FAA TECHNICAL CENTER LETTER REPORT

MATH MODEL STUDY OF GLIDE SLOPE SITES FOR RUNWAY 30L
LAMBERT-ST. LOUIS INTERNATIONAL AIRPORT, ST. LOUIS, MISSOURI

by

JOHN WALLS

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U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
TECHNICAL CENTER
Atlantic City Airport, N.J. 08405

PURPOSE

The purpose of this study was to provide computer modeled glide slope performance data for several candidate locations of the ILS glide slope which will service Runway 30L at Lambert-St. Louis International Airport, St. Louis, Missouri.

BACKGROUND

The St. Louis Airport Authority is adding a 1,000 foot extension to Runway 30L at Lambert-St. Louis International Airport, St. Louis, Missouri. This extension includes significant earth movement and grading of the airport surface in the area adjacent to the runway and its extension.

Several potential locations are being considered by the Central Region for the Capture Effect Glide Slope System which will service the extended runway. The Central Region, ACE-425, requested that a math model study be made of the proposed locations and terrain modifications for the Runway 30L glide slope system to assist them in decision making as to final site selection. This request was referred to the Federal Aviation Administration (FAA) Technical Center by the Airway Facilities Service, Terminal Aids Branch, AAF-420.

GENERAL

The FAA Technical Center conducted glide slope computer model studies through application of an ILS glide slope mathematical model which was developed by the Transportation Systems Center (TSC) and converted for use on the Technical Center's Honeywell 66/60 computer. This model is detailed in references 1, 2, and 3. The model was modified by the Technical Center to correct a deficiency which was discovered when dealing with rising terrain. It was found that the original TSC program ignored shadowing of the ILS signal energy by terrain strips located above the antenna elevation. The program modification corrected this shortcoming by applying shadowing techniques to terrain rising above the antennas.

The original TSC program was further modified by the addition of a pseudo 3D feature which was developed by Ohio University. In the original TSC model, all computations were based on a single terrain profile originating at the antennas and extending at least to the middle marker. This profile was extended to include significant far field features, as required. The pseudo 3D modification considers additional terrain features by computing a new terrain profile for each observation point (aircraft position). The term "pseudo 3D" is used to indicate that the model is not truly three-dimensional. Once the program computes the new profile, the signal energy contribution from the terrain at the observation point is computed using an integration process that assumes that the terrain is infinite in the direction transverse to the runway. Additional description of this modification is included in the discussion of figures 2 through 5 of this report.

The results presented are considered preliminary since this model has not been validated. Model validation methodology is currently being developed by Ohio University under a FAA Technical Center contract. The objective of this development effort is to quantitatively assess a model's performance using actual flight test data at different types of ILS glide slope sites. The modified TSC model utilized in this study and any subsequent ILS math models developed will be validated using this methodology.

MODEL INPUT DESCRIPTION

Figure 1 shows the extended runway layout with elevation contour lines depicting the proposed topography in the immediate area of the candidate glide slope locations. As shown, three potential sites are recommended by ACE-425 for consideration: 1450 feet, 1600 feet, and 1800 feet back from the extended runway end. The 1450 foot location requires no displacement of the planned threshold. Selection of the 1600 or 1800 foot locations would require approximately a 200 or 400 foot displacement, respectively, of the operational threshold to achieve the desired threshold crossing height (TCH) of 55 feet.

Terrain input files to the model were assembled using detailed drawings provided by ACE-425. For the pseudo 3D computation, each terrain file is a matrix consisting of x, y, and z coordinate values that provide a three-dimensional characterization of the terrain on the glide slope side of runway centerline from the glide slope site out to the middle marker (and beyond, if required by terrain features). Based on this file, the math model computes a new terrain profile for each observation point along the approach path using an interpolation process. The new profile is that of the terrain directly below a line drawn from the observation point to the ILS antennas. This profile is the reflecting surface used in the physical optics computation of the glide slope signal energy at the observation point. Figure 2 is a composite of terrain profiles computed for the existing glide slope site with existing terrain. The runway point of intercept (RPI), the distance reference for the horizontal axis, is the point on the runway centerline directly opposite the glide slope antenna mast. Figures 3 through 5 are composite plots of terrain profiles computed from the proposed terrain for the 1450 foot, 1600 foot, and 1800 foot proposed glide slope locations, respectively.

Antenna heights for the proposed sites were computed to produce actual glide path angles of approximately 3 degrees. Measured antenna heights provided by Central Region were used for the existing site. Antenna drive current phasing was computed using the airborne reference phasing technique by flying the simulated aircraft along an elevation angle of 1.5 degrees at a distance of 8 to 4 nautical miles from the site and adjusting antenna current phasing. Ten samples of antenna current phase were recorded for the lower, middle, and upper antennas over the distance interval and an average phase was computed for each antenna. Using average phase values, the phases of the lower and upper antenna currents were adjusted for zero-phase difference with respect to the phase of the middle antenna current. The result obtained is the equivalent of airborne phasing of the glide slope system. This antenna phasing method was suggested by Ohio University engineers for math modeling applications. The antenna heights and reference phasing used in all data runs are summarized in table 1. Aircraft altitude for all level runs was 1250 feet (above antenna base elevation).

DATA PRESENTATION

Four glide slope site locations were modeled: the existing site with existing terrain and three proposed sites located 1450 feet, 1600 feet, and 1800 feet back from the extended threshold. The output data for each site consists of two plots. The first plot, a structure run, shows computed course deviation indicator (CDI) error versus distance from treshold. The threshold location for the 1600 foot and 1800 foot sites is the displaced threshold. This displacement is 200 feet and 400 feet, respectively back from the extended threshold toward the site. The threshold for the 1450 foot location is the extended threshold. The second plot for each site is a level run showing CDI versus elevation angle for path width information. Figures 6 and 7 are existing site results. Figures 8 and 9 show results for the 1450 foot location. The 1600 foot site results are given in figures 10 and 11. Figures 12 and 13 provide the 1800 foot site results. Table 2 summarizes computation of actual path angle, path width, and symmetry (between ± 75 microamps CDI current) which are presented on individual plots.

DATA ANALYSIS

The existing site was modeled to provide a basis for comparison with proposed site results. The computed existing site output data was also compared with airborne measured data. This comparison showed agreement in the trend of the data, but the airborne measured CDI errors were higher, particularly at point B (on glide path, 3500 feet from runway threshold). The measured data showed CDI errors exceeding Category 1 tolerances in this area, while computed existing site results (figure 6) remain within Category 1 limits. This disagreement should be considered when assessing absolute performance at the proposed locations.

Level run results for the three proposed locations, figures 9, 11, and 13, exhibit almost identical glide path crossover and linearity characteristics. Examination of figures 8, 10, and 12, course structure runs for the three candidate sites, reveals very similar path quality in Zone 2 (area bounded by dashed lines). Comparison of CDI errors in Zone 3 (threshold to 3500 feet) shows appreciably greater errors for the 1600 foot proposed site). The source for this error has not been identified. However, further investigation could be performed if required.

CONCLUSIONS

Modeled results indicate that the proposed sites under consideration provide similar glide path structure and level run performance in Zone 2. However, the Zone 3 structure of the proposed 1600 foot site exhibits appreciably greater CDI errors than the other candidate locations.

This math modeling study was performed under TPD 07-115, Subprogram Number 071-313, Project 071-313-840, ILS Math Models. The author of this technical letter report is John Walls, ACT-100E, and the Program Manager is Edmund A. Zyzys, ACT-100E. Messrs. John Walls or Jesse Jones may be contacted for additional information at 346-3807 (FTS).

