APPENDIX T

Glide Slope Evaluation

THALES
AIR TRAFFIC MANAGEMENT

EVALUATION OF PROPOSED TERRAIN GRADING ON GLIDE SLOPE GFL SIGNAL IN SPACE

FLOYD BENNETT MEMORIAL AIRPORT
QUEENSBURY, NEW YORK

1. INTRODUCTION

The following report encloses the analysis results based on the Glide Slope siting criteria and the math modeling done to predict the effect of the proposed terrain grading on the signal in space of the projected Glide Slope at Floyd Bennett Memorial Airport, Queensbury, New York. This analysis does not include any evaluation regarding the siting of the Glide Slope antenna tower in terms of Obstacle Free Zone (OFZ) or Lateral Distance Criteria.

2. EXECUTIVE SUMMARY

In a first instance, the proposed Glide Slope terrain grading was evaluated against the grading criteria for Instrument Landing System described in FAA Order 6750.16E and was not found fully compliant. Refer to Section 4 of this report.

In a second instance, the proposed graded terrain was digitized and the signal in space was modeled, mainly in the beam forming area of the Glide Slope signal, to predict the performance in approach, level and orbital runs. The math modeling predicted that with the proposed grading, the Glide Slope will fully meet Category I tolerances. Refer to Section 5.5 of this report.

3. METHODOLOGY

The analysis and conclusion in this report are based on the drawings and documents provided by the customer:

- Word © Document:
  - → **FAA NAVAIDS_GFL Meeting Attachment.doc**
- AutoCAD © drawing:
  - → **107035001_ILS Modeling Plan.dwg**
- Acrobat © documents:
  - → **GFL RWY 1 Extension PROPOSED SITE PLAN_1-14-16_b&w.pdf**
  - → **GFL RWY 1 Extension PROPOSED SITE PLAN_12-16-15.pdf**
  - → **GFL Prelim GS Calcs.pdf**

Any changes in dimensions, elevation or distance data, as depicted in these documents or drawings, may have a significant effect on the results presented in this report. Figure 1 illustrates a snapshot of the area of concern used in the study.

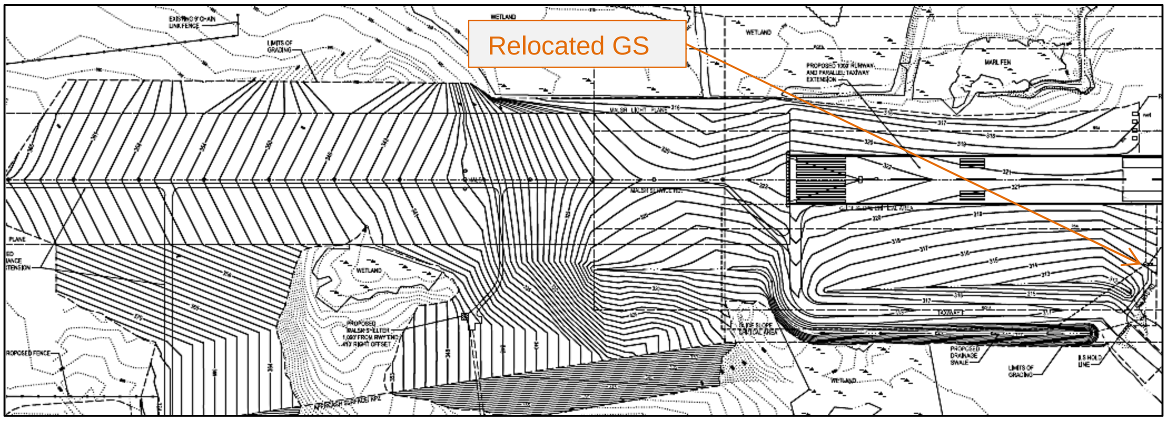


Figure 1 – Site Proposed Grading and Layout Plan

4. GRADING CRITERIA

FAA Order 6750.16E provides guidance that is used in conjunction with a thorough understanding of ILS facility operation, and math modeling when needed, to select the optimum location of each subsystem, based on the site specific details. Refer to Appendix 1 for an illustration and details of the grading criteria for an image-type Glide Slope.

Figure 2 below is an illustration of areas “A”, “B” and “C”, as described in Appendix 1 and overlaid over the proposed site plan.

