.85	72.22	7.63
	3	71.55			
	4	71.43			
	5	71.06			
	6	70.69			
	7	70.64			
	8	70.47			
	9	69.51			
	10	69.51			
LINES	1	6094.37	6094.38	0.01	6094.37
	2	125.95	126.54	0.58	125.95
	3	109.74			
	4	104.74			
	5	103.60			
	6	98.31			
	7	97.62			
	8	92.73			
	9	89.54			
	10	86.93			

Table 23 shows the results for the 1-hr SO₂ impacts with the three buoyant lines and the two point sources modeled. The MAXDCONT output option was specified for source groups ALL, STACKS, and BLINES. The emission rate was 1.0 g/s/m² for all three lines, i.e. no emission factors were applied.

Table 23. Concentration Estimates (µg/m³) for Test G (1-hr SO₂)

Group	Rank	Average Concentration	Contribution ALL	Contribution STACKS	Contribution BLINES
ALL	1	146052.19	146052.19	0.00	146052.19
	2	1825.36	1825.36	0.00	1825.36
	3	1488.07			
	4	1171.84			
	5	841.63			
	6	831.39			
	7	790.26			
	8	787.33			
	9	763.23			
	10	761.52			
STACKS	1	471.12	475.09	471.12	3.97
	2	466.96	469.95	466.96	2.98
	3	464.74			
	4	459.90			
	5	456.18			
	6	446.70			
	7	437.29			
	8	436.62			
	9	427.32			
	10	413.75			
LINES	1	146052.19	146052.19	0.00	146052.19
	2	1825.36	1825.36	0.00	1825.36
	3	1488.07			
	4	1171.84			
	5	841.62			
	6	831.39			
	7	790.26			
	8	787.32			
	9	763.23			
	10	761.52			

The next three tests demonstrate the impacts resulting from different orientations of the buoyant line source: rotated 90 degrees, vertical, and horizontal. In these tests, the receptor and the buoyant line that caused the extremely large impact seen in the tables above do not coincide, thus the smaller impacts. The purpose of these tests is to show consistency between the results, i.e. there is no apparent anomalous behavior.

Table 24 shows the impacts when the buoyant lines are oriented from the WSW to the ENE, i.e. rotated 90 degrees from the orientation shown in Figure 1.

Table 24. Concentration Estimates ($\mu\text{g}/\text{m}^3$) for Test H -
Buoyant Lines Oriented ENE to WSW

Rank	1-hour	3-hour	24-hour	Annual
1	468.59	297.76	73.06	20.67
2	465.44	294.39	72.85	19.33
3	465.26	294.32	72.62	18.47
4	459.41	292.62	72.41	17.83
5	452.37	288.80	71.67	17.38

Table 24 shows the impacts when the buoyant lines are oriented from the WSW to the ENE, i.e. rotated 90 degrees from the orientation shown in Figure 1.

Table 25. Concentration Estimates ($\mu\text{g}/\text{m}^3$) for Test I -
Buoyant Lines Vertically

Rank	1-hour	3-hour	24-hour	Annual
1	608.86	325.94	89.16	30.85
2	608.85	314.33	87.73	28.59
3	566.36	314.33	85.22	26.04
4	566.36	314.33	81.96	23.81
5	566.36	304.85	78.68	20.50

Table 24 shows the impacts when the buoyant lines are oriented from the WSW to the ENE, i.e. rotated 90 degrees from the orientation shown in Figure 1.

Table 26. Concentration Estimates ($\mu\text{g}/\text{m}^3$) for Test J -
Buoyant Lines Horizontally

Rank	1-hour	3-hour	24-hour	Annual
1	469.16	297.88	81.28	25.27
2	465.80	294.54	81.05	25.09
3	465.70	294.52	80.44	24.64
4	459.92	292.72	80.31	24.39
5	452.98	288.97	79.98	24.26

4. Differences between AERMOD/BLP and BLP

Some differences between the two models (AERMOD/BLP and BLP) are to be expected due in part, to:

- 1) The AERMOD/BLP meteorology has a variable reference height as developed by AERMET. However, in BLP the measurement height (ZMEAS in the METIN namelist) is a constant 50 meters. Some tests were run to see if this made a difference. Although it changed the AERMOD/BLP results, the changes were not significant.
- 2) Filling of missing meteorological data for BLP.
- 3) Use of a compiler option to enforce double precision versus explicit declaration in the code - the effect of this option may contribute to differences.

Further testing may yield insights of other reasons differences are seen between AERMOD/BLP and BLP.

5. Additional Changes to AERMOD/BLP

5.1 Background Concentration

Investigation of the use of the background keyword was initiated. The results were not as expected, but there was no opportunity to determine why the results were not as expected.

5.2 Event Processing

A couple lines of code were added in the file evcalc.f for event processing but did not go any further. The buoyant_line module was added as was code to save the ambient temperature (note that when processing point sources, AERMOD changes the value of the ambient temperature stored in the variable TA), and a comment about the P-G stability class.

5.3 BLP Source Group

The BLPGROUP keyword was not added since it would not provide any additional capabilities at this stage of incorporating a single buoyant line source (composed of multiple lines). This keyword will be useful as a future enhancement to allow more than one buoyant line source to be processed in a single model run.

6. Recommendations

A primary recommendation for AERMOD/BLP is to develop the meteorology and source information associated with the 1979 SF₆ tracer study at the Reynolds Metals Patterson Plant. Since all the relevant data are hardcopy (paper), time will be needed to enter the data electronically.

APPENDIX

1. AERMOD Keywords for Buoyant Line Sources

One LOCATION record for each line that comprises the buoyant line source.

SO LOCATION *sourceID* *BUOYLINE* *Xb* *Yb* *Xe* *Ye* (*Zs*)

Xb, Yb = coordinate of the beginning of the line source (m)

Xe, Ye = coordinate of the end of the line source (m)

Zs = line elevation (m) - optional; defaults to 0.0 if omitted

One SRCPARAM record for each line that comprises the buoyant line source.

SO SRCPARAM *sourceID* *blemis* *relhgt*

Blemis = emission rate (g/s/m²)

Relhgt = release height (m)

The BLPINPUT keyword defines the average values for the buoyant line (as a whole and not as the individual lines that comprise the buoyant line source). The order shown is the same as the input in BLP (in the namelist RISE), with the variable name used in BLP shown in parentheses. This keyword can only appear once.

SO BLPINPUT *blavgblen blavgbhgt blavgbwid blavglwid blavgbsep blavgfprm*

blavgblen (L) = average building length (m)

blavgbhgt (HB) = average building height (m)

blavgbwid (WB) = average building width (m)

blavglwid (WM) = average line source width (m) (of the individual lines)

blavgbsep (DX) = average building separation (m) (between the individual lines)

blavgfprm (FPRIME) = average buoyancy parameter (m⁴/s³)

United States
Environmental Protection
Agency

Office of Air Quality Planning and Standards
Air Quality Assessment Division
Research Triangle Park, NC

Publication No. EPA-454/P-15-004
July 2015