REFERENCES

1. ILS Glide Slope Performance Prediction, DOT/FAA, Report No. FAA-RD-74-157, 1974.

2. User's Manual for Generalized ILS GLD-ILS Glide Slope Performance Prediction: Multipath Scattering, DOT/FAA, Report No. FAA-RD-76-186, 1976.

3. Computer Study of Tulsa International Airport Runway 17R Glide Slope Sites, DOT/FAA, Report No. FAA-RD-79-27, 1979.

TABLE 1. SUMMARY - ANTENNA INPUT DATA

Site	Antenna Heights (Feet)		A Ratio (1)	Antenna Current Amplitude/Phase		
				ISS (2)	ICS (3)	ICC (4)
Existing	Lower	16.3	.270	$-.5/19^{\circ}$	$1/19^{\circ}$	$.484/19^{\circ}$
	Middle	32.5		$1/0^{\circ}$	$-.5/0^{\circ}$	$0/0^{\circ}$
	Upper	48.5		$-.5/-23^{\circ}$	$0/-23^{\circ}$	$.484/-23^{\circ}$
1450 Feet	Lower	18.67	.209	$-.5/25^{\circ}$	$1/25^{\circ}$	$.484/25^{\circ}$
	Middle	37.35		$1/0^{\circ}$	$-.5/0^{\circ}$	$0/0^{\circ}$
	Upper	56.02		$-.5/-39^{\circ}$	$0/-39^{\circ}$	$.484/-39^{\circ}$
1600 Feet	Lower	19.27	.199	$-.5/28^{\circ}$	$1/28^{\circ}$	$.484/28^{\circ}$
	Middle	38.54		$1/0^{\circ}$	$-.5/0^{\circ}$	$0/0^{\circ}$
	Upper	57.80		$-.5/-33^{\circ}$	$0/-33^{\circ}$	$.484/-33^{\circ}$
1800 Feet	Lower	18.43	.247	$-.5/23^{\circ}$	$1/23^{\circ}$	$.484/23^{\circ}$
	Middle	36.86		$1/0^{\circ}$	$-.5/0^{\circ}$	$0/0^{\circ}$
	Upper	55.29		$-.5/-23^{\circ}$	$0/-23^{\circ}$	$.484/-23^{\circ}$

(1) A Ratio - Ratio of separate sideband amplitude to carrier sideband signal amplitude.

(2) ISS - Separate sideband current.

(3) ICS - Carrier sideband current.

(4) ICC - Clearance carrier current.

TABLE 2. SUMMARY - GLIDE PATH DATA

Site	Actual Angle	Width	Symmetry 90 Hz/150 Hz
Existing	2.99°	.69°	47%/53%
1450 Feet	2.97°	.70°	49%/51%
1600 Feet	2.95°	.70°	49%/51%
1800 Feet	2.98°	.70°	51%/49%

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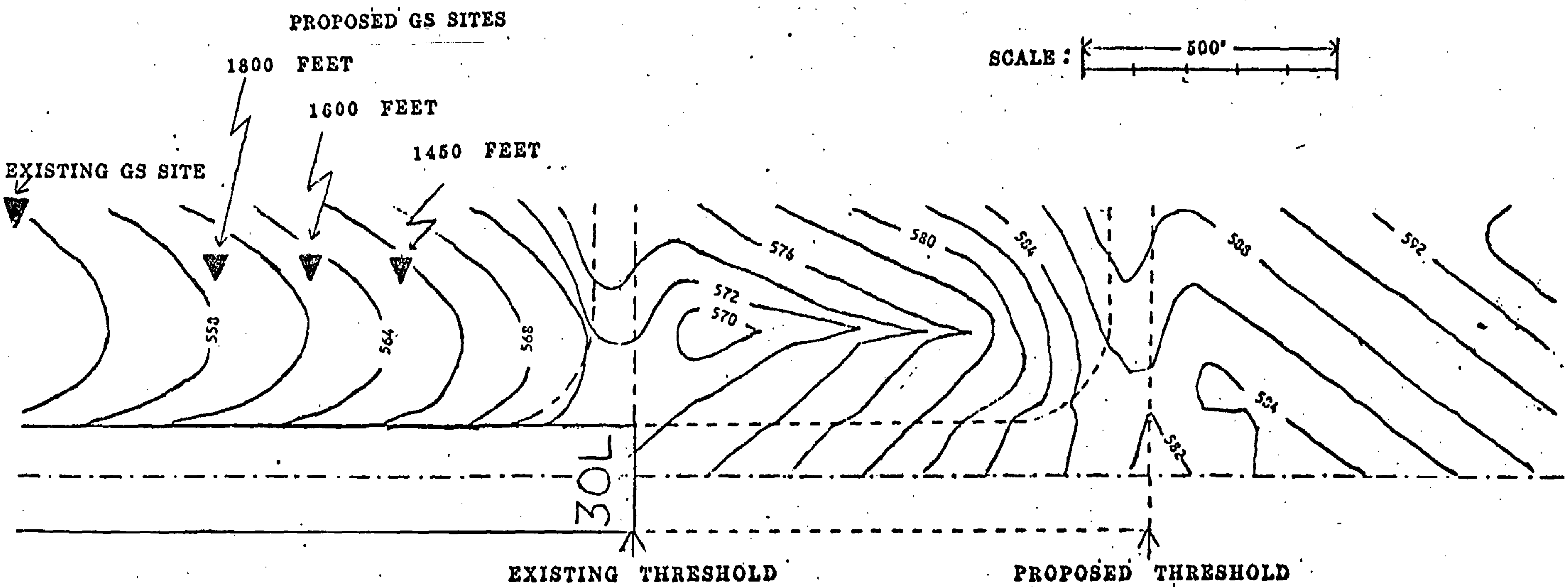

Figure 1. Extended Runway 30L, Proposed Sites and Grading.