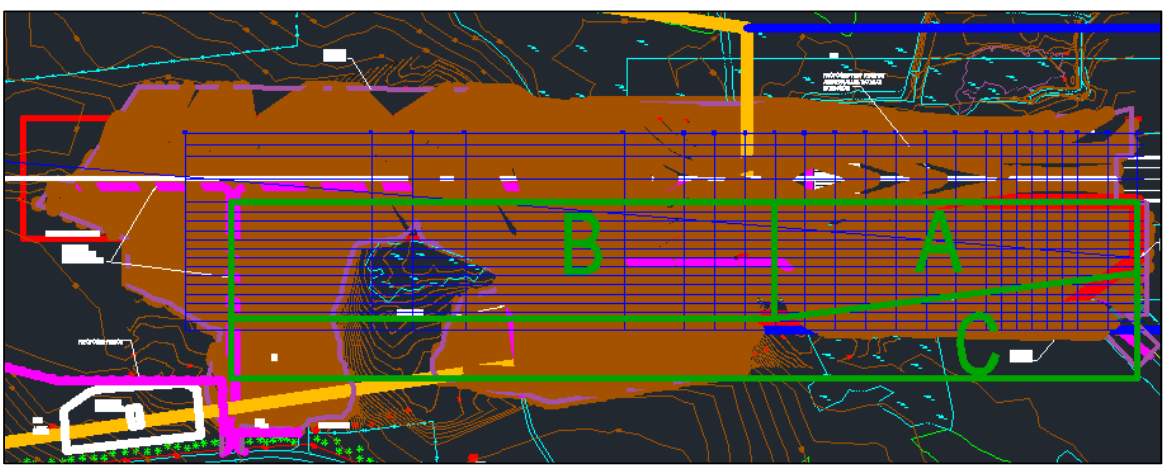


Figure 2 – Site Grading per Area

At the proposed location of the Glide Slope antenna tower, set-back 1090ft and off-set 260ft, the subtended angle from the edge of the reflection ground plane to the highest terrain rise within the approach is 1.12°. This exceeds the maximum recommended subtended angle of 1° of any obstacle, for a Capture Effect Glide Slope (CEGS) with a path angle of 3°. The peak at 385ft ASL is outside the airport limit; it is not part of the proposed grading and it does not extend over a long distance. Optimization during fine tuning and flight inspection should allow overcoming any signal distortion, if detected.

Area "A" should be uniformly graded and should have the same longitudinal slope as the runway. Figure 3 illustrates the longitudinal slopes along the runway and along the Glide Slope major axis, starting from the Glide Slope originating point and the runway point abeam it. As seen, the slopes differ in gradient.

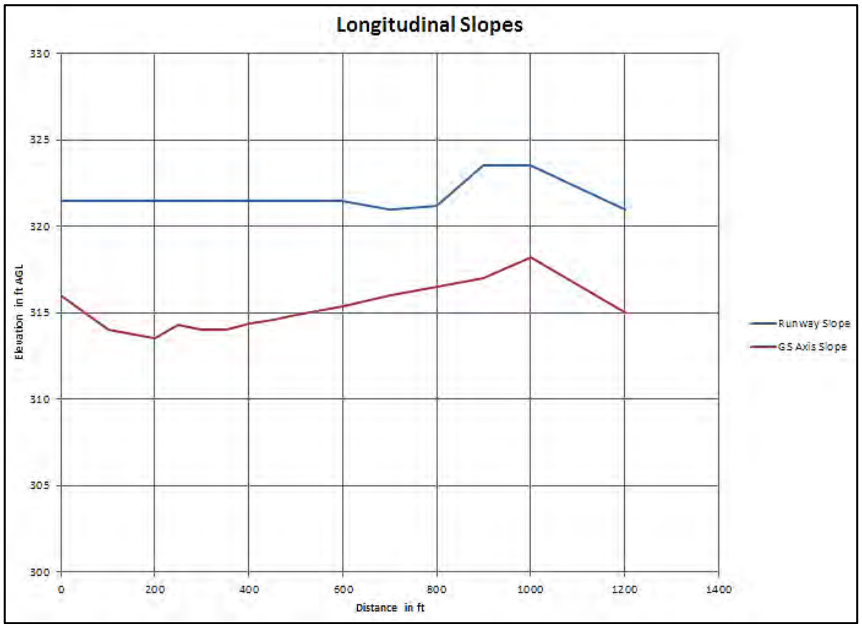


Figure 3 – Slopes along Runway and GS Major Axis, Area "A"

Area "B" should be smoothly graded to comply with the roughness criterion. For a 3° path angle, terrain irregularities exceeding 1.22ft per 1000ft from the antennas are considered as roughness when the irregularities exceed 10ft in length. Figure 4 illustrates the terrain profile along multiple longitudinal slices, with lateral offsets between 75ft and 380ft from the runway centerline. As indicated, some of the variations along the depicted terrain profiles do not meet the smoothness criteria.

