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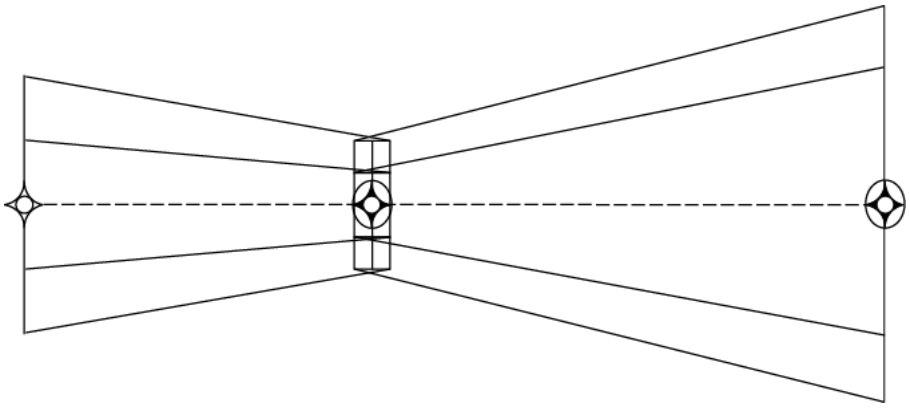
TP 308/GPH 209

CRITERIA FOR THE DEVELOPMENT OF INSTRUMENT PROCEDURES

TP 308 / GPH 209 – CHANGE 9.0



TRANSPORT CANADA
NATIONAL DEFENCE

1 January 2024

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RECORD OF AMENDMENTS

Amendment Number	Effective Date	Date Published	Revoked Date for Development of Instrument Procedures
Change 1	01 July 1996	1 July 1996	Revoked
Change 2	30 November 2001	30 November 2001	Revoked
Change 3	15 May 2006	15 May 2006	Revoked
Change 4	01 January 2008	01 January 2008	Revoked
Change 5	01 January 2009	01 January 2009	Revoked
Change 5.2	11 February 2010	11 February 2010	Revoked
Change 5.3	15 December 2011	15 December 2011	Revoked
Change 6.0	17 October 2013	17 October 2013	5 January 2017
Change 7.0	5 January 2017	5 January 2017	1 January 2020
Change 7.1	1 January 2018	1 January 2018	1 January 2020
Change 7.2	1 January 2020	1 January 2019	1 January 2023
Change 8.0	1 January 2023	1 January 2020	1 January 2024 or New CAR 602.129*
Change 8.1	1 January 2023	1 January 2023	New CAR 602.129*
Change 9.0	New CAR 602.129*	1 January 2024	

Note: (*) **Upon coming into force of the new approach ban regulation CAR 602.129** – TP308/GPH209 Change 9.0 is effective and instrument procedures based on the new Chapter 3 criteria may be published. Change 8.1 and 8.0 will no longer be authorized for the development of new instrument procedures.

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FOREWORD

This publication prescribes standardized methods for use in designing instrument flight procedures. It is to be used by personnel charged with the responsibility for the preparation, approval and promulgation of instrument procedures. Compliance with criteria contained herein is not a substitute for sound judgment and common sense. These criteria do not relieve procedure designers and supervisory personnel from exercising initiative or taking appropriate action in recognizing both the capabilities and limitations of aircraft and navigational aid performance to ensure safety of flight operation. These criteria are predicated on normal aircraft operations for considering obstacle clearance requirements.

Obstacle clearance is the primary safety consideration in the development of instrument procedures. Obstruction clearances quoted in this publication are the lowest or smallest values that can be accepted consistent with flight safety.

In the event of a conflict or disaccord between English and French versions of this criteria, the English version is considered the authority.

Recommendations concerning changes or additions should be provided to one of the following:

Department of National Defense (DND)
Division Instrument Check Pilot (DICP)
1 Canadian Air Division Headquarters
PO Box 17000
Station Forces
Winnipeg, MB R3J 3Y5

Transport Canada
Chief of Standards (AARTA)
Aerodromes and Air Navigation
Place de Ville, Tower "C",
330 Sparks St.
Ottawa, ON K1A 0N5

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- Appendix C: PBN Transition to ILS/GLS/LPV Final
- Appendix D: Radar Vector SID Implementation
- Appendix E: Geospatial Standard

ANNEXES:

A Acronyms and Abbreviations

B Definitions

C Precipitous Terrain Algorithms

D Mathematics convention

E Procedures

F Flight Validation (Flight Check/Evaluation)

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CHANGE 9.0 REVISION—CHANGE PAGE

EXPLANATION OF CHANGES

To support the regulatory changes pertaining to approach ban, Change 9.0 of the *Criteria for the Development of Instrument Procedures* (TP 308/GPH 209) focuses on Chapter 3, Take-off and Landing Minima, and the determination of prescribed visibility minima.

CARs 803.02(b) states that no person shall publish or submit for publishing in the Canada Air Pilot an instrument procedure unless the procedure has been developed by a person who has successfully completed training in the interpretation and application of the standards and criteria specified in the manual entitled Criteria for the Development of Instrument Procedures. To apply the criteria in this document, the instrument procedure design training has to be accepted by the Minister.

The volume and chapter numbers are identified on the inside top right corner of the page. The chapter and page numbers (example 1-1) are on the bottom centre of the page. The revision number (Change 9.0) is on the bottom left corner and the date of issue is bottom right. The vertical change lines located outside of the left border indicate modifications or corrections made from TP308/GPH 209 Change 8.1.

For administrative purposes, most table and figure numbers have continued to be revised to be compatible with the FAA's Terminal Instrument Procedures Criteria (TERPs). Most tables and diagrams for each chapter remain at or near the text where they are first mentioned.

Training requirements for criteria in adherence to CARs 803.02 is contained in the AC announcing the implementation of a change to the Criteria for the Development of Instrument Procedures (TP308/GPH209).

TP308/GPH209 will be amended as required. Updates and notices will be posted via AC, at:

https://www.tc.gc.ca/eng/civilaviation/opssvs/managementservices-referencecentre-acs-800-menu-512.htm

ADVISORY CIRCULARS

Publication of Change 9.0 supersedes the following TP 308/GPH 209 ACs:

- AC 803-001, Issue 13, dated 2020-11–14 TP308/GPH209 – Change 8.1 – Criteria for the Development of Instrument Procedures.

EFFECTIVE DATE

1 January 2024.

Significant areas of new direction, guidance, and policy included in this change are as follows:

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(1) **RECORD OF AMENDMENTS**

Revised.

(2) **TABLE OF CONTENTS**

Revised.

Volume 1, General Criteria

(1) **Chapter 1 – Administration**

(a) Para 120.d. Procedure Development Requirements – Reference changed.

(2) **Chapter 2 – General Criteria**

(a) Para 2.1.4.d. Sloping Obstacle Clearance Surfaces (OCS) – Reference changed;

(b) Para 2.1.5.c. Distance – Reference changed;

(c) Para 2.3.2. Altitude Selection – Reference changed;

(d) Figure 2-3-3.c.: Obstacle Clearance – Reference changed;

(e) Formula 2-3-2: Straight/Arc Initial Segment Minimum Secondary ROC – Reference changed;

(f) Para 2.3.4.c. Obstacle Clearance – Reference changed;

(g) Para 2.3.5.c. Obstacle Clearance – Reference changed;

(h) Para 2.3.6.c. Obstacle Clearance – Reference changed;

(i) Para 2.4.2. Altitude Selection – Reference changed;

(j) Para 2.4.3.c. Obstacle Clearance – Reference changed;

(k) Figure 2-4-2: Obstacle Clearance Area – Reference changed;

(l) Para 2.4.4.c. Obstacle Clearance – Reference changed;

(m) Para 2.6.1.b. Obstacle Clearance – Reference changed;

(n) Para 2.7.5. Straight Missed Approach Obstacle Clearance – Reference changed;

(o) Para 2.7.8.e. Determine – Reference changed;

(p) Para 2.8.10. Obstacle Close To a FAF or a Final Approach Segment – Reference changed; and

(q) Figure 2-8-12: 7:1 Slope Worksheet (Example) – Reference changed.

(3) **Chapter 3 – Take-Off and Landing Minima – New Revised.**

(4) **Chapter 5 – TACAN, VOR/DME and VOR WITH FAF**

(a) Para 513.c. Obstacle Clearance – Reference changed;

(b) Para 513.f. Minimum Descent Altitudes – Reference changed;

(c) Para 523.b.(3) Obstacle Clearance – Reference changed;

(d) Para 523.b.(6) Minimum Descent Altitudes – Reference changed;

(e) Figure 5-51a.: Minimum Obstacle Clearance. Par 513.c(1) – Reference changed; and

(f) Figure 5-54a.: Minimum Obstacle Clearance. Par 523.b(3) – Reference changed.

(5) **Chapter 6 – NDB PROCEDURES ON-AIRPORT FACILIT, NO FAF**

(a) Para 613.f Minimum Descent Altitudes – Reference changed; and

(b) Figure 6-57a: Secondary ROV. Para 613c. – Reference changed.

(6) **Chapter 7 – NDB WITH FAF**

(a) Para 713. Final Approach Segment – Reference changed; and

(b) Figure 7-66a.: Minimum Obstacle Clearance. Par 713.c. – Reference changed.

(7) **Chapter 9 – Localizer (LO) and Localizer Type Directional Aids (LDA)**

(a) Para 9.1.4. Obstacle Clearance – Reference changed; and

(b) Para 9.1.6. Minimum Descent Altitudes – Reference changed.

(8) **Chapter 10 – Radar Approach Procedures and Vectoring Charts**

(a) Para 10.2.3. PAR Final Approach Segment – Reference changed.

(9) **Chapter 11– HELICOPTER PROCEDURES**

(a) Para 1126. Altitudes – Revised;

(b) Para 1127. Visibility – Revised;

(c) Para 1174.b. Obstacle Clearance – Reference changed; and

(d) Table 11-25: Effect of HAL on Visibility Minima. Para 1127 – Reference changed.

(10) **Chapter 12 – DEPARTURE PROCEDURE**

(a) Para 12.4.3. VCOA Assessment – Reference changed.

(11) **Chapter 13 – Precision Approach and LDA With Glide Slope**

(a) Para 13.2.1. Final Segment – Revised;

(b) Section 13-4 Special Authorization (SA) CAT I Missed Approach – Revised;

(c) Table 13-4-1: Minimum RVR Values (Note) – New;

(d) Table 13-5-1: Minimum Authorized CAT II RVR (Note) – New; and

(e) Para 13.5.5. Requirements for CAT III ILS – Revised.

(12) **Chapter 18 – HOLDING CRITERIA**

(a) Para 19.0.4. Obstacle Clearance for Level Holding – Reference changed.

Volume 2, Performance Based Navigation (PBN)

(1) **Chapter 4 – RNAV (RNP) Approach**

(a) Para 4.2.1. General – Reference changed.

(2) **Chapter 8 – STANDARD FOR HELICOPTER AREA NAVIGATION (RNAV)**

(a) Figure 2-11: Enroute/Feeder/Initial Segment ROC (Note) – Reference changed; and

(b) Para 8.3.1. Approach Configuration (Note) – Reference changed.

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Director Aerospace Readiness
1 Canadian Air Division Headquarters
P.O. Box
17000
Station Forces
Winnipeg, MB
R3J 3Y5
Attention: DICP

Transport Canada
Directeur des Normes – Aviation Civil
330 Sparks St
Ottawa, ON
K1A 0N5

CRITERIA FOR THE DEVELOPMENT OF INSTRUMENT PROCEDURES

TP 308 / GPH 209 – CHANGE 9.0

VOLUME 1

GENERAL CRITERIA

TRANSPORT CANADA
NATIONAL DEFENCE

1 January 2024

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CHAPTER 1. ADMINISTRATION

100. Purpose

This manual contains the criteria that shall be used to formulate, review, approve and publish instrument procedures within Canada.

101. Submission of Aeronautical Data / Information

a. No person shall introduce new or modify existing aeronautical data or information comprising or affecting any instrument procedure intended for use in Aeronautical Information Products of Canada, except:

(1) in accordance with the standards set out in Annexes 4 and 15 to the Convention; and

(2) in accordance with the processes and procedures established in a formal arrangement with NAV CANADA, the provider of aeronautical information services for Canada.

b. Where ICAO Annexes 4 & 15 refers to PANS-OPS Doc 8168, reference shall be made to the applicable section(s) of the Criteria for the Development of Instrument Procedures (TP308/GPH209).

102. Audience.

All personnel who are responsible for IFP development and/or evaluation.

103. Cancellation

This document supersedes all previous editions of TC TP308/DND GPH209, Criteria for the Development of Instrument Procedures.

104. Existing Procedures

Existing procedures, when subject to periodic review, shall be assessed for changes to criteria to determine if action to revise the procedure is required. New procedures shall be developed in accordance with these standards and criteria.

105. Type of Procedure

For use in Table 1-1 third column “type of procedure”

a. Precision Approach (PA)

An instrument approach based on a navigation system that provides course and glidepath deviation information meeting the precision standards of International Civil Aviation Organization (ICAO) Annex 10 is considered a PA procedure. Precision Approach Radar (PAR) and Instrument Landing System (ILS) are examples of PA procedures.

b. Non-Precision Approach (NPA)

An instrument approach based on a navigation system that provides course deviation information, but no glidepath deviation information is considered an NPA procedure. Very high frequency omnidirectional range (VOR), tactical air navigation (TACAN), very high frequency omnidirectional radio range collocated with tactical air navigational aid (VORTAC), LNAV, localizer performance (LP), nondirectional radio beacon (NDB), localizer (LOC), and airport surveillance radar (ASR) approaches are examples of NPA procedures.

c. Approach Procedure with Vertical Guidance (APV)

An instrument approach based on a navigation system that is not required to meet the PA standards of ICAO Annex 10 but provides course and glidepath deviation information is considered an APV procedure. APVs are divided into two types, those that use vertical guidance provided by:

i. Lateral Navigation / Vertical Navigation (LNAV/VNAV) a path derived by the Baro-altimeter and the flight management systems, and

ii. Localizer Performance with Vertical Guidance (LPV) where the vertical guidance is provided by the Wide Area Augmentation System (WAAS).

d. Departure procedures (DP). Procedures designed to provide obstacle clearance during instrument departures.

e. Standard terminal arrival (STAR). A procedure that provides obstacle clearance and routing from the en route structure to a fix in the terminal area.

f. En route Air Traffic Service (ATS) routes. Routes including VOR and L/MF-based airways and PBN Routes which provide obstacle clearance.

g. Holding procedure: A predetermined manoeuvre which keeps an aircraft within a specified airspace.

106. Operating Minima

For use with Table 1-1 first column “NAVAID / Approach System Capability”

Approach operations are classified based on the lowest designed operating minima as:

a. Non precision: At or above 250 ft; and

b. Precision: below 250 ft.

107. Word Meanings.

a. Must/Shall. This means that application of the criteria is mandatory.

b. Should. This means that application of the criteria is recommended.

c. May. This means that application of the criteria is optional.

108. Height Above Touchdown (HAT)/ Height Above Threshold (HATh)

Throughout this document all references to “HAT” should be interpreted to read “Height Above Touchdown/ Height Above Threshold “HAT/HATh” (as applicable)

109. Reserved

110. Formulas.

Refer to Annex D, Mathematics Convention, for definitions and abbreviations of formula inputs that are commonly used throughout this document.

111—119. Reserved

120. Procedure Development Requirements

Prior to the publishing of any instrument procedure, the following associated minimum standards shall be met:

a. Aerodrome. Table 1-1 represents the type of instrument procedure, associated minima and application (public or restricted use) authorized for any combination of NAVAID/approach system capability versus the landing surface and applicable aerodrome design standards or aerodrome authorization. Table 1-1 does not apply to PINSA procedures or non-instrument Heliports.

b. Navigation Facility. All electronic and visual navigation facilities used shall meet the applicable standard and the requirements of flight inspection and calibration.

c. Obstruction Marking and Lighting. Buildings, structures and objects, including objects of natural growth shall be marked and lighted in accordance with CAR 621.19, Standards *Obstruction Markings* or DND CETO C-98-01 0-003/MG-004.

d. Altimeter Setting Source. All instrument approach procedures shall be predicated on the availability of a usable altimeter-setting source in accordance with CAR 804.01. See Para 3.2.2.c.

e. Communications. In controlled airspace air-to-ground communications with an ATS facility shall be available at the initial approach fix minimum altitude and at the missed approach clearance limit altitude. At lower altitudes communications shall be required where essential to the safe and efficient use of airspace. Air-to-ground communication normally consists of UHF or VHF radio, but other communications may be approved at locations that have a special need and capability.

f. Ground Validation. Ground validation is a review of the entire instrument flight procedure package by a person(s) trained in procedure design and with appropriate knowledge of flight validation. It is meant to catch errors in criteria and documentation, and evaluate on the ground, to the extent possible, those elements that will be evaluated in a flight validation. Issues identified in the ground validation should be addressed prior to any flight validation.

g. Flight Validation. A Flight Validation shall be conducted for all instrument approach procedures, departure procedures, airways and air routes prior to approval and at least once within a 5 year period for existing procedures. Flight validations shall be conducted by a person who has successfully completed training in the interpretation and application of the criteria found in this publication. Guidance material for Flight validations can be found in Annex F.

h. Quality Management System. An instrument flight procedure design service provider must utilize a quality management system (QMS) and apply quality assurance at each stage of the instrument flight procedure design process. The QMS should be based on International Standards Organization (ISO) 9001.

Note. The quality assurance methodology such as that described in PANS-OPS Doc 8168, Volume II should be considered. Guidance for implementing such a methodology is contained in the ICAO Quality Assurance Manual for Flight Procedure Design Doc 9906.

121. Retention and Cancellation

Before an instrument procedure is cancelled, coordination with civil and military users shall be

effected. Care shall be taken not to cancel procedures required by the military or required by air carrier operators at provisional or alternate airports. Military procedures shall be retained or cancelled as required by the appropriate military authority.

122—129. Reserved

130. Responsibility

a. Military Aerodromes. The DND shall establish and approve terminal instrument procedures for aerodromes under their jurisdiction and be responsible for the publication of these procedures.

b. Civil Procedures at Military Aerodrom*es*. At those military aerodromes where a need for civil approach procedures is identified, the appropriate civil authority shall coordinate with the DND and the procedure sponsor, before any approval/ publication/ revision/ cancellation of such procedures.

c. Civil Aerodromes. The appropriate civil authority shall establish terminal instrument procedures for civil aerodromes in accordance with this publication and be responsible for the publication of these procedures.

d. Military Procedures at Civil Aerodromes. At those civil aerodromes where the DND has a special requirement for approach or departure procedures the DND shall formulate, coordinate with the appropriate civil authorities, approve and publish such procedures. The civil authority shall be informed prior to cancellation of any of these DND procedures.

131. Continuous Maintenance of Instrument Flight Procedure

a. Continuous maintenance is established after the initial publication of the IFP. The IFPs shall be monitored by the sponsor for changes impacting the procedure during its entire life cycle. These changes are to include but are not limited to:

(1) changes to aerodrome data;

(2) changes to airspace structure;

(3) changes to NAVAID data;

(4) an operational assessment dictates;

(5) updated obstacle data;

(6) change to standards or criteria that may affect flight safety; or

(7) anything that could constitute a hazard.

b. Records are maintained for all maintenance showing the date that the activity was completed and including a synopsis specifying what actions, if any, were taken. The record of change(s) for the IFP design must be kept with the IFP design package along with all required authentications (such as sponsor, designer, independent reviewer and/or flight validation pilot).

c. The sponsor must advise NAV CANADA if he is no longer able to provide continuous maintenance to the IFP.

132. Periodic Review

All procedures shall be subjected to a periodic review. The maximum interval for this review is five years.

133. VALIDITY OF AN INSTRUMENT FLIGHT PROCEDURE (IFP)

The initial publication of an IFP is valid for 5 years after the flight validation date. This date marks the beginning of the maximum interval of 5 years for both, the periodic review and flight validation. In order to remain valid, periodic review and flight validation must each be less than 5 years and continuous maintenance of the IFP must be established.

134—139. Reserved

140. Formulation

Procedures shall be prepared in accordance with this publication as determined by the types of navigation facility and procedure to be used. To permit use by aircraft with limited navigational equipment the complete procedure should be, whenever possible, formulated on the basis of a single navigation facility. However, the use of an additional facility in the procedure may be considered if its use would provide an operational advantage.

141. Non-Standard Procedures

The standards contained in this publication are based on reasonable assessment of the factors that contribute to flight technical errors in aircraft navigation and maneuvering, and errors in airborne and ground facility accuracy. They are designed primarily to assure the safety of all users. The dimensions of obstacle assessment areas are influenced by the need to provide for a smooth transition to and from the en route system. Every effort shall be made to formulate procedures in accordance with these standards and criteria; however, peculiarities of terrain, navigation information, obstacles, etc. may require special consideration. In such cases, Transport Canada or Department of National Defense (DND), as appropriate, may approve non-standard procedures provided the deviations are fully documented and an equivalent level of safety exists. A non-standard procedure is not a substandard procedure, but is one that has been approved after special study of the local problems has demonstrated that no degradation of safety is involved. These procedures must also include a cautionary note identifying the divergence from the standards or criteria.

142—149. Reserved

Certified Aerodromes		TP312		
NAVAID/ Approach System Capability	**Landing Surface[1]**	**Type of Procedure**	**Minima Authorized**	**Application**
Precision	Precision	PA CAT I, II, III, NPA or APV	Applicable Minima	Public or Restricted
Precision	Non-Precision	PA, NPA or APV	250 feet HAA/HAT	Public or Restricted
Precision	Non-Instrument	PA, NPA or APV	500 feet HAA/HAT	Public or Restricted
Non-Precision	Precision	NPA or APV	250 feet HAA/HAT	Public or Restricted
Non-Precision	Non-Precision	NPA or APV	250 feet HAA/HAT	Public or Restricted
Non-Precision	Non-Instrument	NPA or APV	500 feet HAA/HAT	Public or Restricted
Non-Certified Aerodromes with attestation as per AC 301-001				
NAVAID/ Approach System Capability	**Aerodrome Operator Attestation Landing Surface**	**Type of Procedure**	**Minima Authorized**	**Application**
Precision	Non-Precision	PA, NPA or APV	250 feet HAA/HAT	Public or Restricted
Precision	Non-Instrument	PA, NPA or APV	500 feet HAA/HAT	Public or Restricted
Non-Precision	Non-Precision	NPA or APV	250 feet HAA/HAT	Public or Restricted
Non-Precision	Non-Instrument	NPA or APV	500 feet HAA/HAT	Public or Restricted
Non-Certified Aerodromes				
NAVAID/ Approach System Capability	**No Aerodrome Status Landing Surface**	**Type of Procedure**	**Minima Authorized**	**Application**
Precision, Non-Precision	Landing surface designed to no standards	PA, NPA or APV	500 feet HAA/HAT	Restricted

Table 1-1: Instrument Procedure & Minima Authorized Versus Aerodrome Status, Para 120.a.

Note 1: See TP312, *Aerodrome Standards and Recommended Practices*, for the definition and standards applicable to different landing surfaces (i.e. non-instrument runway, non-precision runway, and precision runway).

150. Coordination

It is necessary to coordinate terminal instrument procedures to protect the interests of all users of airspace.

a. Military Aerodromes. Military and/or civilian procedures at a military aerodrome shall be coordinated with the appropriate base authorities. When a military and/or civilian procedure conflicts with other military/civil activities it shall be coordinated with all appropriate authorities concerned. Coordination shall occur between the procedure sponsor, procedure designer, the appropriate military (DND) authorities and the appropriate civil AIS Authority.

b. Civil Aerodromes. Prior to establishing or revising terminal instrument procedures related to aircraft performance, e.g., descent profiles, the appropriate civil authority shall coordinate with the appropriate users as considered necessary. Coordination with DND is required when a military operating unit is based at a civil aerodrome or when the proximity of a military aerodrome may cause a procedural conflict. New or revised military procedures at civil aerodromes shall be coordinated by the appropriate Wing Instrument Check Pilot (WICP) and the civil AIS Authority. Complete coordination will be evidenced by the appropriate signatures being included in the Instrument Procedure Design File. Required signatures include the procedure designer, independent reviewer, flight check pilot, and applicable Air Traffic Services (ATS) representative.

c. Air Traffic Control. Prior to establishing or revising terminal instrument procedures for a military or civil aerodrome, the initiating office shall coordinate with the appropriate Air Traffic Control office.

d. Airspace Action. Where action to designate or restructure controlled airspace for a procedure is planned, such action shall be approved by Transport Canada AARTA and should be initiated sufficiently in advance so that effective dates of the procedure and the airspace action coincide. Effective dates should also coincide with approved AIRAC dates.

e. NOTAM. A NOTAM to change minimum altitudes may be issued in case of emergencies, i.e., facility outages, facility out of tolerance, new penetrations of critical surfaces, etc. However, a complete new procedure may not be issued by NOTAM, except where military requirements dictate.

151. Coordination Conflicts

Coordination conflicts amongst stakeholders that cannot be satisfactorily resolved by the AIS Authority shall be submitted to Transport Canada and/or the appropriate Military Aeronautical Authority for resolution.

152. – 159. Reserved

160. Identification of Procedures.

IFPs must be uniquely identified to permit differentiation on charts/publications, airborne equipment displays, and during ATC communications.

161. Straight-In Procedure Identification.

Instrument procedures that meet criteria for authorization of straight-in landing minima shall be identified by a prefix describing the navigational system providing the final approach guidance and the runway to which the final approach course is aligned:

a. General – The following items shall be included in procedure identification of straight-in procedures.