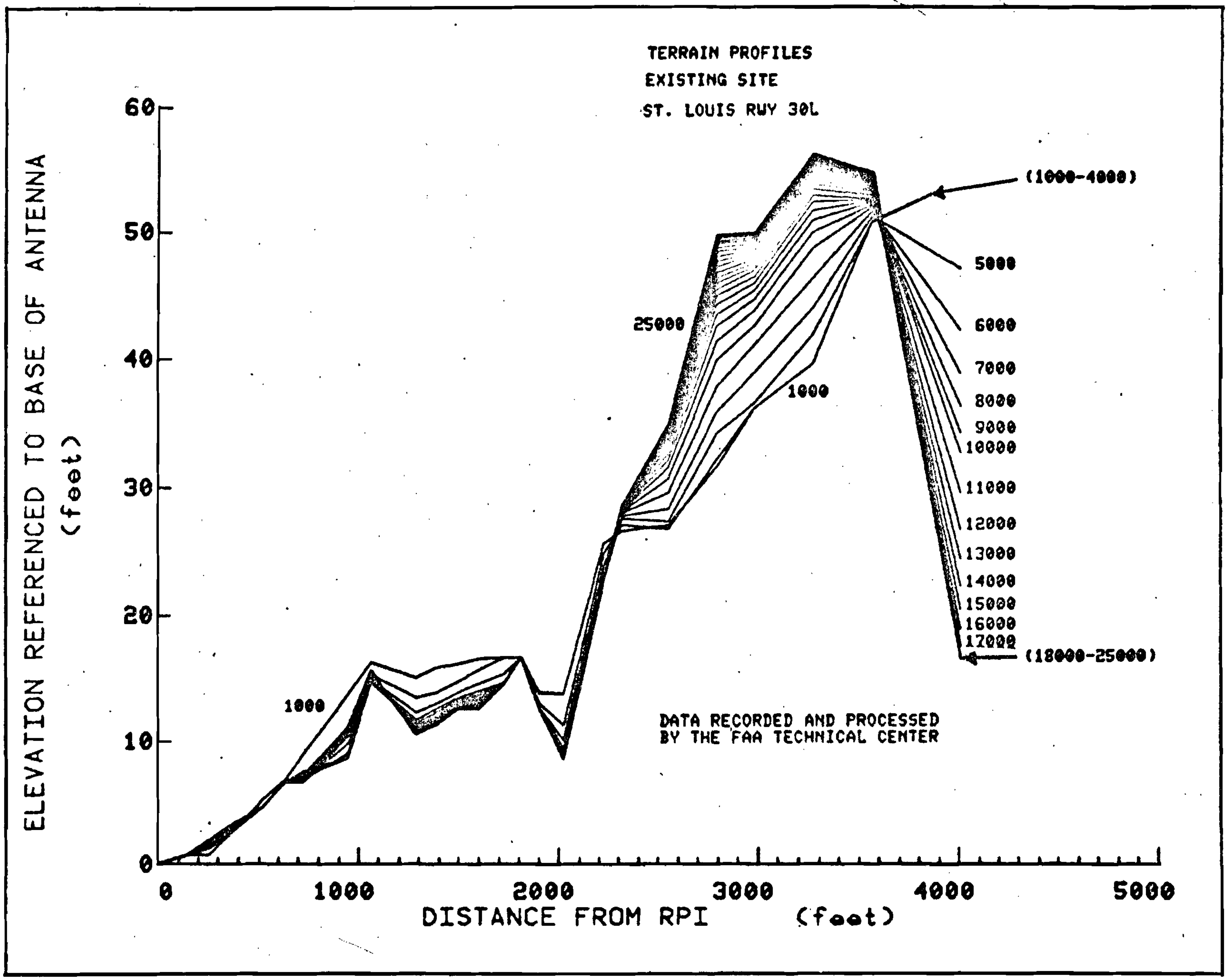

Figure 2. Composite of Terrain Profiles - Existing Site

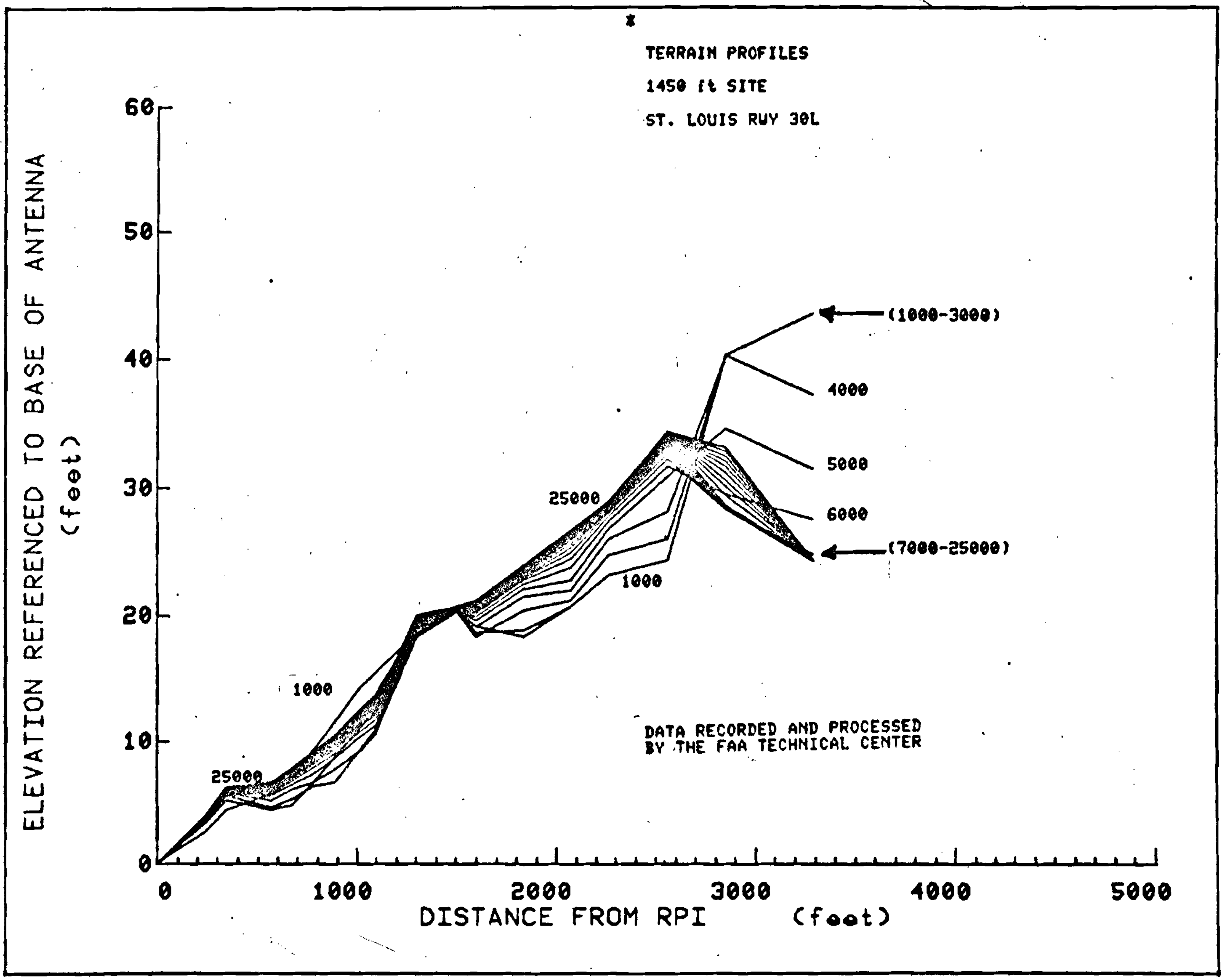

Figure 3. Composite of Terrain Profiles - 1450 Foot Site