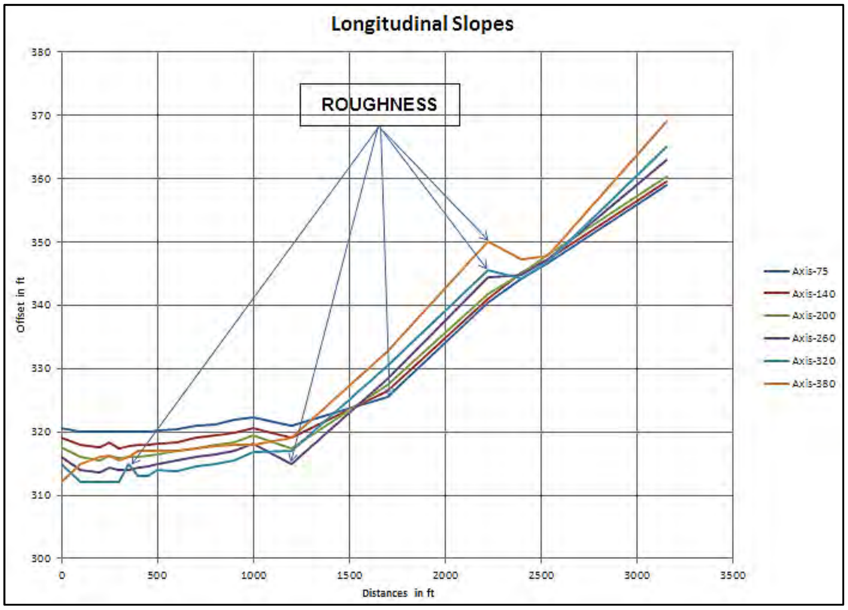


Figure 4 – Longitudinal Slopes Areas "A" and "B"

Area "C" does not include any hill which would affect the signal in the usable area.

Since the existing terrain and proposed grading do not fully comply with the siting criteria as described in FAA Order 6750.16E, math modeling was further considered and done to evaluate the effect of terrain on the signal in space.

5. MATH MODELING

5.1. MODELING SOFTWARE

The math modeling for performance prediction of the Glide Slope was done using OUGTM (Ohio University Glide Slope Terrain Model) software that uses the signal scattering models based on reflection theory UTD and GTD, (Uniform and Geometric Theory of Diffraction) given a terrain topography.

These modeling techniques predict the signal behavior with accuracy but cannot be used as an absolute guarantee of performance, because of the varied nature of material surfaces and the complex reflective, diffracting and shadowing characteristics of radio signals.

5.2. SIMULATION RUNS

Three simulation runs were conducted: the Approach run conducted to predict the structure of the signal in final approach, the Level run to predict the displacement sensitivity (or width), symmetry and structure below path, and the Orbital run to predict the angle tilt within the transverse required coverage sector.

5.2.1. Approach Run Mode

The approach run mode simulates the navigation signals an aircraft would receive while on final approach. The simulation begins on the theoretical glide path, approximately 10NM out and continues inward to touchdown. This model is based on a theoretical perfect approach tracked from the base of the Glide Slope antenna mast. Refer to Figure 5 for an illustration of the approach run.

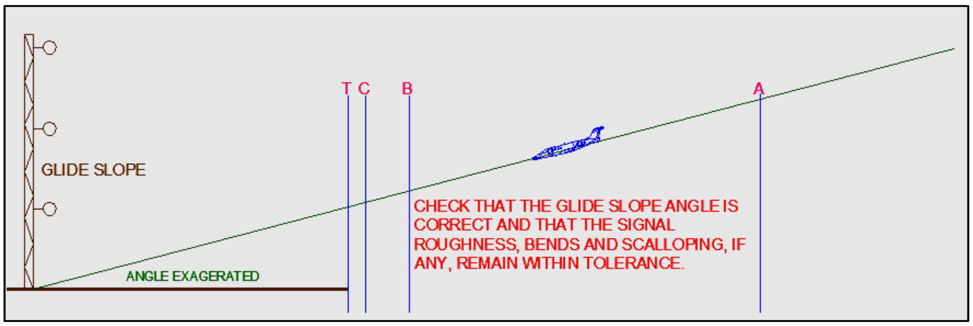


Figure 5 – Glide Slope Approach Run

5.2.2. Level Run Mode

The level run mode simulates the navigation signal above and below the path angle at 1500' levelled run. This simulation will ensure that the aircraft will receive proper sensing of "fly up" and "fly down" signals when below or above the 3-degree glide path, that the symmetry of the half-width sector (±75 µA) is within tolerance and that the Structure Below Path (Angle at 190µA of fly-up) is compliant. Refer to Figure 6 for illustration of the level run.

