COMPUTER SIMULATION EVALUATION OF VISIBILITY DISTANCES PROVIDED BY FIFTEEN HEADLAMP SYSTEMS

Rudolf G. Mortimer and Judith M. Becker

Highway Safety Research Institute
University of Michigan
Ann Arbor, Michigan 48105

Report No. UM-HSRI-HF-TM-73-4

Contract No. 361380

May 17, 1973

Ford Motor Company
Dearborn, Michigan 48124

TABLE OF CONTENTS

SUMMARY

TEST CONDITIONS

A computer simulation evaluation of visibility distances provided by fifteen headlighting systems was conducted, in the same manner as described in a previous report (HF-TM-73-3).

Systems A-1, A-2, and A-3 and D-1 consist of two identical lamps with two filaments each, providing low and high beams. System XD-1 has two lamps, each with different low and high beams. Systems B-1, B-2 and B-3 consist of two pairs of identical lamps, one pair having low and high beam filaments and the second having only a high beam. System XB-1 is similar except that the first pair of lamps has only low beam filaments. Systems C-1, C-2 and C-3 have two identical lamps with low and high beams and two more lamps; one a mid beam and the other a high beam. The photometric data supplied for the system C-2 mid beam was insufficient in that the section above the horizontal was missing when the pattern was correctly aimed. Therefore mid and high beams could not be run. Systems E, XE-1 and XE-2 have two lamps; one with low and mid beams and the other with low and high beams.

Lamps were located so that the low beam lamps were nearest the edges of the vehicle and additional lamps were inboard. The mid beam lamp was always located on the driver's side of the car. The lamps were mounted such that their horizontal/vertical axes were 27 inches above the road, with inter-lamp distances between outboard lamps of 58 inches and 42 inches between inboard lamps. The driver's eyes were placed 46 inches above the road. The two cars in the simulated meeting were in the center of lanes 12 feet wide.

The visibility was computed for a specific 10% reflectance target, as used in experimental tests, whose orientation had to be identified. The visibility was computed for the target located at the right edge of the road and in the center of the lane. During the meetings the visibility was computed beginning at an inter-car longitudinal separation distance of 3500 feet, with the same beam being used throughout. In other words, beams were not switched during or after the meeting.

For headlamp systems that were comprised of three beams, the mid beam was used to form part of the high beam.

Photometric data, in the form of strip chart outputs of candela values taken at half degree vertical intervals between 20° left and 20° right of an estimated H-V point, were hand reduced to digital values to provide an intensity grid with the true H-V located as accurately as possible from the beam pattern. This was done by locating the H-V at 2° right and 1.5° down for the low beams; 2° right and 1° down for mid beams; and at V and 0.5° down for high beams.

The photometric data were taken from 35 different headlamps and involved a total of 49 different beams.

RESULTS

The output of the simulation is shown in Figures 1-30 and summarized in Tables 1 and 2.

High beams provide greater maximum visibility than low or mid beams, and generally provide greater visibility in the center of the lane than the right side.

Mid beams provide up to 16% greater visibility at the right side target and up to 20% greater visibility at the center target than the low beams in their systems. This is shown by the maximum visibility distance ratios in the tables. Also, the minimum visibility distance ratios of the mid beams are generally greater than unity, showing that the mid beams provide a greater minimum visibility than the low beams. Therefore, the mid beams provide greater visibility throughout the meeting.

The ratio of the maximum visibility distance/minimum visibility provides an indication of the disability glare effect. Those beams that show a large ratio are ones that cause a large fall in visibility due to glare during the meeting. In all cases the low beams show the least visibility decrement, with somewhat greater ratios obtained with mid beams, and large values being found for high beams. The latter would be expected since such beams are not intended to be used during the full course of a meeting.

The most effective inter-vehicle separation distance at which dimming from high to low or mid beams should occur can be found from the Figures, as the distance at which the high beam visibility curve crosses those for the other beams. Thus, dimming from high beam should generally occur at about 1200 feet.

Of the systems evaluated it would appear that C-3 (or C-1) offers the best visibility for the right side target location, and C-1 (or C-3) for the center target. This conclusion is based on a criterion of high maximum (unopposed) visibility for the high beam, high maximum and minimum visibility during the meeting for the mid beam and low beam, with low beam performance considered to be of secondary importance in three beam systems compared to the mid beam.

Of the systems consisting of two beams, it would appear that B-2 was somewhat more effective than B-3 and others, on a criterion of high maximum and minimum visibility for the low beam and high unopposed (max) visibility for the high beam.

The mid beam of system C-1 provides about 5% and 3% greater maximum visibility for the right and center targets, respectively, than the low beam of system B-2; and about 9% and 13% greater minimum visibility for the right and center targets, indicating that moderate gains in visibility would result from introduction of a mid beam.

The results that are shown are based on visibility distance. Selection of headlamp beams should also be based on evaluations of their effects on discomfort glare in night driving meeting situations, and effects of factors affecting headlamp aim.

TABLE 1. Maximum and Minimum Visibility Distances Obtained for Each Beam, for the 10% Reflectance Target at the Right of the Lane.

RIGHT TARGET						
System	Beam	Max. Vis. Dist. (feet)	Max. Vis. Dist. Ratio: High or Mid / low	Min. Vis. Dist. (feet)	Min. Vis. Dist. Ratio: High or Mid / low	Ratio: Max. Vis. Dist. / Min. Vis. Dist.
A-1	Low	248	1.00	223	1.00	1.11
	High	280	1.12	159	.71	1.76
A-2	Low	201	1.00	190	1.00	1.06
	High	263	1.30	174	.92	1.51
A-3	Low	247	1.00	226	1.00	1.09
	High	278	1.12	166	.77	1.68
B-1	Low	221	1.00	205	1.00	1.08
	High	301	1.36	162	.79	1.86
B-2	Low	271	1.00	220	1.00	1.23
	High	292	1.08	166	.76	1.76
B-3	Low	236	1.00	216	1.00	1.09
	High	284	1.20	163	.75	1.74
C-1	Low	249	1.00	214	1.00	1.16
	Mid	2[illegible]6	1.15	2[illegible]9	1.12	1.20
	High	313	1.26	184	.86	1.70
C-2	Low	239	1.00	215	1.00	1.11
C-3	Low	243	1.00	222	1.00	1.10
	Mid	282	1.16	246	1.11	1.14
	High	318	1.30	202	.91	1.57
D-1	Low	250	1.00	220	1.00	1.14
	High	290	1.16	183	.83	1.58
E-1	Low	260	1.00	226	1.00	1.15
	Mid	292	1.12	239	1.06	1.22
	High	306	1.18	209	.92	1.46
XB-1	Low	217	1.00	206	1.00	1.05
	High	340	1.56	147	.71	2.31
XD-1	Low	252	1.00	224	1.00	1.12
	High	280	1.11	162	.72	1.73
XE-1	Low	234	1.00	206	1.00	1.13
	Mid	263	1.12	231	1.12	1.14
	High	282	1.21	202	.98	1.39
XE-2	Low	252	1.00	201	1.00	1.25
	Mid	264	1.12	201	1.00	1.31
	High	284	1.12	195	.97	1.46

TABLE 2. Maximum and Minimum Visibility Distances Obtained for Each Beam, for the 10% Reflectance Target in the Center of the Lane.

CENTER TARGET						
System	Beam	Max. Vis. Dist. (feet)	Max. Vis. Dist. Ratio: High or Mid / low	Min. Vis. Dist. (feet)	Min. Vis. Dist. Ratio: High or Mid / low	Ratio: Max. Vis. Dist. / Min. Vis. Dist.
A-1	Low	208	1.00	174	1.00	1.19
	High	289	1.39	129	.74	2.24
A-2	Low	182	1.00	162	1.00	1.12
	High	275	1.51	150	.93	1.83
A-3	Low	239	1.00	193	1.00	1.24
	High	285	1.19	139	.72	2.05
B-1	Low	216	1.00	180	1.00	1.20
	High	302	1.39	135	.75	2.24
B-2	Low	261	1.00	184	1.00	1.42
	High	311	1.19	139	.76	2.24
B-3	Low	241	1.00	193	1.00	1.25
	High	312	1.30	145	.75	2.15
C-1	Low	226	1.00	183	1.00	1.24
	Mid	269	1.19	208	1.14	1.29
	High	313	1.38	155	.85	2.02
C-2	Low	230	1.00	180	1.00	1.28
C-3	Low	224	1.00	193	1.00	1.16
	Mid	249	1.11	205	1.05	1.21
	High	300	1.34	161	.83	1.86
D-1	Low	234	1.00	187	1.00	1.30
	High	295	1.26	154	.82	1.91
E-1	Low	215	1.00	170	1.00	1.26
	Mid	233	1.08	176	1.04	1.32
	High	273	1.27	169	.99	1.61
XB-1	Low	211	1.00	185	1.00	1.14
	High	343	1.62	113	.61	3.04
XD-1	Low	233	1.00	190	1.00	1.22
	High	287	1.23	136	.72	2.11
XE-1	Low	226	1.00	167	1.00	1.35
	Mid	273	1.20	205	1.23	1.33
	High	303	1.34	174	1.04	1.74
XE-2	Low	244	1.00	169	1.00	1.44
	Mid	251	1.03	164	.97	1.53
	High	295	1.21	164	.97	1.80

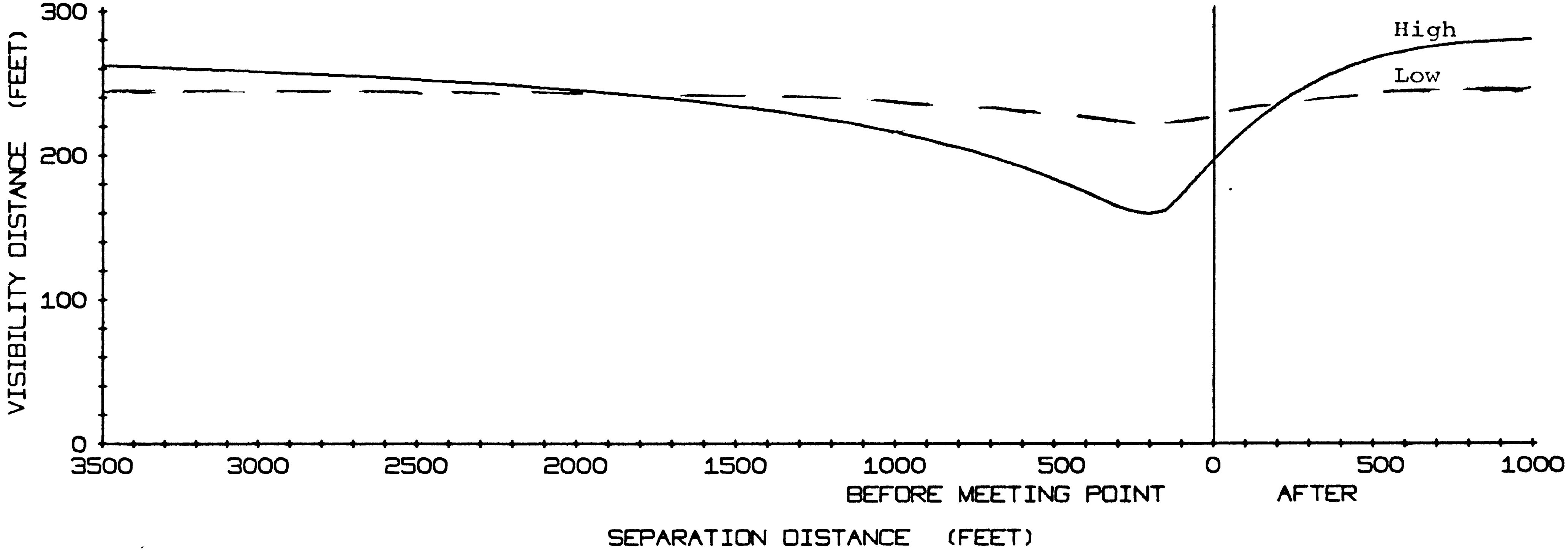

Figure 1. Computer simulation predicted visibility distances for System A-1 with target on right side, 10% reflectance.