The acronym for the navigational system used for guidance on the final approach segment
The acronym "RWY" to denote a straight-in procedure
The runway number of the straight-in runway

Example(s): VOR RWY 18R

b. Duplicate Procedures – When there is more than one separately published procedure using the same final approach guidance to the same runway, a duplicate procedure character shall be used to uniquely identify the approach procedures. This character shall begin with "Z" and proceed through the alphabet in reverse order.

Example(s): ILS Z RWY 28L RNAV (GNSS) Z RWY 12
ILS Y RWY 28L RNAV (RNP) Y RWY 12

c. Multiple Procedures – When procedures are combined on one chart, the word 'or' shall indicate that either type of equipment may be used to execute the final approach.

Example(s): ILS or NDB RWY 02

d. DME Requirement – if DME is required for a VOR or NDB procedure, then a slash "/" followed by "DME" shall be included in the identification.

Example(s): VOR/DME RWY 18 NDB/DME RWY 27L

e. Northern Domestic Airspace – When the procedure is within northern domestic airspace and the procedure tracks are specified in true degrees, the procedure identification may be suffixed with "(TRUE)".

Example(s): RNAV (GNSS) RWY 34 (TRUE)

f. Non-RNAV – Conventional procedures identification examples include:

Category 2 or 3 Instrument Landing System (ILS CAT II or III)
..... ILS CAT II or III RWY 05
Category 1 Instrument Landing System (ILS) .....ILS RWY 24R
Microwave Landing System (MLS) ..... MLS RWY 12
Localizer Only (LOC) ..... LOC RWY 06
Localizer Back Course (LOC(BC)) ..... LOC (BC) RWY 18
VHF Omni Directional Range (VOR).....VOR RWY 27
VOR with Distance Measuring Equipment (DME) ..... VOR/DME RWY 27R

Tactical Air Navigational Aid (TACAN) ..... TACAN RWY 09

Non Directional Beacon (NDB) ..... NDB RWY 12

NDB with DME..... NDB/DME RWY 12

g. RNAV – Area Navigation (RNAV) procedures identification examples include:

Procedures with LNAV, LP, LNAV/VNAV, or LPV minimums use RNAV based on the Global Navigation Satellite System (GNSS)

..... RNAV (GNSS) RWY 12

RNAV based on Required Navigational Performance (RNP) with Authorization Required (AR)

..... RNAV (RNP) RWY 29R

Ground Based Augmentation System (GBAS) Landing System (GLS)

..... GLS RWY 06

h. Exception. High altitude approaches, prefix the navigation system with "HI-." This prefix does not eliminate the requirement to use an alphabetical suffix when more than one procedure uses the same navigational guidance to the same runway (see paragraph 161.b).

Examples: HI-TACAN RWY 31, HI-ILS X RWY 13

i. Precision runway monitor (PRM) modifier. This element is applicable to ILS, GLS, RNAV (GNSS), and LDA procedures authorized for closely spaced parallel approach operations. Include "PRM" following the navigation system (and RNAV sensor if applicable) when requested by ATC to support closely spaced parallel operations.

162. Circling Procedure Identification.

Instrument procedures which do not meet criteria for authorization of straight-in landing minima shall be identified by a prefix describing the navigational system providing the final approach guidance and an alphabetical suffix. The first procedure formulated shall bear the suffix "A" even though there may be no intention to formulate additional procedures. If additional procedures are formulated they shall be identified alphabetically in sequence. A revised procedure will bear its original identification.

Example(s): RNAV (GNSS) A VOR B
NDB/DME C (TRUE)

163. Differentiation.

Where high altitude procedures are required, the procedure identification shall be prefixed with the letters "HI".

Example(s): HI TACAN RWY 15.

164. – 169. Reserved

170. Reserved

171. Issuance

a. DND is responsible for the release of military approved instrument procedures.

b. NAV CANADA is responsible for the release and distribution of all other instrument procedures.

172. Effective Date

Instrument procedures and revisions thereto shall be processed in sufficient time to permit publication and distribution in advance of the effective ICAO, Aeronautical Information Regulation and Control (AIRAC) date. Effective dates should normally coincide with scheduled airspace changes except when safety or operational effectiveness is jeopardized. In this case the originator shall specify an appropriate effective date.

173—179. Reserved

180. TP308/GPH209 Amendment Procedures

Amendments to TP308/GPH209 should normally be produced once per year. Bases/Agencies may submit amendment proposals to DICP/Transport Canada AARTA at anytime. DICP and Transport Canada AARTA staff shall meet to review proposals for incorporation as appropriate. DND/TC Aviation will liaise with the DOD/FAA regarding U.S. TERPS.

181. Amendment Printing/Distribution

DICP and TC AARTA shall incorporate the adopted amendments into TP308/GPH209. Transport Canada AARTA shall prepare the amendment directive and coordinate the publishing requirements.

182—199. Reserved

CHAPTER 2. GENERAL CRITERIA

SECTION 1. COMMON INFORMATION

2.1 Common Information

2.1.1 Scope

This chapter contains only that information common to all types of terminal instrument procedures. Criteria that do not have general application are located in the individual chapters concerned with the specific types of facilities.

2.1.2 Required Obstacle Clearance (ROC)

a. TP308/GPH209 specifies the minimum measure of obstacle clearance that is considered by Transport Canada, to supply a satisfactory level of vertical protection. The validity of the protection is dependent, in part, on assumed aircraft performance. In the case of TP308/GPH209, it is assumed that aircraft will perform within certification requirements.

b. The following is an excerpt from the foreword of this document: "These criteria are predicated on normal aircraft operations for considering obstacle clearance requirements." Normal aircraft operation means all aircraft systems are functioning normally, all required navigational aids (NAVAID's) are performing within flight inspection parameters, and the pilot is conducting operations utilizing instrument procedures based on TP308/GPH209 standards to provide the required obstacle clearance (ROC).

c. While the application of TP308/GPH209 criteria indirectly addresses issues of flyability and efficient use of NAVAID's, the major safety contribution is the provision of obstacle clearance standards. This facet of TP308/GPH209 allows aeronautical navigation in instrument meteorological conditions (IMC) without fear of collision with unseen obstacles. ROC is provided through application of level and sloping Obstacle Clearance Surfaces (OCS).

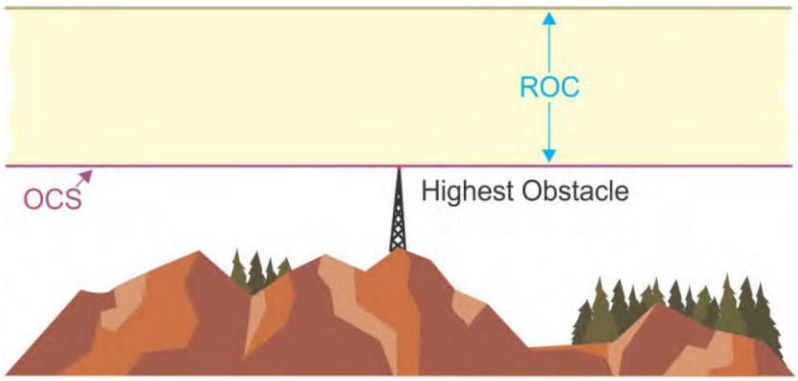
2.1.3 Level OCS

The level OCS concept is applicable to “level flight” segments. These segments are level flight operations intended for enroute, STAR, feeder, initial, intermediate, and non-precision final approach segments. A single ROC value is applied over the length of the segment. These values were determined through testing and observation of aircraft and pilot performance in various flight conditions. Typical ROC values are: for enroute procedure segments, 1,000 feet (1,500 or 2,000 over mountainous terrain), as designated in TP1820 - Designated Airspace Handbook; and for initial segments, 1,000 feet, 500 feet in intermediate segments, and 350/300/250 feet in final segments.

a. This method of applying ROC results in a horizontal band of airspace that cannot be penetrated by obstacles. Since obstacles always extend upward from the ground, the bottom surface of the ROC band is mathematically placed on top of the highest obstacle

within the segment. The depth (ROC value) of the band is added to the obstacle height to determine the minimum altitude authorized for the segment. The bottom surface of the ROC band is referred to as the level OCS. Therefore, level flight segments are evaluated by the level OCS application standard (see Figure 2-1-1).

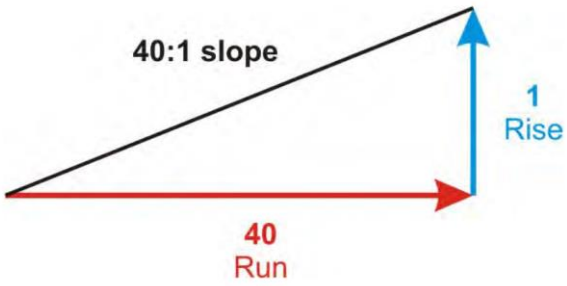
Figure 2-1-1. Minimum Segment Altitude



2.1.4 Sloping Obstacle Clearance Surfaces (OCS)

The method of applying ROC, in segments dedicated to descending on a glidepath or climbing in a departure or missed approach segment, requires a different obstacle clearance concept than the level OCS because the ROC value must vary throughout the segment. The value of ROC near the runway is relatively small, and the value at the opposite end of the segment is sufficient to satisfy one of the level surface standards as per Para 2.1.3. It follows then, that a sloping OCS is a more appropriate method of ROC application.

Figure 2-1-2. Slope Ratio

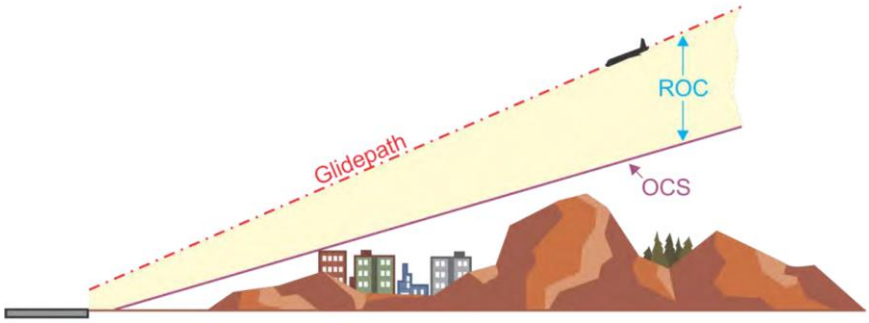


Note: Slope ratios are normally expressed in terms of rise over run in engineering and professional technical jargon. However, TP308/GPH209 has traditionally expressed slope ratios in terms of run over rise; e.g., 34:1, 40:1 (see Figure 2-1-2).

a. **Descending on a PA/APV**. The obstacle evaluation method for descent on a glidepath is the application of a descending OCS below the glidepath. The vertical distance between the glidepath and the OCS is ROC; i.e., ROC = (glidepath height) - (OCS height). The ROC decreases with distance from the FAF as the OCS and glidepath are converging towards the landing surface (see Figure 2-1-3). The OCS slope and

glidepath angle values are interdependent: OCS Slope = 102 ÷ glidepath angle; or glidepath angle = 102 ÷ OCS slope. This relationship is the standard that determines the ROC value since ROC = (glidepath height)-(OCS height).

Figure 2-1-3. PA/APV Glidepath Descent



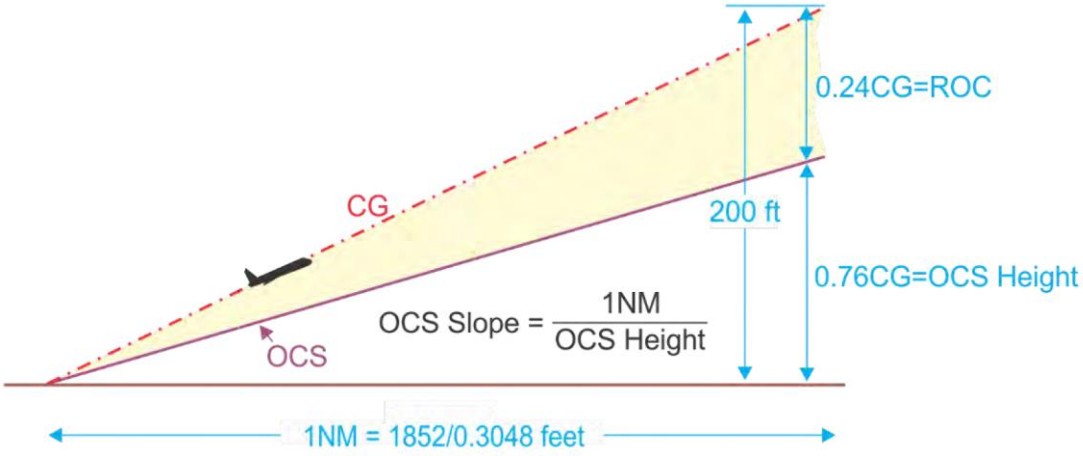
(1) If the OCS is penetrated, the OCS slope may be adjusted upward, thereby increasing the glidepath angle. The glidepath angle would increase because it is dependent on the required slope.

(2) Descent on an ILS/LPV glidepath and descent on other type of glidepath generated by systems that do not meet the system precision requirements of ICAO Annex 10, such as barometric vertical navigation (BARO-VNAV), provide ROC through application of a descending sloping surface based on standards using differing formulas, but the concept is the same.

b. **Climbing on departure or missed approach**. The concept of providing obstacle clearance in the climb segment of an Instrument Flight Procedure (IFP), is based on the aircraft maintaining a minimum climb gradient. The climb gradient must be sufficient to increase obstacle clearance along the flightpath so that the minimum ROC for the subsequent segment is achieved prior to leaving the climb segment. For TP308/GPH209 purposes, the MINIMUM climb gradient that will provide adequate ROC in the climb segment is 200 ft/NM (400 ft/NM for COPTER procedures) unless a higher gradient is specified.

(1) The obstacle evaluation method for a climb segment is the application of a rising OCS below the minimum climbing flightpath. Whether the climb is for departure or missed approach is immaterial. The vertical distance between the climbing flightpath and the OCS is ROC. ROC for a climbing segment is defined as ROC = 0.24 x CG. This concept is often called the “24 percent rule”. Altitude gained is dependent on climb gradient (CG) expressed in feet per NM. The minimum ROC supplied by the 200 ft/NM CG is 48 ft/NM (0.24 x 200 = 48). Since 48 of the 200 feet gained in 1 NM is ROC, the OCS height at that point must be 152 feet (200 – 48=152), or 76% of the CG (152 ÷ 200=0.76). The slope of a surface that rises 152 over 1 NM is 40 (6076.11548 ÷ 152 = 39.97 ≈ 40). (See figure 2-1-4)

Figure 2-1-4. Climb Segment



(2) Where an obstruction penetrates the sloping OCS, a climb gradient in excess of 200 feet/NM (400 feet/NM for COPTER procedures) is required to provide adequate ROC. Since the climb gradient will be greater than 200 ft/NM, ROC will be greater than 48 ft/NM since ROC is equal to 24% of the climb gradient. The ROC expressed in ft/NM can be calculated using the formula: ROC = (0.24 x h) ÷ (0.76 x d) where "h" is the height of the obstacle above the altitude from which the climb is initiated, and "d" is the distance in NM from the initiation of climb to the obstacle. Normally, instead of calculating the ROC value, the required climb gradient is calculated directly using the formula: CG = h ÷ (0.76 x d). Refer to Volume 2 for PBN climb gradient calculations.

Supplementary note: Military Option Climb Gradient for departure and missed approach will provide 48 ft of ROC for each NM of the flight path.

c. In the case of an instrument departure, the OCS is applied during the climb until at least the minimum enroute value of ROC is attained, except as specified in Para 12.2. The OCS begins at the departure end of runway, at the elevation of the runway end. Operationally, the aircraft will cross the departure end-of-runway at a height of at least 35 feet. However, for TP308/GPH209 purposes, aircraft are assumed to lift off at the runway end (unless the procedures state otherwise). The ROC value is zero at the runway end, and increases along the departure route until the appropriate ROC value is attained to allow enroute flight to commence.

d. In the case of a missed approach procedure, the climbing flight path starts at the height of minimum descent altitude (MDA) or decision altitude (DA) minus height loss (HL). The OCS starts approximately at the MAP/DA point at an altitude of MDA/DA minus the final segment ROC and adjustments (see Para 3.2.2). Therefore, the final segment ROC is assured at the beginning of the OCS, and increases as the missed approach route progresses. The OCS is applied until at least the minimum initial or enroute value of ROC is attained, as appropriate.

e. Extraordinary circumstances, such as a mechanical or electrical malfunction, may prevent an aircraft from achieving the minimum climb gradient assumed by TP308/GPH209. In these cases, adequate obstacle clearance may not be provided by

published instrument procedures. Operational procedures contained outside TP308/GPH209 guidelines are required to cope with these abnormal scenarios.

2.1.5 Units of Measurement

a. **Bearings, Courses and Radials.**

(1) Bearings and courses shall be expressed in degrees magnetic, except that true and/or grid shall be used within the Northern Domestic Airspace;

(2) Radials. VOR/TACAN radials shall normally be identified as the magnetic bearing FROM the facility and shall be prefixed with the letter "R" (e.g., R-130). When the facility is within the Northern Domestic Airspace and is oriented with grid (DND) or true north, radials shall be so indicated (e.g., R-130G, R-130T).

b. **Altitudes**. The unit of measure for altitude in this publication is feet

(1) Published altitudes in the areas of the Altimeter Setting Region shall be expressed in feet above MSL, e.g. 17,900 feet. Published altitudes above the transition level (18,000 ft.) shall be expressed as flight levels (FL); e.g. FL190. Normally, altitudes at the transition level will not be used.

(2) MSA, 100 NM Safe Altitude, TAA and Fix/WP up to the FAF, as well as the MA altitudes are rounded up to the next higher 100 foot increment;

(3) All other altitudes expressed in the approach shall be rounded off to the next higher 20-foot increment, except the ILS glide path check altitude which shall be rounded off to the nearest 10-foot increment.

(4) DA and DH values shall be rounded off to the next higher 1-foot increment.

c. **Distances**. Distances are to be expressed in nautical miles (6,076.11548 feet or 1852.0 meters per NM) and hundredths thereof, except:

(1) Where feet are required,

(2) Visibilities are expressed in statute miles (5280 feet per SM) and fractions thereof (see Chapter 3 Section 3); and

(3) Runway Visual Range (RVR) is expressed in multiples of one hundred feet by increments of:

(a) 200 feet from 600 feet to 3,000 feet; and

(b) 500 feet from 3,000 feet to 6,000 feet.

Use the following formulas for feet and meter conversions:

$$\text{feet} = \frac{\text{meters}}{0.3048} \qquad \text{meters} = \text{feet} \times 0.3048$$

d. **Speeds**. Aircraft speeds shall be expressed in knots indicated airspeed (KIAS).

2.1.6 Positive Course Guidance (PCG)

Positive Course Guidance (PCG) is achieved where pilots receive a continuous display of navigation data which enable the aircraft to be flown along a specific course line or track. For courses based on a ground-based navigation facility, PCG is possible only within the standard or expanded service volume of the facility. PCG shall be provided for feeder routes, initial (except as provided for in Para 2.3.4.b), intermediate, and final approach segments.

2.1.7 Aircraft Categories (CAT)

Aircraft performance differences have an effect on the amount of airspace and the visibility, required for maneuvering during instrument procedures. Because of these differences, aircraft manufacturer/operational directives assign an alphabetical category to each aircraft. The categories used and referenced throughout this document are CAT A, B, C, D, and E. For helicopter-only approaches, COPTER is an authorized category. The authorized CAT must be used to determine obstacle evaluation areas (OEAs) for circling and missed approaches and used to establish landing minimums.

a. Category A — speed less than 91 knots
b. Category B — speed 91 knots or more but less than 121 knots
c. Category C — speed 121 knots or more but less than 141 knots
d. Category D — speed 141 knots or more but less than 166 knots
e. Category E — speed 166 knots and greater

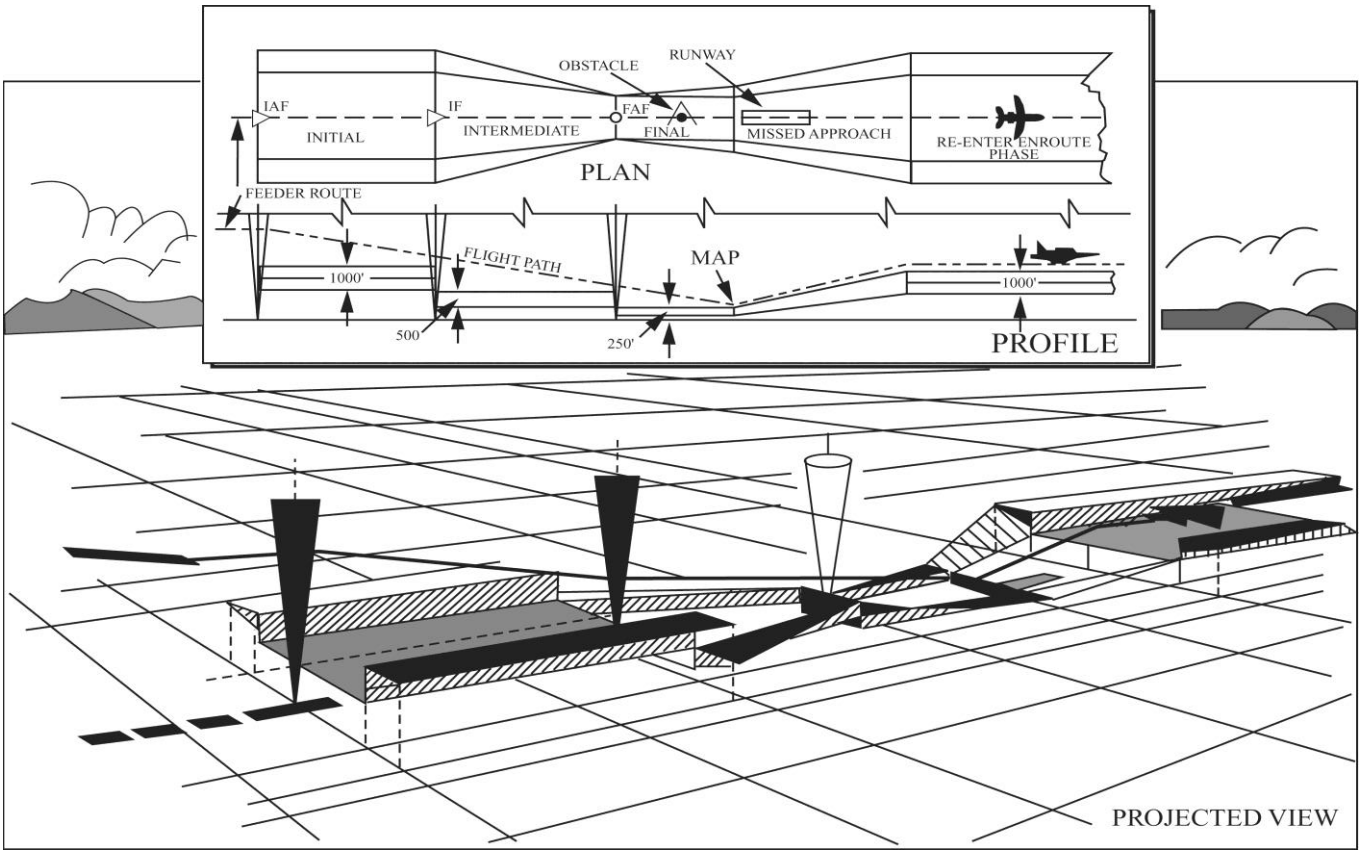
2.1.8 Aircraft Category Application

The approach category operating characteristics shall be used to determine turning radii, minimums, and obstacle clearance areas for circling, missed approach and certain departure procedures. When designing an instrument procedure, Category A, B, C and D normally will be considered for civil procedures and Category B, C, D and E will be considered for military procedures.

2.1.9 Procedure Construction

An instrument approach procedure (IAP) may have four separate segments. They are the initial, the intermediate, the final, and the missed approach segments. In addition, an area for circling the airport under visual conditions shall be considered. An approach segment begins and ends at the plotted position of the fix; however, under some circumstances certain segments may begin at specified points where no fixes are available. The fixes are named to coincide with the associated segment. For example, the intermediate segment begins at the intermediate fix (IF) and ends at the final approach fix (FAF). The order in which this chapter discusses the segments is the same order in which the pilot would fly them in a completed procedure; that is from an initial, through an intermediate, to a final approach. Only those segments that are required by local conditions need to be included in a procedure. In constructing the procedure, the final approach course (FAC) should be identified first because it is the least flexible and most critical of all the segments. When the final approach has been determined, the other segments should be blended with it to produce an orderly maneuvering pattern that is responsive to the local traffic flow. Consideration shall also be given to any accompanying controlled airspace to the extent it is feasible (see Figure 2-1-5).

Figure 2-1-5. Segments of an Approach Procedure



2.1.10 Instrument Procedures And Class "F" Airspace

Instrument procedures may come in conflict with Class “F” airspace. Normally, the primary area obstacle clearance surface shall not penetrate the Class “F” airspace, however, instrument approach procedures may exist within Class “F” airspace when it is established for security reasons.

The vertical clearance from Class “F” airspace will vary depending upon the activity within the Class “F” airspace and the potential for conflict. The ROC for the instrument approach procedure segment overlying the Class “F” should be used as a guideline to establish a separation with Class “F” airspace. In no case shall the separation be less than 100 feet.

a. Where Class “F” restricted or advisory airspace has been established for military purposes or flight training activities, then the maximum ROC shall be applied for separation purposes.

b. Where Class “F” restricted airspace has been established for security reasons e.g. over a prison, the instrument procedure designer may elect to use a minimum of 100 feet of separation.

c. Where Class “F” restricted airspace has been established for security reasons, e.g. visiting dignitaries, instrument procedures may exist within the Class “F”, and authorization to fly the procedure may be given by the Controlling Agency.

d. For missed approach and departure procedures Class F airspace shall not penetrate the OCS.