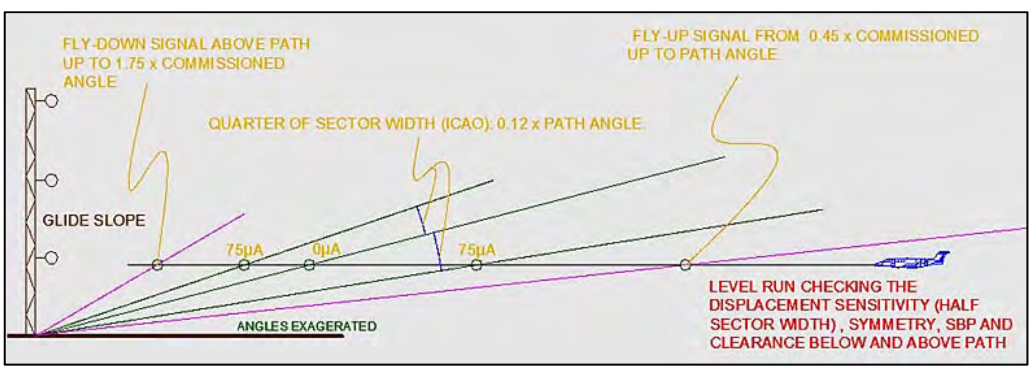


Figure 6 – Level Run Mode

5.2.3. Orbital Run Mode

The orbital run mode simulates a circular movement in a given sector across the course line at a point 6NM (or further) from the runway threshold. This mode verifies that the glide path angle and clearances are within the authorized tolerance at the extremities of the localizer course sector and may extend all the way to the required coverage ± 8 degrees on both sides of the approach path. Refer to Figure 7 for illustration of the orbital run.

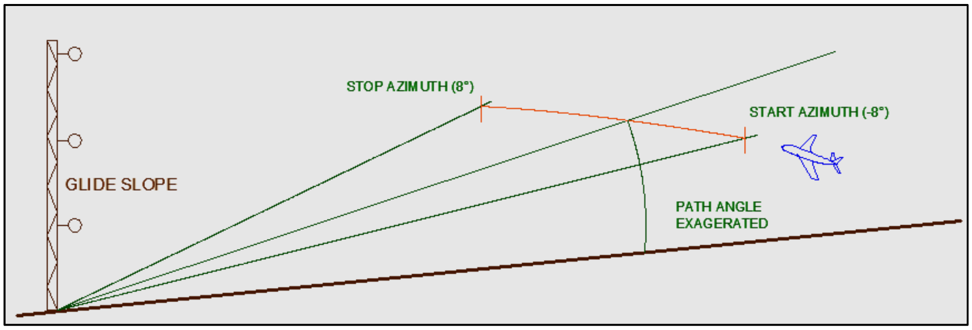


Figure 7 – Orbital Run Mode

5.3. TOLERANCES

The tolerances of concern are listed below, as referenced in FAA 8200.1D Order, "United States Standard Flight Inspection Manual".

04/15/15 8200.1D

b. Glide Slopes.

Parameter	Reference	Inspection C	Inspection P	Tolerance/Limit
Width	15.5.f	X		0.7° ± 0.05° (Site Survey, USAF test van: 0.7° ± 0.1°)
			X	0.7° ± 0.2°
Tilt	15.5.i	X	X	Within + 10.0% to -7.5% of the commissioned angle. Clearance Above Path, Modulation Clearance Below Path - 180µA
Symmetry	15.5.f	X	X	The following criteria are applied with the facility in a normal configuration: CAT I 67-33%. CAT II 58-33%. (Also CAT I authorized use below CAT I minima). CAT III 58-42%.

b. Glide Slopes.

Parameter	Reference	Inspection		Tolerance/Limit
		C	P	
Structure below Path	15.5.f	X	X	190 µA of fly-up signal occurs at an angle which is at least 30% of the commissioned angle.
		X	X	Exception: If this tolerance cannot be met, apply clearance procedures and tolerances.
Structure With AFIS or Tracking Device.	15.5.j	X	X	Category I Zone 1- From graphical average: ± 30 µA Zone 2 – From actual path angle: ± 30 µA Zone 3 – From graphical average: ± 30 µA Category II and III (Also CAT I authorized use below CAT I minima) Zone 1 – From graphical average ± 30 µA Zone 2 - From actual path angle ± 30 µA at Point A, then a linear decrease to ± 20 µA at Point B. Zone 3 – From graphical average ± 20 µA
Without AFIS or tracking device			X	Category I Zone 1– From graphical average: ± 30 µA Zone 2 – From graphical path angle: ± 30 µA Zone 3 – From graphical average: ± 30 µA
	15.8.a	X	X	Exception: An aggregate out-of-tolerance condition for 354 ft may be acceptable in a 7,089-foot segment.
Change/ Reversal	15.8.b	X	X	25 µA per 1,000 ft in a 1,500-foot segment.