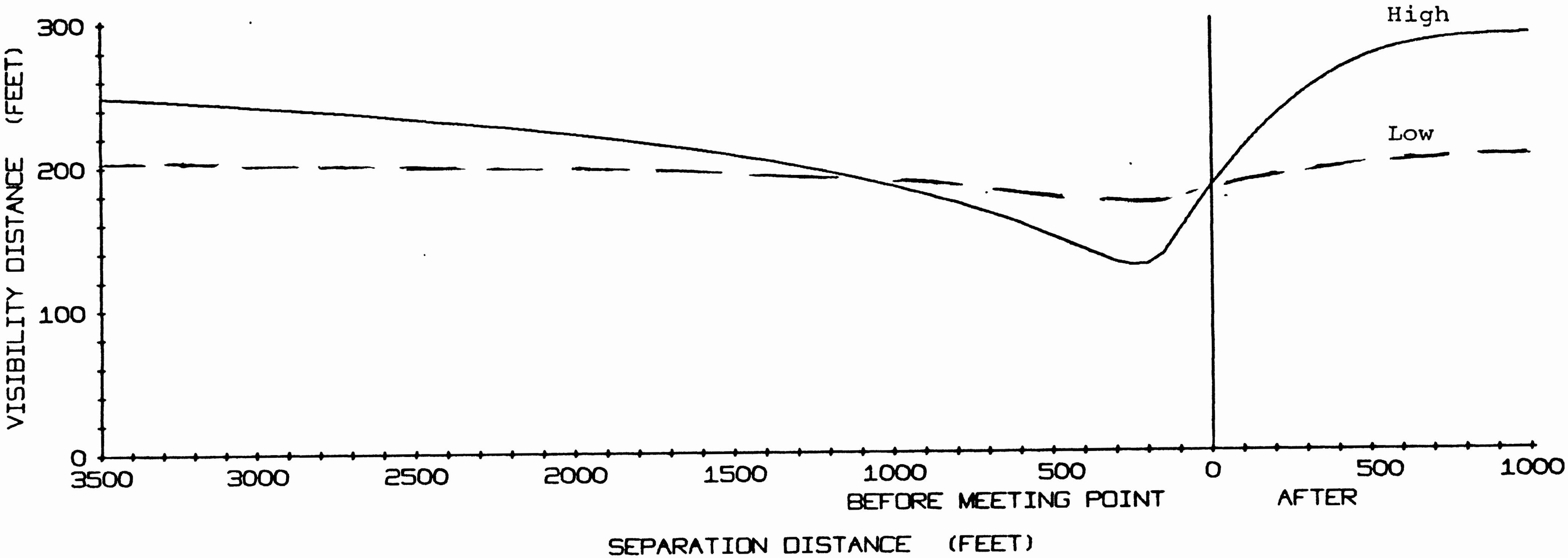

Figure 2. Computer simulation predicted visibility distances for System A-1 with target at center, 10% reflectance.

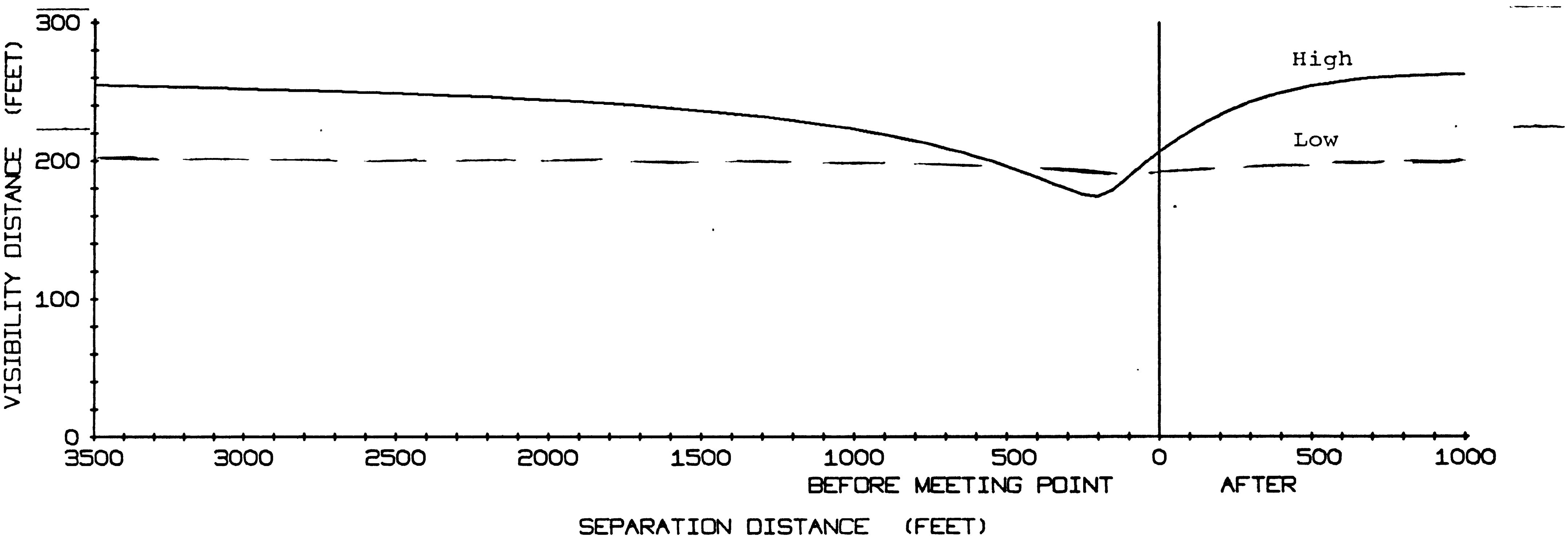

Figure 3. Computer simulation predicted visibility distances for System A-2 with target on right side, 10% reflectance.

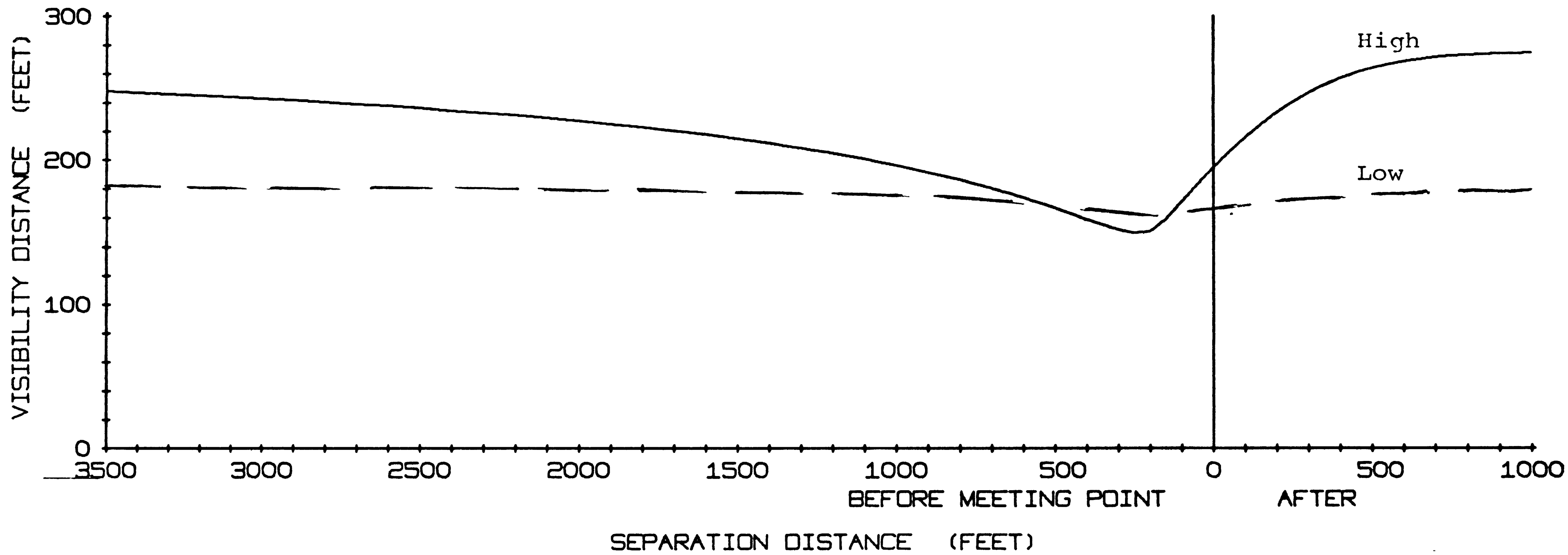

Figure 4. Computer simulation predicted visibility distances for System A-2 with target at center, 10% reflectance.

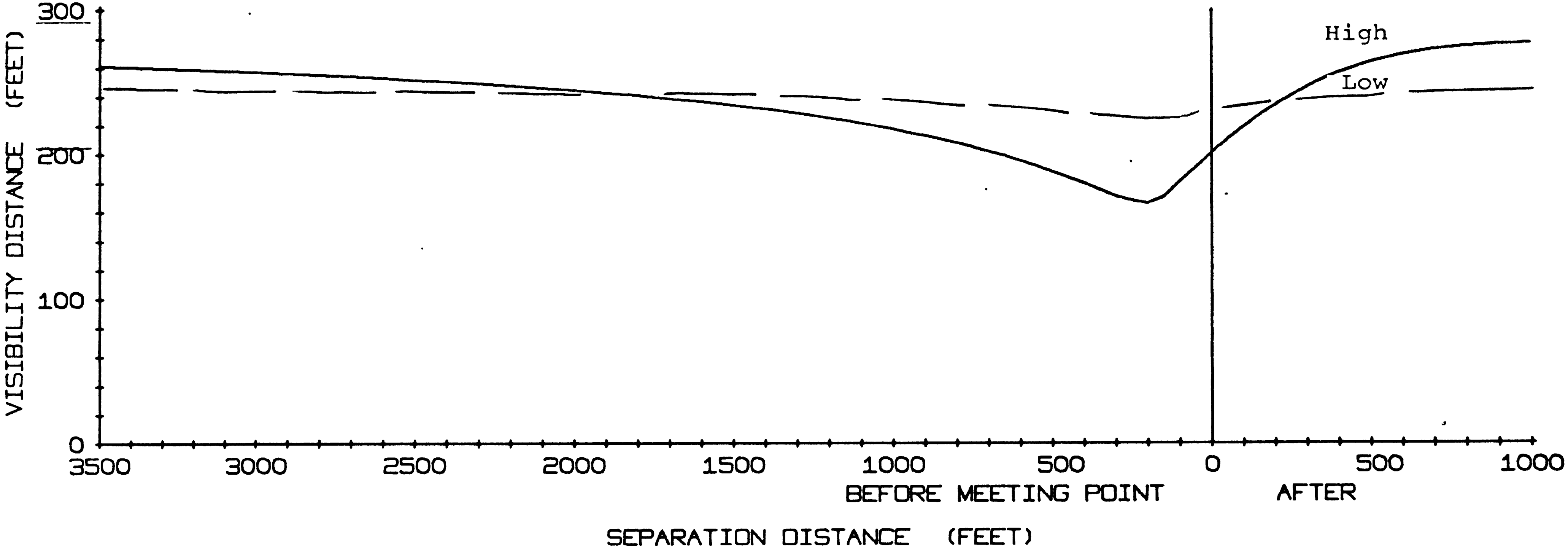

Figure 5. Computer simulation predicted visibility distances for System A-3 with target on right side, 10% reflectance.

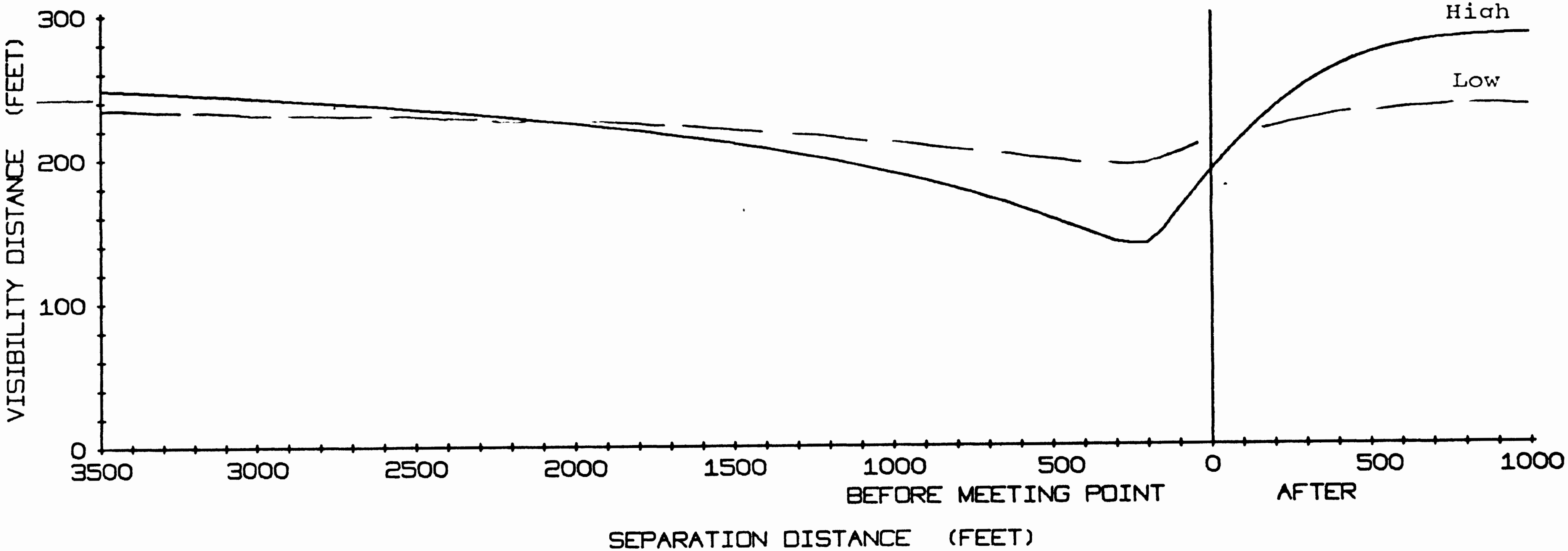

Figure 6. Computer simulation predicted visibility distances for System A-3 with target at center, 10% reflectance.