Note: Where Class “F” airspace influences an instrument procedure, the type of activity within the Class “F” shall be documented, as well as the amount of separation that has been applied. Other known areas that could constitute a hazard, such as known blasting areas, fireworks (certified by Natural Resources Canada based on the “National Fireworks Certification Program”), should be treated as Class “F” airspace and documented.”

2.1.11 Controlling Obstacle(s)

The controlling obstacle in the segments of procedure shall be identified in the documentation submitted with the procedure. The minimum accuracy standards (Annex E, paragraph 2.11) apply to all controlling obstacles. For sloping surface evaluations, the standard in Annex E, paragraph 2.11.5, shall be used to identify the controlling obstacles.

2.1.12 Obstacle Height Assessments

When assessing contour lines on a topographical map to determine obstacle height, the accepted method is to use the contour that is on or in the trapezoid being assessed. To this figure, add the next contour interval MINUS one contour unit (foot/meter as appropriate). If the area is treed, then the average tree height (determined from local forestry authorities) is added to the terrain elevation. A survey or a well-documented flight validation process may confirm controlling obstacle elevations that are questionable.

In determining the height of mobile objects, the following standard shall be used:

a. 17.0 feet for mobile obstacles traversing multi-lane controlled access highways where over crossings are designed for a maximum of 17.0 feet vertical distance;

b. 15 feet for any other public roadway;

c. for a private roadway, 10 feet or the height of the highest mobile object, whichever is greater, that would normally traverse the road;

d. 23 feet for a railroad; and

e. for a waterway or any other traverse way not previously mentioned, an amount equal to the height of the highest mobile object that would normally traverse it.

SECTION 2. FEEDER ROUTES/EMERGENCY SAFE AREA/ STANDARD TERMINAL ARRIVAL (STAR)

2.2 Feeder Routes/Emergency Safe Areas/Standard Terminal Arrival (STAR)

2.2.1 Feeder Routes

Establish non-radar feeder routes where the IAF is not part of the enroute structure and where preferred over other options [for example, radar vectors, terminal arrival area (TAA)]. Limit the number of feeder routes where radar vectoring is provided on a 24-hour basis, but where practical provide at least one route per location to account for radar/communications failure. Feeder routes originate at a navigation facility or named fix on an airway and terminate at another feeder fix or at an IAF. The feeder route must not extend beyond the operational service volume of the facility which provides navigational guidance.

a. Alignment.

(1) The angle of intersection between a ground-based feeder route course and the enroute structure must not exceed 120 degrees.

(2) The angle of intersection between a ground-based feeder route course and the next segment (feeder/initial) course must not exceed 120 degrees except when connecting to a course reversal segment. .

(3) Do not establish a feeder route that terminate at a course reversal fix if both the angle of intersection between the route and the segment that follows the course reversal fix is 120 degrees or less (90 degrees or less for RNAV), and if the required descent is within initial segment limitations (see paragraph 2.3.3.). Under these conditions, the route must be developed as an initial segment based on straight course criteria.

b. Area. For routes based on ground-based NAVAIDs, apply chapter 17. When connecting to a course reversal segment, the area terminates at a line perpendicular to the feeder course through the course reversal fix.

c. Obstacle clearance. Feeder routes greater than 25 NM shall have airways obstacle clearance (see Chapter 17), however feeder routes that are 25 NM or less may have 1000 feet ROC applied. . The published minimum feeder route altitude must provide at least the minimum ROC value and must not be less than the altitude established at the IAF. Establish minimum altitudes in 100-foot increments; when necessary round to the next higher 100-foot increment (for example, when obstacle elevation plus ROC equals 3001, round up to 3100).

d. Descent gradient. The optimum descent gradient in the feeder route is 250 ft/NM. Where a higher descent gradient is necessary, the maximum gradient is 500 ft/NM. The optimum descent gradient for feeder routes associated with high altitude procedures is 800 ft/NM. Where a higher descent gradient is necessary, the maximum gradient is 1000 ft/NM.

2.2.2 Minimum Sector Altitude (MSA)

For all approach procedures, establish an MSA within a 25-NM radius of a specified point for use during emergency situations. See figure 2-2-1.

a. Altitude selection. Specify altitudes in 100-foot increments; when necessary round to the next higher 100-foot increment (for example, when obstacle elevation plus ROC equals 1501, round up to 1600).

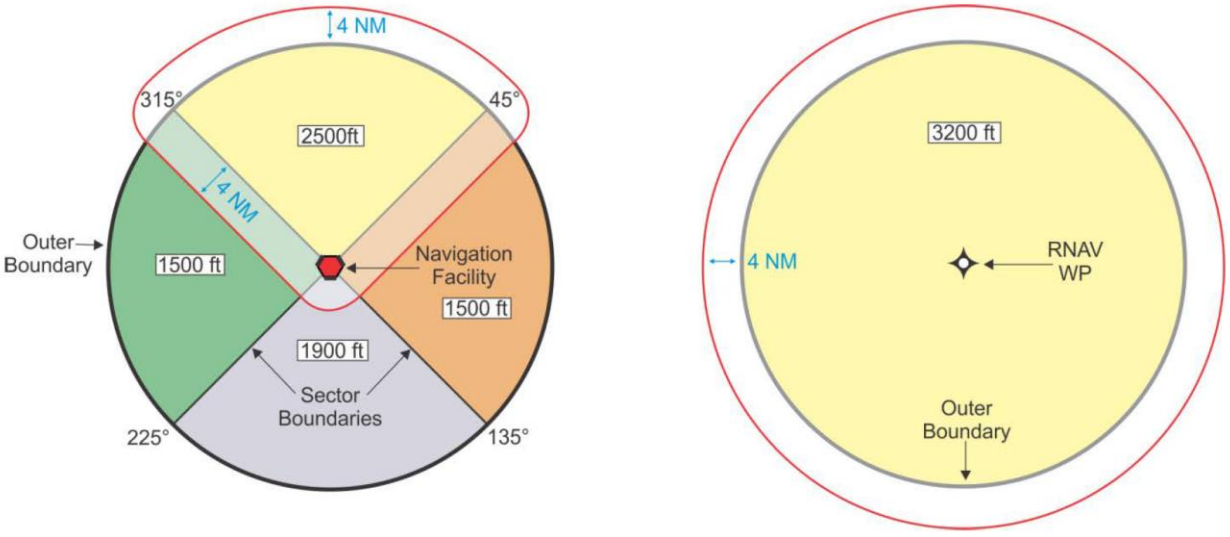
b. Area.

(1) Non-RNAV procedures. Center the MSA on the omni-directional facility upon which the procedure is based. When the distance from the facility to the airport exceeds 25 NM, extend the radius to include the airport landing surfaces up to a maximum distance of 30 NM. When the procedure does not use an omnidirectional facility (for example, an ILS), use the primary omnidirectional facility in the area. If no omni-directional NAVAID is located within 30 NM of the airport landing surfaces, then center the MSA on the aerodrome reference point (ARP). Establish a common area (no sectors) around the facility or ARP. If necessary to offer relief from obstacles, sector divisions may be established for an MSA based on a facility. Sectors must not be less than 90 degrees in spread.

(2) RNAV procedures. For RNAV straight-in approach procedures, and GNSS-based RNAV circling procedures, establish a common safe altitude within the specified radius of the runway threshold (preferred) or the MAP waypoint (WP); for RNAV (VOR/DME) circling procedures use the airport waypoint (APT WP).

c. Obstacle clearance. Common safe altitudes and sector altitudes must provide 1000 feet of obstacle clearance to include a 4-NM buffer area beyond the 25-NM radius, and a 4-NM buffer area in any adjacent sector. Sector altitudes should be raised and combined with adjacent higher sectors when the altitude difference is 300 feet or less.

Figure 2-2-1. MSA



2.2.3 Safe Altitude 100 NM

A safe altitude shall be established within a 100-NM radius of the aerodrome reference point. Where a requirement exists for these altitudes, these shall be established with a common altitude for the entire area. Where these altitudes are established in designated mountainous

regions, they shall provide the appropriate obstacle clearance, either 1,500 or 2,000 feet. These altitudes shall be identified in published procedures as "Safe Altitude 100 NM".

Notes:

(1) With respect to the 100 NM safe altitudes, only the obstacles located within the designated mountainous regions receive the mountainous ROC, other obstacles receive the normal 1000 ft ROC

(2) Use 2000 ft of ROC over eastern U.S. designated mountainous terrain areas.

2.2.4 STAR, Descent Gradient (DG).

Calculate DGs between fixes with an altitude restriction by using the guidance in this paragraph and the calculation methods in Vol 1 Chapter 2 Section 8. When deceleration is required, also use paragraphs 2.2.5 and 2.2.6. Normally, the DG past the termination fix of the STAR is not calculated as part of the STAR design; the overall airspace design should optimize the location and altitude for the STAR termination fix and that becomes an input to the STAR design.

a. The maximum DG (see figure 2-2-3) is based on altitude, deceleration, and airspeed constraints, as follows:

(1) The maximum permissible DG 10000 feet MSL and above is 330 ft/NM (approximately 3.11 degrees).

(2) The maximum permissible DG below 10000 feet MSL is 318 ft/NM (approximately 3.0 degrees).

(3) When a STAR contains a descent between fixes that passes through 10000 feet MSL, the maximum permissible DG is between 318 ft/NM and 330 ft/NM and is in proportion to the amount of the altitude change that is below/above 10000 feet MSL. Use formula 2-2-1 to determine the maximum DG (DG_{max}) between fixes that contain a descent that passes through 10000 feet MSL.

Formula 2-2-1. Maximum DG Passing Through 10000 Feet MSL (ft/NM)

$$DG_{max} = \frac{(Alt_1 - 10000) \times 12}{(Alt_1 - Alt_2)} + 318$$

Where:
Alt_1 = Altitude at the fix prior to crossing 10000 feet MSL
Alt_2 = Altitude at the fix after crossing 10000 feet MSL

Example 1: From BRAVO to CHRLY in figure 2-2-3, the altitude of 11000 minimum at BRAVO and 9000 maximum at CHRLY, will have 1/2 of the gradient at 330 ft/NM and 1/2 at 318 ft/NM, Maximum DG = (11000 – 10000) × 12 / (11000 – 9000) + 318 = 324.

Example 2: In the previous example if there were no altitude restrictions at BRAVO, the gradient applies from ALPHA to CHRLY. Maximum DG = (19000 – 10000) × 12 / (19000 – 9000) + 318 = 328.8.

Example 3: From GOLFF to HOTEL in figure 2-2-4, the mandatory altitude of 15000 at GOLFF and a mandatory altitude of 4000 at HOTEL, will have 5/11 of the gradient at 330 ft/NM and 6/11 at 318 ft/NM, Maximum DG = (15000 – 10000) × 12 / (15000 – 4000) + 318 = 323.45.

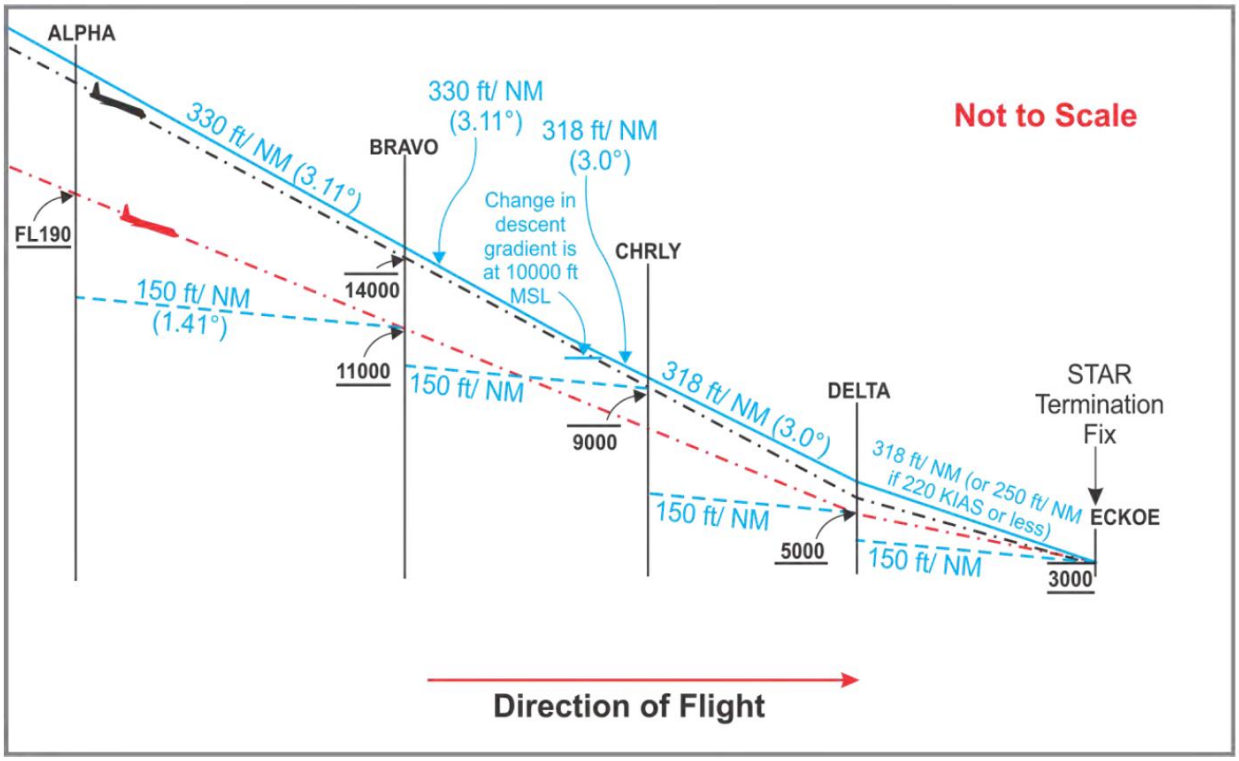
Note: Descent below 10000 feet MSL requires a deceleration calculation unless an airspeed restriction of 250 KIAS or less exists prior to the point where the descent below 10000 feet MSL occurs.

(4) Gradient after deceleration to 220 KIAS. After a speed restriction of 220 KIAS or less is used, for subsequent fixes along the route of the STAR the maximum permissible descent gradient is 250 ft/NM (approximately 2.36 degrees).

(5) Evaluation of a fix with no altitude restriction. The evaluation is done from the previous fix that has an altitude restriction to the subsequent fix that has an altitude restriction using the overall distance between the fixes with the restrictions.

(6) If more than one of paragraphs 2.2.4.a(1) through 2.2.6.a(5) applies, use the lower of the resulting values for the maximum DG.

Figure 2-2-3. Altitude Restrictions and Maximum Descent Gradient



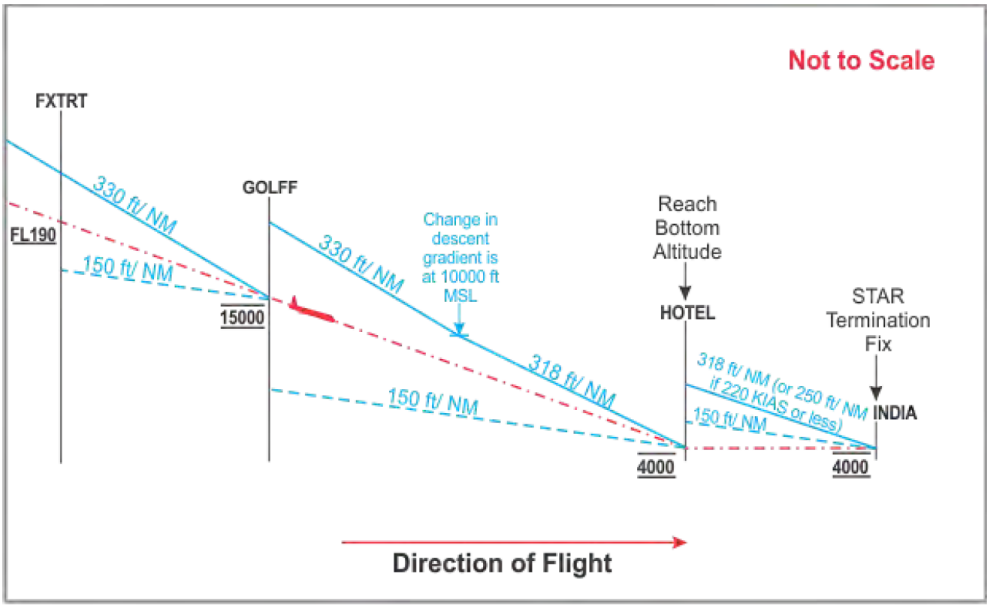
b. When a gradient exceeds the maximum DG allowed in paragraph 2.2.4.a, the STAR is non standard (see Vol 1, paragraph 141).

c. The descent gradient between any two consecutive fixes with an altitude restriction should be at least 150 ft/NM (approximately 1.41 degrees). Descent gradients of less than 150 ft/NM (or no descent as depicted between HOTEL and INDIA in figure 2-2-4) should not be used except to support an operational requirement.

d. Figure 2-2-3 and figure 2-2-4 illustrate examples of STAR design. Figure 2-2-3 shows different flight paths to illustrate the recommended design of allowing some flexibility in

the descent, preferably through the use of minimum altitudes. Figure 2-2-3 shows the recommended design of all altitude constraints being on or above the 150 ft/NM line; an ATC and/or airspace requirement is shown in figure 2-2-4 with no descent between HOTEL and INDIA. The solid blue line, depicting the maximum descent gradient, depicts the upper design limit for fixes prior to an altitude constraint. As shown in figure 2-2-4, the use of mandatory altitude constraints reduces the range of altitudes allowed at previous fixes and may result in an inefficient descent for aircraft on the STAR.

Figure 2-2-4. Altitude Restrictions With Mandatory Altitudes



2.2.5 STAR, Speed Restrictions.

Minimize the use of speed restrictions as much as practicable. Optimum values are 280 KIAS above 10000 feet MSL and 240 KIAS below 10000 feet MSL.

a. Speed restrictions above FL 200 should only be published to support an operational requirement.

b. Do not establish more than one speed restriction per fix (for example, one speed applicable to jets and one applicable to props).

c. If a STAR terminates at a fix charted on an approach procedure, and the fix has a charted speed restriction, then you may establish a speed restriction on the STAR with the same numerical airspeed value. The STAR's speed restriction could be a mandatory ("at") speed restriction or maximum ("at or below") speed restriction and the approach procedure could have a maximum ("at or below") speed restriction.

d. If a STAR terminates at a fix charted on an instrument approach procedure, and the fix does not have a speed restriction, then verify if the approach procedure contains a speed restriction located prior to the fix. If the approach procedure contains a speed restriction, then establish the same numerical speed restriction at or prior to the fix.

2.2.6 STAR, Deceleration.

Sufficient distance and a reduced descent gradient are required prior to any fix with a speed restriction.

a. Where deceleration is required but descent is not permitted (for example, between two fixes with the same mandatory altitudes) or is not required (for example, between two fixes with the same minimum altitudes), provide a minimum distance of at least 4 NM prior to a fix with a speed reduction of 40 KIAS or less. For deceleration greater than 40 KIAS, allow 1 NM between fixes for every 10 knots of deceleration required. For example, a deceleration of 10, 20, 30, or 40 KIAS requires a minimum length of 4 NM; a deceleration of 50 KIAS requires a minimum length of 5 NM; a deceleration of 60 K IAS requires 6 NM.

b. When descent is permitted, the descent gradient leading to the fix with the speed restriction must be reduced. Apply formula 2-2-2 to determine the minimum deceleration distance ($\boldsymbol{Decel_D}$) required before the fix; the greater distance leads to a reduced descent gradient.

   (1) In determining the applicable formula gradient value, “G,” use 330 ft/NM (approximately 3.11 degrees) when the ending speed restriction is greater than or equal to 250 K IAS; use 318 ft/NM (approximately 3.0 degrees) when the ending speed restriction is less than 250 KIAS but greater than 220 KIAS; use 250 ft/NM (approximately 2.36 degrees) when the ending speed restriction is 220 KIAS or less.

   (2) In determining “K,” use 310 KIAS, or the previous speed restriction if less than 310 knot s, as the reference speed at or above 10000 feet MSL. For the reference speed below 10000 feet MSL, use 250 KIAS or the previous speed restriction if less. For a block altitude, use the minimum altitude when selecting 310 or 250 to use to determine the “K” value.

   (3) The first altitude restriction that is below 10000 feet MSL requires a deceleration evaluation unless an airspeed restriction of 250 KIAS or less exists prior to the point where descent below 10000 feet MSL occurs. If no speed is published at the first altitude restriction that is below 10000 feet MSL, then use the lower of 250 KIAS or the previous speed restriction (if applicable). When the first fix that allows descent below 10000 feet MSL has no charted speed restriction and the altitude constraint allows continued flight above 10000 feet MSL, the calculation is extended to the subsequent fix using the total descent and total distance for the applicable fixes.

   (4) Some examples are as follows: If deceleration from a fix with no speed restriction to 280 KIAS is required above 10000 feet MSL, then “K” is equal to 3 NM(K = 310-280 / 10). If an aircraft is decelerating from a fix with a speed restriction of 280 KIAS to a fix with no speed restriction that is below 10000 feet MSL, use 250 KIAS as the reference airspeed; then “K” is equal to 3 NM(K = 280-250 / 10). If an aircraft is decelerating from a fix with no speed restriction that is below 10000 feet MSL, use 250 KIAS as the reference airspeed for the deceleration to the next fix; if the deceleration is to a fix with a speed restriction of 230 KIAS, then “K” is equal to 2 NM(K = 250-230 / 10).

Formula 2-2-2. Minimum Deceleration Distance (NM)

$$\boldsymbol{Decel_D = \frac{Alt_1 - Alt_2}{G} + K}$$

Where:
$\boldsymbol{Alt_1}$ = Minimum altitude at the fix prior to the speed restriction.
$\boldsymbol{Alt_2}$ = Minimum altitude at the fix with the speed restriction.
G = The applicable gradient value (330/318/250).
K = 1 NM for every 10 KIAS of deceleration required.

Example 1: If the termination fix has a mandatory altitude of 3000 feet and a published speed restriction of 210 KIAS and is preceded by a fix with a minimum altitude of 7500 feet and a published speed restriction at or before that fix of 230 KIAS, the values are: $\boldsymbol{Alt_1}$ -$\boldsymbol{Alt_2}$ = 4500 feet (7500-3000); G = 250, based on an ending speed of 220 KIAS or less; K = 2 NM (K = 230-210 / 10); $\boldsymbol{Decel_D}$ = 20 NM ($\boldsymbol{Decel_D}$= 4500/250 + 2) and the resulting descent gradient will be no more than 225.0 ft/NM (DG = 4500 / 20).

Example 2: In example 1, if the preceding fix has no speed restriction, use 250 KIAS based on the altitude of 7500 feet being below 10000 feet MSL (or previous speed restriction if less than 250 KIAS). The values are: $\boldsymbol{Alt_1}$ -$\boldsymbol{Alt_2}$ = 4500 feet; G = 250, K = 4 NM (K = 250-210 / 10); $\boldsymbol{Decel_D}$= 22 NM ($\boldsymbol{Decel_D}$= 4500/250 + 4). The resulting descent gradient will be no more than 204.5 ft/NM (DG = 4500 / 22).

SECTION 3. INITIAL APPROACH

2.3 Initial Approach

2.3.1 Initial Approach Segment

The instrument approach commences at the IAF. In the initial approach the aircraft has departed the enroute phase of flight, and is maneuvering to enter the intermediate segment. When the IF is part of the enroute structure, it may not be necessary to designate an initial approach segment. In this case the approach commences at the IF and intermediate segment criteria apply. An initial approach may be made along an arc (DME), radial, course, heading, radar vector, or a combination thereof. Procedure turns, holding pattern descents, and high altitude penetrations are initial segments. Positive course (track) guidance is required except when dead reckoning (DR) courses can be established over limited distances. Although more than one initial approach may be established for a procedure, the number should be limited to that which is justified by traffic flow or other operational requirements. Where practical, establish at least one initial segment that does not require a course reversal. Where holding is required prior to entering the initial approach segment, the holding fix and IAF should coincide. When this is not possible the IAF shall be located within the holding pattern on the inbound holding course. Where alignment and/or descent gradient cannot be met and/or where otherwise operationally advantageous, initial segments requiring a course reversal may be established such as a procedure turn (PT), holding pattern descent, or high altitude teardrop turn.

a. When the IAF is part of the enroute structure, the angle of intersection between the enroute structure and a ground-based initial approach segment course must not exceed 120 degrees. For RNAV routes, apply Vol 2.

b. When the IF is part of the enroute structure, it may not be necessary to establish an initial approach segment. In this case, the fix is designated as an IF/IAF and intermediate segment standards apply (see section 2.5).

c. When the IAF is collocated with an IF (for example, in the case of a course reversal over the IF), the fix is also designated as an IF/IAF. The course reversal is considered to be the initial segment.

d. Where holding is required prior to entering the initial approach segment, the holding fix and IAF should coincide. When this is not possible, the IAF must be located within the holding pattern on the inbound holding course.