In the Approach run, we will be looking at the Structure (Referenced as 15.5j in the tolerance table) and for any Change / Reversal (Ref. 15.8b). The angle may be adjusted in the field during commissioning support and will not be considered.

In the Level run, we will be looking at the Width (Ref.15.5f), Symmetry (Ref. 15.5f) and Structure below Path (Ref. 15.5f).

In the Orbital run, we will be looking at the Tilt (Ref. 15.5i).

5.4. DIGITALIZED TERRAIN

Topographical data was extracted from the Site Grading and Layout Plan. Figures 8 and 9 illustrate two different views of the digitalized terrain in the area of concern. Figure 8 shows the location of the lateral cuts used in digitalizing the elevation data. Figure 9 shows the changes in gradient slopes with changing colors.

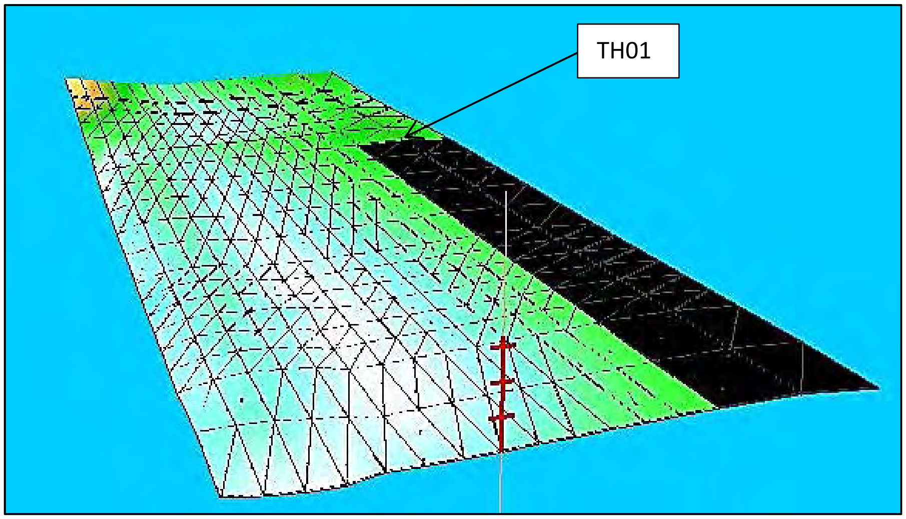


Figure 8 – Digitalized Terrain with Line Grids

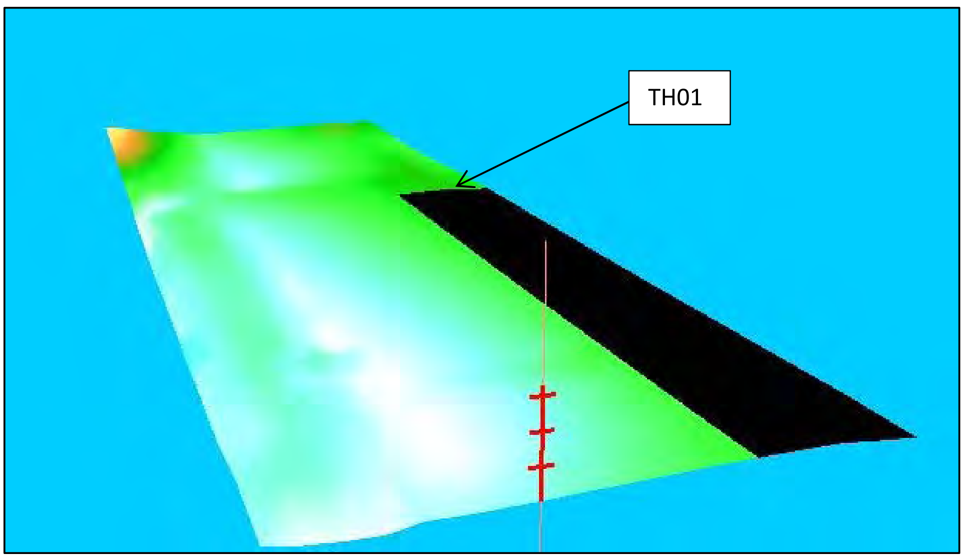


Figure 9 – Digitalized Terrain with Gradient Slopes

5.5. PERFORMANCE PREDICTION

Approach, Level and Orbital runs were modeled with the proposed grading terrain. The predicted results showed that the signal in space will fully meet Category I standards.