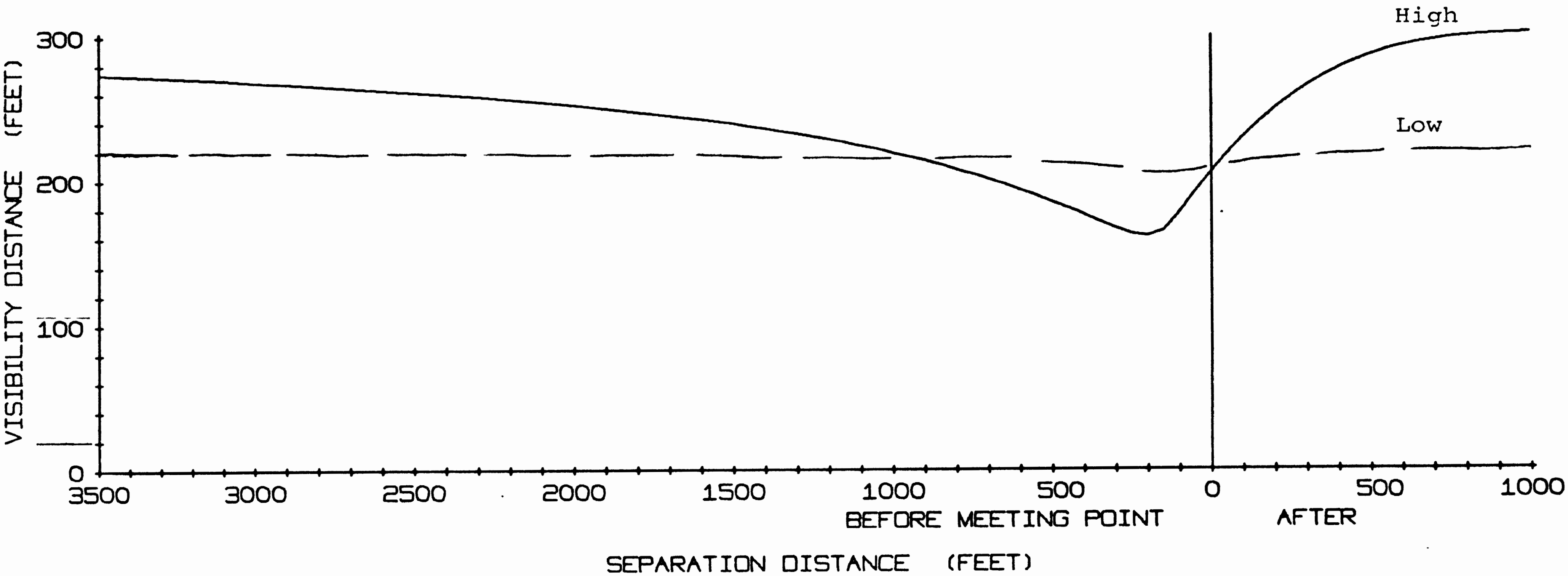

Figure 7. Computer simulation predicted visibility distances for System B-1 with target on right side, 10% reflectance.

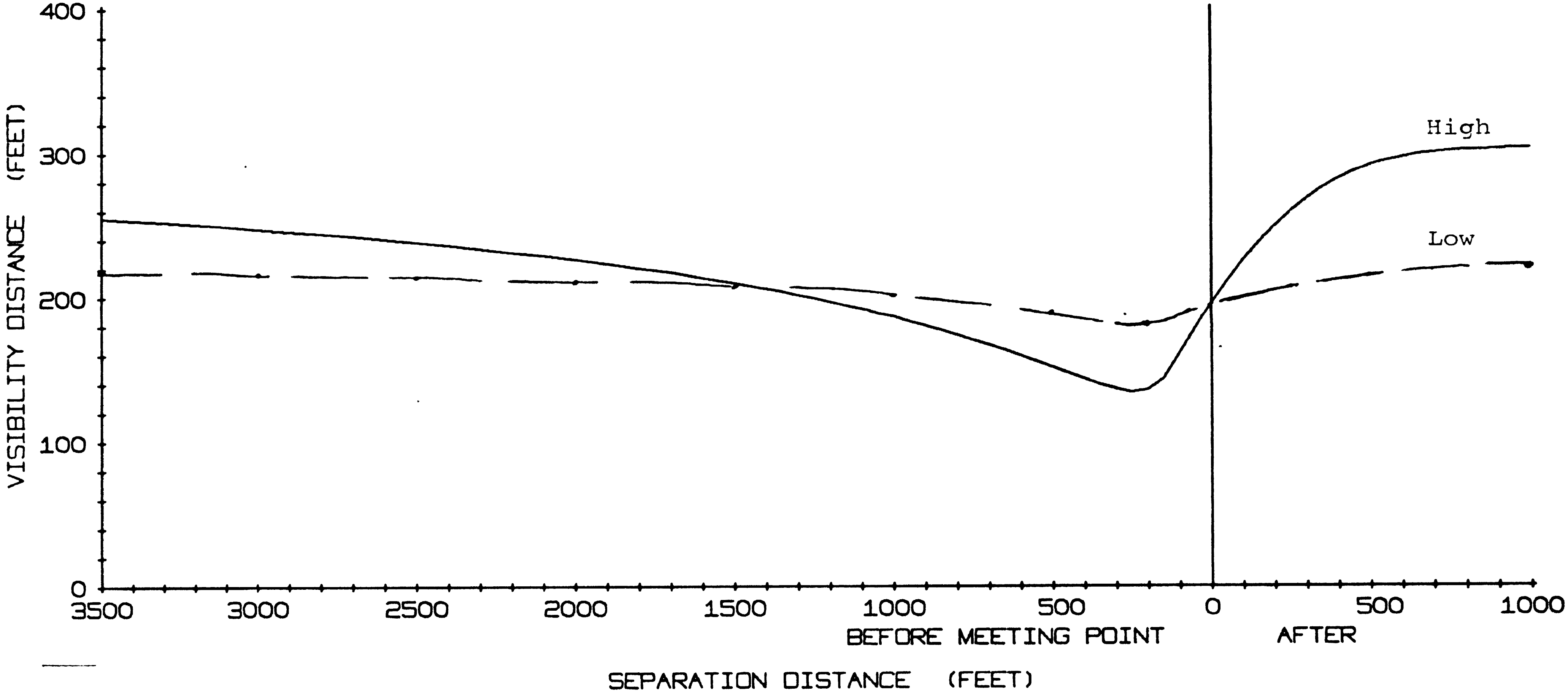

Figure 8. Computer simulation predicted visibility distances for System B-1 with target at center, 10% reflectance.

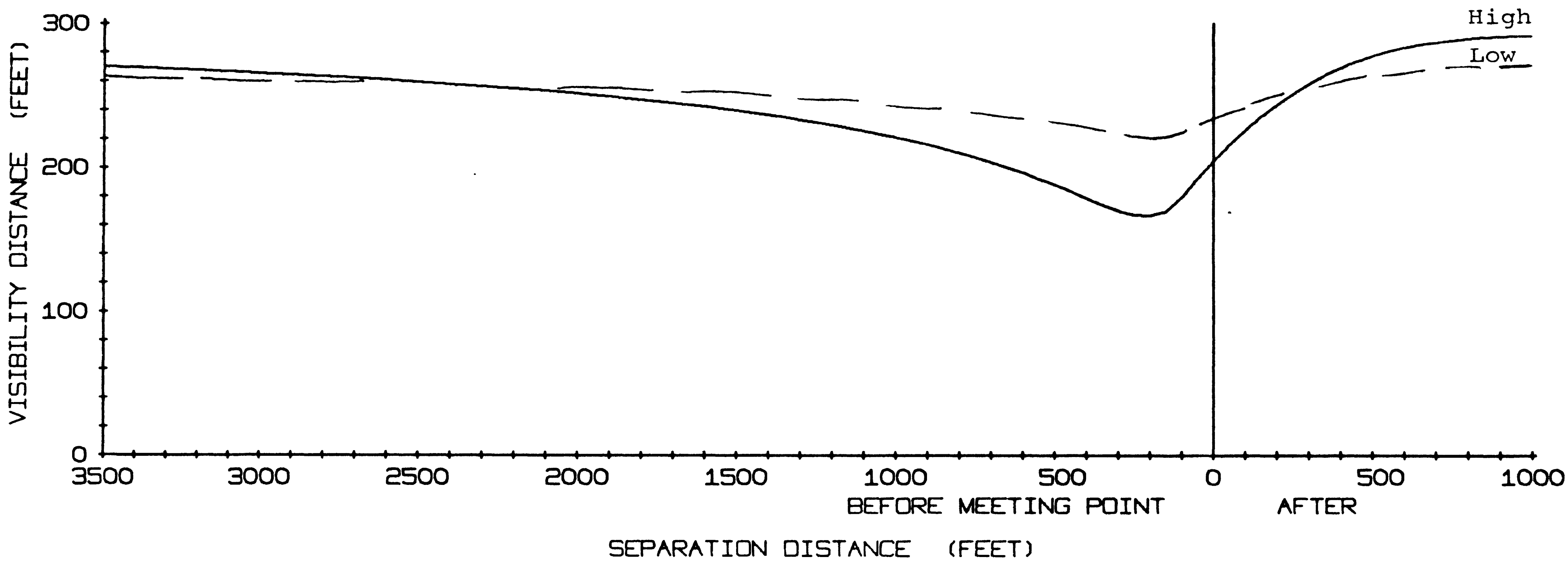

Figure 9. Computer simulation predicted visibility distances for System B-2 with target on right side, 10% reflectance.

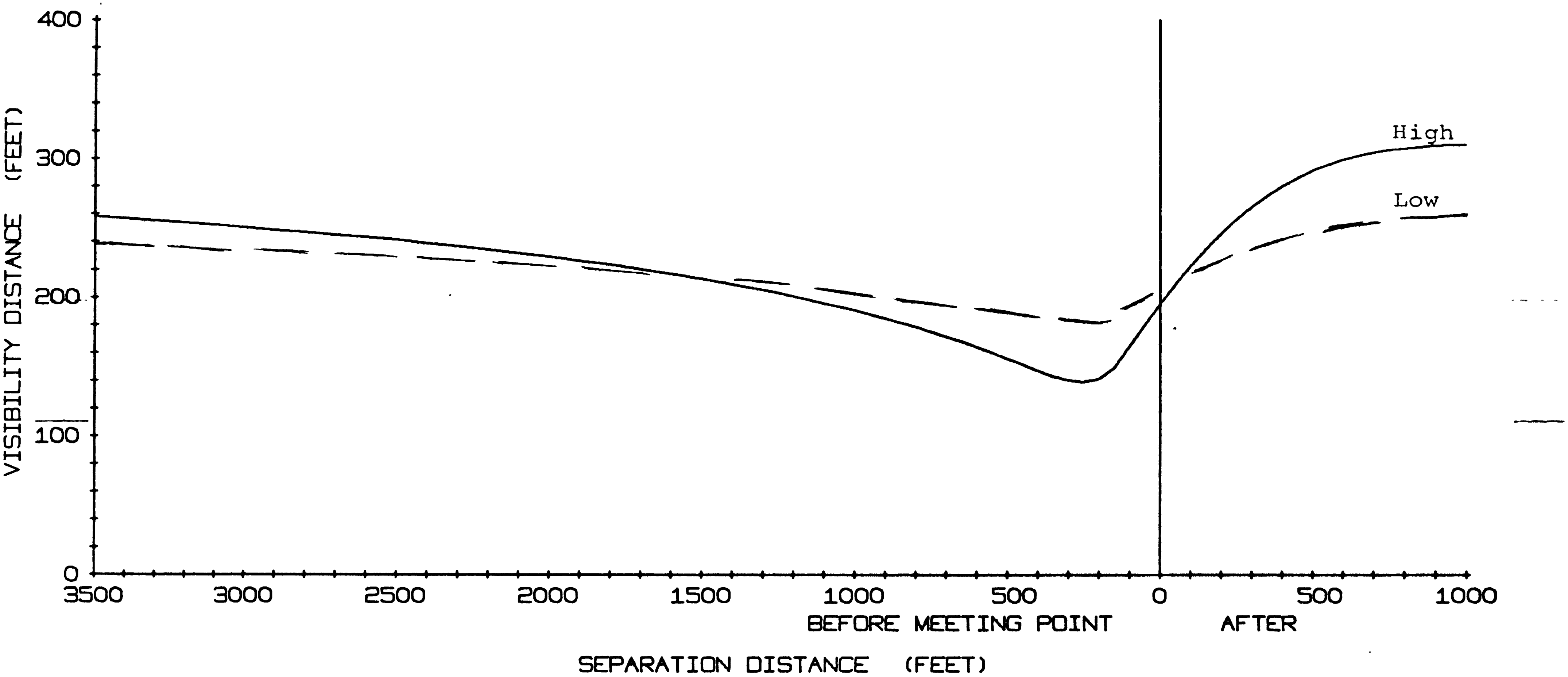

Figure 10. **Com**puter simulation predicted visibility distances for System B-2 with target at center, 10% reflectance.