2.3.2 Altitude Selection

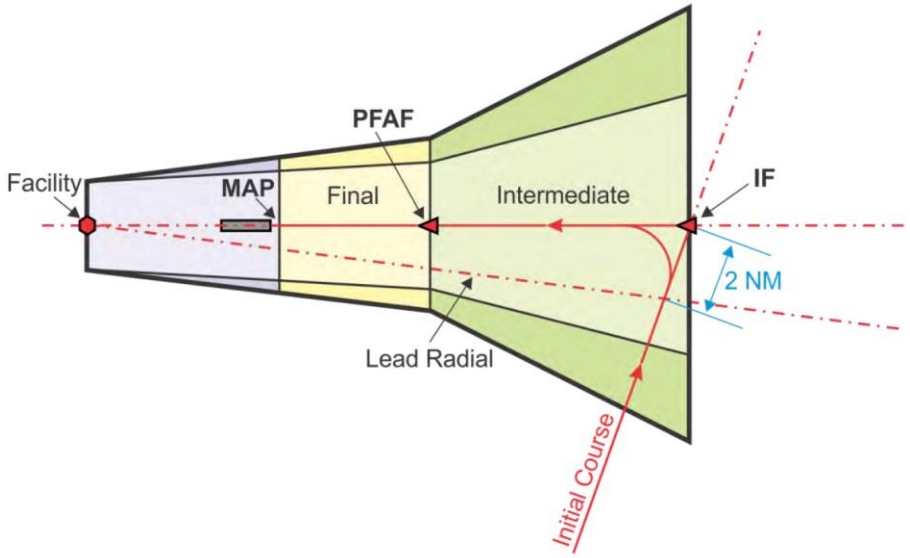
Minimum altitudes in the initial approach segment shall be established in 100-foot increments. The selected altitude must provide the minimum ROC (plus adjustments as specified by paragraph 3.2.2); for example, when obstacle elevation plus ROC equals 1501, round up to 1600. The altitude selected shall not be below the PT altitude where a PT is required. In addition, altitudes specified in the initial approach segment must not be lower than any altitude specified for any portion of the intermediate or final approach segments.

2.3.3 Initial Approach Segments Based On Straight Courses And Arcs With Positive Course Guidance (PCG)

a. **Alignment**.

(1) **Straight Courses**. The angle of intersection between two successive initial approach courses, or the angle between the initial approach course and the intermediate course shall not exceed 120°. When the angle is 90° or greater, a lead radial/bearing, which provides 2 NM of lead, shall be identified to assist in leading the turn onto the intermediate course (see Figure 2-3-1).

Figure 2-3-1: Initial approach interception angle greater than 90 degrees



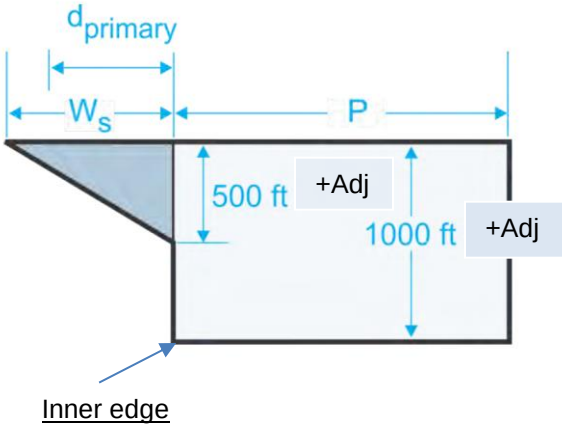
(2) **Arcs**. A DME arc may provide course guidance for all or a portion of an initial approach. The minimum arc radius shall be 7 NM, except for high altitude procedures, in which the minimum radius shall be at least 15 NM. When an arc of less than 15 NM radius is used in high altitude procedures, the descent gradient along the arc shall not exceed the criteria in Para 2.3.3.d and Table 2-3-1. An arc may join a course at or before the IF. When joining a course on or before the IF, the angle of intersection of the arc and the fix course shall not exceed 120°. When the angle is 90° or greater, a fix, lead radial or lead bearing which provides at least 2 NM of lead shall be identified to assist in leading the turn onto the intermediate course. DME arc courses should be predicated on collocated VOR/DME, NDB/DME or TACAN facilities. Where an operational advantage can be achieved non-collocated facilities may be used providing the two facilities are within 4 NM of each other and the angle subtended by the line joining the aircraft to the DME source and the bearing to the track guidance facility does not exceed 8°.

Formula 2-3-1. Distance Flown Along Arc, Distance to Lead Radial/Bearing.	
Math Notation	$D_{ARC} = \frac{Radius * Angle}{57.3}$ $LRorLB = \frac{(2 * 57.3)}{Radius}$
Standard Text	D_{ARC} = (Radius * Angle) / 57.3 LR or LB = (2 * 57.3) / Radius
Given Values	
Radius =	Radius of arc flown (NM)
D_{ARC} =	Distance flown along arc (NM)
LR or LB =	Lead Radial (LR) or Lead Bearing (LB)
Angle =	number of degrees of arc flown

b. **Area**. The initial approach segment has no standard length. The length shall be sufficient to permit the altitude change required by the procedure and shall not exceed 50 NM unless an operational requirement exists. The total width of the initial approach segment shall be 6 NM on each side of the initial approach course. This width is divided into a primary area, which extends laterally 4 NM on each side of the course, and a secondary area, which extends laterally 2 NM on each side of the primary area (see Figure 2-3-1). When any portion of the initial approach is more than 50 NM from the navigation facility, the criteria for enroute airways shall apply to that portion.

c. **Obstacle Clearance**. The obstacle clearance in the initial approach primary area shall be a minimum of 1,000 feet. In the secondary area 500 feet of obstacle clearance shall be provided at the inner edge, tapering uniformly to zero feet at the outer edge (see Figure 2-3-2). Allowance for precipitous terrain should be made, as specified in Para 3.2.2.b. & c. The altitudes selected by application of the obstacle clearance specified in this paragraph shall be rounded to the next higher 100-foot increment (see Para 2.3.2.).

Figure 2-3-2. Straight/Arc Initial Segment Minimum ROC



Formula 2-3-2. Straight/Arc Initial Segment Minimum Secondary ROC

$$ROC_{Secondary} = (500 + adj) \times \frac{(W_S - d_{primary})}{W_S}$$

Where:

$d_{primary}$ = perpendicular distance form primary inner edge to obstacle (ft)

W_S = Width of secondary area (ft)

adj= adjustments (ft) as per Para 3.2.2

d. **Descent Gradient. T**he OPTIMUM descent gradient in the initial approach is 250 feet per nautical mile. Where a higher descent gradient is necessary, the MAXIMUM gradient is 500 feet per nautical mile. The OPTIMUM descent gradient for high altitude penetrations is 800 feet per nautical mile. Where a higher descent gradient is necessary, the MAXIMUM gradient is 1,000 feet per nautical mile. When an arc of less than 15 NM is used in high altitude procedures, the descent gradient along the arc must not exceed the values in table 2-4-1 (values may be interpolated). The maximum descent gradient for a high altitude arc of less than 15 NM radius is found in Table 2-3-1.

Table 2-3-1: Descent Gradient on High Altitude Arc.

Arc Radius (NM)	Max ft/NM
≥15	1,000
14	720
13	640
12	560
11	480
10	400
9	320
8	240
7	160

2.3.4 Initial Approach Segment Based On Dead Reckoning (DR)

a. **Alignment**. Each DR course shall intercept the extended intermediate course. For LOW altitude procedures the intercept point shall be at least 1 NM from the IF for each 2 NM of DR flown. For HIGH altitude procedures the intercept point shall be 1 NM prior to the IF for each 3 NM of DR flown. The intercept angle shall:

(1) not exceed 90 degrees; and

(2) not be less than 45 degrees except when DME is used or the DR distance is 3 NM or less.

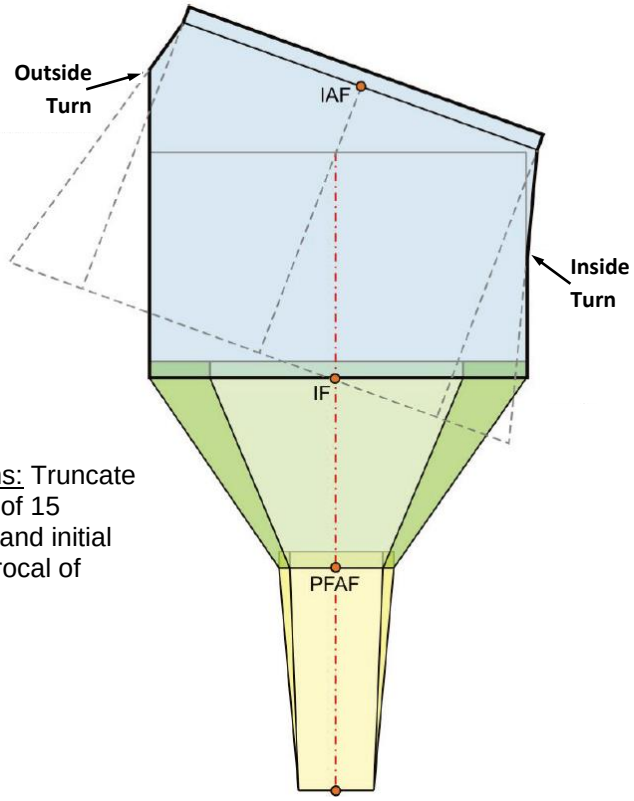
b. **Area**. The MAXIMUM length of the DR portion of the initial segment is 10 NM (except Para 2.3.3.b applies for HIGH altitude procedures where DME is available throughout the DR segment). Where the DR course begins, the width is 6 NM on each side of the

course, expanding outward by 15 degrees until joining the points as depicted in Figures 2-3-3, 2-3-4, 2-3-5, 2-3-6, and 2-3-7.

c. **Obstacle Clearance**. The minimum ROC in the DR initial approach segment is 1000 feet. There is no secondary area. Allowance for precipitous terrain shall be considered as specified in Para 3.2.2.b. & c. The altitudes selected by application of the obstacle clearance specified in this paragraph shall be rounded in accordance with Para 2.3.2.

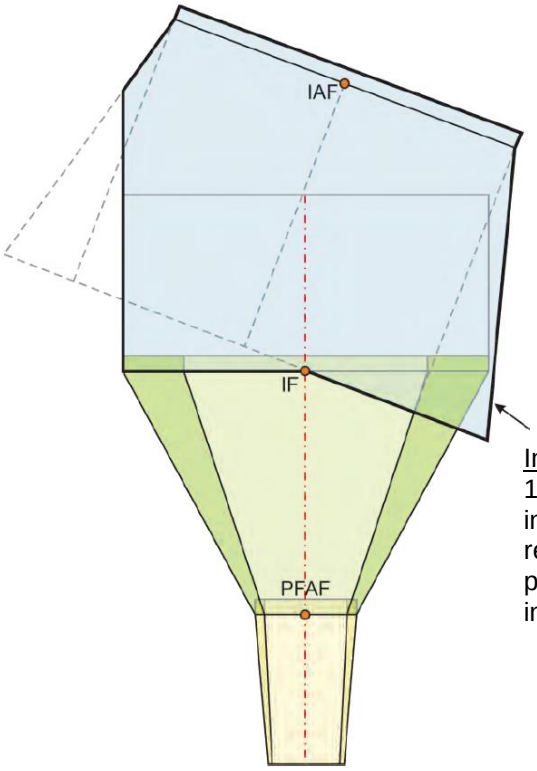
d. **Descent Gradient**. The OPTIMUM descent gradient in the initial approach is 250 ft/NM. Where a higher descent gradient is necessary, the maximum permissible gradient is 500 ft/NM. The OPTIMUM descent gradient for high altitude penetrations is 800 ft/NM. Where a higher descent gradient is necessary, the maximum permissible gradient is 1000 ft/NM.

Figure 2-3-3: Example DR Segment



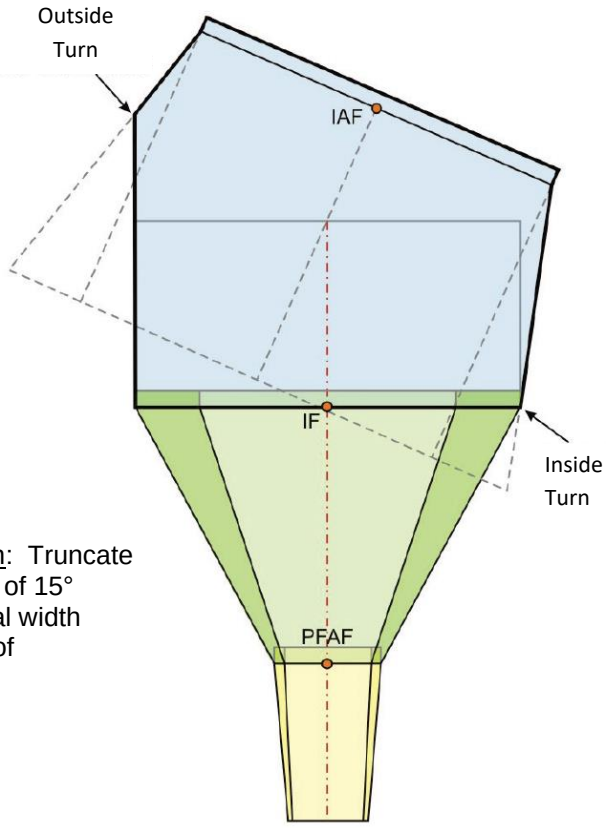
Outside and Inside Turns: Truncate segment at intersection of 15 degrees expansion line and initial width centered on reciprocal of intermediate

Figure 2-3-4: Example DR Segment



Inside Turn: Do not truncate when 15 degree expansion line does not intersect initial width centered on reciprocal of intermediate. When this part of the initial dies not overlap the intermediate. DME is required.

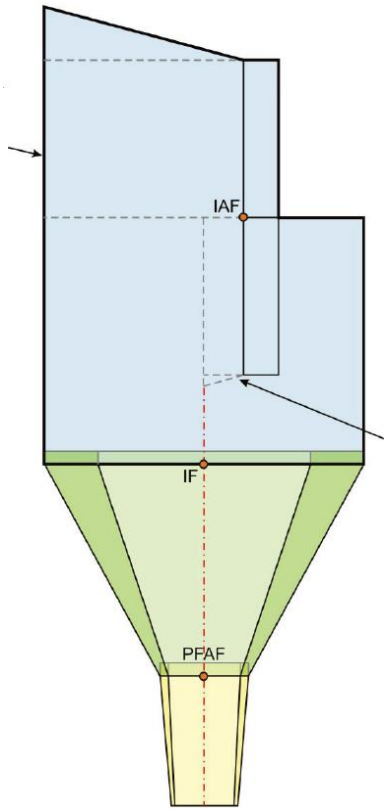
Figure 2-3-5: Example DR Segment



Outside and Inside Turn: Truncate segment at intersection of 15° expansion line and initial width centered on reciprocal of intermediate.

Figure 2-3-6: Example DR Initial Segment

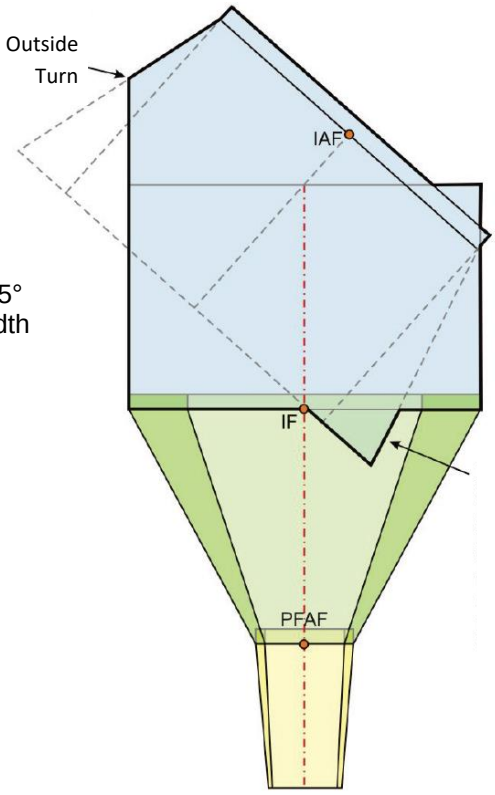
Outside Turn: Extend segment to intersection of 15° expansion line and initial width centered on reciprocal of intermediate.



Inside Turn: Do not truncate when 15° expansion line does not intersect initial width centered on reciprocal of intermediate. Continue to expand until reaching line perpendicular to DR course abeam IF.

Figure 2-3-7: DR Initial Segment With Boundary Outside The Intermediate Segment

Outside Turn: Truncate segment at intersection of 15° expansion line and initial width centered on reciprocal of intermediate.



Inside Turn: Do not truncate when 15° expansion line does not intersect initial width centered on reciprocal of intermediate. Continue to expand until reaching line perpendicular to DR course abeam IF.

2.3.5 Initial Approach Segment Based On A Procedure Turn (PT)

Establish a PT when it is necessary to reverse direction to establish the aircraft on an intermediate or final approach course (FAC) except as specified in Para 2.3.5.e. A PT begins by overheading a facility or fix which meets the criteria for a holding fix (see Para 2.8.8.b) or for a FAF (see Para 2.8.8.c). The procedure shall specify the PT fix, the outbound and inbound course, the distance within which the PT shall be completed, and the direction of the PT. When a teardrop turn is used, the angle of divergence between the outbound course and the reciprocal of the inbound course shall be a MINIMUM of 15° or a MAXIMUM of 30° (see Para 2.3.6.a for high altitude teardrop penetrations). When the beginning of the intermediate or final approach segment associated with the PT is marked by no fix, the segment is deemed to begin on the inbound PT course at the maximum distance specified in the procedure. Where neither segment is marked by a fix, the final segment begins at the maximum distance specified in the procedure.

a. **Alignment**. When the inbound course of the procedure turn becomes the intermediate course it must meet the intermediate course alignment criteria. (See Para 2.4.3.a.) When the inbound course becomes the final approach course it must meet the final approach course alignment criteria. (See Para 2.5.1.) The wider side of the procedure turn area shall be oriented in the same direction as that prescribed for the procedure turn.

b. **Area**. The procedure turn areas are depicted in Figure 2-3-8. The normal procedure turn distance is 10 NM, (see Table 2-3-2). Decrease this distance to 5 NM where only CAT "A" aircraft or helicopters are to be operating, and increase to 15 NM to accommodate operational requirements, or as specified in Para 2.3.5.d. No extension of the PT is permitted without a FAF. When a procedure turn is authorized for use by Category "E" aircraft, a 15-NM PT distance shall be used. The PT segment is made up of the entry and maneuvering zones. The entry zone terminates at the inner boundary which extends perpendicular to the PT inbound course at the PT fix. The remainder of the procedure turn segment is the maneuvering zone. The entry and maneuvering zones are made up of primary and secondary areas. The PT primary area dimensions are based on the PT completion altitude, or the highest feeder route altitude, whichever is greater. To allow additional maneuvering area as the true airspeed increases at higher altitudes, the dimension of the PT primary area increases (see Table 2-3-2). The PT secondary area is 2 NM on the outside of the primary area.

c. **Obstacle Clearance**. A minimum of 1,000 feet of clearance shall be provided in the primary area. In the secondary area, 500 feet of obstacle clearance shall be provided at the inner edge, tapering uniformly to zero feet at the outer edge (see Figure 2-3-2 and 2-3-9). Allowance for precipitous terrain shall be considered as specified in Para 3.2.2.b. The primary and secondary areas determine obstacle clearance in both the entry and maneuvering zones. The use of entry and maneuvering zones provides further relief from obstacles. The entry zone is established to control the obstacle clearance until proceeding outbound from the procedure turn fix. The maneuvering zone is established to control obstacle clearance AFTER proceeding outbound from the procedure turn fix. (see Figure 2-3-8). The altitudes selected by application of the obstacle clearance specified in this paragraph shall be rounded to the next higher 100 feet increment (see Para 2.3.2.).

d. **Descent Gradient**. The OPTIMUM descent gradient in the initial approach is 250 feet per nautical mile. Where a higher descent gradient is necessary, the MAXIMUM permissible gradient is 500 feet per nautical mile. Where a PT is established over a FAF, the PT completion altitude should be as close as possible to the FAF altitude. The difference between the PT completion altitude and the altitude over the FAF shall not be greater than those shown in Table 2-3-3. If greater differences are required for a 5 or 10 nautical mile PT, the PT distance limits and maneuvering zone shall be increased at the rate of 1 nautical mile for each 200 feet of required altitude.

e. **Elimination of PT**. A PT is NOT required when an approach can be made direct from a specified IF to the FAF. The abbreviation "No PT" is used to denote that no procedure turn is necessary and will normally be shown adjacent to the IF. However, if the minimum altitude IF to FAF is not readily apparent, the No PT abbreviation will be shown at some point between the fix and the FAF. Design criteria outlined in Para 2.4.1.-2.4.5. applies. Publishing an IF to permit a No PT approach does not preclude the publishing of a procedure turn as well, where operationally appropriate. A PT NEED NOT be established when an approach can be made from a properly aligned holding pattern. See Para 18.9.2. In this case, the holding pattern in lieu of a PT, shall be established over a final or intermediate approach fix and the following conditions apply:

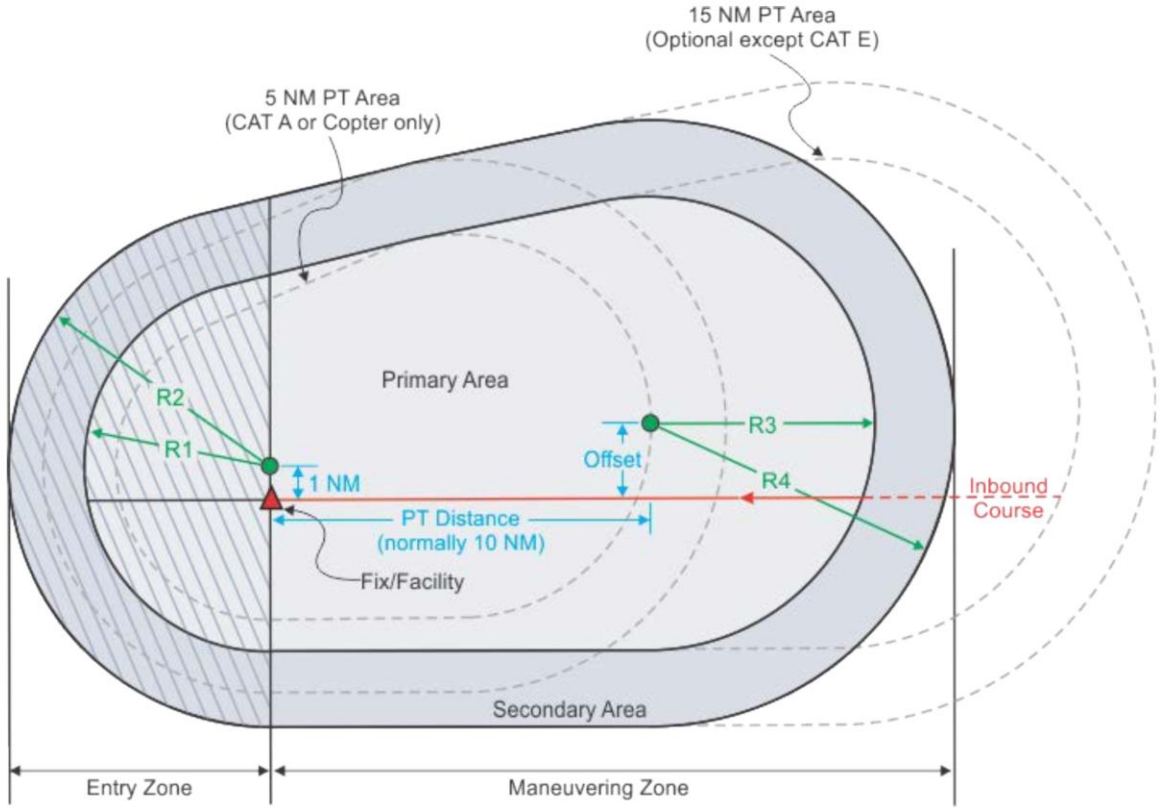
(1) If the holding pattern is established over the FAF (not applicable to RNAV procedures), an intermediate segment is not constructed. Ideally, establish the minimum holding altitude at the FAF altitude. In any case, the published holding altitude shall not be more than 300 feet above the FAF altitude.

(2) If the holding pattern is established over the IF, the minimum holding altitude (MHA) shall permit descent to the FAF altitude within the descent gradient tolerances prescribed for the intermediate segment (see Para 2.4.3.d).

≤ 6,000					
PT Length	Offset	R_1	R_2	R_3	R_4
5	2	4	6	5	7
>5-10	2	5	7	6	8
>10-15	β-4	5	7	β	β+2
β = 0.1 x (d – 10) + 6					
Where d = PT Length (NM)					
> 6,000 ≤ 10,000					
PT Length	Offset	R_1	R_2	R_3	R_4
5	2	4	6	5	7
>5-10	2	6	8	7	9
>10-15	β-5	6	8	β	β+2
β = 0.1 x (d – 10) + 7					
Where d = PT Length (NM)					
> 10,000					
PT Length	Offset	R_1	R_2	R_3	R_4
5	2	4	6	5	7
>5-10	2	7	9	8	10
>10-15	β-6	7	9	β	β+2
β = 0.1 x (d – 10) + 8					
Where d = PT Length (NM)					

Table 2-3-2: Procedure Turn Variables According To ASL Altitude.

Figure 2-3-8: Procedure Turn Areas.



Note:

In the **normal** PT area example above:
R1 = 5 NM, R2 = 7 NM, R3 = 6 NM, and R4 = 8 NM.

In the **optional** PT area example above:
R1 = 4 NM, R2 = 6 NM, R3 = 5 NM, and R4 = 7 NM.