5.5.1. Approach Run – Proposed Grading

Figure 10 shows the predicted approach run trace taking into account the terrain grading. The horizontal red lines above and below the trace represent the maximum structure distortion levels allowable for Category I. The model, in this run, predicts that the facility would fully meet Category I tolerances.

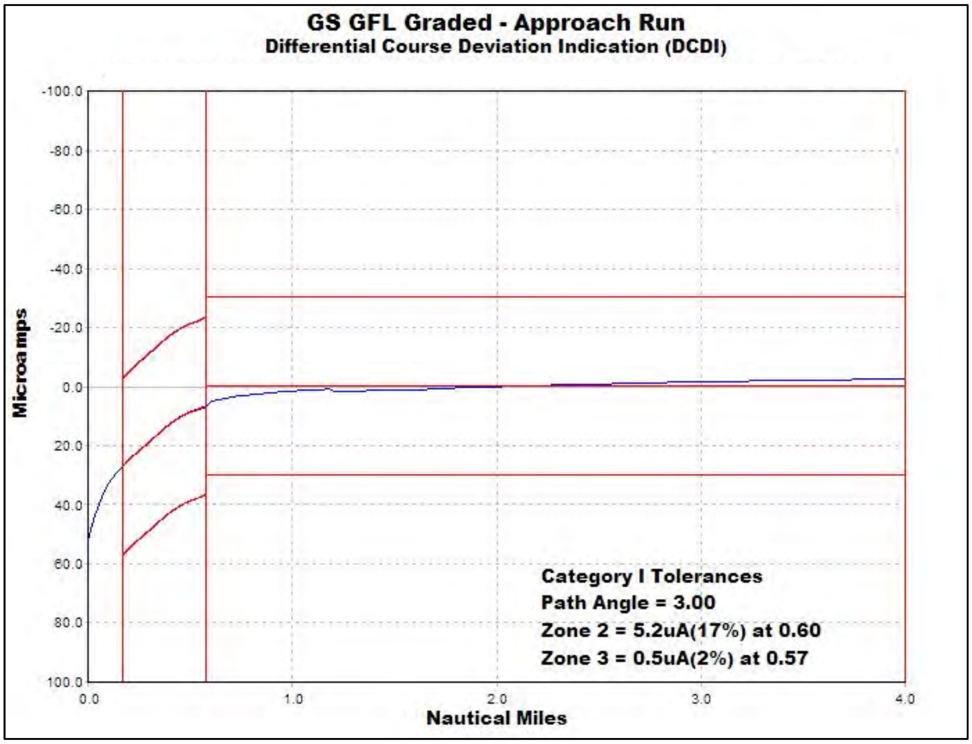


Figure 10 – Approach Run Trace with the Proposed Terrain Grading

5.5.2. Level Run – Recommended Grading

Figure 11 shows the predicted level run trace taking into account the terrain grading. The trace runs smoothly and linearly from strong “Fly-Up Signal” (below path), passing by “On-Path” at slope angle and continuing linearly to strong “Fly-Down Signal” (above path). The width, symmetry and Structure below Path fully meet Category I tolerances.