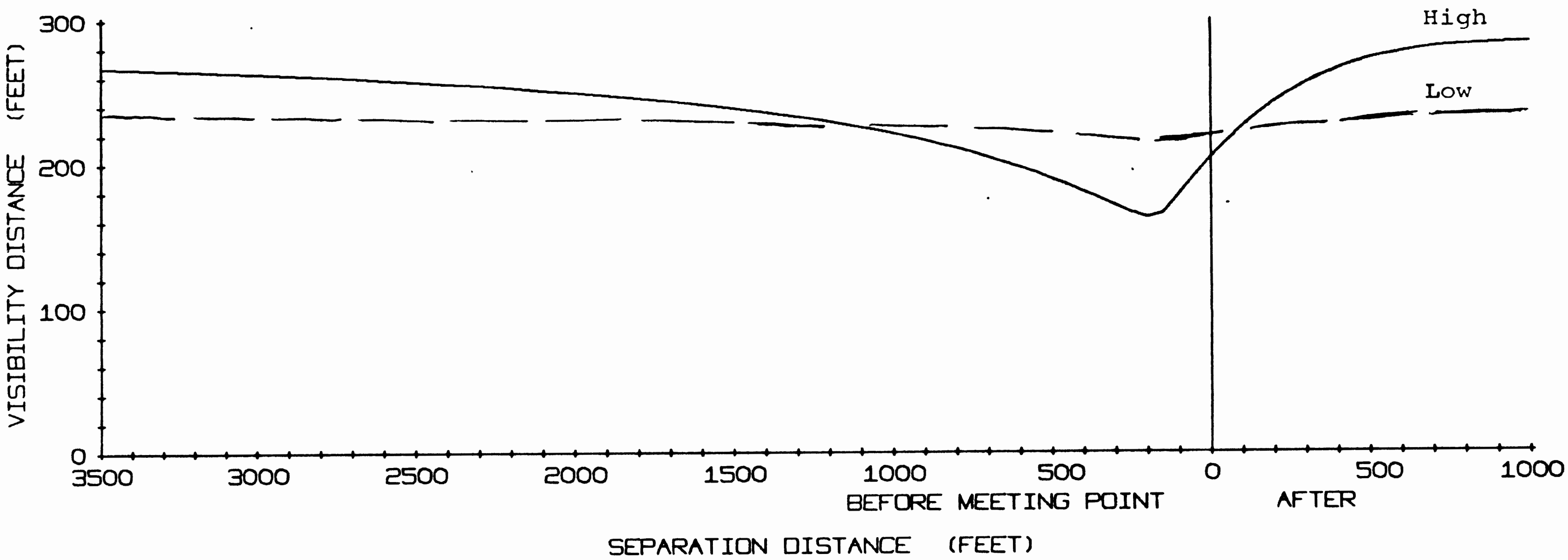

Figure 11. Computer simulation predicted visibility distances for System B-3 with target on right side, 10% reflectance.

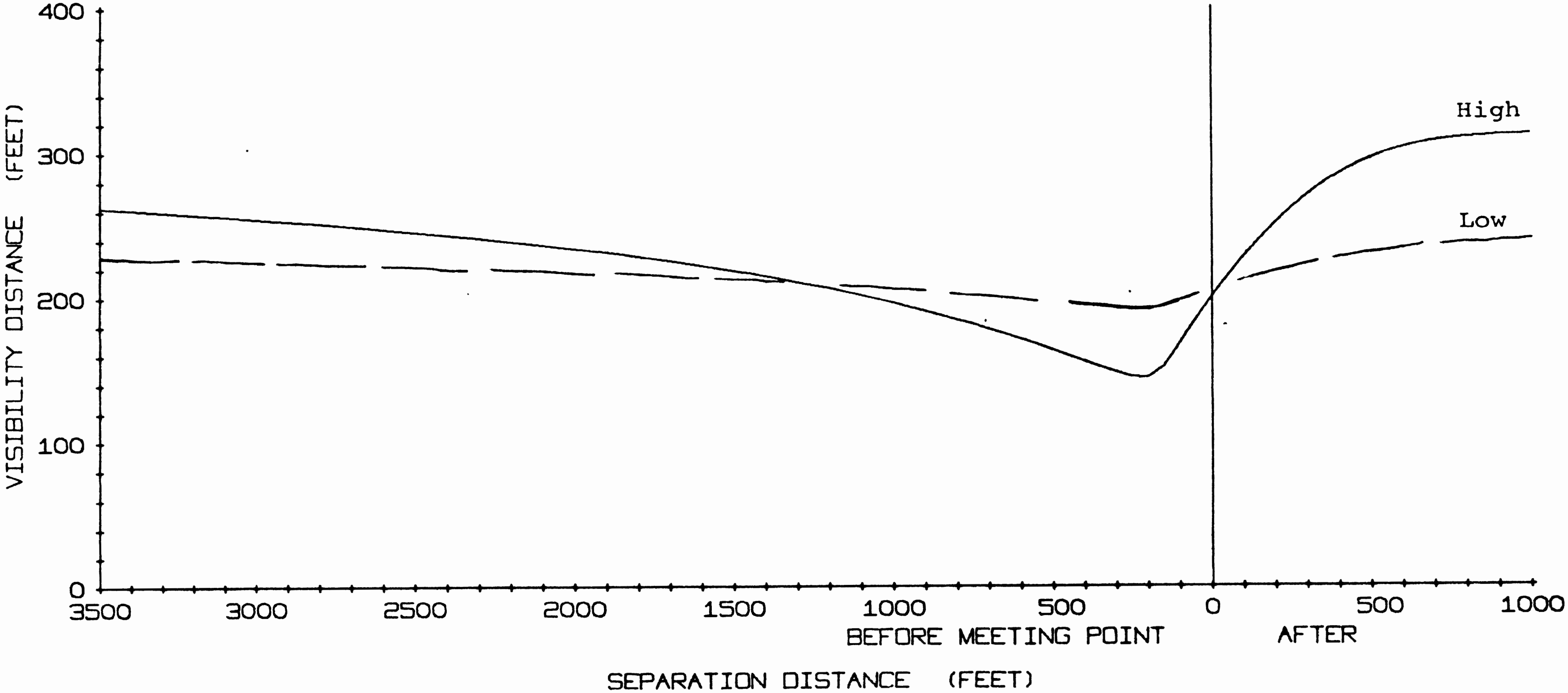

Figure 12. Computer simulation predicted visibility distances for System B-3 with target at center, 10% reflectance.

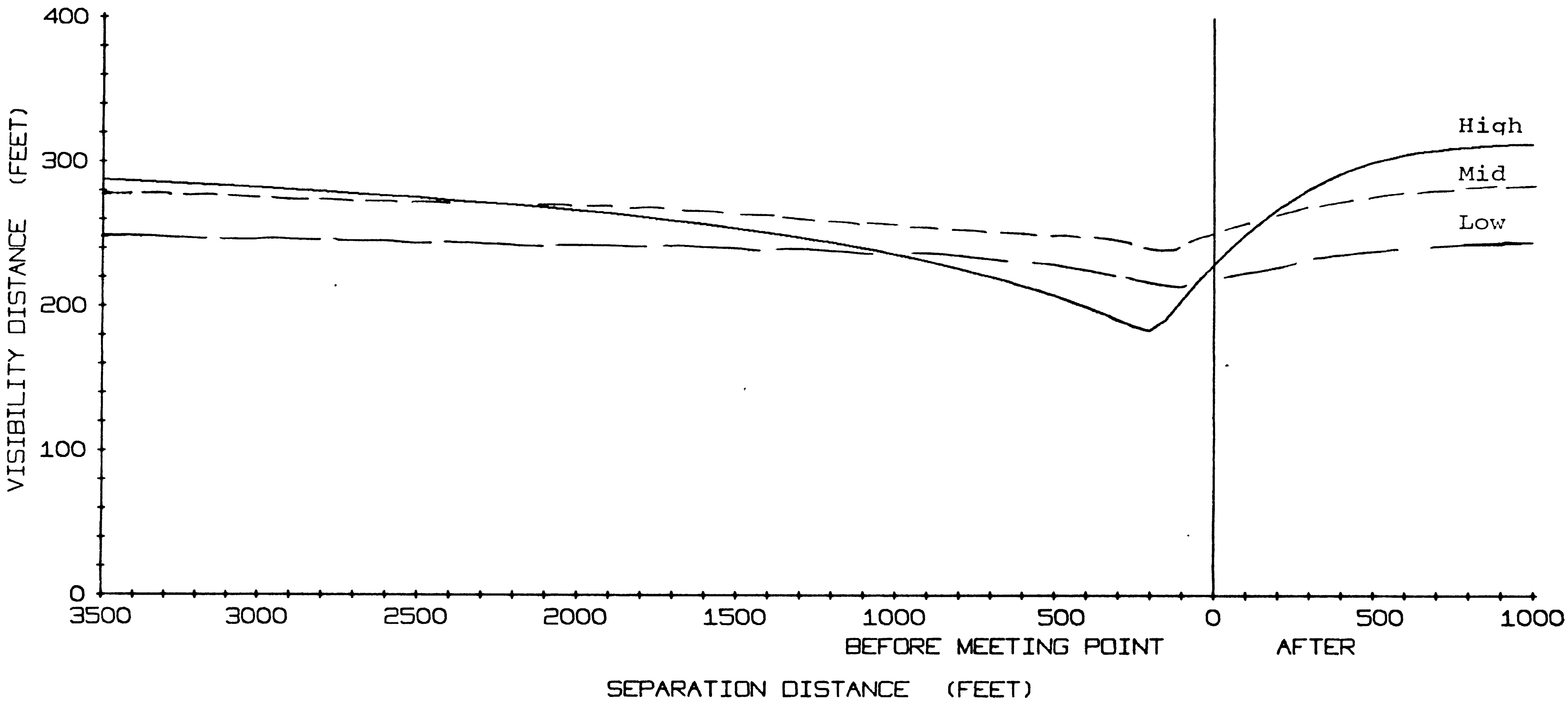

Figure 13. Computer simulation predicted visibility distances for System C-1 with target on right side, 10% reflectance.

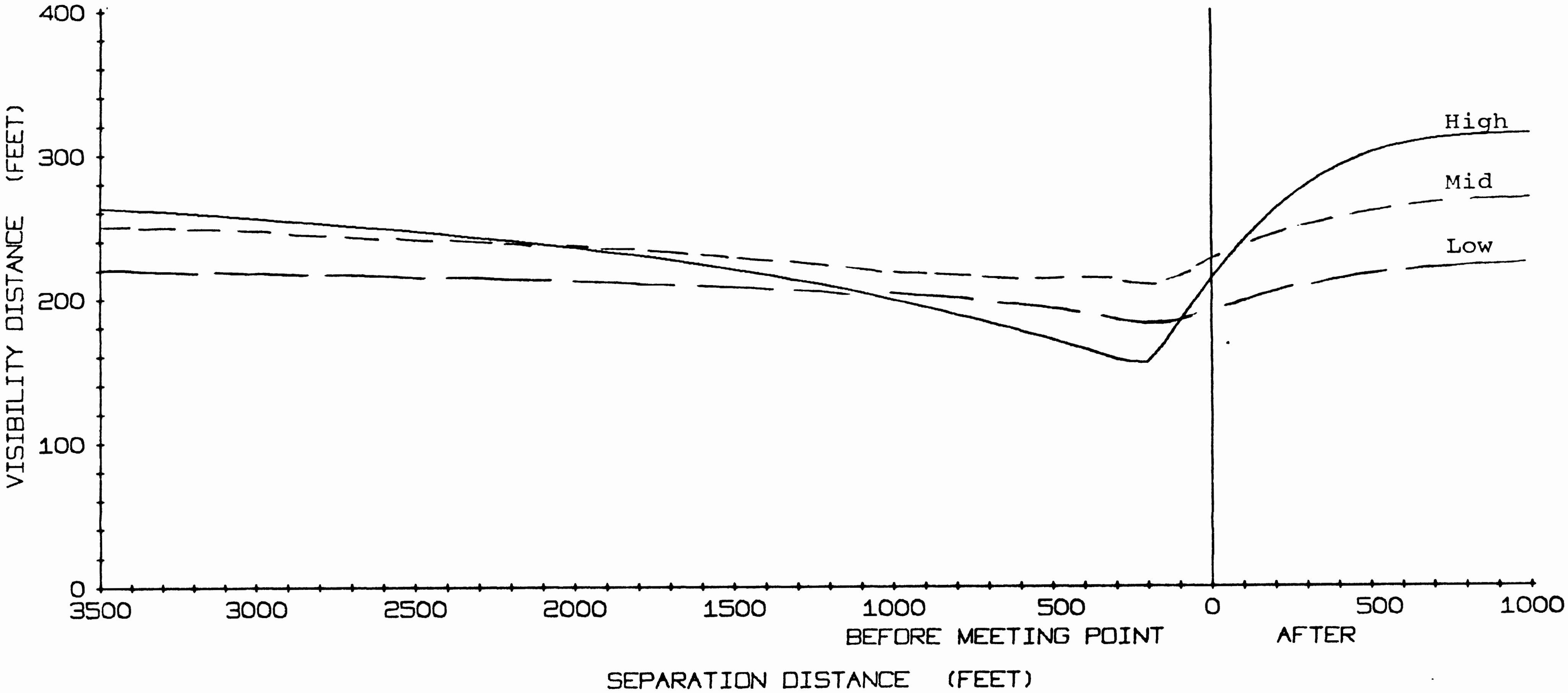

Figure 14. Computer simulation predicted visibility distances for System C-1 with target at center, 10% reflectance.