Figure 2-3-9: Procedure Turn Initial Approach Area

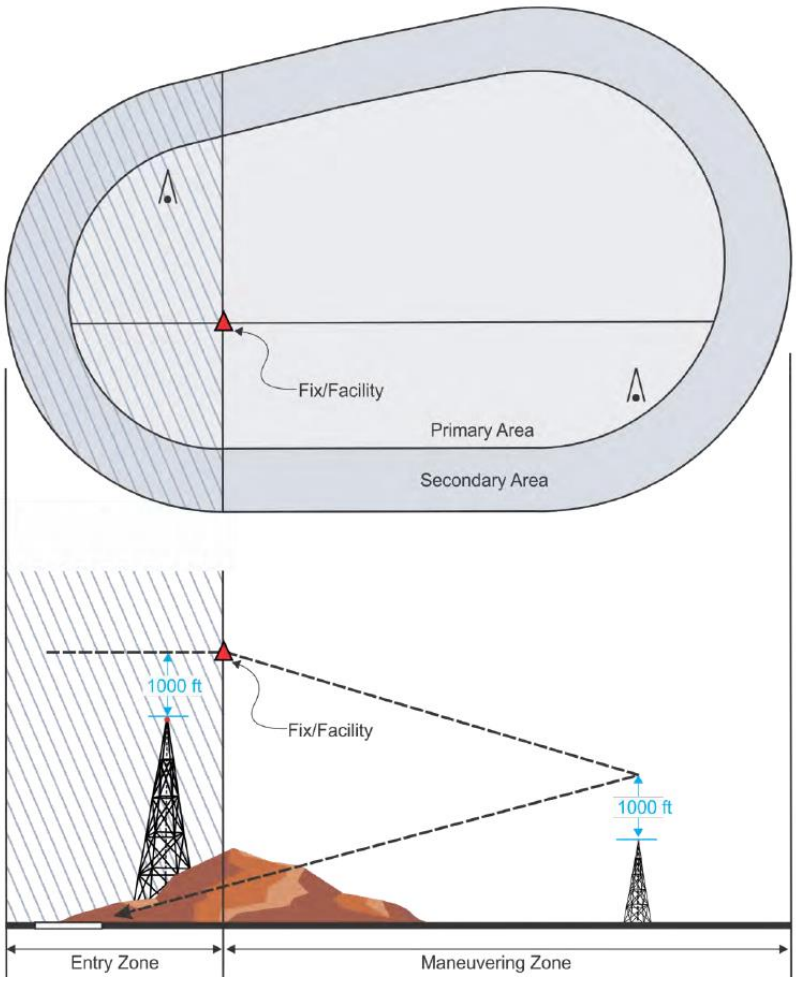


Table 2-3-3: PT Completion Altitude Difference.

Type of PT	Altitude Difference
15 NM PT from FAF	≤ 3000 ft over FAF altitude
10 NM PT from FAF	≤ 2,000 ft over FAF altitude
5 NM PT from FAF	≤ 1,000 ft over FAF altitude
15 NM PT, no FAF	Not Authorized
10 NM PT, no FAF	≤ 1,500 ft over MDA on Final
5 NM PT, no FAF	≤ 1,000 ft over MDA on Final

2.3.6 Initial Approach Based On High Altitude Teardrop Turn

A teardrop penetration consists of departure from an IAF on an outbound course, followed by a turn toward and intercepting the inbound course at or prior to the IF or point used in lieu of

an IF when no IF exists (see Para 2.3.6.c). Its purpose is to permit an aircraft to reverse direction and lose considerable altitude within reasonably limited airspace. Where no IF is available to mark the beginning of the intermediate segment, it shall be assumed to commence at a point 10 NM prior to the FAF. When the facility is located on the airport, and no fix is available to mark the beginning of the final approach segment the criteria in Para 423 applies.

a. **Alignment**. The outbound penetration course shall be between 18 and 26° to the left or right of the reciprocal of the inbound course. The actual angular divergence between the courses will vary inversely with the distance from the facility at which the turn is made (see Table 2-3-4).

b. **Area.**

(1) **Size**. The size of the penetration turn area must be sufficient to accommodate both the turn and the altitude loss required by the procedure. The penetration turn distance shall not be less than 20 NM from the facility. The penetration turn distance depends on the altitude to be lost in the procedure and the point at which the descent is started (see Table 2-3-4). The aircraft should lose half the altitude or 5,000 ft., whichever is greater, outbound prior to starting the turn. The penetration turn area has a width of 6 NM on both sides of the flight track up to the IF or point, and shall encompass all the areas within the turn (see Figure 2-3-10).

(2) **Penetration Turn Table**. Table 2-3-4 should be used to compute the desired course divergence and penetration turn distances, which apply when a specific altitude loss outbound is required. It is assumed that the descent begins at the plotted position of the fix. When the procedure requires a delay before descent of more than 5 NM, the distance in excess of 5 NM should be added to the distance the turn commences. The course divergence and penetration turn distance should then be adjusted to correspond to the adjusted turn distance. Extrapolations may be made from the table.

(3) **Primary and Secondary Areas**. All of the penetration turn area, except the outer 2 NM of the 6 NM obstacle clearance area on the outer side of the penetration track, is primary area (see Figure 2-3-10). The outer 2 NM is secondary area. The outer 2 NM on both sides of the inbound penetration course should be treated as secondary area (see figure 2-3-11).

c. **Obstacle Clearance.** The minimum ROC in the primary is 1000 feet. The minimum ROC in the secondary area is 500 feet, tapering to zero feet at the outer edge (see Figure 2-3-2). The minimum ROC at any given point in the secondary area is determined by formula 2-3-2. Where no IF is available, a 10 NM intermediate segment is assumed and intermediate ROC is applied to the controlling obstacle. The controlling obstacle, as well as the minimum altitude selected for the intermediate segment, may depend on the availability of an IF (see Figure 2-3-11). Allowance for precipitous terrain should be considered in the penetration turn area as specified in Para 3.2.2.b. The altitudes selected by application of the obstacle clearance specified in this paragraph shall be rounded to the next higher 100 feet increment. (See Para 2.3.2.)

d. **Descent Gradient**. The OPTIMUM descent gradient is 800 ft/NM. The MAXIMUM gradient is 1000 feet per nautical mile.

e. **Penetration Turn Altitude**. When an IF is NOT provided, the penetration turn completion altitude shall not be more than 4000 feet above the FAF altitude.

Table 2-3-4: Penetration Turn Distance/Divergence.

ALT to be Lost Prior to Commencing Turn (ft)	Distance Turn Commences (NM)	Course Divergence (Degrees)	Specified Penetration Turn Distance (NM)
12,000	24	18	28
11,000	23	19	27
10,000	22	20	26
9,000	21	21	25
8,000	20	22	24
7,000	19	23	23
6,000	18	24	22
5,000	17	25	21
4,000	16	26	20

Figure 2-3-10: Typical Penetration Turn Initial Approach Area

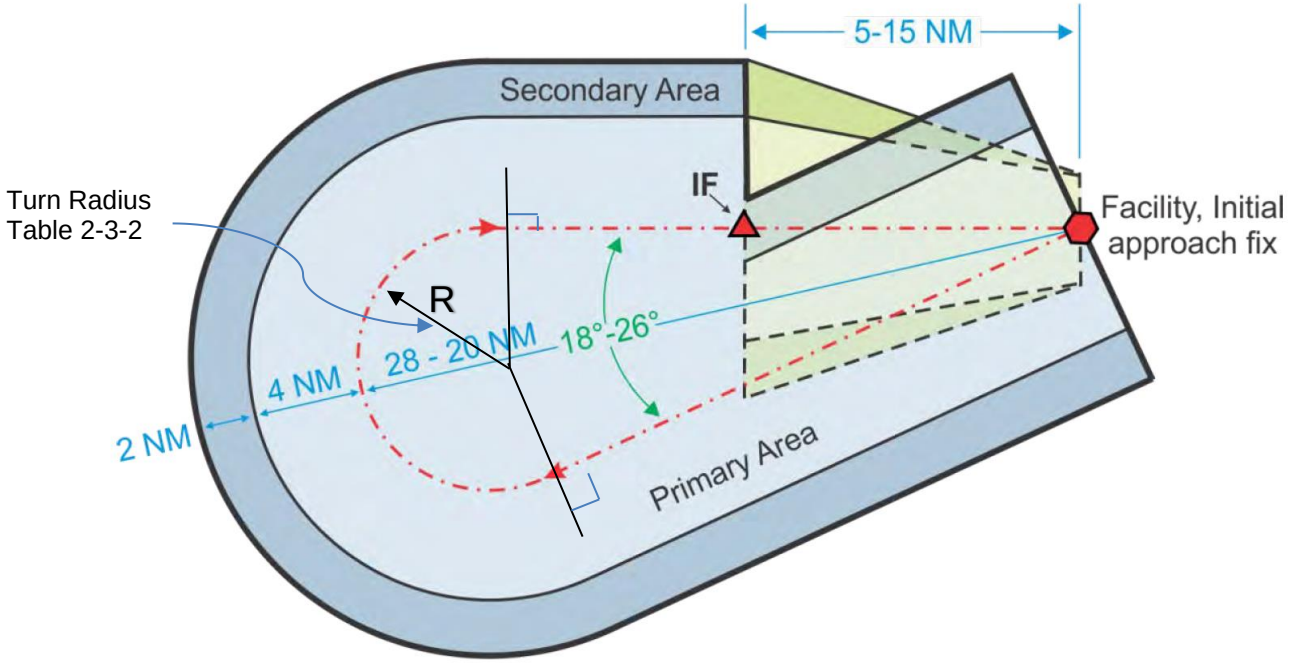
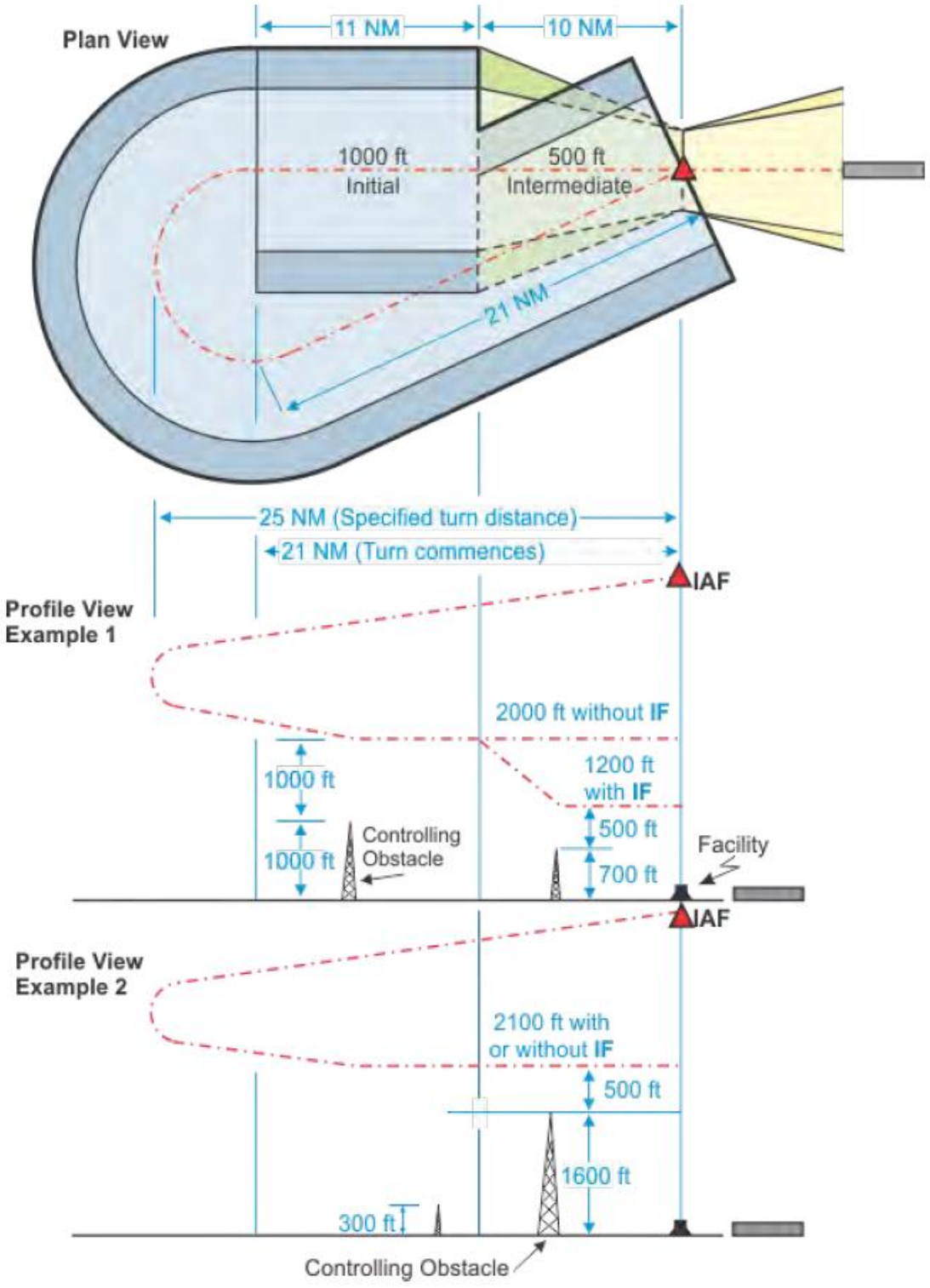


Figure 2-3-11: Penetration Turn Initial Approach Obstacle Clearance



2.3.7 Initial Approach Course Reversal Using Non-Collocated Facilities And A Turn Of 120° Or Greater To Intercept The Inbound Course (see Figures 2-3-12, 2-3-13, and 2-3-14)

a. **Common Criteria.**

(1) A turn point (TP) fix shall be established as shown in the figures. The fix error shall meet section 8 criteria, and shall not exceed ± 2 NM.

(2) A flight path radius (R) of 2.8 NM shall be used for procedures where the altitude at the TP fix is at or below 10000 feet MSL, or 4 NM for procedures where the altitude at the TP fix is above 10000 feet MSL.

(3) Construct the primary boundary (and secondary if applicable) of the turn by swinging an arc(s) from the intersection of the bisector line and the turn point's fix error line.

(4) Descent Gradient. Para 2.3.3.d applies.

(5) Obstacle Clearance. Para 2.3.6.c applies.

(6) **Initial Distance**. When the course reversal turn intercepts the extended intermediate course, and when the course reversal turn intercepts a straight segment prior to intercepting the extended intermediate course, the minimum distance between the rollout point and the FAF is 10 NM.

(7) **ROC Reduction**. No reduction of secondary ROC is authorized in the course reversal area unless the TP fix is DME.

b. Figures 2-3-12 and 2-3-13. The rollout point shall be at or prior to the intermediate fix/point.

(1) Select the desired rollout point on the inbound course.

(2) Place the appropriate flight path arc tangent to the rollout point.

(3) From the outbound facility, place the outbound course tangent to the flight path arc. The point of tangency shall be the TP fix.

c. Figure 2-3-14.

(1) The point of intersection shall be at or prior to the IF/point (Para 2.4.3. applies). The angle shall be 90° or less.

(2) The distance between the rollout point and the point of intersection shall be no less than the distance shown in Table 2-3-5.

(3) Para 2.3.6. and Table 2-3-4 should be used for high altitude procedures up to the point of intersection of the two inbound courses.

(4) Select the desired point of intersection. From the outbound facility draw a line through the point of intersection.

(5) At the outbound facility, measure the required number of degrees course divergence (may be either side of the line through the point of intersection) and draw the outbound course out the required distance. Connect the outbound course and the line through the point of intersection with the appropriate arc.

(6) Determine the desired rollout point on the line through the point of intersection.

(a) Place the appropriate flight path arc tangent to the rollout point.

(b) From the outbound facility draw the outbound course tangent to the flight path arc. The point of tangency is the TP fix.

Table 2-3-5: Minimum Distance from Roll Out Point to Point of Intersection.

Angle "a" (Degrees)	NM
0 – 15	1
> 15 – 30	2
> 30 – 45	3
> 45 – 60	4
> 60 – 75	5
> 75 – 90	6

Figure 2-3-12: Example of Initial Course Reversal

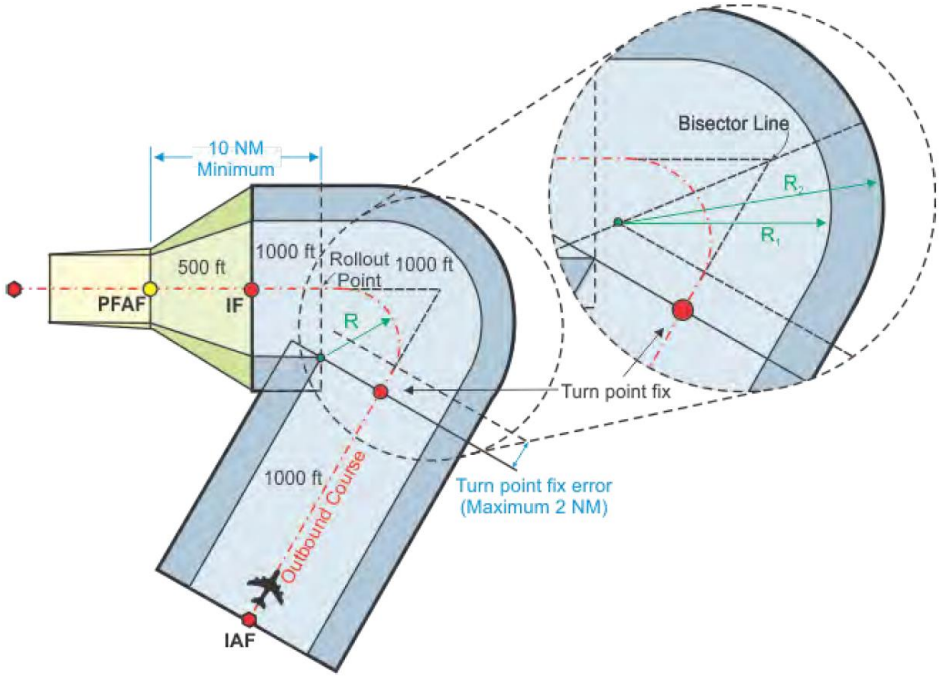


Figure 2-3-13: Examples of Initial Course Reversal

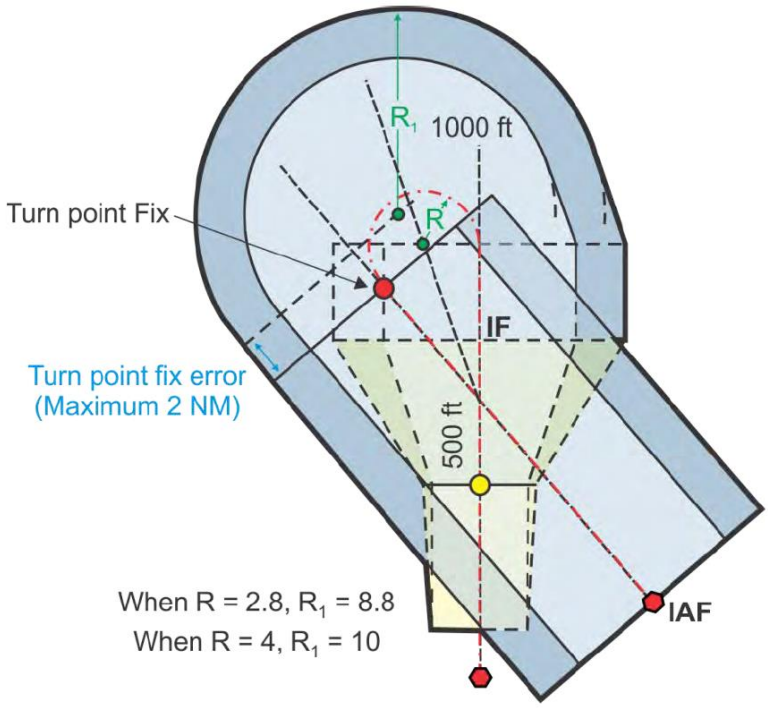
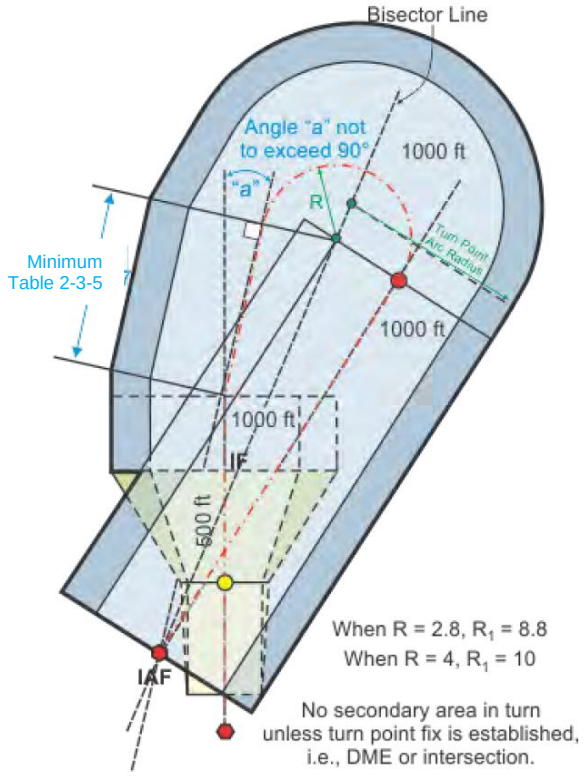


Figure 2-3-14: Examples of Initial Course Reversal



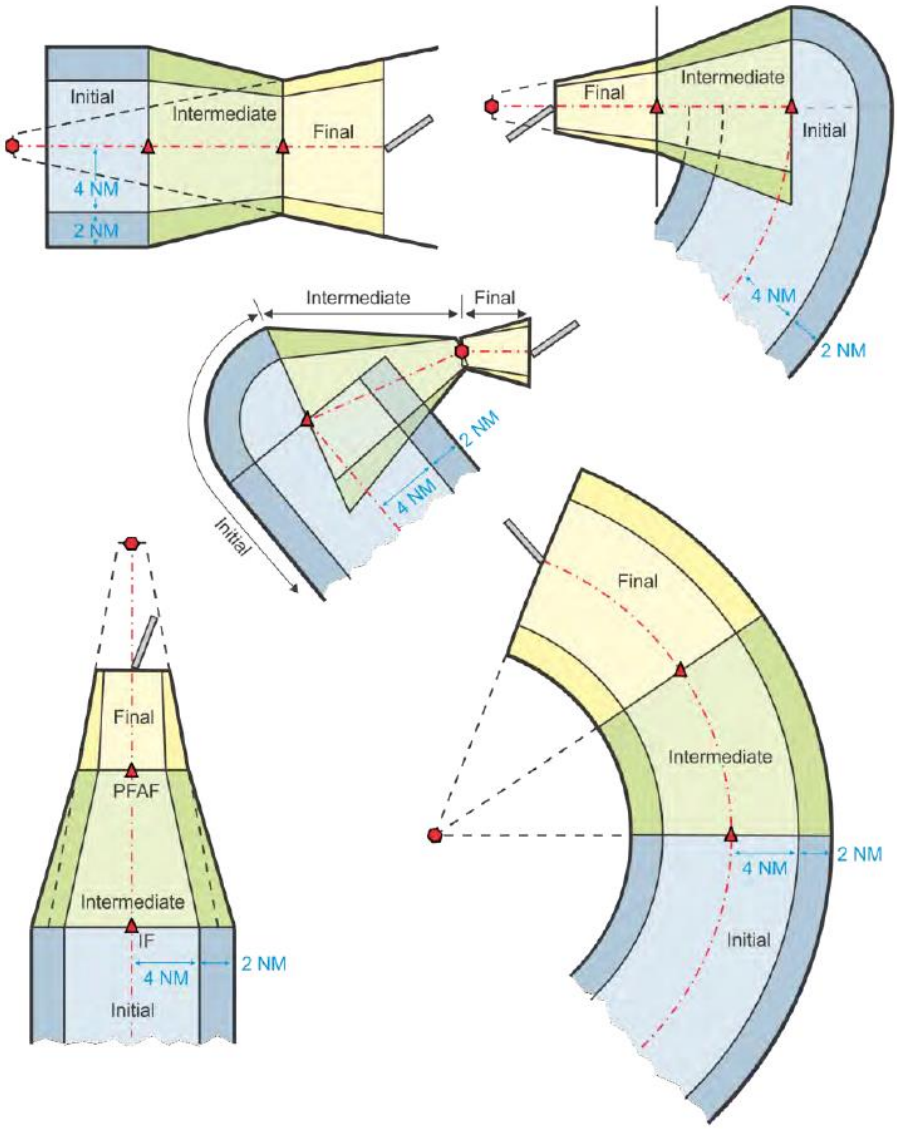
SECTION 4. INTERMEDIATE APPROACHES

2.4 Intermediate Approaches

2.4.1 Intermediate Approach Segment

This is the segment which blends the initial approach segment into the final approach segment. It is the segment in which aircraft configuration, speed, and positioning adjustments are made for entry into the final approach segment. The intermediate segment begins at the IF point (or point used in lieu of) and ends at the FAF. There are two types of intermediate segments: the "radial" or "course" intermediate segment and the "arc" intermediate segment. In either case, positive course guidance (PCG) shall be provided. See Figure 2-4-1 for typical approach segments.

Figure 2-4-1: Typical Approach Segments



2.4.2 Altitude Selection

The MINIMUM altitudes in the intermediate segment shall be established in 100-foot increments, without violating the ROC (plus adjustments as specified in Para 3.2.2); i.e., for example, when obstacle height plus ROC and adjustments equals 701 feet, round up to 800 feet. The altitude selected for arrival over the FAF should be low enough to permit descent from the FAF to the airport for a straight-in landing whenever possible. In addition, the altitude selected for the FAF must not be lower than the highest straight-in or circling MDA (CMDA)

2.4.3 Intermediate Approach Segment Based On Straight Courses

a. **Alignment**. The course to be flown in the intermediate segment shall be the same as the final approach course, except when the FAF is the navigation facility and it is not practical for the course to be identical. In such cases, the intermediate course shall not differ from the final approach course by more than 30° (see Figure 2-4-1).

b. **Area**.

(1) **Length**. The length of the intermediate segment is measured along the course to be flown. Where the initial segment joins the intermediate segment at angles up to 90°, the MINIMUM length is 5 NM for CAT A/B, and 6 NM for CAT C/D/E (except as specified in Volume 1, chapter 10, 13 and 16). Table 2-4-1 lists the minimum segment length where the initial approach course joins the intermediate course at an angle greater than 90° (see Figure 2-3-1). The MAXIMUM segment length is 15 NM. The OPTIMUM length is 10 NM. A distance greater than 10 NM should not be used unless an operational requirement justifies a greater distance.