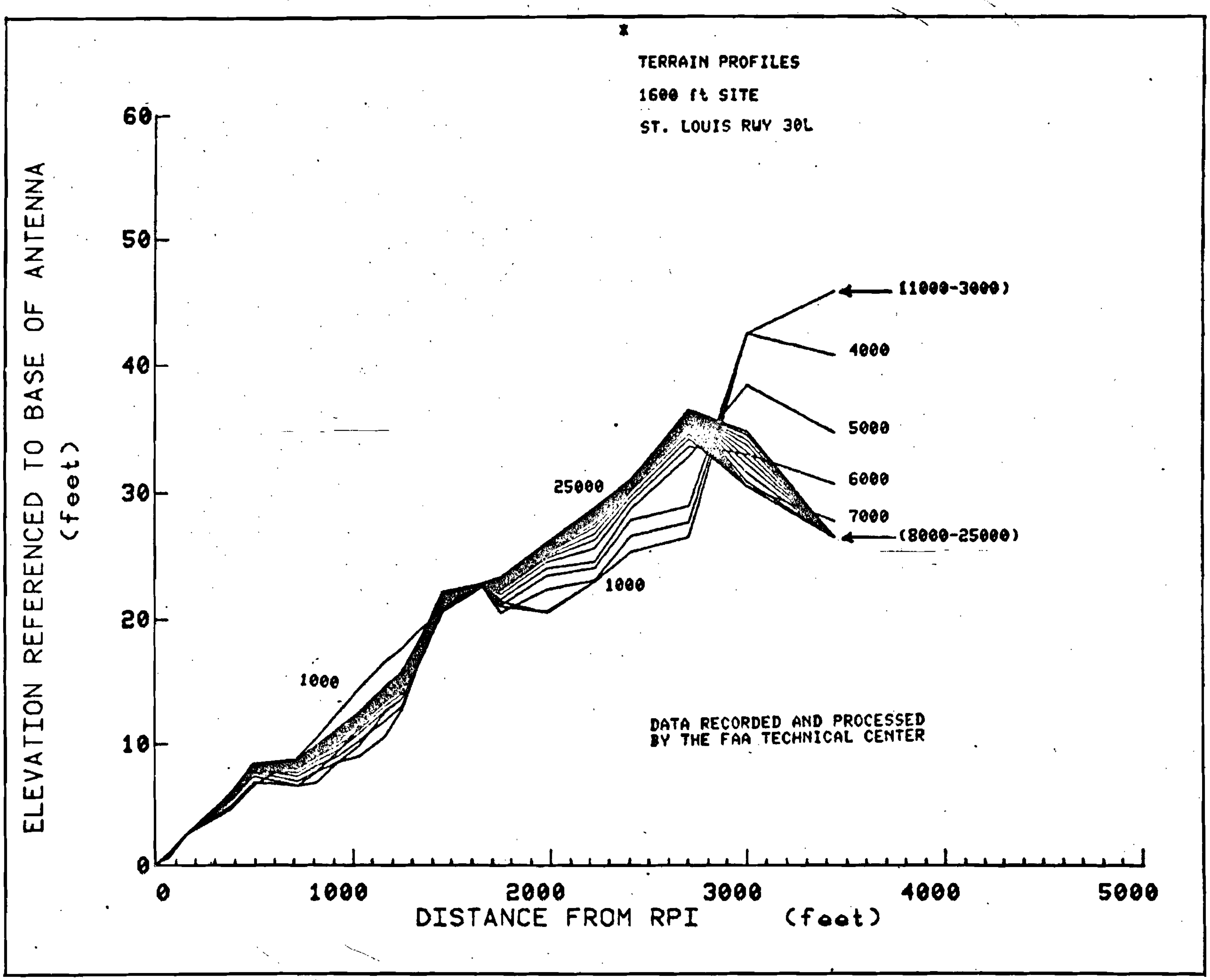

Figure 4. Composite of Terrain Profiles - 1600 Foot Site

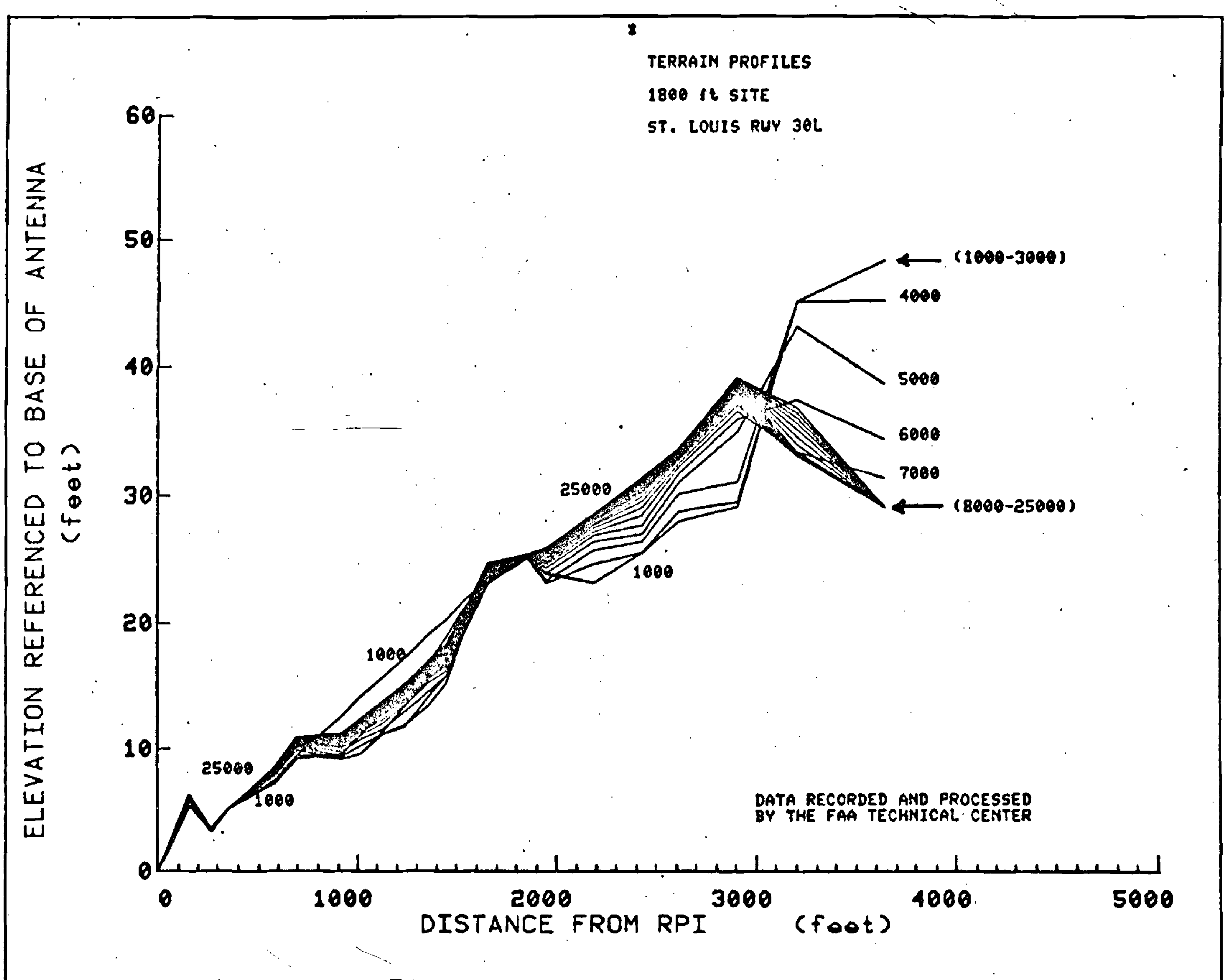