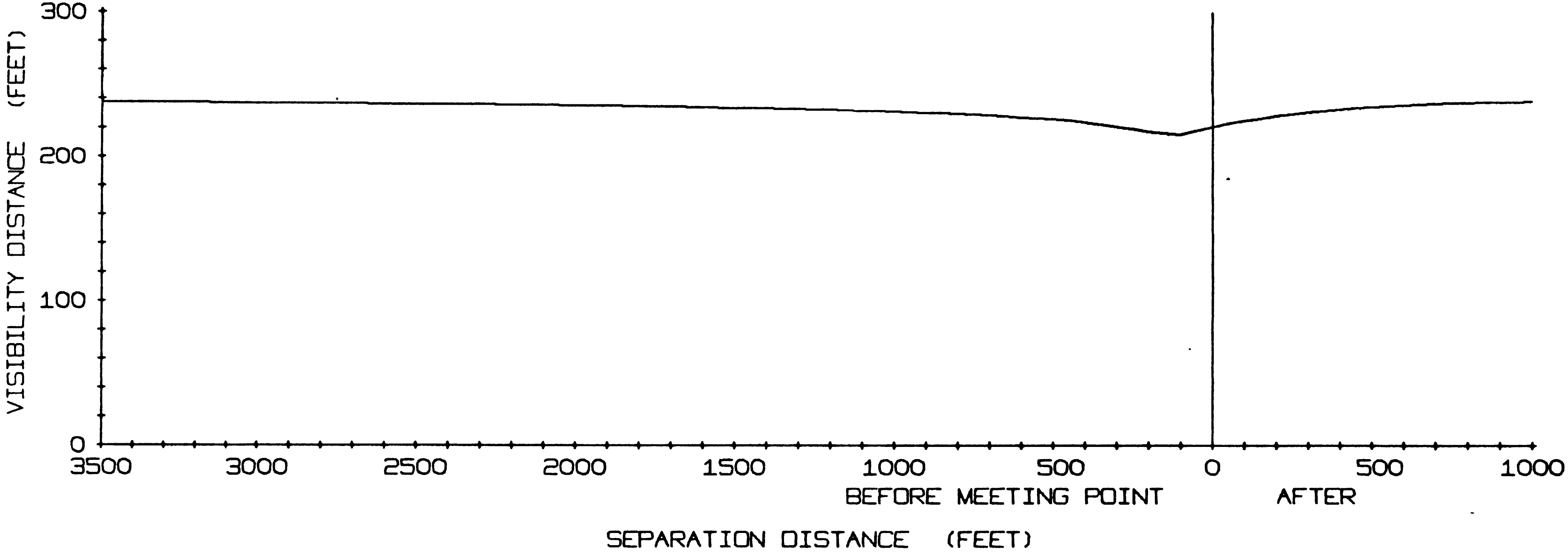

Figure 15. Computer simulation predicted visibility distances for System C-2 with target on right side, 10% reflectance.

Note: Insufficient data for mid beam pattern. Therefore Mid and High beams could not be run.

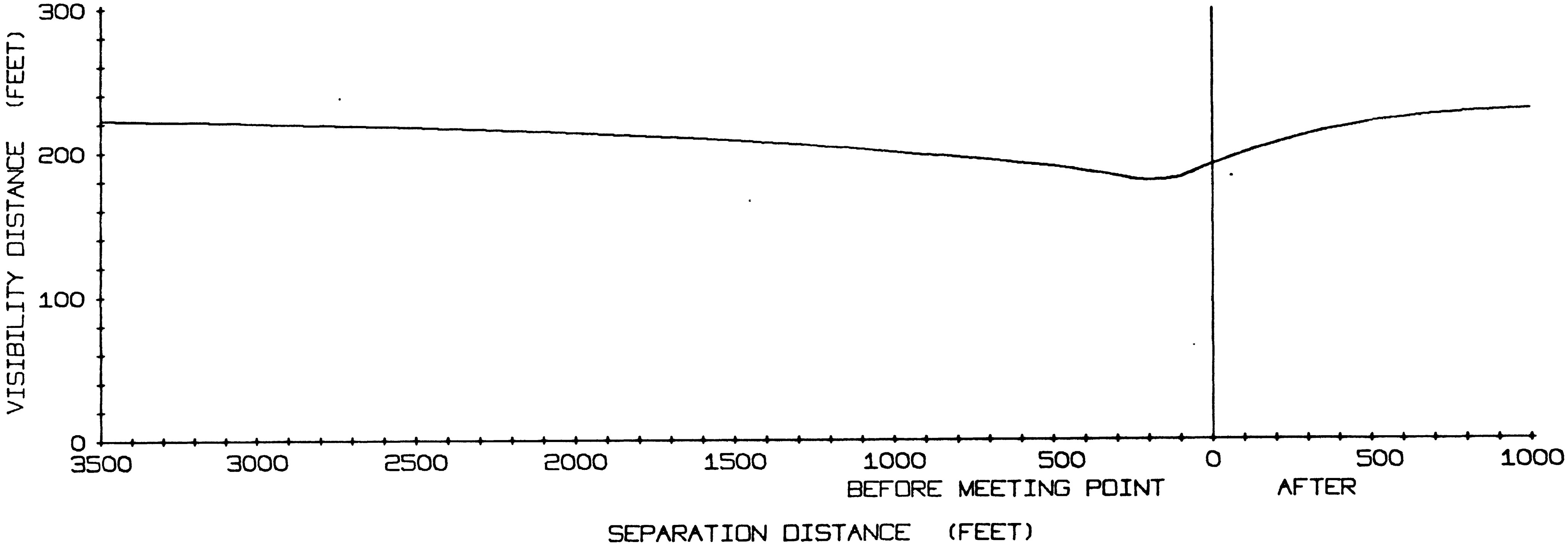

Figure 16. Computer simulation predicted visibility distances for System C-2 with target at center, 10% reflectance.

Note: Insufficient data for mid beam pattern. Therefore Mid and High beams could not be run.

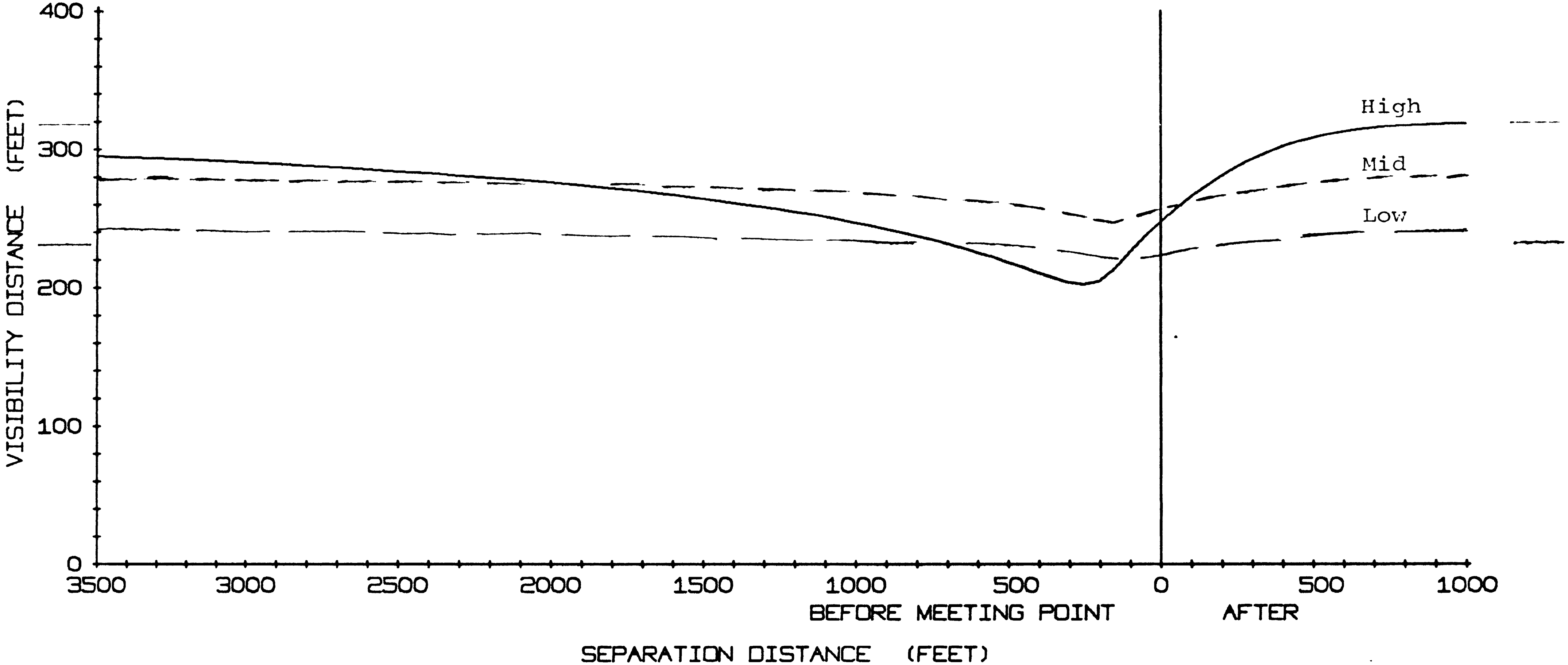

Figure 17. Computer simulation predicted visibility distances for System C-3 with target on right side, 10% reflectance.

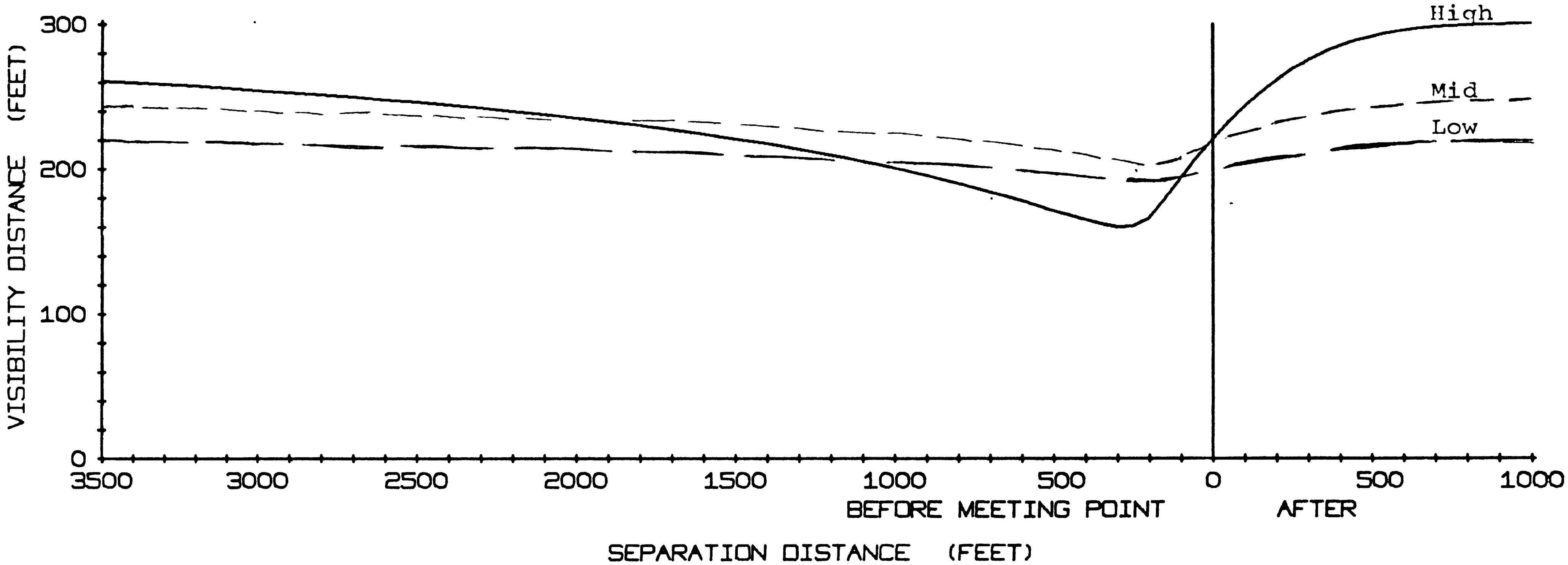

Figure 18. Computer simulation predicted visibility distances for System C-3 with target at center, 10% reflectance.