(2) **Width**. The width of the intermediate segment is the same as the width of the segment it joins. When the intermediate segment is aligned with the initial or final approach segments, the width of the intermediate segment is determined by joining the outer edges of the initial segment with the outer edges of the final segment. When the intermediate segment is not aligned with the initial or final approach segments, the resulting gap on the outside of the turn is part of the preceding segment is closed by the appropriate arc (see Figure 2-4-1). For obstacle clearance purposes the intermediate segment is divided into a primary and a secondary area.

Table 2-4-1: Minimum Intermediate Course Length (NM).

Angle (Degrees)	Minimum Length (NM) based on CAT	
	A/B	C/D/E
> 90 – 96	5	6
> 96 – 102	6	7
> 102 – 108	6	8
> 108 – 114	6	9
> 114 – 120	7	10

c. **Obstacle Clearance**. A minimum of 500 feet of obstacle clearance shall be provided in the primary area of the intermediate approach segment. In the secondary area, 500 feet of obstacle clearance shall be provided at the inner edge, tapering to zero feet at

the outer edge (see Figure 2-4-2). Allowance for precipitous terrain and RASS shall be considered as specified in Para 3.2.2.b. & c. The altitudes selected by application of the obstacle clearance specified in this paragraph may be rounded to the nearest 100 feet, provided the ROC is not violated (see Para 2.4.2). Apply adjustment as specified in Para 3.2.2.

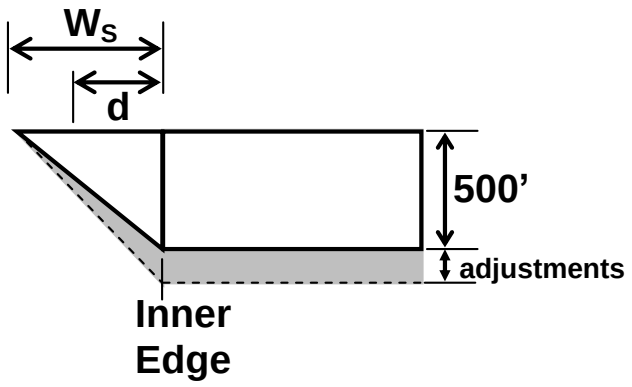
d. **Descent Gradients**. Because the intermediate segment is used to prepare the aircraft speed and configuration for entry into the final approach segment, the gradient should be as flat as possible. The OPTIMUM descent gradient is 150 feet per nautical mile. The MAXIMUM gradient is 318 feet per nautical mile, except for a localizer approach published in conjunction with an ILS procedure. In this case, a higher descent gradient equal to the commissioned GS angle (provided it does not exceed 3°) is permissible. Higher gradients resulting from arithmetic rounding are also permissible.

Supplementary Notes:

1) The intent of paragraph 2.4.3.d. is that the localizer descent gradient must not be higher than the published glideslope angle. For example, a localizer published in conjunction with an ILS that has a 2.75° glide slope, must not have an intermediate segment descent gradient greater than 291 ft/NM. In this case, the maximum gradient of 318ft/NM specified in para 2.4.3.d. would not be applicable.

2) When the descent gradient exceeds 318 feet per nautical mile, the procedure specialist should assure an initial segment is provided prior to the intermediate segment to prepare the aircraft speed and configuration for entry into the final segment. The initial segment should be a minimum length of 5 NM and its descent gradient should not exceed 318 feet per nautical mile.

Figure 2-4-2: Obstacle Clearance Area



Secondary ROC = $(500 + adj) \times \frac{(W_S - d)}{W_S}$

Where:
d = distance from inner edge to obstacle (ft)
W_S = Width of secondary area (ft)
Adjustments = adjustments (ft) as per para 3.2.2.

2.4.4 Intermediate Approach Segment Based On An Arc

Arcs with a radius of less than 7 NM or more than 30 NM from the navigation facility shall NOT be used. DME arc courses shall be predicated only on a DME collocated with a facility providing omnidirectional course information.

a. **Alignment**. The same arc shall be used for the intermediate and the final approach segments. No turns shall be required over the FAF.

b. **Area**.

(1) **Length**. The intermediate segment shall NOT be less than 5 NM or more than 15 NM in length, measured along the arc. The OPTIMUM length is 10 NM. A distance greater than 10 NM should not be used unless an operational requirement justifies the greater distance.

(2) **Width**. The total width of an arc intermediate segment is 6 NM on each side of the arc. For obstacle clearance purposes, this width is divided into a primary and a secondary area. The primary area extends 4 NM laterally on each side of the arc segment. The secondary areas extend 2 NM laterally on each side of the primary area (see Figure 2-4-1).

c. **Obstacle Clearance**. A minimum of 500 feet of obstacle clearance shall be provided in the primary area. In the secondary area, 500 feet of obstacle clearance shall be provided at the inner edge, tapering to zero feet at the outer edge (see Figure 2-4-2). Allowance for precipitous terrain should be considered as specified in Para 3.2.2.b. The altitudes selected by application of the obstacle clearance specified in this paragraph may be rounded to the nearest 100 feet, provided the ROC is not violated. (See Para 2.4.2.)

d. **Descent Gradients**. Criteria specified in Para 2.4.3.d. apply.

2.4.5 Intermediate Approach Segment Within A PT Segment

a. **PT Over a FAF. When the FAF is a Facility** (see Figure 2-4-3).

(1) The MAXIMUM intermediate length is 15 NM, the OPTIMUM is 10 NM, and the MINIMUM is 5 NM. Its width is the same as the final segment at the facility and expanding uniformly to 6 NM on each side of the course at 15 NM from the facility.

(2) The intermediate segment considered for obstacle clearance shall be the same length as the PT distance; e.g., if the procedure requires a PT to be completed within 5 NM, the intermediate segment shall be only 5 NM long, and the intermediate approach shall begin on the intermediate course 5 NM from the FAF.

(3) When establishing a step down fix within intermediate segment underlying a PT area:

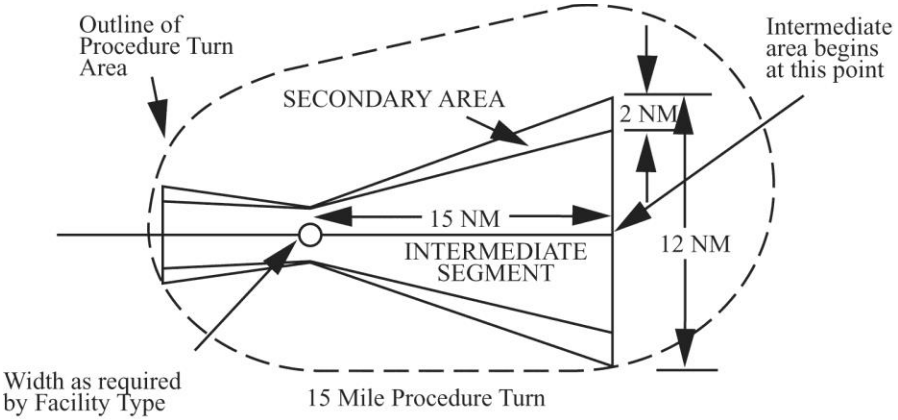
(a) Table 2-3-2 shall be applied.

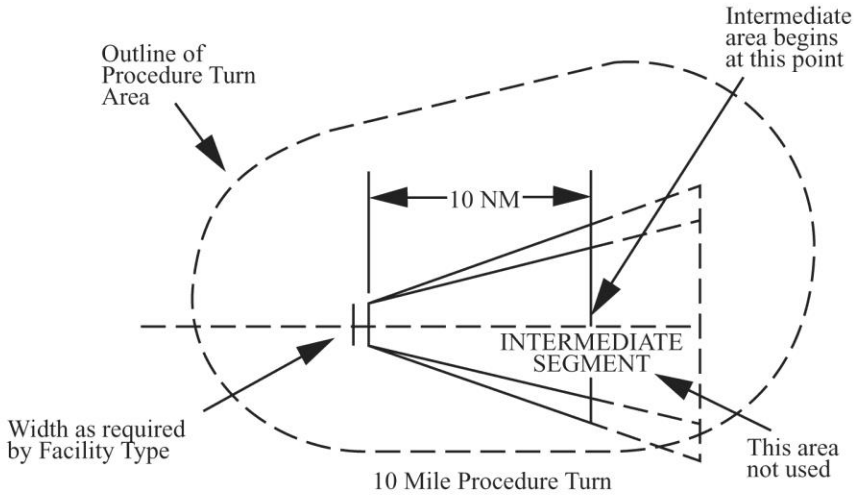
(b) Only one step down fix is authorized within the intermediate segment that underlies the PT maneuvering area.

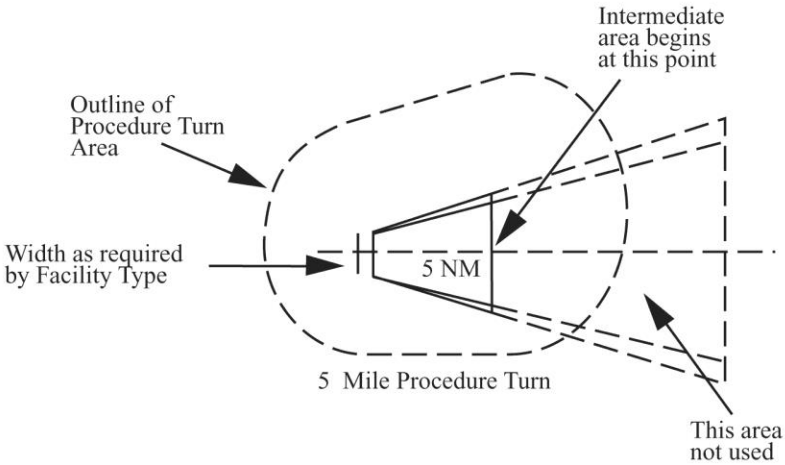
(c) The distance between the PT fix/facility and a SDF underlying the PT area shall not exceed 4 NM.

(d) The MAXIMUM descent gradient from the IF point to the SDF is 200 feet/NM. The MAXIMUM descent gradient from the SDF to the FAF is 318 feet/NM.

Figure 2-4-3: Intermediate Area Within a PT Area, FAF/PAFAF is the Facility







b. PT Over a FAF When the FAF is Not a Facility (see Figure 2-4-4).

(1) The intermediate segment shall be 6 NM wide each side of the intermediate course at the PT distance.

(2) When establishing a step down fix within intermediate/initial segment underlying a PT area:

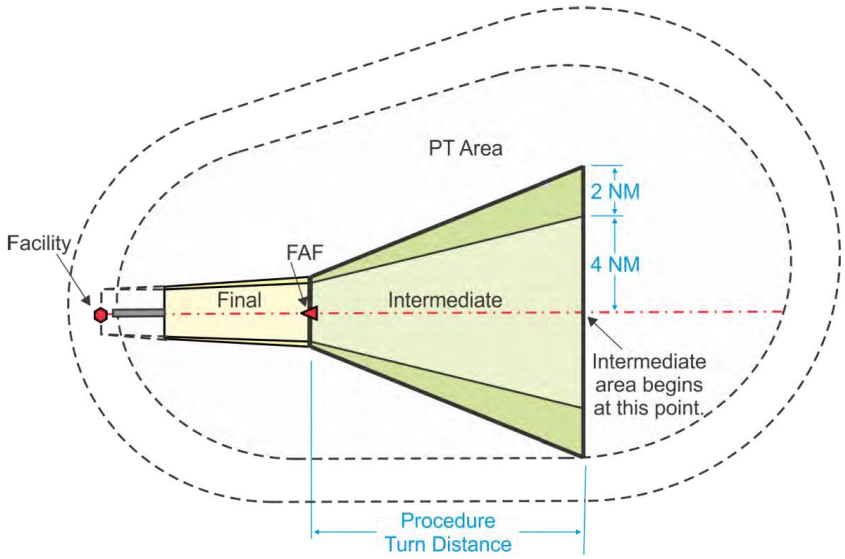
(a) Table 2-3-2 shall be applied.

(b) Only one step down fix is authorized within the intermediate segment that underlies the PT maneuvering area.

(c) The distance between the PT fix/facility and a SDF underlying the PT area shall not exceed 4 NM.

(d) The MAXIMUM descent gradient from the IF point to the SDF is 200 feet/NM. The MAXIMUM descent gradient from the SDF to the FAF is 318 feet/NM.

Figure 2-4-4: Intermediate Area Within the PT Area, FAF is not the Facility



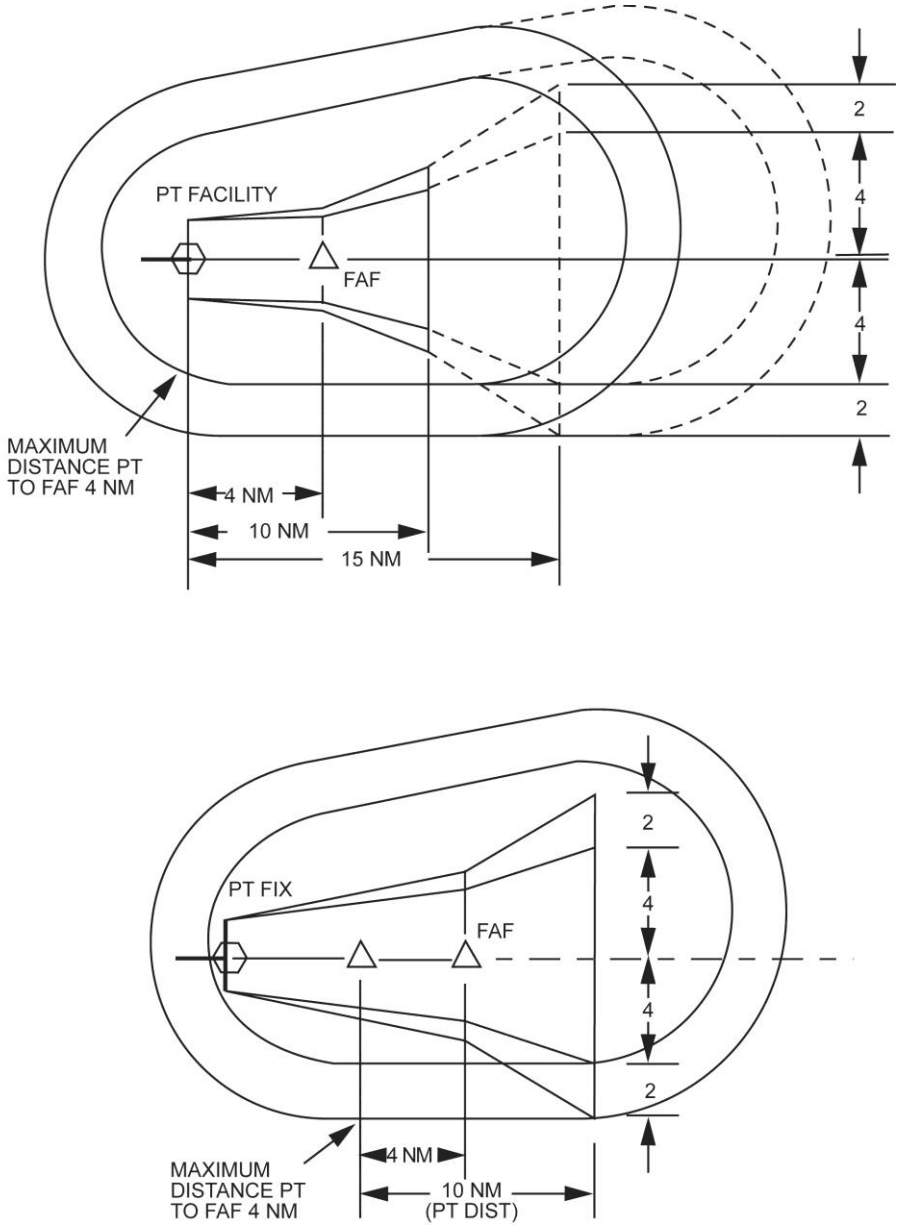
c. **PT Over a Facility/Fix After the FAF** (see Figure 2-4-5).

(1) The PT facility/fix to FAF distance shall not exceed 4 NM.

(2) The MAXIMUM PT distance is 15 NM.

(3) The length of the intermediate segment is from the start of the PT distance to the FAF and the MINIMUM length shall be 5 NM.

Figure 2-4-5: Intermediate Area Within the PT, PT over the Facility/Fix After the FAF



(4) Intermediate Segment Area.

(a) PT Over a Facility. The intermediate segment starts 15 NM from the facility at a width of 6 NM each side of the inbound course and connects to the width of the final segment at the FAF. The area considered for obstacle clearance is from the start of the PT distance to the FAF.

(b) PT Over a Fix (NOT a Facility). The intermediate segment starts at the PT distance at a width of 6 NM each side of the inbound course and connects to the width of the final segment at the FAF. The area considered for obstacle clearance is from the start of the PT distance to the FAF.

(5) The MAXIMUM descent gradient in the intermediate segment is 200 feet/NM. The PT distance may be increased in 1 NM increments up to 15 NM to meet descent limitations.

(6) When establishing a step down fix within intermediate/initial segment underlying a PT area:

(a) Only one step down fix is authorized within the intermediate segment that underlies the PT maneuvering area.

(b) The distance between the PT fix/facility and a stepdown fix (SDF) underlying the PT area shall not exceed 4 NM.

(c) The MAXIMUM descent gradient from the IF point to the SDF is 200 feet/NM. The MAXIMUM descent gradient from the SDF to the FAF is 318 feet/NM.

d. PT Over a Facility/Fix PRIOR to the FAF (see Figures 2-4-6 and 2-4-7).

(1) The MINIMUM PT distance is 5 NM.

(2) The length of the intermediate segment is from the start of the PT distance to the FAF and the MAXIMUM length is 15 NM.

(3) Intermediate Segment Area.

(a) PT Over a Facility. The intermediate segment starts 15 NM from the facility at a width of 6 NM each side of the inbound course and connects to the width of the final segment at the FAF. The area considered for obstacle clearance is from the start of the PT distance to the FAF.

(b) PT Over a Fix (NOT a Facility). The intermediate segment starts at the PT distance at a width of 6 NM each side of the inbound course and connects to the width of the final segment at the FAF. The area considered for obstacle clearance is from the start of the PT distance to the FAF.

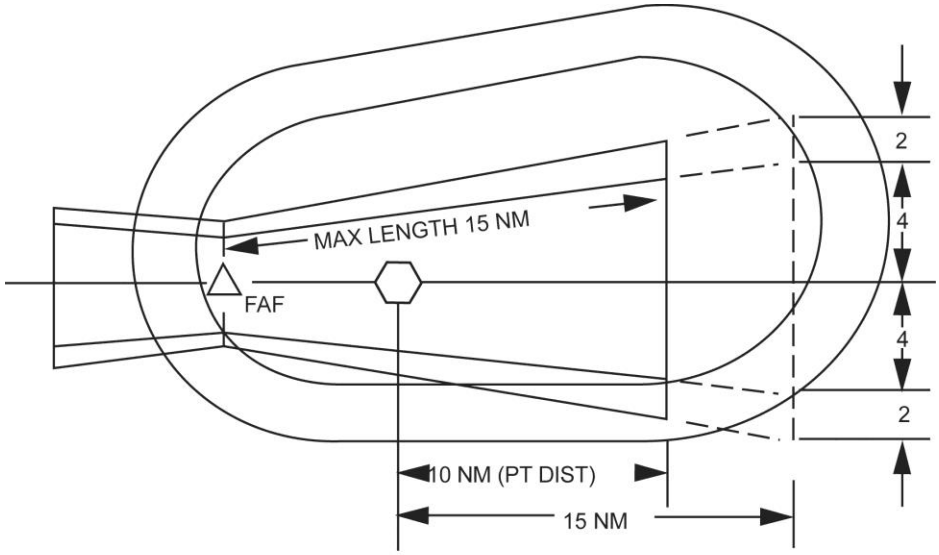
(4) The MAXIMUM descent gradient is 200 feet/NM. If the PT facility/fix is a step-down fix, the descent gradient from the step-down fix to the FAF may be increased to a maximum of 318 feet/NM (see Figure 2-4-7). The PT distance may be increased in 1 NM increments up to 15 NM to meet descent limitations.

(5) When establishing a step down fix within an intermediate/initial segment underlying a PT area:

(a) When the PT fix is over a facility/fix prior to the FAF, the facility/fix is the SDF in the intermediate/initial area, and another SDF within this segment is not authorized.

(b) The MAXIMUM descent gradient from the IF point to the SDF is 200 feet/NM. The MAXIMUM descent gradient from the SDF to the FAF is 318 feet/NM.

Figure 2-4-6: Intermediate Area Within the PT Area, PT Over the Facility/Fix Prior to the FAF



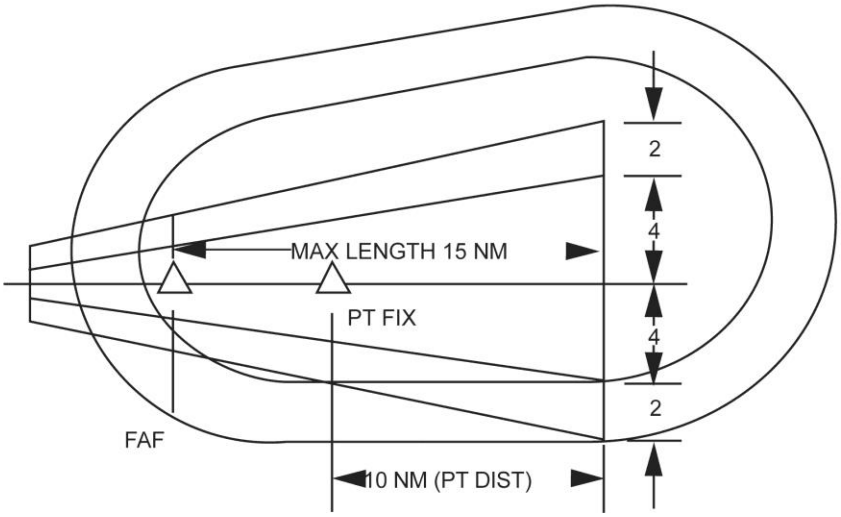
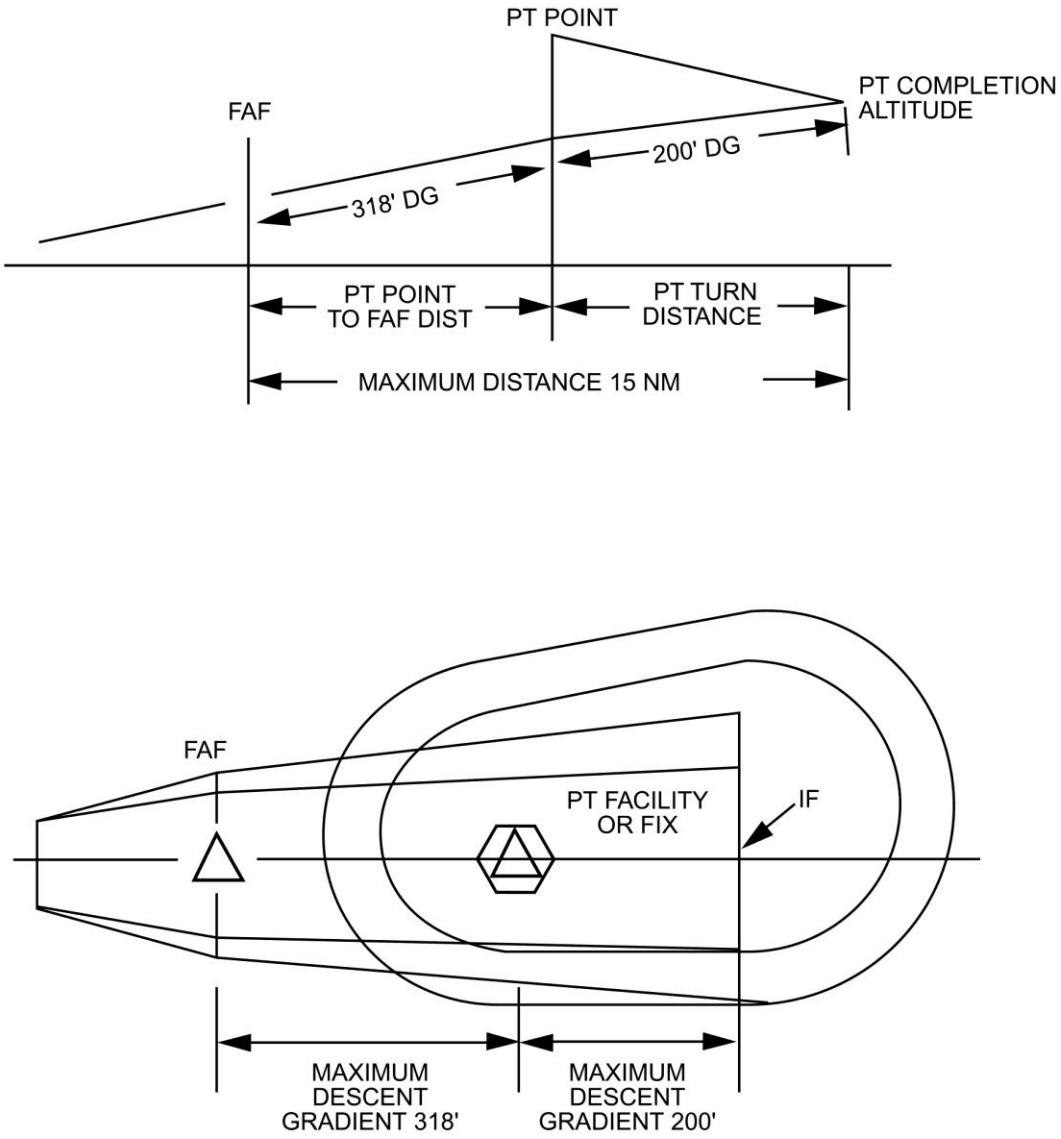


Figure 2-4-7: Intermediate Area Within the PT Area. PT Facility/Fix Used as a Stepdown Fix



e. **PT Facility/Fix Used as an Intermediate Fix** (see Figure 2-4-8).