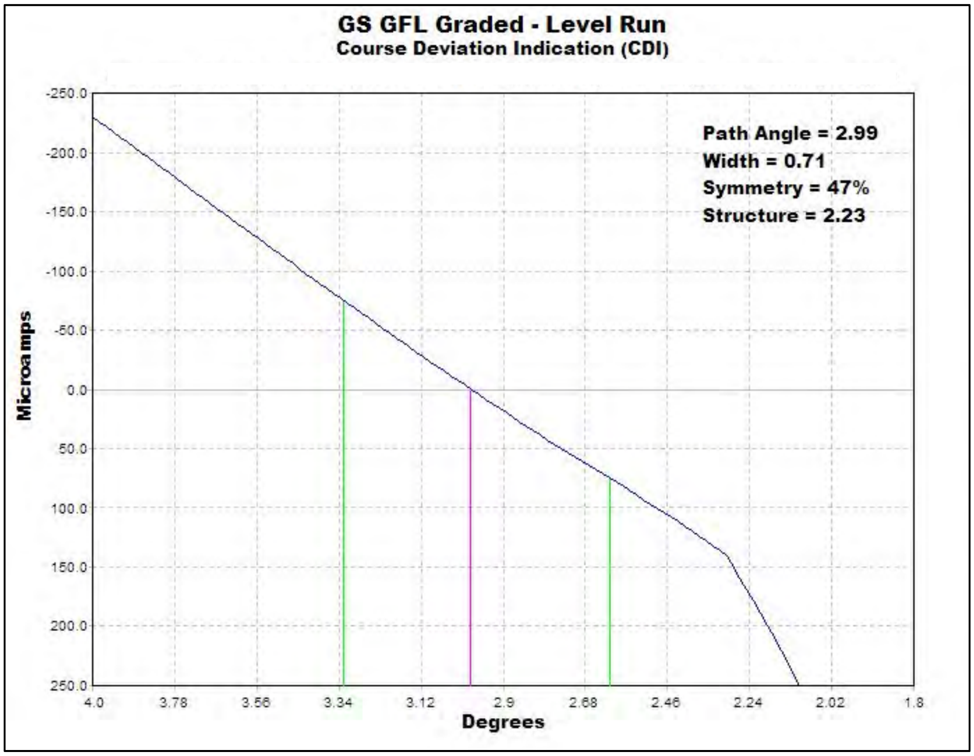


Figure 11 – Level Run Trace with the Proposed Terrain Grading

5.5.3. Orbital Run – Recommended Grading

Figure 12 shows the predicted orbital run trace taking into account the terrain grading. The trace remains within the red square within the required horizontal coverage sector of ±8°.