Figure 5. Composite of Terrain Profiles - 1800 Foot Site

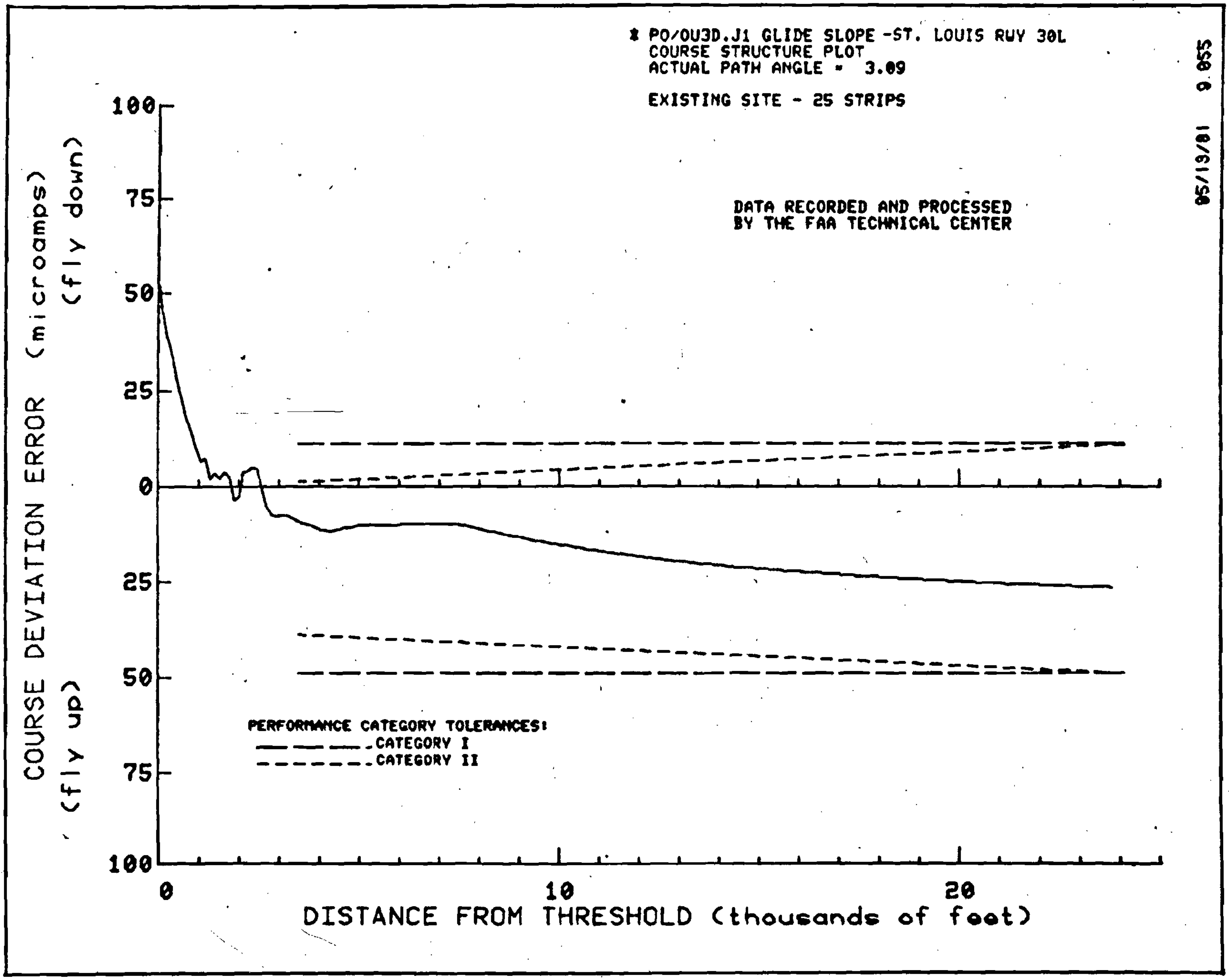

Figure 6. Existing Site, Course Structure

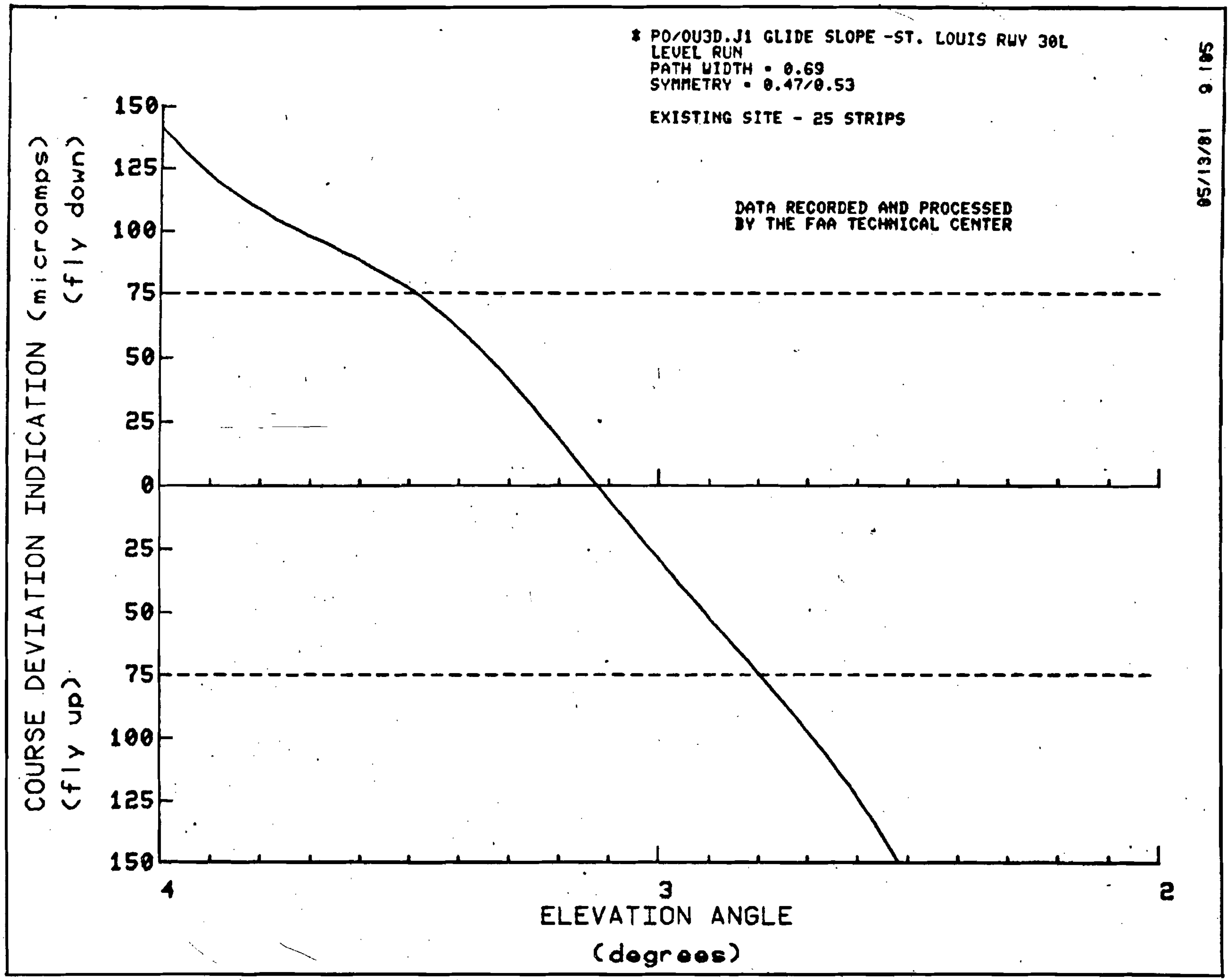