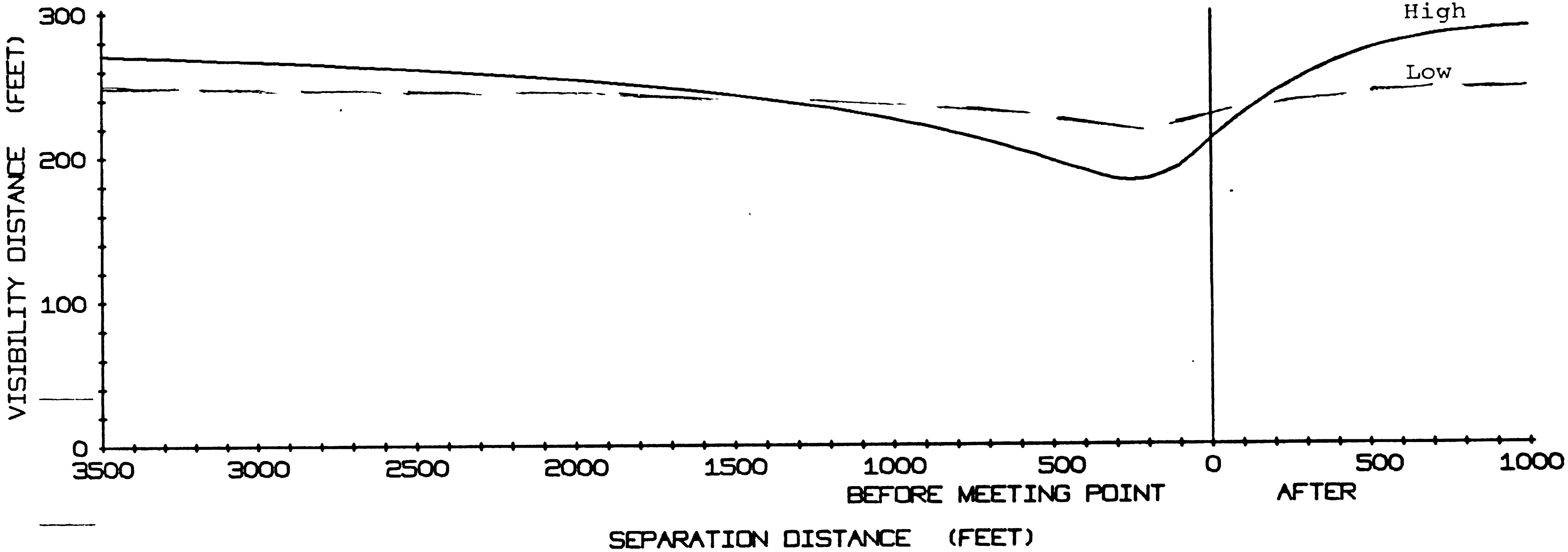

Figure 19. Computer simulation predicted visibility distances for System D-1 with target on right side, 10% reflectance.

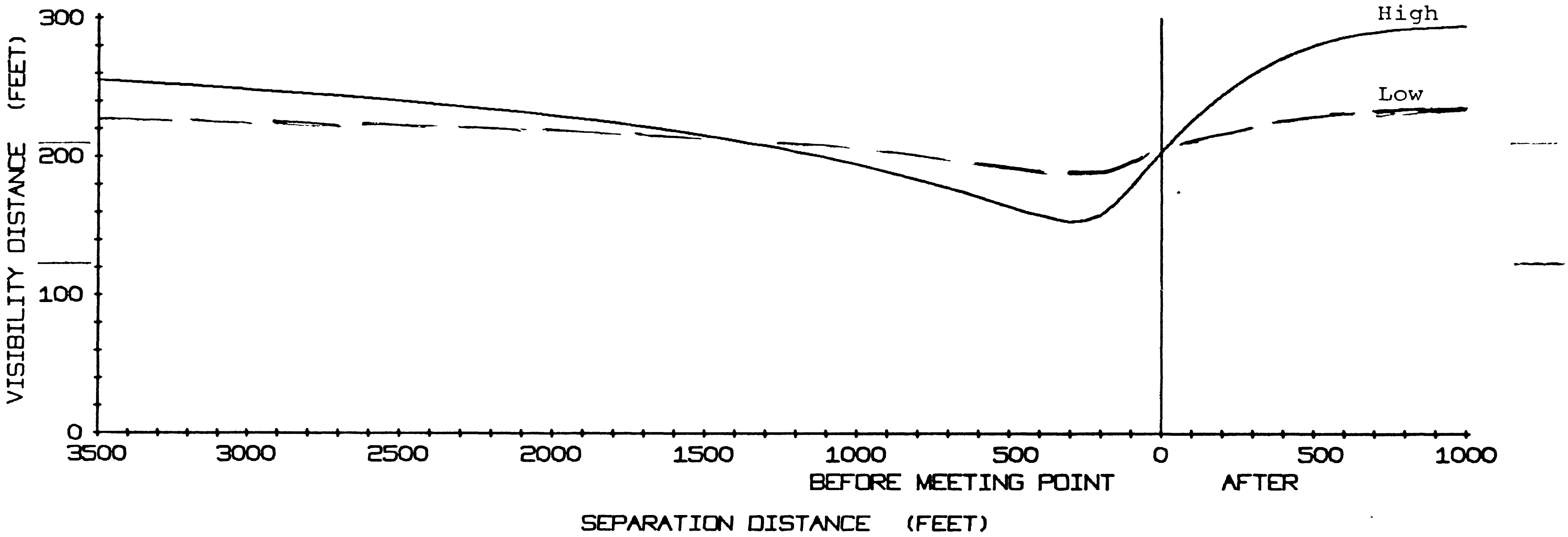

Figure 20. Computer simulation predicted visibility distances for System D-1 with target at center, 10% reflectance.

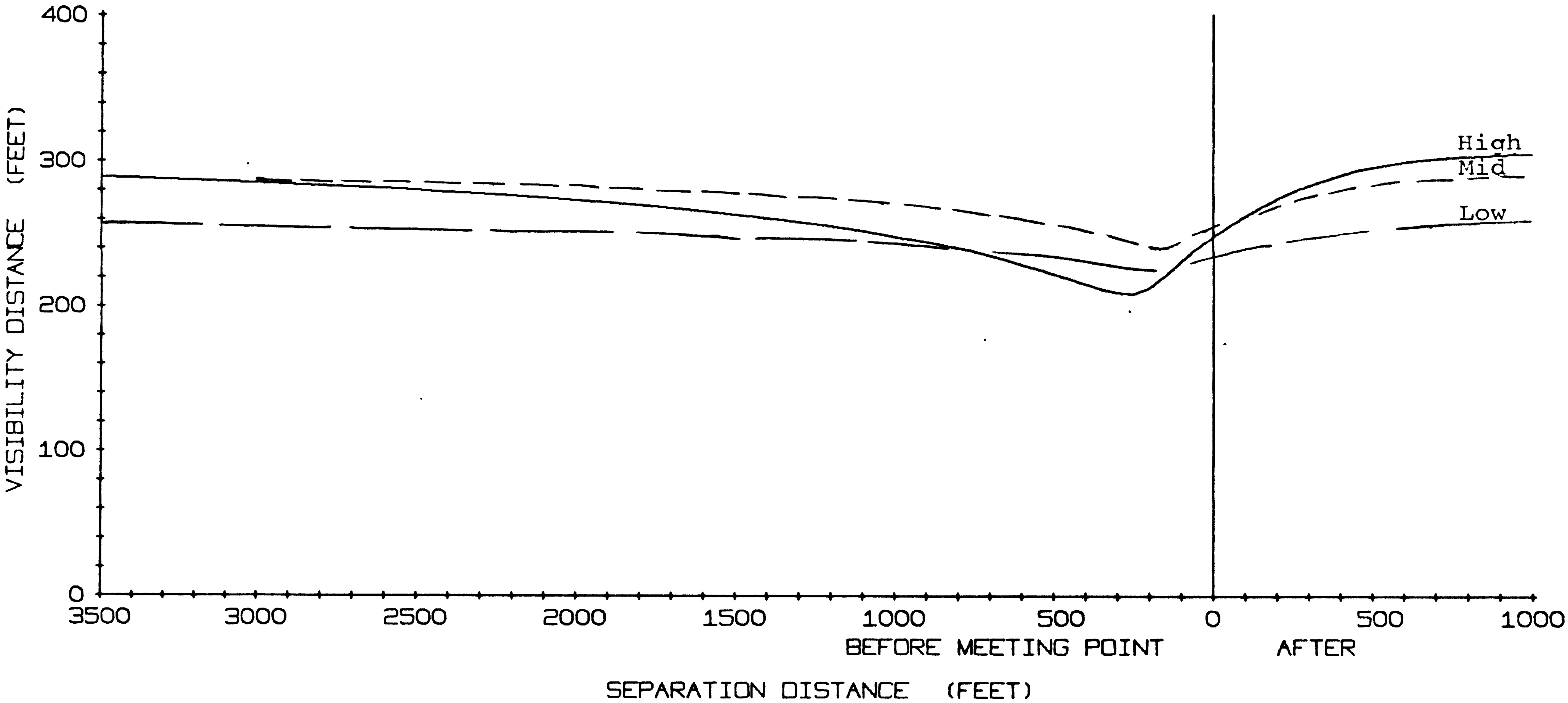

Figure 21. Computer simulation predicted visibility distances for System E-1 with target on right side, 10% reflectance.

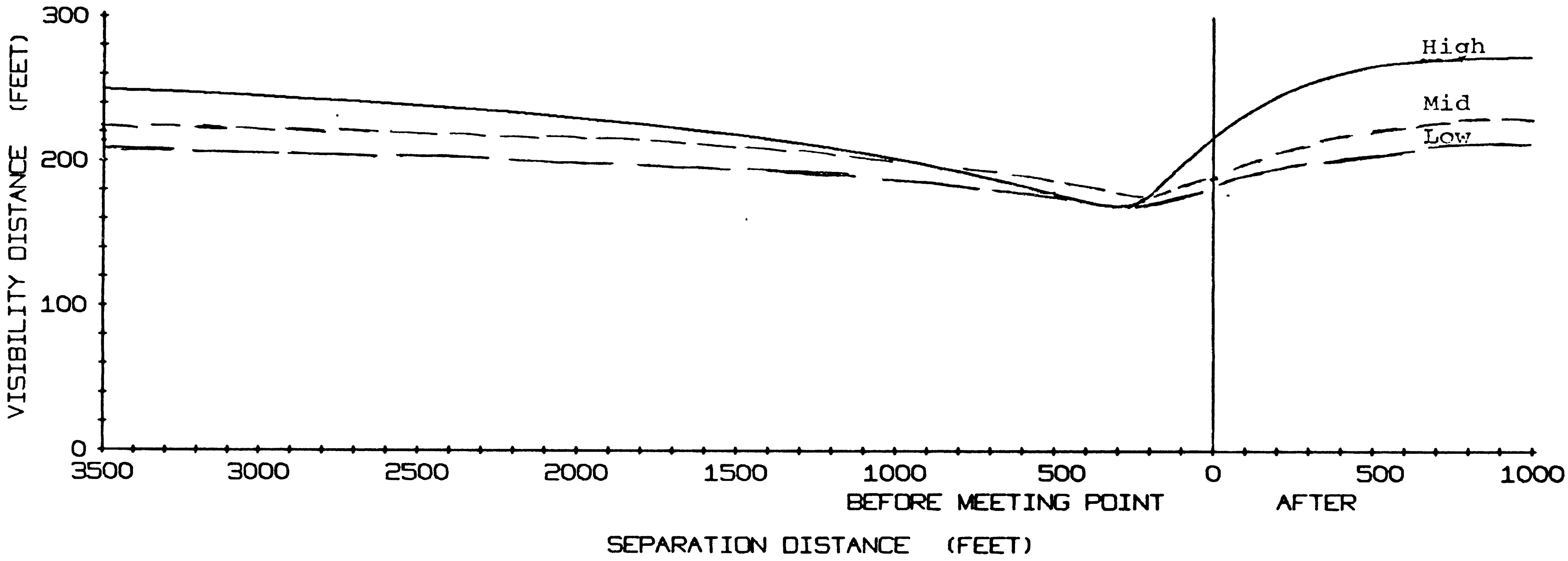

Figure 22. Computer simulation predicted visibility distances for System E-1 with target at center, 10% reflectance.