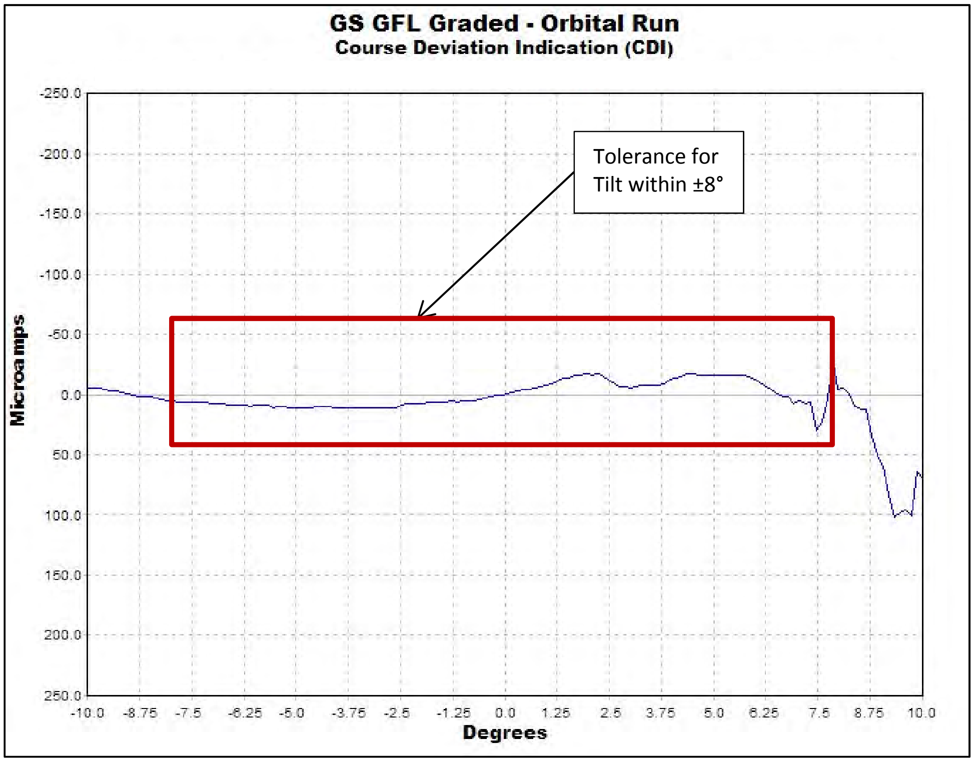


Figure 12 – Orbital Run Trace with the Proposed Terrain Grading

6. CONCLUSION

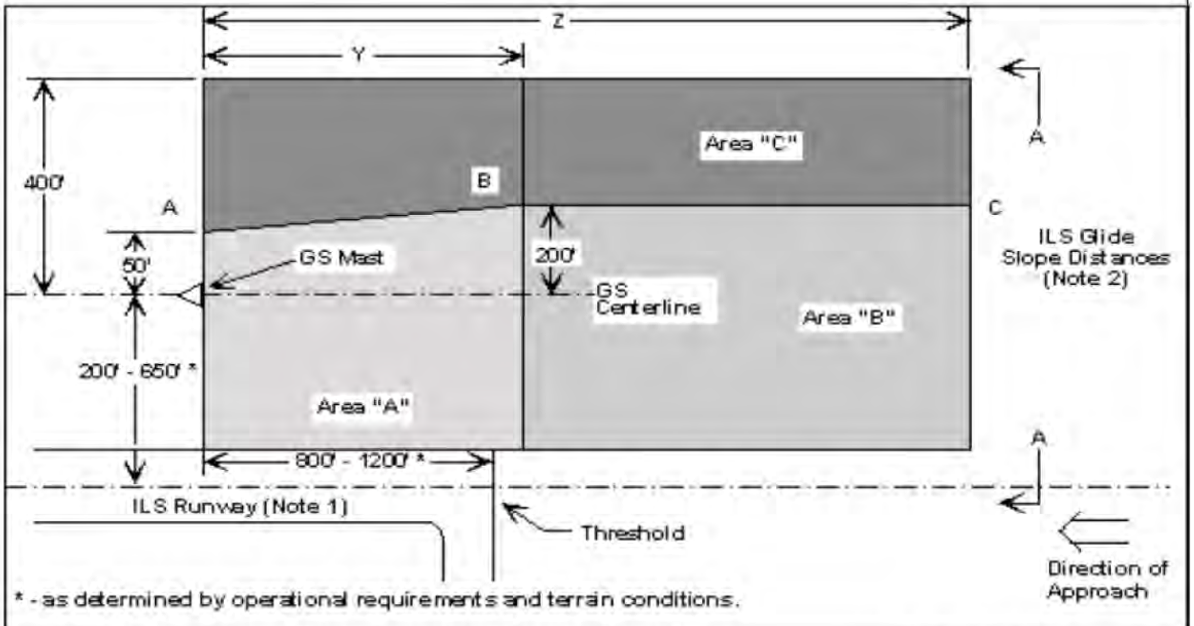
The capability of the Glide Slope to meet the operational requirements depends to a great extent on the terrain conditions between the antenna system and the receiving aircraft. Analysis of the proposed grading showed that the proposed terrain grading does not fully comply with the grading criteria as described in FAA Order 6750.16E.

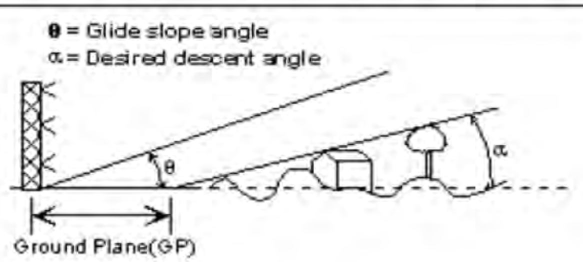
Grading criteria are intended to provide guidelines for the optimum site within the defined limits. Certain criteria may not be met at every site. This is when math modeling and more, such as comparison with other similar conditions with known outcomes, help assess the effect of adverse conditions on the required performance.

In the case of the projected Glide Slope at Floyd Bennett Memorial Airport, Queensbury, New York, and the proposed grading terrain, math modeling of the terrain within the beam forming area and its effect on the radiated signal showed that the Glide Slope signal will fully comply with Category I tolerances.

APPENDIX I

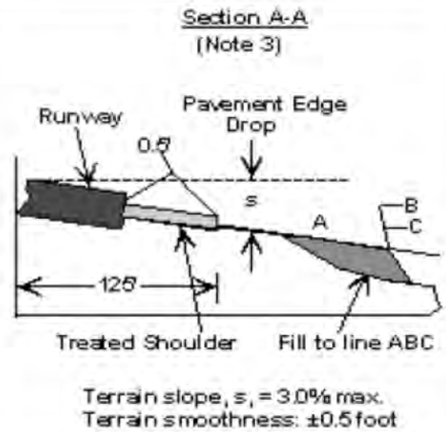
Grading Criteria for Image-Type Glide Slope





System	GP (Feet)	α Max	GP Smoothness (Area "A")
NR	1500-2000	θ/5	±6" from Avg Grade
SBR	800	θ/4	±4" from Avg Grade
CEGS	1200	θ/3	±6" from Avg Grade

(All Values Typical)



NOTES:
1. Locate glide slope on runway side away from taxiways, roads, etc.
2. Distances
   Y - The greater of 1200 feet or the setback of the glide slope from threshold
   Z - The least of : (a) 3000 feet; (b) distance to the airport property line; (c) distance to where smooth terrain terminates.
3. Grading and obstruction removal
   a. Area A should be uniformly graded and should have the same longitudinal slope as the runway.
   b. Area B should be smoothly graded to comply with terrain roughness criterion of paragraph 3-3e(3)(a). Extensive landfill operations determined by feasibility.
   c. Area C grading may be limited to removal of hills which would reflect the glide slope signal into the usable area.
   d. All possible interference sources (metallic structures, fences, etc.) should be removed from areas A, B, and that portion of C that is within 250 feet of the antenna centerline extended. (Refer to paragraph 3-4c.)

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