Figure 7. Existing Site, Level Run

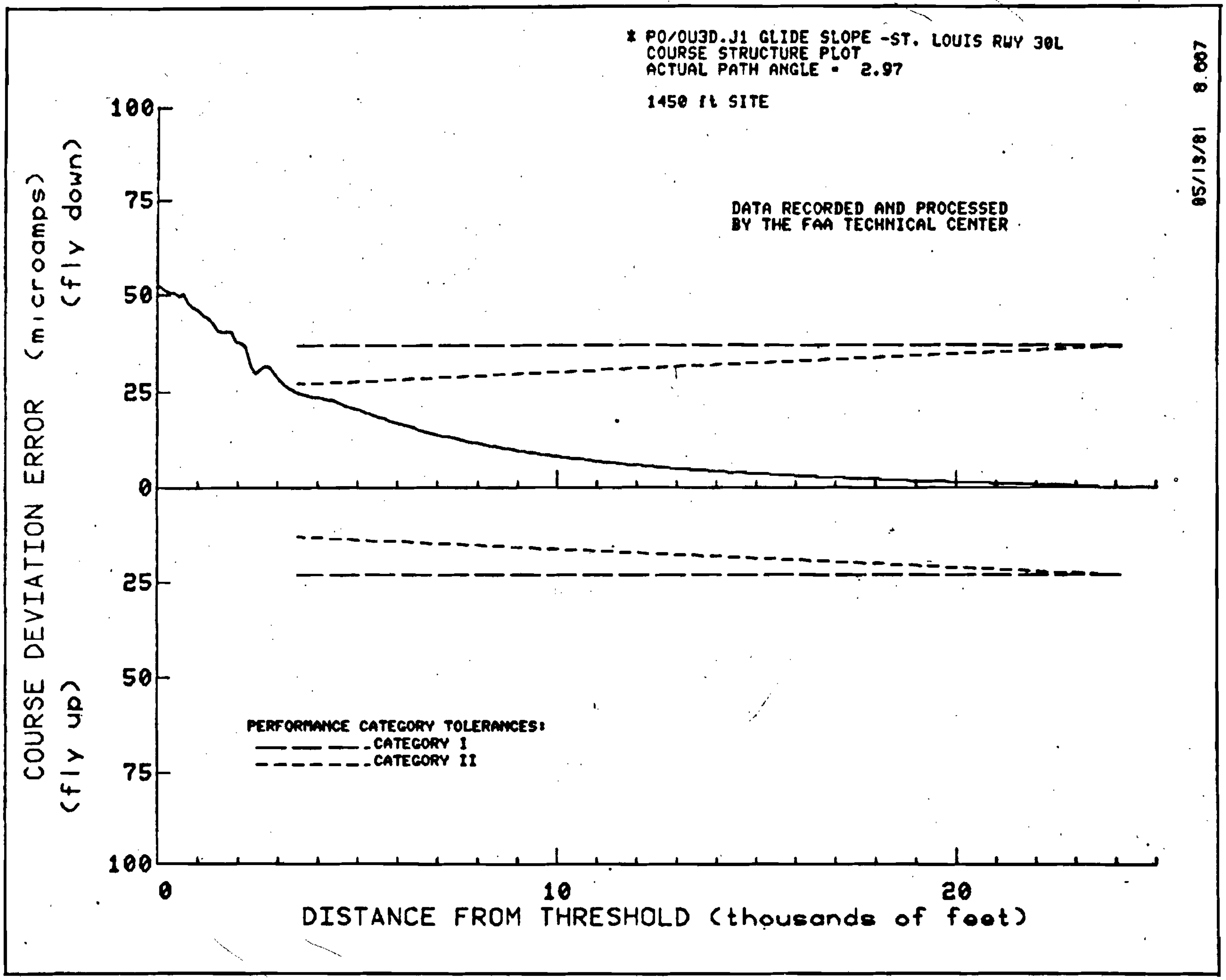

Figure 8. 1450 Foot Site, Course Structure

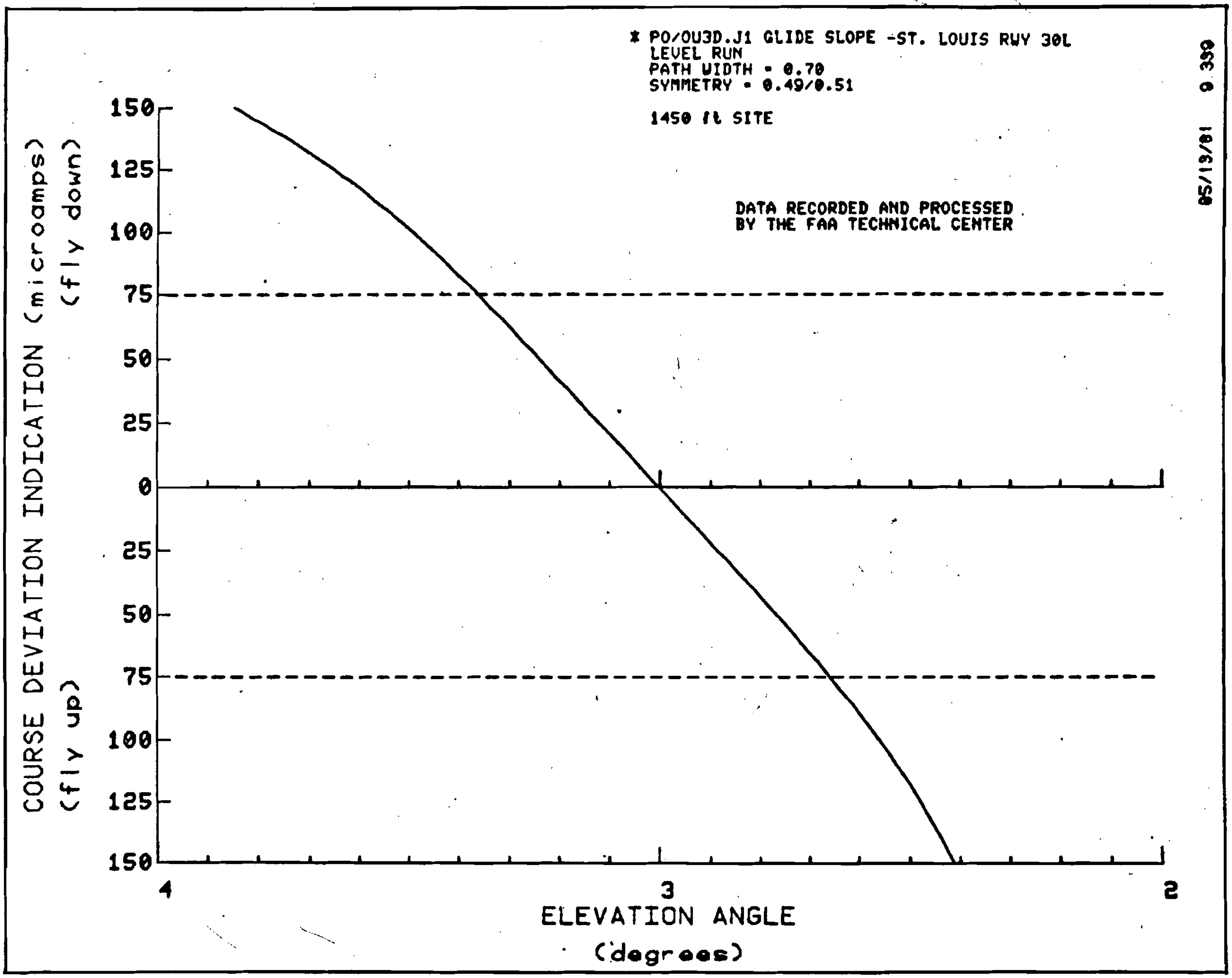