(1) When the PT inbound course is the same as the intermediate course, either Para 2.4.5.d may be used, or a straight initial segment may be used from the start of the PT distance to the PT fix.

(2) When the PT inbound course is NOT the same as the intermediate course, an intermediate segment within the PT area is NOT authorized; ONLY a straight initial segment shall be used from the start of the PT distance to the PT fix.

(3) When a straight initial segment is used, the MAXIMUM descent gradient within the PT distance is 318 feet/NM, the PT distance may be increased in 1 NM increments up to 15 NM to meet descent limitations.

(4) When establishing a step down fix within an intermediate/initial segment underlying a PT area:

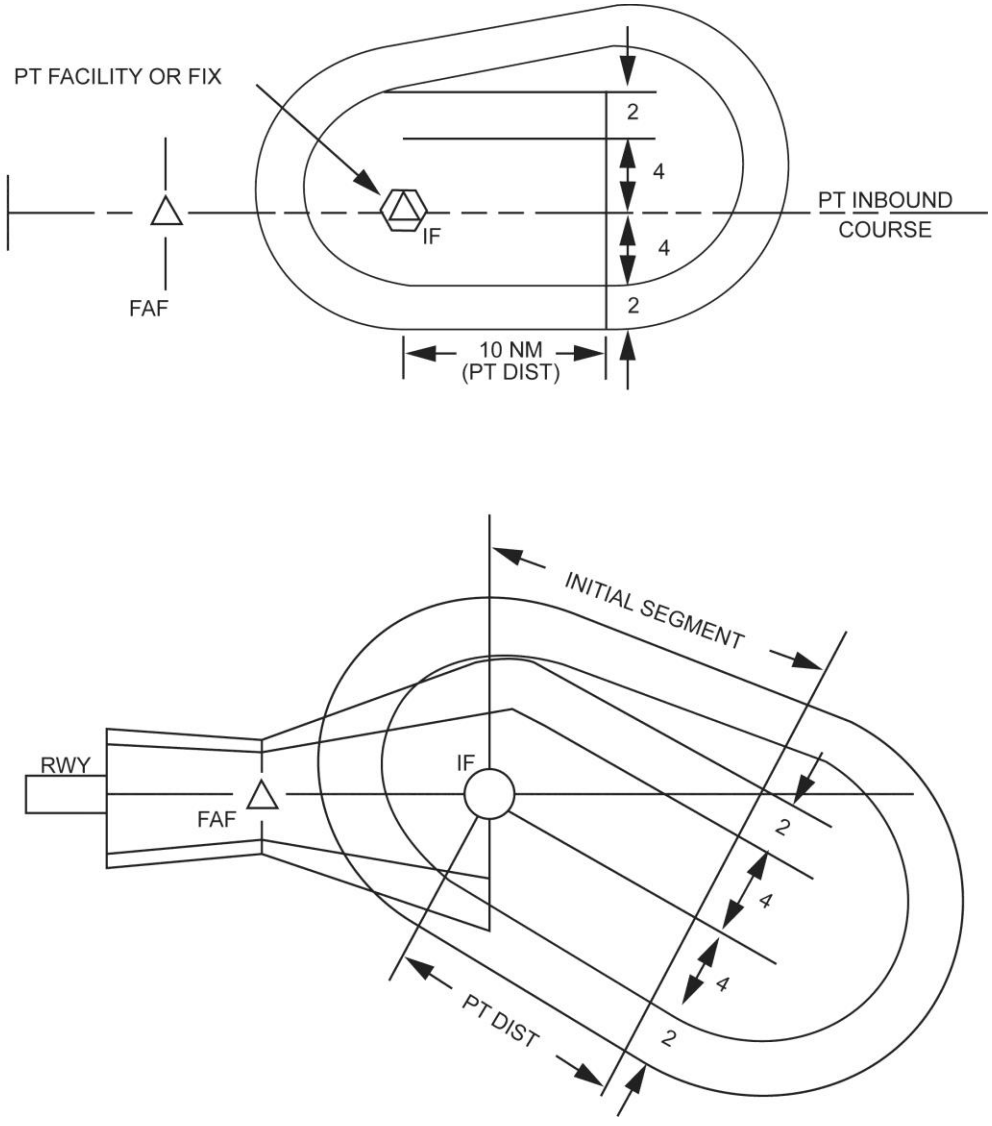
(a) Only one step down fix is authorized within the initial segment that underlies the PT maneuvering area.

(b) The distance from the PT fix/facility and a SDF underlying the PT area shall not exceed 4 NM.

(c) The MAXIMUM descent gradient from the PT completion point (turn distance) to the SDF, and from the SDF to the IAF is 318 feet/NM.

When a PT from a facility is required to intercept a localizer course, the PT facility is considered on the localizer course when it is located within the commissioned localizer course width.

Figure 2-4-8: Use of PT Fix for IF



SECTION 5. FINAL APPROACH

2.5 Final Approach

2.5.1 Final Approach Segment

This is the segment in which alignment and descent for landing are accomplished. Final approach may be made to a runway for a straight-in landing or to an airport for a circling approach. The segment begins at the FAF and ends at the MAP (or LTP/FTP, whichever encounter last) and/or DA. Criteria for alignment, length, OEA, and OCS evaluation are contained in the chapters specific to the facility/system providing navigation guidance. A VGS extends from the LTP to the DA/OCH point (see paragraph 2.5.5).

2.5.2 Glidepath Angle (GPA) and Vertical Descent Angle (VDA)

a. The GPA or VDA (of a procedure where the FAC is straight-in aligned) when possible should not be more than 0.20 degrees greater than the glidepath angle of a visual glide slope indicator (VGSI) installed on the same runway. Publish a note indicating VGSI not coincident with the procedure GPA or VDA when the VGSI angle is more than 0.2° from the GPA or VDA, or when the VGSI TCH is more than 3 feet from the procedure TCH.

b. The VDA (of a procedure where the FAC is straight-in aligned) cannot be less than the angle of a VGSI installed to the same runway.

c. GPA/VDA must not exceed the values specified in table 2-5-1.

Table 2-5-1: Maximum GPA/VDA

CAT	Maximum Angle
A (80 knots or less)	6.40
A (81-90 knots)	5.70
B	4.20
C	3.77
D	3.50
E	3.10*

* Military CAT E maximum is 3.50 degrees.

2.5.3 GPA

Use a standard 3.00 degree GPA where possible. Using GPAs greater than 3.00 degrees but not more than the maximum (see table 2-5-1) is authorized when needed to provide obstacle clearance or to meet other operational requirements. The minimum GPA is 2.50 degrees for DND or ILS systems first installed before January 2019.

2.5.4 VDA

Determine a VDA for all NPA procedures except those published in conjunction with vertically-guided minimums or no-FAF procedures that do not contain a stepdown fix in the final segment. Optimum VDA is 3.00 degrees. Minimum VDA for a procedure with straight-in

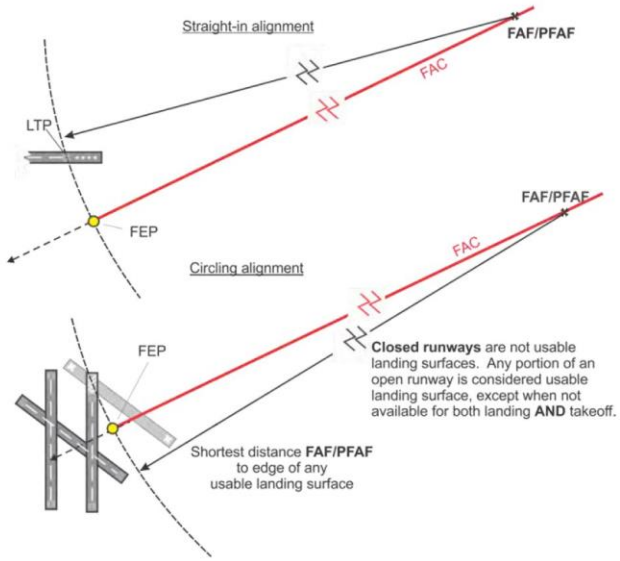
minimums is 2.75 degrees (2.50 degrees for DND); no minimum VDA applies to a procedure with only circling minimums or PINSA procedures.

a. Where the FAC is straight-in aligned, design with a VDA equal to or higher than the lowest PA/APV glidepath angle established to the same runway. If no PA/APV procedure is established but a VGSI to the same runway is installed, then design with a VDA that is at least equal to, but not more than 0.20 degrees greater than the VGSI angle (see paragraph 2-5-2.a).

   (1) If the final is circling aligned, or if a VGSI is not installed, then design the procedure at the optimum VDA when possible.

b. Calculate VDA based on the distance from the plotted position of the FAF or stepdown fix to the plotted position of the final end point (FEP) (see figure 2-5-1). The FEP is a point on the FAC equal to the distance from the FAF to the landing threshold point (LTP) or from FAF to the edge of first usable landing surface for circling only aligned procedures.

Figure 2-5-1. Final End Point (FEP)



c. VDA for procedures meeting straight-in alignment.

   (1) Calculate the VDA from the FAF altitude [or stepdown fix altitude per paragraphs 2.5.4.e(1) or 2.5.4.f] to threshold crossing height (TCH) using formula 2-5-1. Round results to the nearest 0.01 degrees.

Formula 2-5-1. VDA Calculation for Procedure Meeting Straight-in Alignment

$$VDA = atan\left(In\left(\frac{r + alt}{r + THRe + TCH}\right) \times \frac{r}{D_{FIX}}\right)$$

Where:

alt = FAF altitude in feet (stepdown altitude if applicable)
THRe = threshold elevation
TCH = Use Vol 1, Chapter 13, table 13-1-1 value that meets minimum and maximum TCH requirements
D_{FIX} = FAF (stepdown fix if applicable) to FEP distance (feet)

(2) When the maximum VDA calculated in accordance with formula 2-5-1 is exceeded and altitudes/fix locations cannot be modified, straight-in minimums are not authorized. The procedure may be approved when restricted to circling minimums provided the maximum VDA calculated in accordance with paragraph 2.5.4.d is not exceeded. In this case, when the VDA is published, specify the VDA calculated in accordance with formula 2-5-1 (published angle may exceed the maximum).

(3) Use formula 2-5-2 to determine a FAF or stepdown fix location to achieve a specified design angle. Where a VGSI is installed and within the range of minimum/maximum VDAs, select a fix location which permits a VDA equivalent with the VGSI angle. When it is not feasible to achieve equivalency (for example, VGSI is not within the range of acceptable angles, or VGSI is not installed), select a fix location to achieve an optimum VDA or within standard VDA range (see figure 2-5-2).

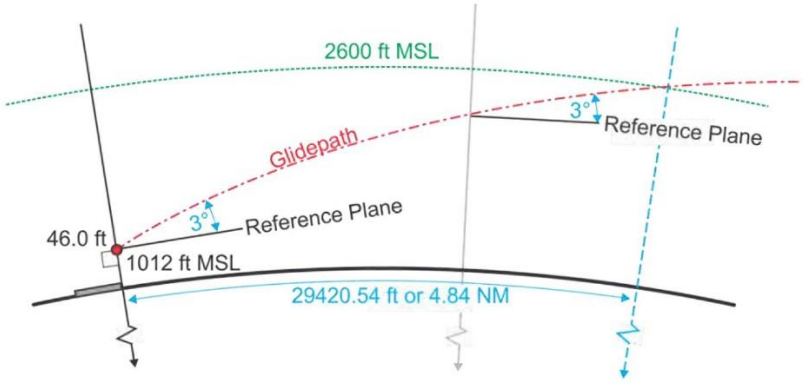
Formula 2-5-2. Determining FAF or Stepdown Fix Location

$$\boldsymbol{D_{FIX}} = \frac{In\left(\frac{r + alt}{r + THRe + TCH}\right) \times r}{\boldsymbol{tan(\theta)}}$$

Where:

D_{FIX} = FAF (stepdown fix if applicable) to FEP distance (feet)
alt = FAF altitude in feet (stepdown altitude if applicable)
THRe = threshold elevation
TCH = Use Vol 1, Chapter 13, table 13-1-1 value that meets minimum and maximum TCH requirements
θ = VGSI or specified VDA (in degrees)

Figure 2-5-2. Straight-In FAF or Stepdown Fix Distance Based on Altitude and Angle



d. VDA for procedures not meeting straight-in alignment or for straight-in aligned procedures not authorized straight-in minimums.

(1) Procedures designed to circling alignment standards are not normally flown using a stabilized descent from the FAF to landing. Therefore, FAF location is not predicated on VDA; however, the achieved angle must not exceed the maximum VDA. Establish the FAF location in accordance with the alignment and segment length criteria applicable to the final approach navigational aid (NAVAID) or system and calculate the circling VDA.

(2) Calculate the VDA from the FAF [or stepdown fix altitude per paragraphs 2.5.4.e(2) or 2.5.4.f] to the lowest CMDA using formula 2-5-3. When the maximum VDA is exceeded, relocate the FAF/stepdown fix and/or raise the CMDA until the angle is compliant.

Formula 2-5-3. VDA Calculation for Procedures Not Authorized Straight-In Minimums

$$VDA = atan\left(In\left(\frac{r + alt}{r + CMDA}\right) \times \frac{r}{D_{FIX}}\right)$$

Where:

alt = FAF altitude in feet (stepdown altitude if applicable)
CMDA = lowest published circling minimum descent altitude
D_{FIX} = FAF (stepdown fix if applicable) to FEP distance (feet)

e. Stepdown fixes (with FAF procedures and/or procedures published without PA/APV minimums). Establish stepdown fixes at the lowest altitude possible that also provides obstacle clearance. Determine the altitude of the vertical path at a stepdown fix using formula 2-5-4. When a minimum fix altitude is above the vertical profile of a VDA calculated in accordance with paragraph 2.5.4.c, adjust the stepdown fix location(s) if feasible. When stepdown fix location(s) cannot be modified, change the FAF location or raise the FAF altitude until stepdown fix(es) are at or below the vertical path of the VDA (must not exceed the maximum angle).

Formula 2-5-4. Vertical Path Elevation at Stepdown Fix

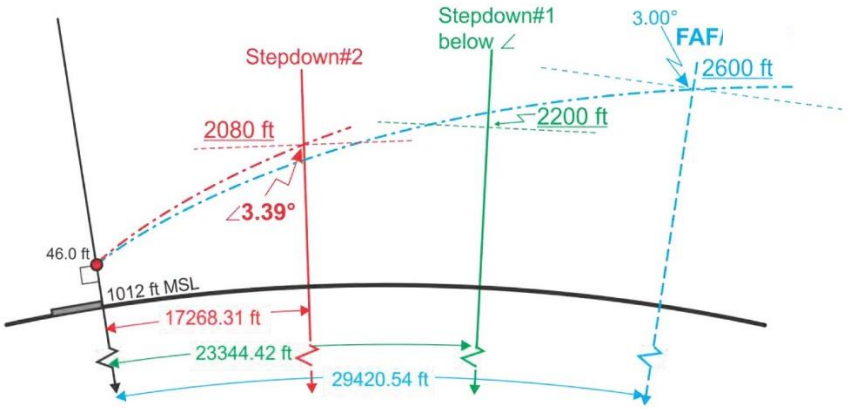
$$Z_{vertpath} = e^{\frac{D_{FIX} \times tan(\theta)}{r}} \times (r + Base_{alt}) - r$$

Where:

D_{FIX} = FAF (stepdown fix if applicable) to FEP distance (feet)
θ = Angle calculated in accordance with paragraph 2.5.4.c or 2.5.4.d
$Base_{alt}$ = (THRe + TCH) for paragraph 2.5.4.c calculations; CMDA for paragraph 2.5.4.d calculations

(1) For straight-in aligned procedures only, when no other option is practical, calculate a VDA from each stepdown fix altitude above the vertical path (apply paragraph 2.5.4.c). Publish the greatest VDA and associate it with the applicable stepdown fix (see figure 2-5-3).

Figure 2-5-3. VDA with Stepdown Fixes



(2) For circling aligned procedures, when no other option is practical, calculate a VDA from each stepdown fix altitude above the vertical path (apply paragraph 2.5.4.d) and ensure each angle is less than or equal to the maximum angle.

(3) Do not raise stepdown fix altitudes higher than needed for obstacle clearance solely to achieve coincidence with the VDA vertical path.

f. Stepdown fixes (no-FAF procedures). Apply paragraph 2.5.4.c or 2.5.4.d to calculate the VDA from the stepdown fix. When there are multiple stepdown fixes, also apply paragraph 2.5.4.e, except the vertical path is calculated from the first stepdown fix (farthest from LTP) instead of from the FAF.

2.5.5 Vertical Guidance Surface (VGS)

The VGS must be evaluated for all PA procedures, APV approach procedures and straight-in aligned NPA procedures.

a. Exception: The VGS evaluation is not required where the landing surface is designed to no standards (see “No Aerodrome Status” Table 1-1).

b. If evaluation results in a penetration of the VGS, eliminate the penetration by increasing the GPA (PA/APV), VDA, procedure turn completion altitude (no-FAF NPA), or TCH until

it no longer penetrates. Offsetting the FAC to achieve a lower DA/MDA (and therefore a shorter VGS) may also be an option to eliminate the penetration. For Certified Aerodromes, penetrations caused by airport lighting, airport signage, and their associated equipment may be disregarded when installed in accordance with TP312 Aerodrome Standards and Recommended Practices. At DND aerodromes, any VGS penetration will also necessitate a TP312 OLS evaluation of the affected runway.

(1) Once the VGS is clear, refer to table 2-5-1 to determine the highest CAT that may be authorized based on the required GPA (PA/APV) to clear the penetration, or the required VDA calculated in accordance with formula 2-5-1.

(2) For a no-FAF NPA without SDF (where a VDA is not normally calculated), apply formula 2-5-1 for the sole purpose of determining an angle, except substitute the procedure turn completion altitude and the maximum procedure turn distance for the FAF altitude and FAF distance. Use the greater of 3.00 degrees and the calculated angle for comparison against the table 2-5-2 values, and for use in place of the VDA within formulas 2-5-5 and 2-5-9.

c. Length. The VGS begins at the LTP and extends to the DA point (highest DA) of a PA or APV. For NPA, determine the length by applying formula 2-5-5 to determine the distance to the Obstacle Clearance Height (OCH). Determine a OCH distance ($\mathbf{d_{OCH}}$) for the highest MDA, and always use the specified VDA and design TCH in the calculations (see figure 2-5-5).

(1) When dual or multiple lines of NPA minimums are published, use the highest minimum descent altitude (MDA) from any CAT to calculate the OCH distance.

(2) For runways served by a VGSI (regardless of coincidence with final VDA), using the VGSI TCH, establish the distance from LTP to a point where the lowest published VGSI glidepath angle reaches the appropriate MDA.

(3) For runways not served by a VGSI, using an appropriate TCH from Vol 2, table 1-3-1, establish the distance from LTP to a point where the greater of a three degree or the final segment VDA reaches the appropriate MDA.

Formula 2-5-5. OCH Distance ($\mathbf{d_{OCH}}$)

$$\mathbf{d_{OCH}} = \frac{\boldsymbol{r} \times \boldsymbol{\pi}}{\mathbf{180°}} \times \left(\mathbf{90} - \boldsymbol{\theta} - \mathbf{asin}\left(\frac{\mathbf{cos}(\boldsymbol{\theta}) \times (\mathbf{r} + \mathbf{THRe} + \mathbf{TCH})}{\mathbf{r} + \mathbf{MDA}} \right) \right)$$

Where:

MDA = highest published MDA
THRe = threshold elevation
TCH = VGSI TCH or TCH from Vol 2, Table 1-3-1
$\boldsymbol{\theta}$ = VGSI or specified VDA (degree)

Note: For VGS purposes, DA and OCH point must be calculated using primary altimeter minimums only.

d. Width. The beginning width is 100 feet each side of the runway edge. It expands towards the DA/OCH point. Calculate the beginning half-width ("k") by applying formula 2-5-6. Calculate the half-width at the DA/OCH point using formula 2-5-7. Apply formula 2-5-8 to calculate the half-width for any other distance from LTP.

Formula 2-5-6. VGS Half-Width at Origin

$$\boldsymbol{k = \frac{runway\ width}{2} + 100}$$

Formula 2-5-7. VGS Half-Width at DA or OCH Point

$$\boldsymbol{E = 0.036 \times d + 392.8}$$

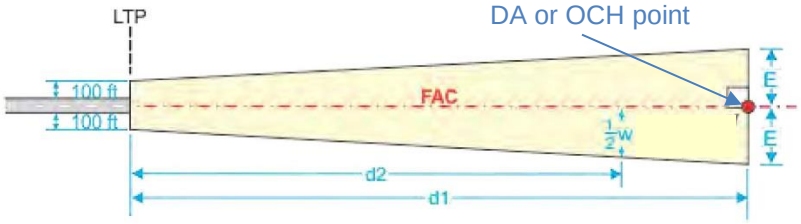
Where:
d = distance (feet) from LTP to DA/OCH point

Formula 2-5-8. VGS Half-Width at Specified Distance

$$\boldsymbol{\frac{1}{2}w = \left(\frac{E - k}{d_1} \times d_2\right) + k}$$

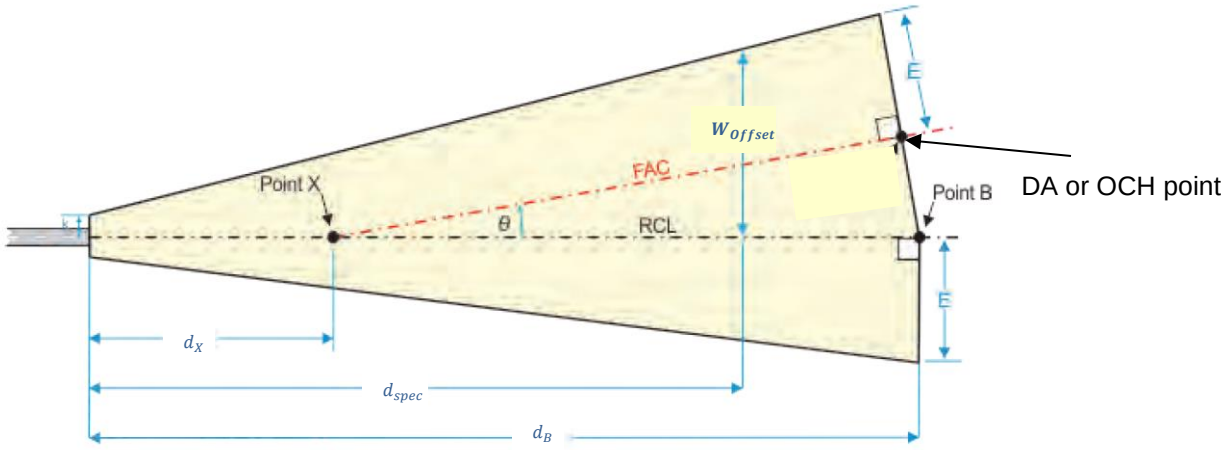
Where:
w = is the full width at $\boldsymbol{d_2}$
E = VGS half-width at DA/OCH point (feet) [see formula 2-5-7]
k = VGS half-width at origin (feet) [see formula 2-5-6]
$\boldsymbol{d_1}$ = distance (feet) from LTP to DA/OCH point
$\boldsymbol{d_2}$ = specified distance (feet) from LTP as measured along RCL

Figure 2-5-5. VGS Area



e. Offset area. Expand the VGS area when the FAC is offset from the RCL by more than three degrees. The area at the DA/OCH point extends perpendicularly from the FAC on the side of the offset for distance "E" (see formula 2-5-7). On the side closest to the RCL, the area extends perpendicularly to the FAC until intersecting the RCL. It then extends perpendicularly to the RCL for distance "E" (see figure 2-5-6). Apply formula 2-5-9 to determine the offset side width from RCL for a specified distance from LTP.

Figure 2-5-6. Offset VGS Area Construction



Formula 2-5-9. VGS Offset Side Width as Special Distance

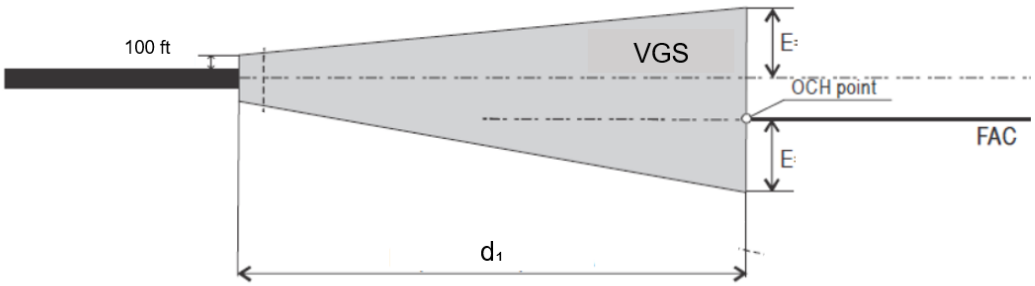
$$W_{Offset} = d_{spec} \times \left(\frac{cos(\theta) \times [sin(\theta) \times (d_B - d_X) + E] - k}{d_B - sin(\theta) \times [sin(\theta) \times (d_B - d_X) + E]} \right) + k$$

Where:

d_{spec} = Specified distance (feet) from LTP as measured along RCL
θ = FAC offset in degrees
d_B= Distance (feet) from LTP to point B
d_X= Distance (feet) from LTP to intersection of RCL and FAC (point X)
E = VGS half-width at DA/OCH point (feet) [see formula 2-5-7]
k = VGS half-width at origin (feet) [see formula 2-5-6]

f. For NPA where the final approach course is offset but does not intersect the extended runway centre line, the VGS at the point where OCH point is reached extends perpendicularly to the final approach course on the side of the offset for distance E (see Figure 2-5-7).