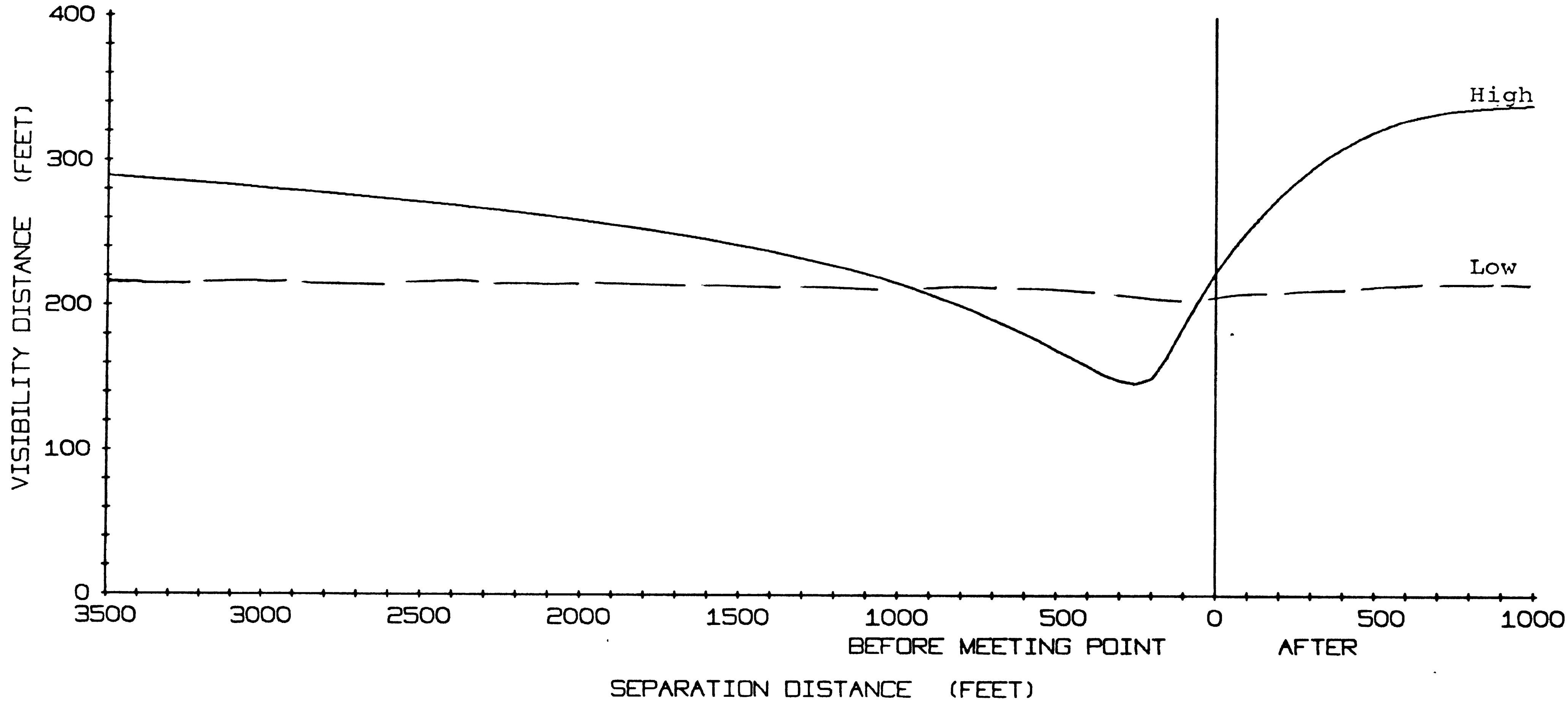

Figure 23. Computer simulation predicted visibility distances for System XB-1 with target on right side, 10% reflectance.

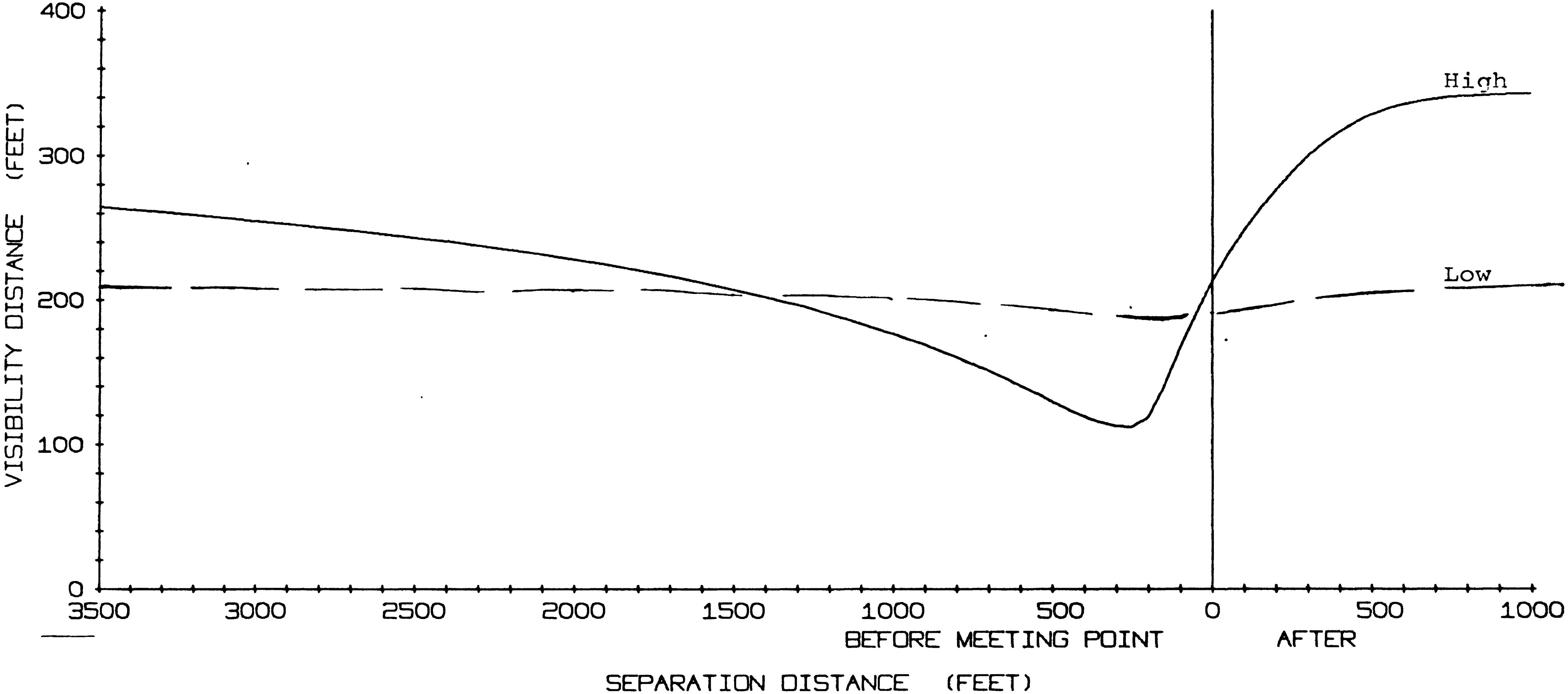

Figure 24. Computer simulation predicted visibility distances for System XB-1 with target at center, 10% reflectance.

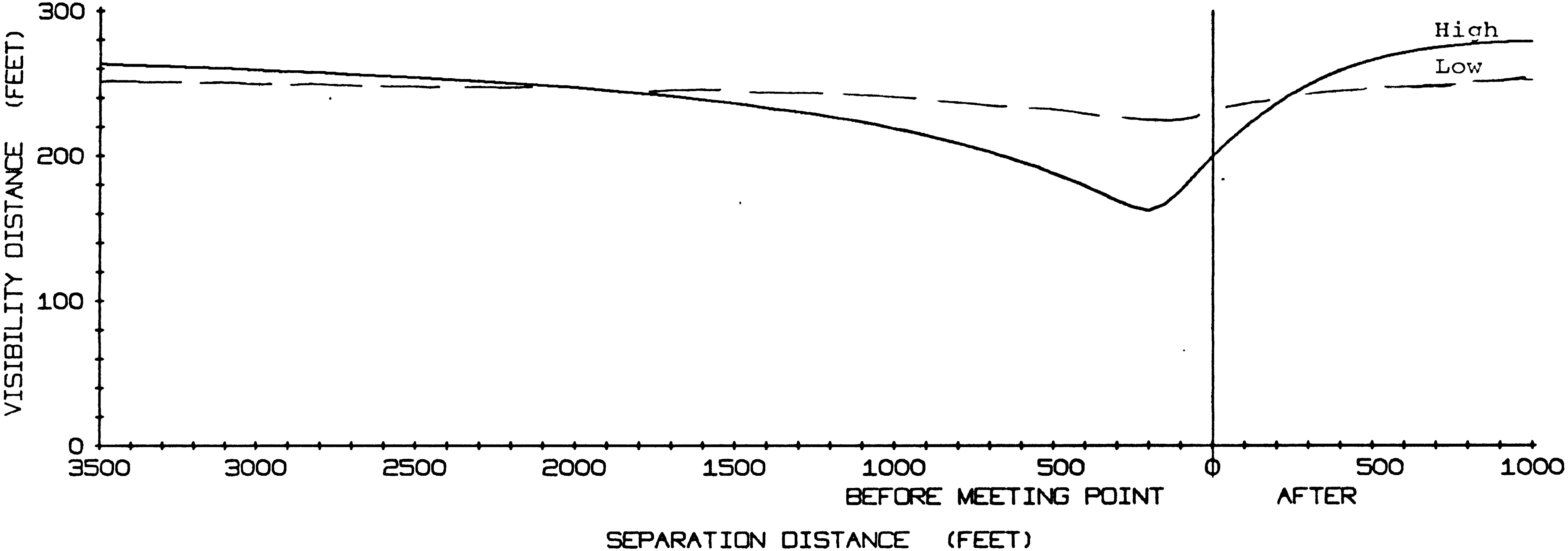

Figure 25. Computer simulation predicted visibility distances for System XD-1 with target on right side, 10% reflectance.

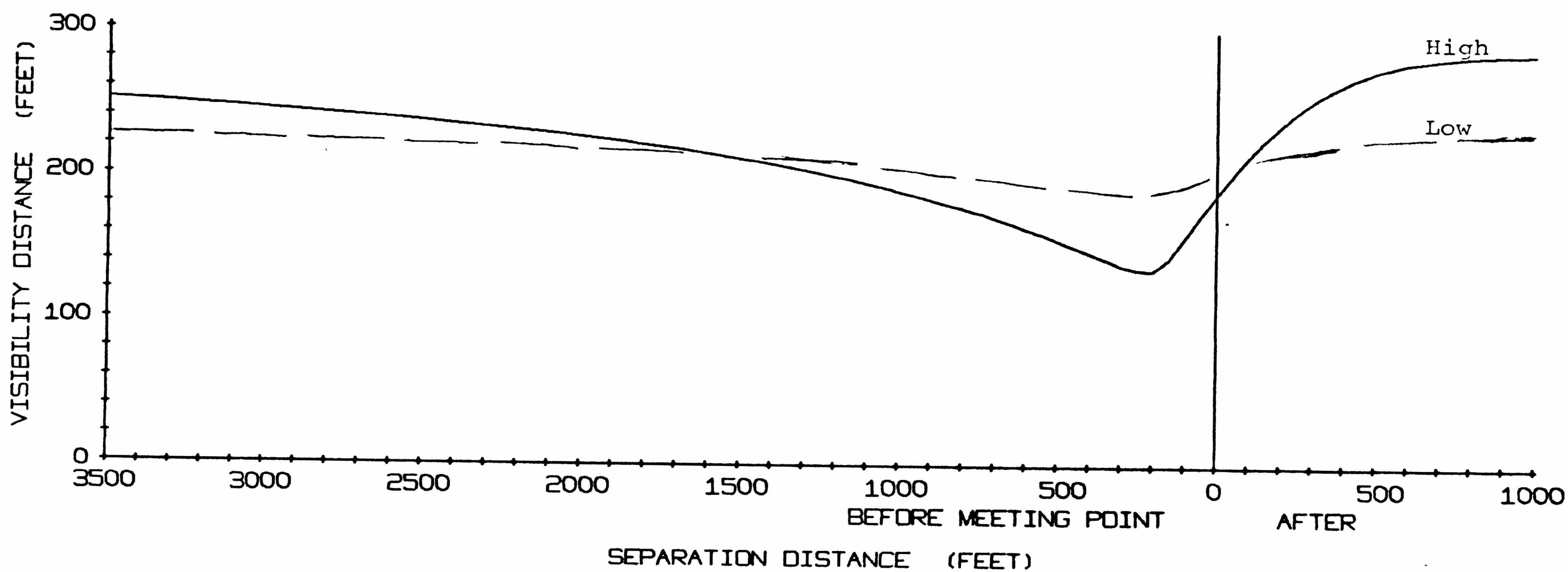

Figure 26. Computer simulation predicted visibility distances for System XD-1 with target at center, 10% reflectance.