Figure 9. 1450 Foot Site, Level Run

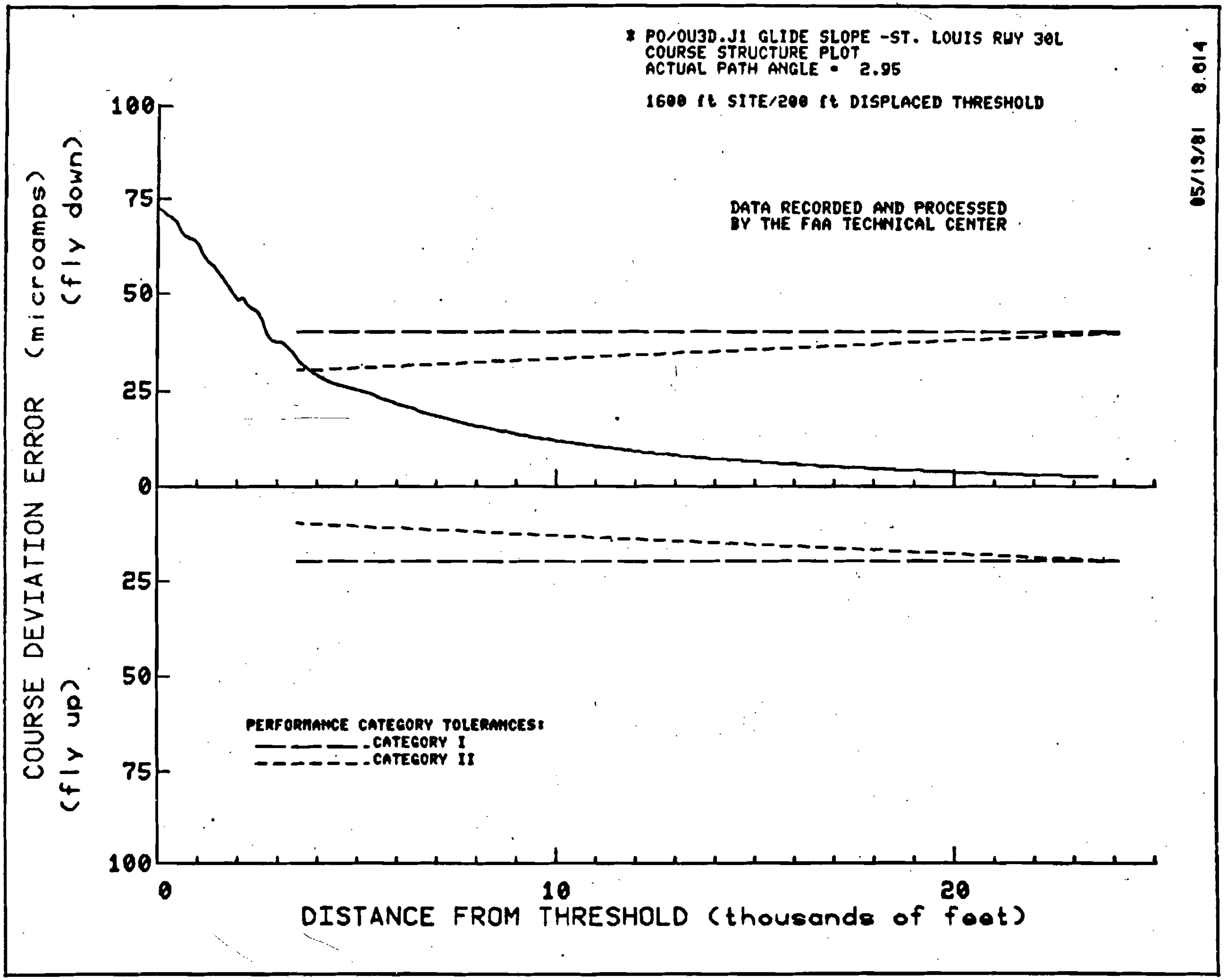

Figure 10. 1600 Foot Site, Course Structure

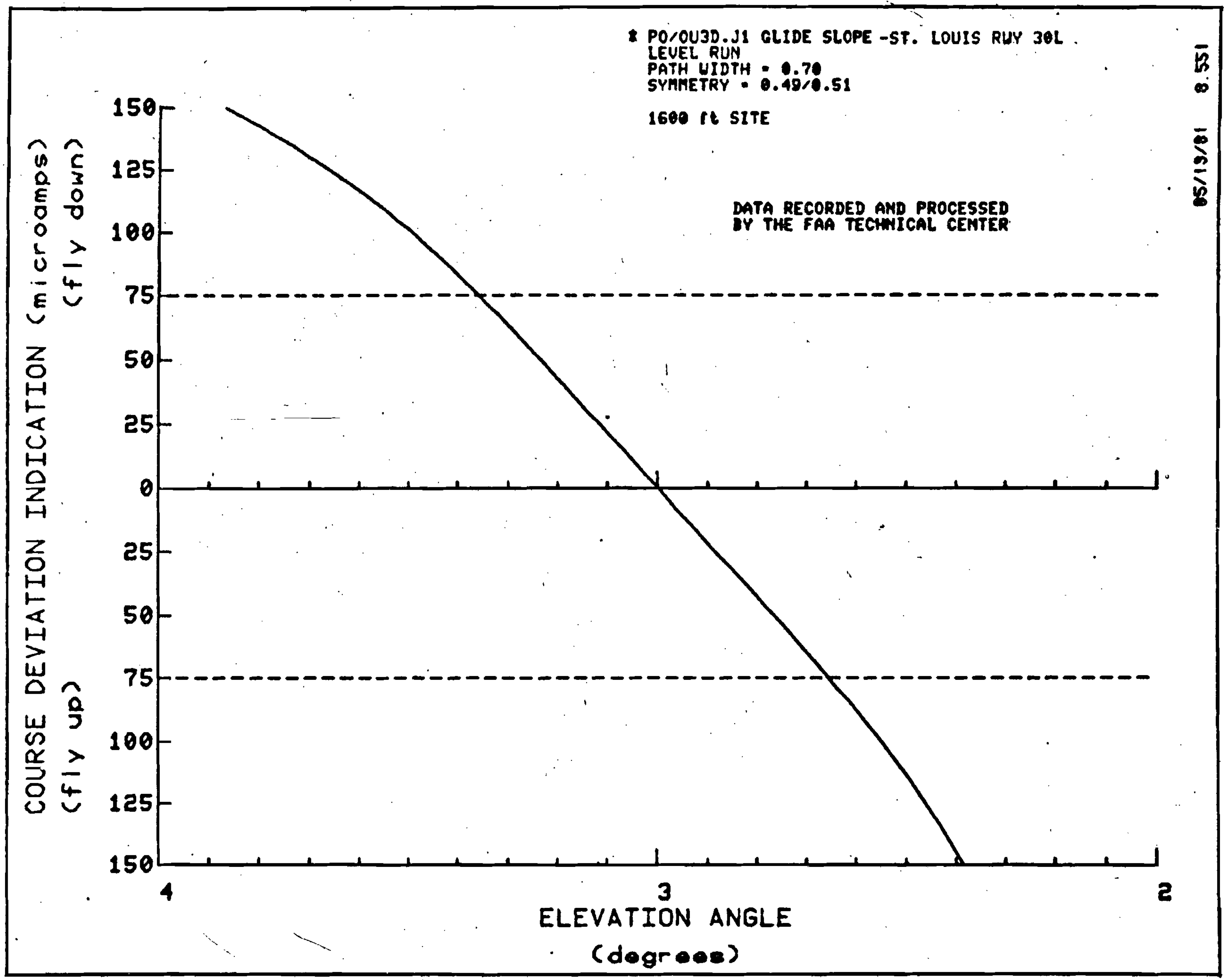

Figure 11. 1600 Foot Site, Level Run