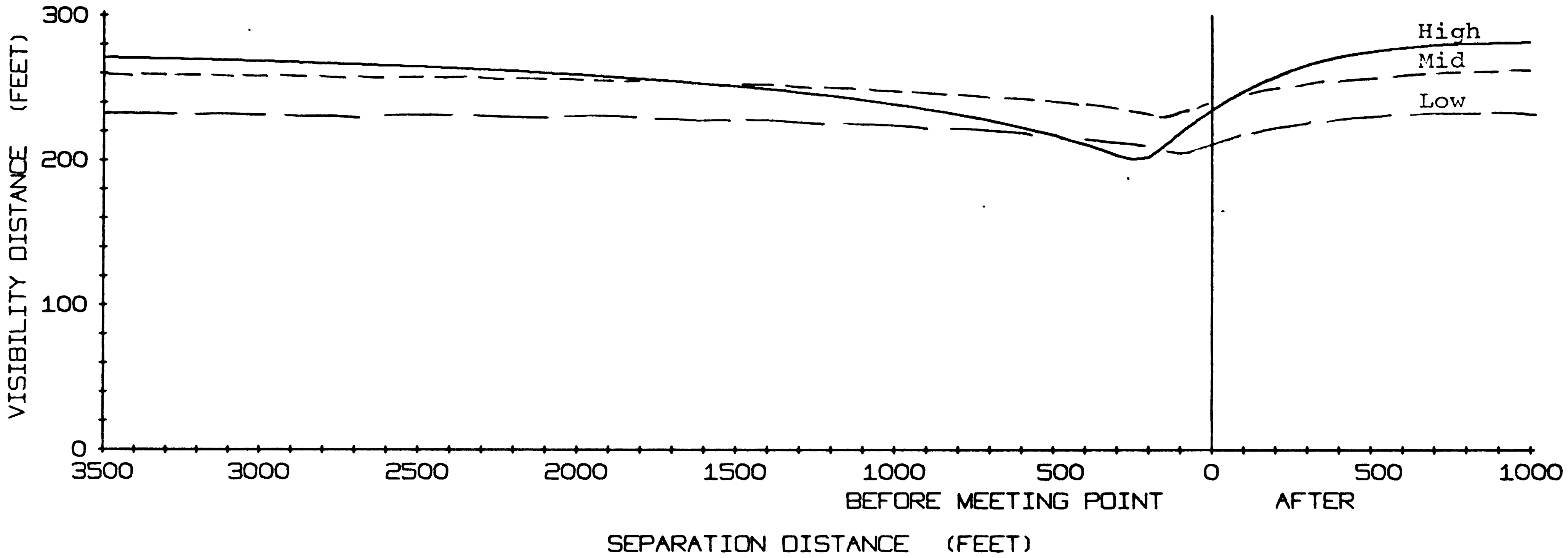

Figure 27. Computer simulation predicted visibility distances for System XE-1 with target on right side, 10% reflectance.

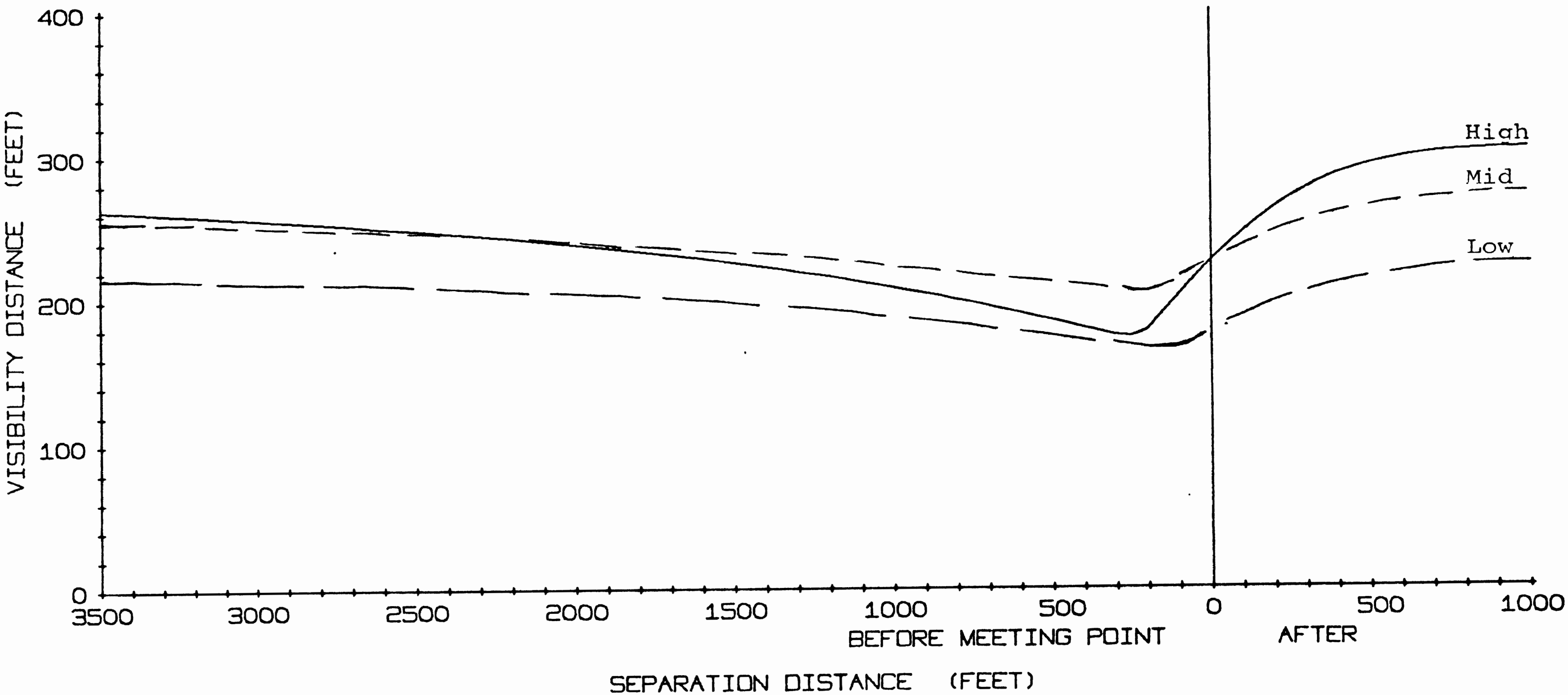

Figure 28. Computer simulation predicted visibility distances for System XE-1 with target at center, 10% reflectance.

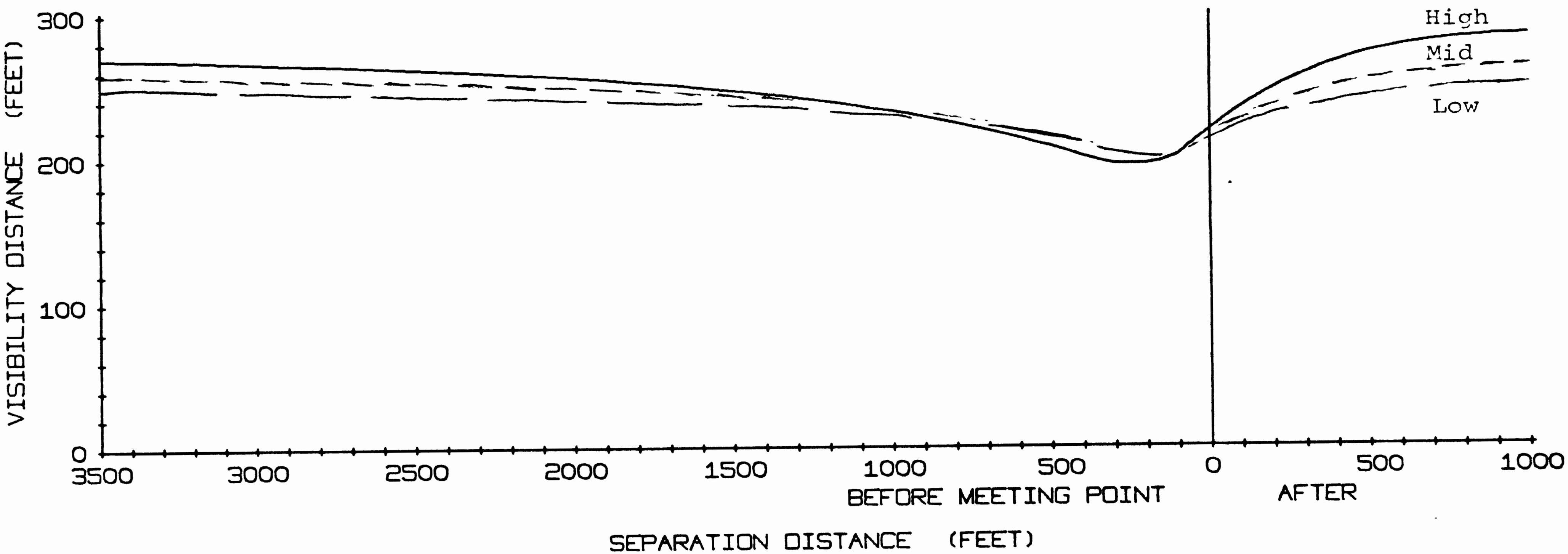

Figure 29. Computer simulation predicted visibility distances for System XE-2 with target on right side, 10% reflectance.

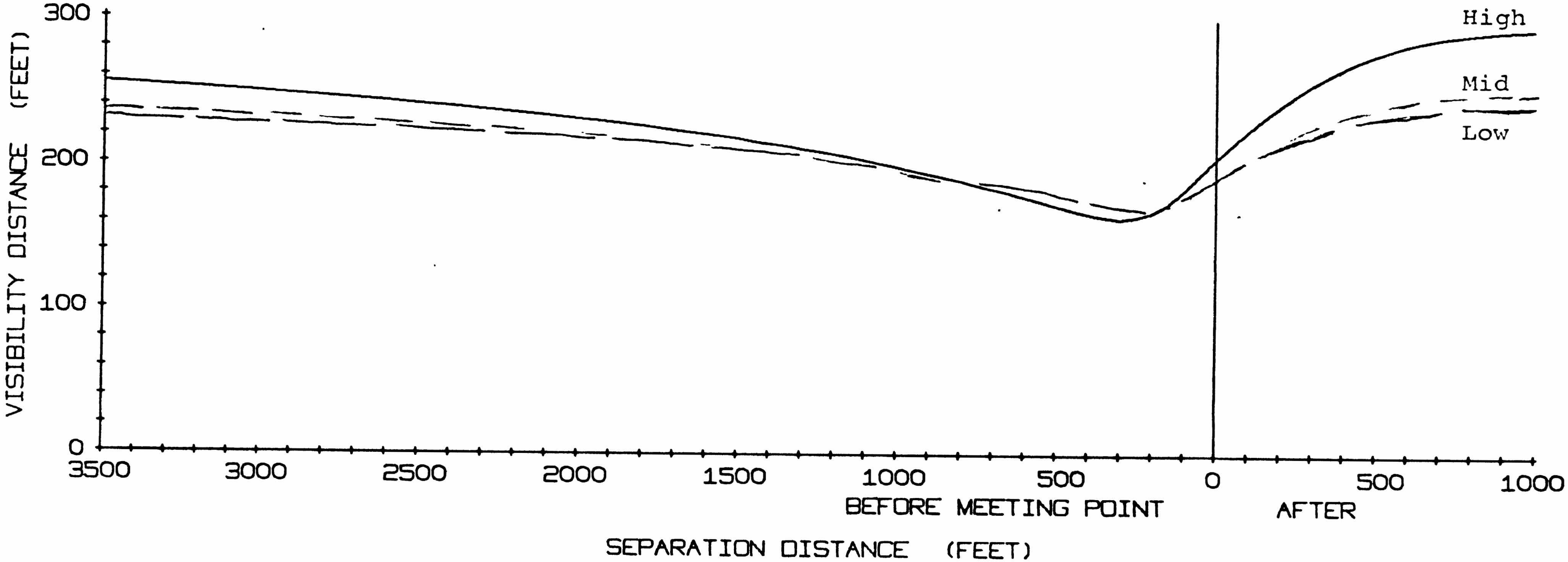

Figure 30. Computer simulation predicted visibility distances for System XE-2 with target at center, 10% reflectance.