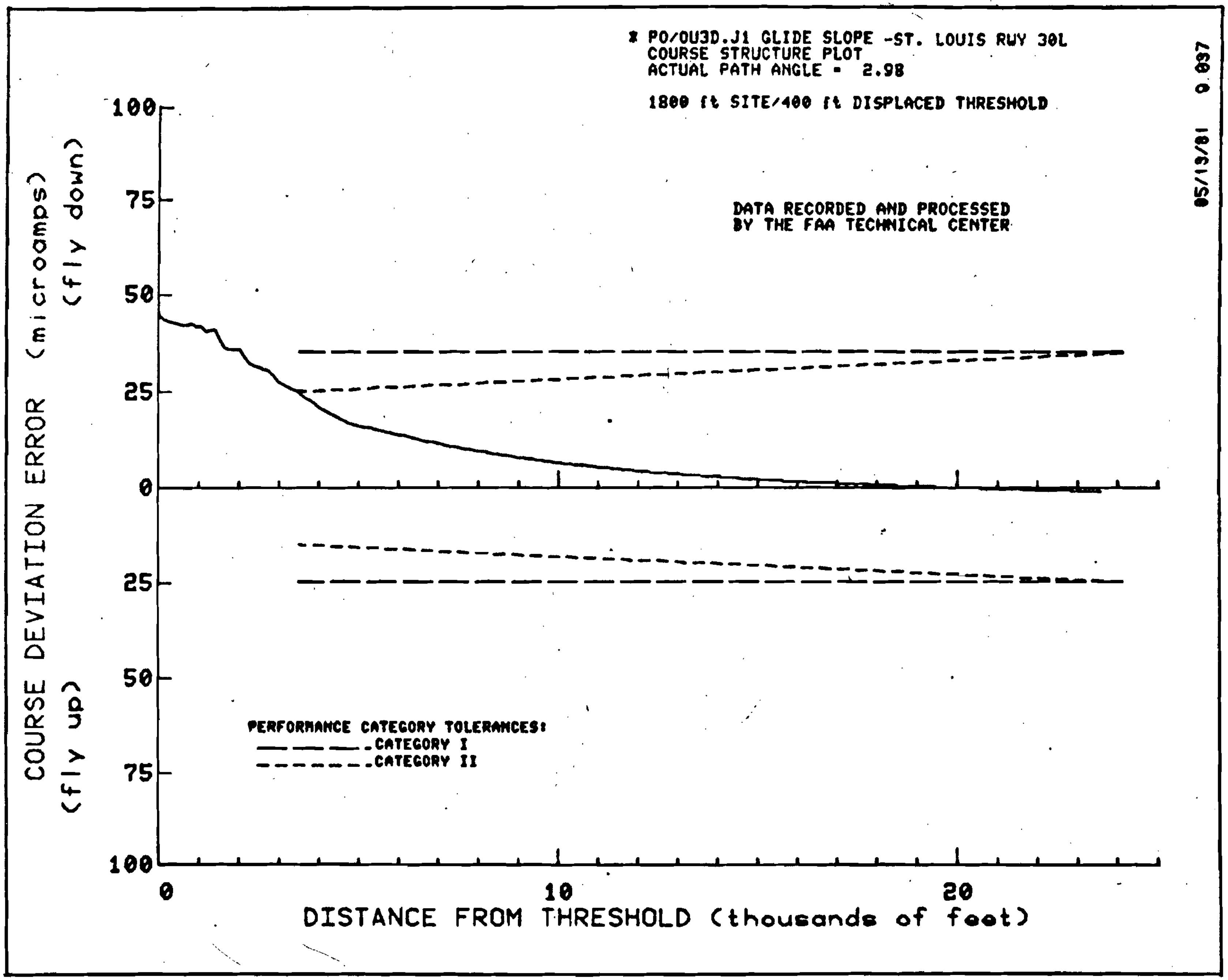

Figure 12. 1800 Foot Site, Course Structure

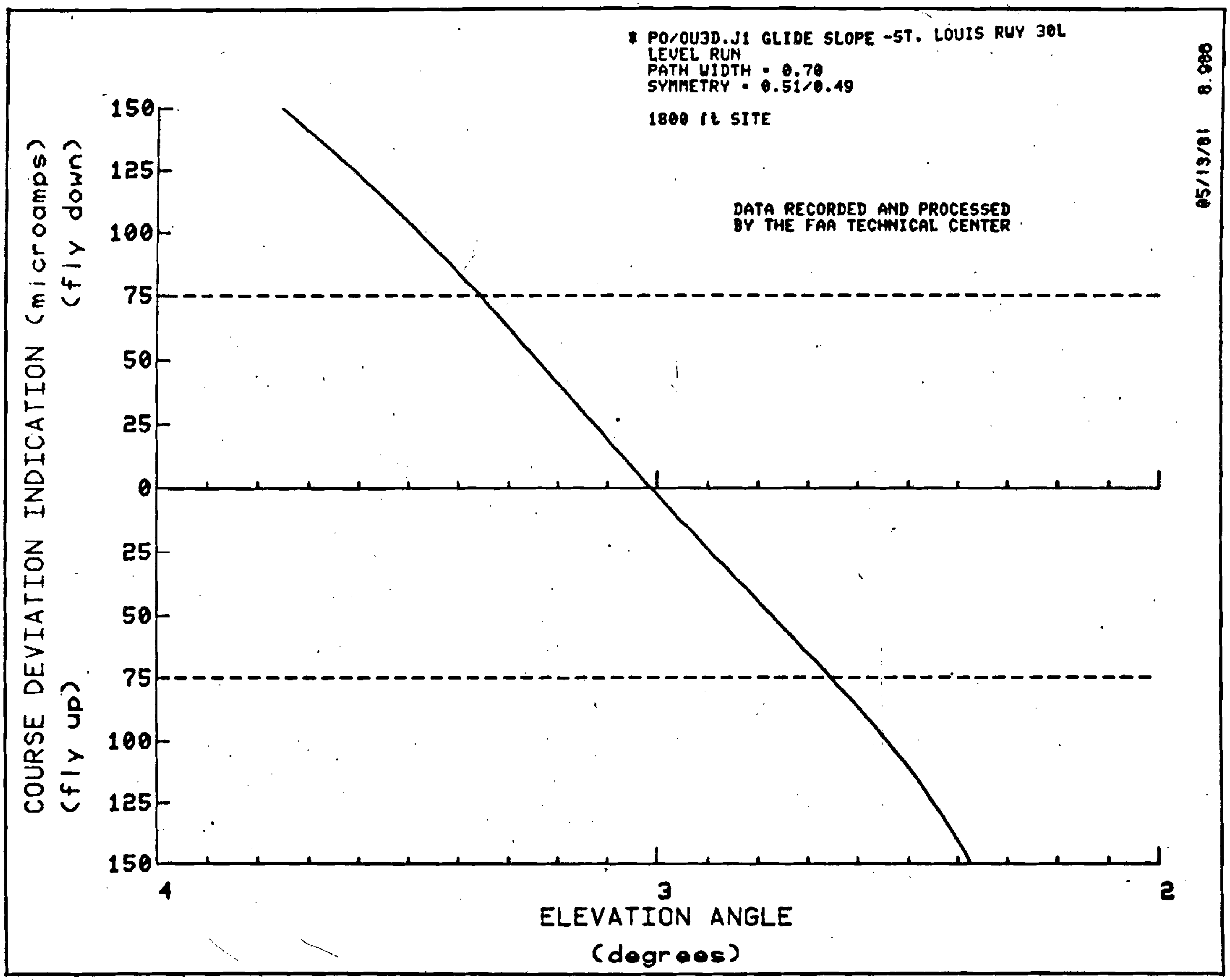

Figure 13. 1800 Foot Site, Level Run