Figure 2-5-7. Plan view VGS offset final approach parallel to the runway centre line



g. VGS Slope Origin. The VGS slope origin and starting elevation is based on TCH (see figure 2-5-8).

(1) Where the TCH is greater than 50 feet, the slope origin is the beginning of the VGS area. Starting elevation is V_{Offset} above THRe. Calculate V_{Offset} by applying formula 2-5-10.

(2) Where the TCH is at least 40 feet but not more than 50 feet, the slope origin is the beginning of the VGS area. Starting elevation is THRe.

(3) Where the TCH is less than 40 feet, the slope origin is X_{Offset} distance from the beginning of the VGS area. Calculate X_{Offset} by applying formula 2-5-11. The VGS area within X_{Offset} distance is a level surface equal to THRe which must be clear of obstacles (see exceptions in paragraph 2.5.5.a).

Formula 2-5-10. V_{Offset} Height for TCH Greater Than 50 Feet

$$V_{Offset} = TCH - 50$$

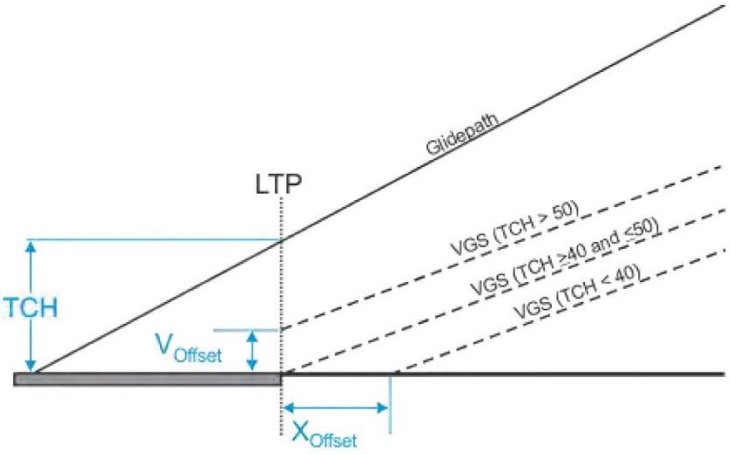
Formula 2-5-11. X_{Offset} Distance for TCH Less than 40 Feet

$$X_{Offset} = \frac{40 - TCH}{\tan(\theta)}$$

Where:

θ = GPA

Figure 2-5-8. VGS Slope Origin



h. VGS Slope Elevation. The VGS slope is based on 2/3 x GPA (or VDA for NPA). Apply formula 2-5-12 to determine the VGS elevation.

Formula 2-5-12. VGS Elevation

$$\boldsymbol{VGS_{Elev} = tan\left(\theta \times \frac{2}{3}\right) \times \left(d - X_{Offset}\right) + THRe + V_{Offset}}$$

Where:

θ = GPA or VDA (for NPA)

d = distance (feet) from LTP

$\boldsymbol{X_{Offset}}$ = Formula 2-5-11 result for TCH less than 40 feet, else 0.

$\boldsymbol{V_{Offset}}$ = Formula 2-5-10 result for TCH greater than 50, else 0.

Example:

$$\boldsymbol{VGS_{Elev} = tan\left(3.1 \times \frac{2}{3}\right) \times (4991.01 - 0) + 1125.4 + 5}$$

$$\boldsymbol{VGS_{Elev} \cong 1310.5}$$

SECTION 6. CIRCLING APPROACH

2.6 Circling Approach

2.6.1 Circling Approach Area

Where circling is authorized, evaluate the circling approach OEA for each CAT published on the procedure. The CMDA is based on the results of the circling approach OEA evaluation and the evaluation of the final segment OEA. Also see paragraph 2.5.2.c.

a. **Obstacle evaluation area.**

(1) The OEA for each CAT is based on true airspeed (V_{KTAS}). The minimum altitude used for true airspeed conversion is 1000 feet above airport elevation. Use formula 2-6-1 to convert indicated airspeed (V_{KIAS}) to true airspeed (V_{KTAS}).

Formula 2-6-1. True Airspeed

$$V_{KTAS} = \frac{V_{KIAS} \times 171233 \times \sqrt{303 - 0.00198 \times (Apt_{elev} + k)}}{\left(288 - 0.00198 \times (Apt_{elev} + k)\right)^{2.628}}$$

Where:

V_{KIAS} = indicated airspeed [see table 2-6-1].
$\mathrm{Apt}_{\mathrm{elev}}$ = airport elevation (MSL).
k = height above airport (minimum 1000 feet).

(2) Calculate the circling approach radius (CAR) based on true airspeed, bank angle, and straight segment using formula 2-6-2. The minimum CAR is 1.30 NM

Formula 2-6-2. Circling Radius

$$CAR = 2 \times \frac{(V_{KTAS} + 25)^2}{tan\left(Bank_{angle}\right) \times 68625.4} + S$$

Where:

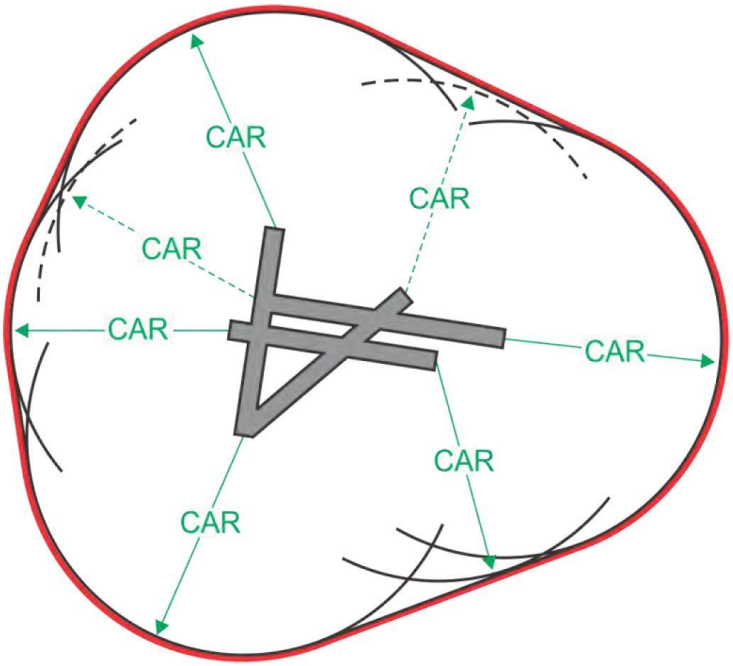
V_{KTAS} = true airspeed from formula 2-6-1.
$Bank_{angle}$= bank angle (see table 2-6-1).
S = straight segment length in NM (see table 2-6-1).

Table 2-6-1: Circling Approach Area Parameters

CAT	V_{KIAS}	$Bank_{angle}$	Straight Segment Length (S) NM
A	90	25	0.4
B	120	25	0.4
C	140	20	0.5
D	165	20	0.6
E	200	22	0.7

(3) Construct the OEA by drawing arcs equal to the CAR for each CAT from the landing threshold point (LTP) of each runway to which circling will be authorized. However, when only one end of the runway is not authorized for circling, the OEA is based on the CAR from both LTPs. Join the outermost arcs with tangential lines. The resulting enclosed area is the circling OEA (no secondary area). See figure 2-6-1.

Figure 2-6-1. Construction of Circling Approach OEA



b. **Obstacle Clearance**. The minimum ROC in the circling approach OEA is 300 feet. Adjustments must be applied as specified in paragraph 3.2.2.c.

c. **Circling minimum descent altitude (CMDA)**

The published CMDA must not result in a height above airport (HAA) lower than permitted by table 2-6-2. Where the CMDA results in a HAA greater than 1000 feet, recalculate V_{KTAS} by increasing the “k” value within formula 2-6-1 to equal the actual HAA, then recalculate

the CAR using formula 2-6-2 and re-evaluate the OEA. If the resulting HAA value increases, recalculate and re-evaluate using the higher value.

Table 2-6-2: Circling Minimum Authorized HAA

CAT	A	B	C	D	E
HAA	350 FT	450 FT		550 FT	

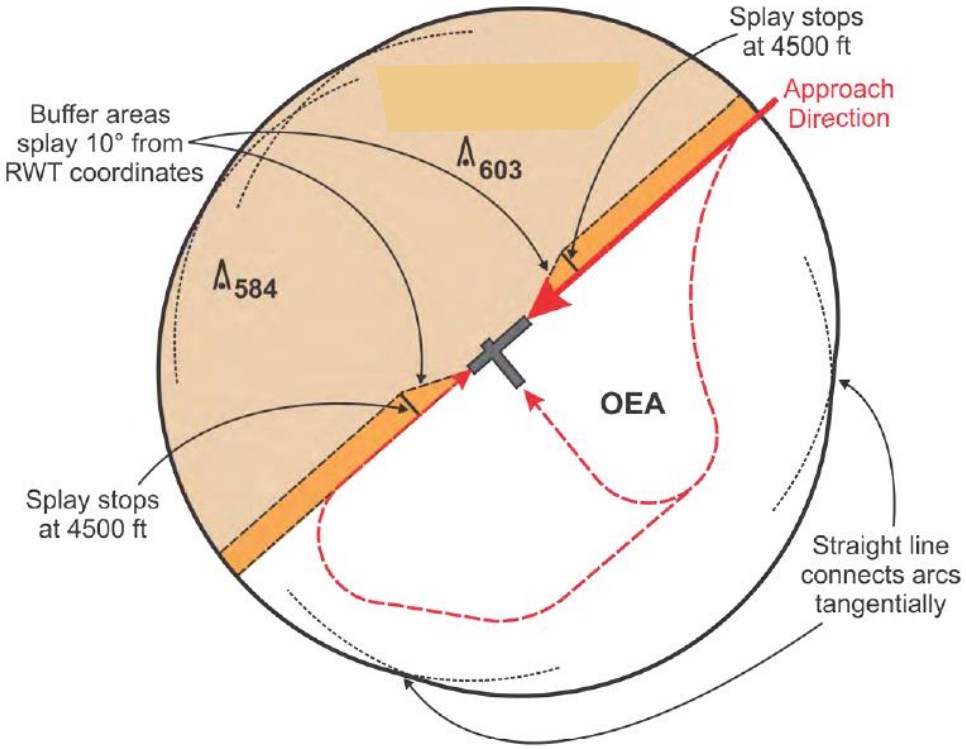
Note: The MDA established by application of the minima specified in this chapter shall be rounded to the next higher 20-foot increment.

2.6.2 Restricted circling area.

The circling OEA may be modified to gain relief from obstacles by establishing a restricted area. This option is only authorized where the restriction can clearly be described as a portion of the airspace where circling is not authorized and the chart is properly shown. The OEA excludes the restricted area except the portion defined by a line originating at the LTP of each runway used to define the area splaying 10 degrees relative to RCL towards the restricted area. Discontinue the splay when it reaches 4500 feet in width from RCL extended. Circling restrictions shall be noted on the procedure.

a. **Simple restricted area.** Establish the restricted area as the right or left half of the OEA relative to RCL(s) extended to the CAR boundary. The chart must include the runway identification numbers. (See Figure 2-6-2)

Figure 2-6-2. Simple Restricted Circling Area



b. **Complex restricted area.** Establish the restricted area as a single contiguous sector bounded by the extended centerlines of intersecting runways, continued outward to the OEA boundary, and truncated or expanded by a direct line from each LTP. The chart annotation must include the runway identification numbers.

Figure 2-6-3 to 2-6-10. Reserved

2.6.3 Establishing Circling Visibility Minimums. (see Chapter 3)

SECTION 7. MISSED APPROACH

2.7 Missed Approach

2.7.1 Missed Approach Segment

a. A missed approach procedure shall be established for each IAP. The missed approach shall be initiated at the decision altitude (DA) for PA/APV procedures and missed approach point (MAP) for NPA procedures. The missed approach procedure must be simple, specify a missed approach altitude (altitude at the clearance limit), and a clearance limit fix/facility. When required by obstacles or deemed operationally advantageous, the missed approach may also specify an interim “climb-to” altitude to identify a turn point. Any other interim altitude restriction may be used for traffic flow and operational constraints. The missed approach altitude specified in the procedure shall be sufficient to permit holding or enroute flight. This means that the missed approach altitude must provide sufficient ROC to allow the pilot to hold at the missed approach holding fix (using the appropriate holding template), or must provide sufficient ROC to allow the pilot to proceed enroute. Where the missed approach altitude is below an initial approach altitude or enroute altitude, the 40:1 obstacle identification surface (OIS) must be assessed beyond the missed approach holding fix. If a climb in hold is required, it shall be assessed in accordance with Chapter 18, Holding Criteria. A note indicating that a shuttle climb or climb-in-hold is required prior to proceeding on course shall be included in the missed approach instructions. Example: Shuttle climb to 5000' BPOC. (See ILS and PAR chapters for special provisions).

b. Design alternate missed approach procedures using the criteria in this section. The area considered for obstacles has a width equal to that of a final approach area at the MAP and expands uniformly to the width of the initial approach segment at a point 15 nautical miles from the MAP (see Figure 2-16). When PCG is available, a secondary area for the reduction of obstacle clearance is identified within the missed approach area, which has the same width as the final approach segment area at the MAP, and which expands uniformly to a width of 2 NM at a point 15 NM from the MAP (see Figure 2-16). Where PCG is not available beyond this point, expansion of the area continues until PCG is achieved or segment terminates. Where PCG is available beyond this point, the area tapers at a rate of 30° inward relative to the course until it reaches initial segment width.

c. A missed approach procedure that maintains a heading (or track) to an altitude for the commencement of ATC vectors is a permissible missed approach procedure provided pertinent communication failure instructions are also included. The missed approach procedure shall be designed as per this section in accordance with the following:

(1) The OCS shall be assessed up to 1000 feet below the altitude that is suitable for the commencement of ATC vectors; and

(2) ATC surveillance service must be available 24 hours.

2.7.2 Missed Approach Alignment

Wherever practical, the missed approach course should be a continuation of the FAC. Turns are permitted, but should be minimized in the interest of safety and simplicity.

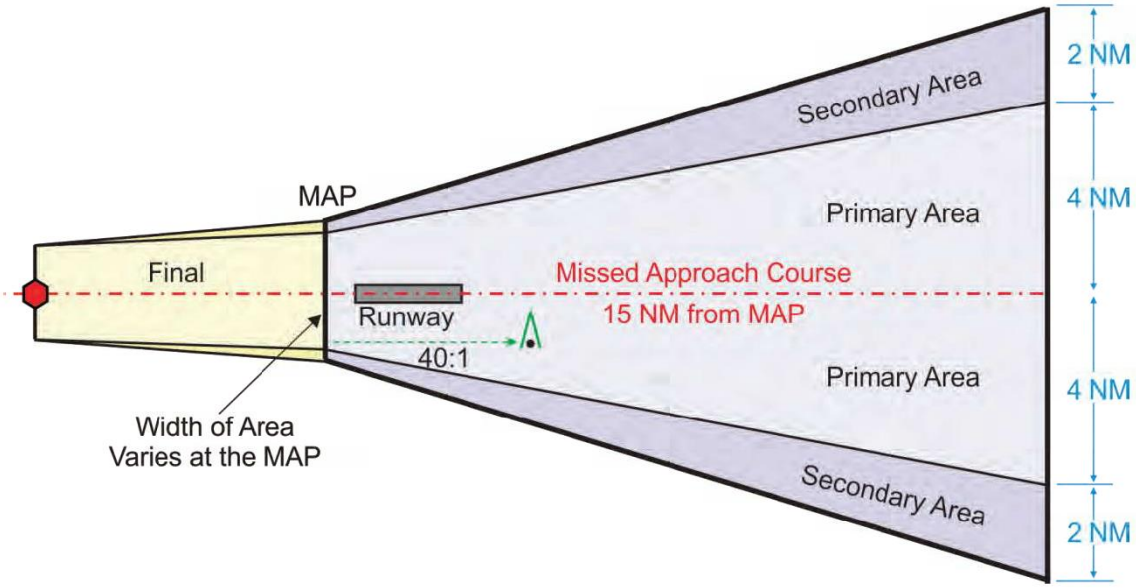
2.7.3 Missed Approach Point (MAP)

The MAP specified in the procedure may be the point of intersection of an electronic glide path with a DA, a navigation facility, a fix, or a specified distance from the FAF. The specified distance may not be more than the distance from the FAF to the usable landing surface. Specific criteria for the MAP are contained in the appropriate facility chapters.

2.7.4 Straight Missed Approach Area

When the missed approach course is within 15° of the final approach course, it is considered a straight missed approach (see Figure 2-7-1). The area considered for obstacle clearance is specified in Para 2.7.1.

Figure 2-7-1: Straight Missed Approach Area



2.7.5 Straight Missed Approach Obstacle Clearance

Within the primary missed approach area, no obstacle shall penetrate the missed approach surface. This surface begins over the MAP at a height determined by subtracting the required final approach primary area ROC and any minima adjustments, in accordance with Para 3.2.2, from the MDA. It rises uniformly at a rate of 1 foot vertically for each 40 feet horizontally (40:1) (see Figure 2-7-2). Where the 40:1 surface reaches a height of 1,000 feet below the missed approach altitude (Para 2.7.1), further application of the surface is not required. In the secondary area, no obstacle shall penetrate a 12:1 slope that extends outward and upward from the 40:1 surface at the inner boundaries of the secondary area (see Figure 2-7-3). Evaluate the missed approach segment to ensure obstacle clearance is provided.

a. Evaluate the 40:1 surface from the MAP to the clearance limit (end of the missed approach segment). The height of the missed approach surface over an obstacle is determined by measuring the straight-line distance from the obstacle to the nearest point on the line defining the origin of the 40:1 surface. If obstacles penetrate the surface, take action to eliminate the penetration.

b. The preliminary charted missed approach altitude is the highest of the minimum missed approach obstruction altitude, minimum holding altitude (MHA) established in accordance with Chapter 18 Section 2, or the lowest airway minimum enroute altitude (MEA) at the clearance limit. To determine the minimum missed approach obstruction altitude for the missed approach segment, identified the highest obstacle in the primary area; or if applicable, the highest equivalent obstacle in the secondary area. Then add the appropriate ROC (plus adjustments), for holding or enroute to the highest obstacle elevation. Round the total value to the nearest hundred-foot value, provided the ROC is not penetrated.

c. Determine if a climbing in holding pattern (climb-in-hold) evaluation is required (see Chapter 18 Section 7). If a climb in hold is intended at the clearance limit, a climb-in-hold evaluation is mandatory.

(1) Calculate the elevation of the 40:1 surface at the end of the segment (clearance limit). The 40:1 surface starts at the same elevation as it does for obstacle evaluations. Compute the 40:1 rise from a point on the line defining the origin of the 40:1 surface in the shortest distance and perpendicular to the end-of-segment line at the clearance limit.

(2) Compute the ROC surface elevation at the clearance limit by subtracting the appropriate ROC (plus adjustments) from the preliminary charted missed approach altitude.

(3) Compare the ROC surface elevation at the clearance limit with the 40:1 surface elevation.

(a) If the computed 40:1 surface elevation is equal to or greater than the ROC surface elevation, a climb-in-hold evaluation is NOT required.

(b) If computed 40:1 surface elevation is less than the ROC surface elevation, a climb-in-hold evaluation is required. TP308/GPH209 Chapter 18 Section 7, climb-in-hold, specifies higher speed groups and, therefore, larger template sizes are usually necessary for the climb-in-hold evaluation. These templates may require an increase in minimum holding altitude (MHA) under TP308/GPH209 Chapter 18, Para 18.2.4. If this evaluation requires an increase in the MHA, evaluate the new altitude using the higher speed group specified in Chapter 18 Section 7. This sequence of review shall be used until the MHA does not increase, then the 40:1 surface is re-evaluated. If obstacles penetrate the 40:1 surface, take action to eliminate the penetration.

(4) The charted missed approach altitude is the higher of the preliminary charted missed approach altitude or the MHA established under Para 2.7.5.c.3.b.

Figure 2-7-2: Straight Missed Approach Obstacle Clearance

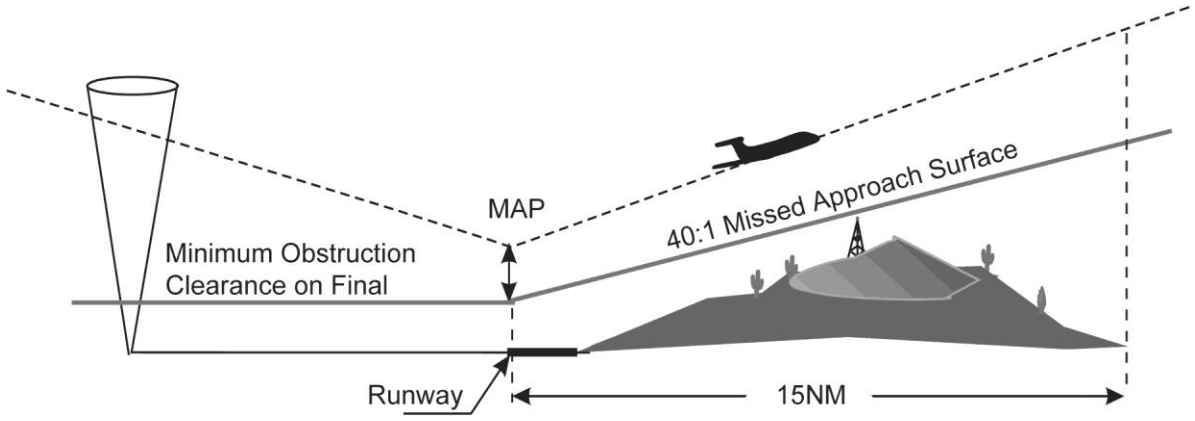
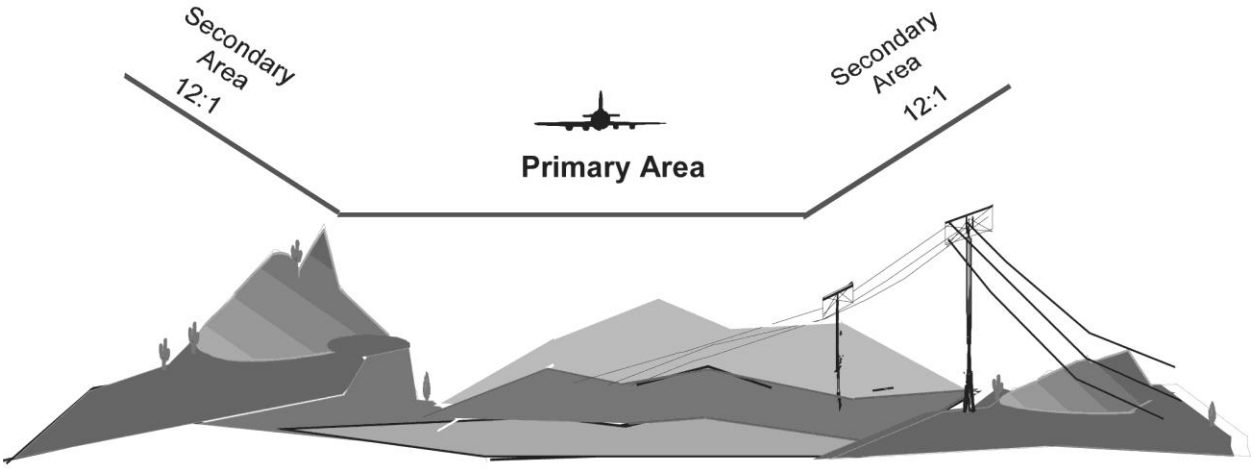


Figure 2-7-3: Missed Approach Cross-Section



2.7.6 Turning Missed Approach Area

If a turn of more than 15 degrees from the FAC is required, a turning or combination straight and turning missed approach area must be constructed. If the HAT or HAA value associated with the DA/MDA/CMDA is less than 400 feet, construct a combination straight and turning missed approach (see paragraph 2.7.8.). The minimum turn altitude is 400 feet above the TDZE or Airport elevation, round to the nearest foot increment.

a. **The dimensions and shape** of this area are affected by three variables:

(1) Width of final approach area at the MAP.

(2) All categories of aircraft authorized to use the procedure (the obstacle area for each aircraft category, authorized to fly the procedure, shall be assessed).

Note: Turning areas must be constructed for each CAT. Plotting only the highest CAT will not assure proper OEA protection for lower CATs.

(3) Number of degrees of turn required by the procedure.

b. **Secondary areas** for the reduction of obstacle clearance are permitted when PCG is provided. The secondary area begins where a line perpendicular to the straight flightpath, originating at the point of completion of the turn, intersects the outer boundaries of the missed approach segment. The width of the secondary area expands uniformly from 0 (zero) to 2 NM at the 15 NM flight track point.

c. **Primary areas**. Figures 2-7-4 to 2-7-9 show the manner of construction of some typical turning missed approach areas. The radii specified in table 2-7-1 are used in the construction of these areas:

Approach Category	Obstacle Clearance Radius (R)	Flightpath Radius (R_1)
A	2.6	1.30
B	2.8	1.40
C	3.0	1.50
D	3.5	1.75
E	5.0	2.50

Table 2-7-1: Turning Missed Approach Radii (Nautical Miles).

(1) **90° Turn or Less**. Narrow final approach area at MAP (see Figure 2-7-4). To construct the area:

(a) Draw an arc with the radius (R_1) from the MAP. This line is then extended outward to a point 15 NM from the MAP, measured along the line. This is the assumed flight path. (see Table 2-7-1).

(b) Establish Points "A_2" and "B_1" by measuring 6 NM perpendicular to the flight path at the 15 NM point.

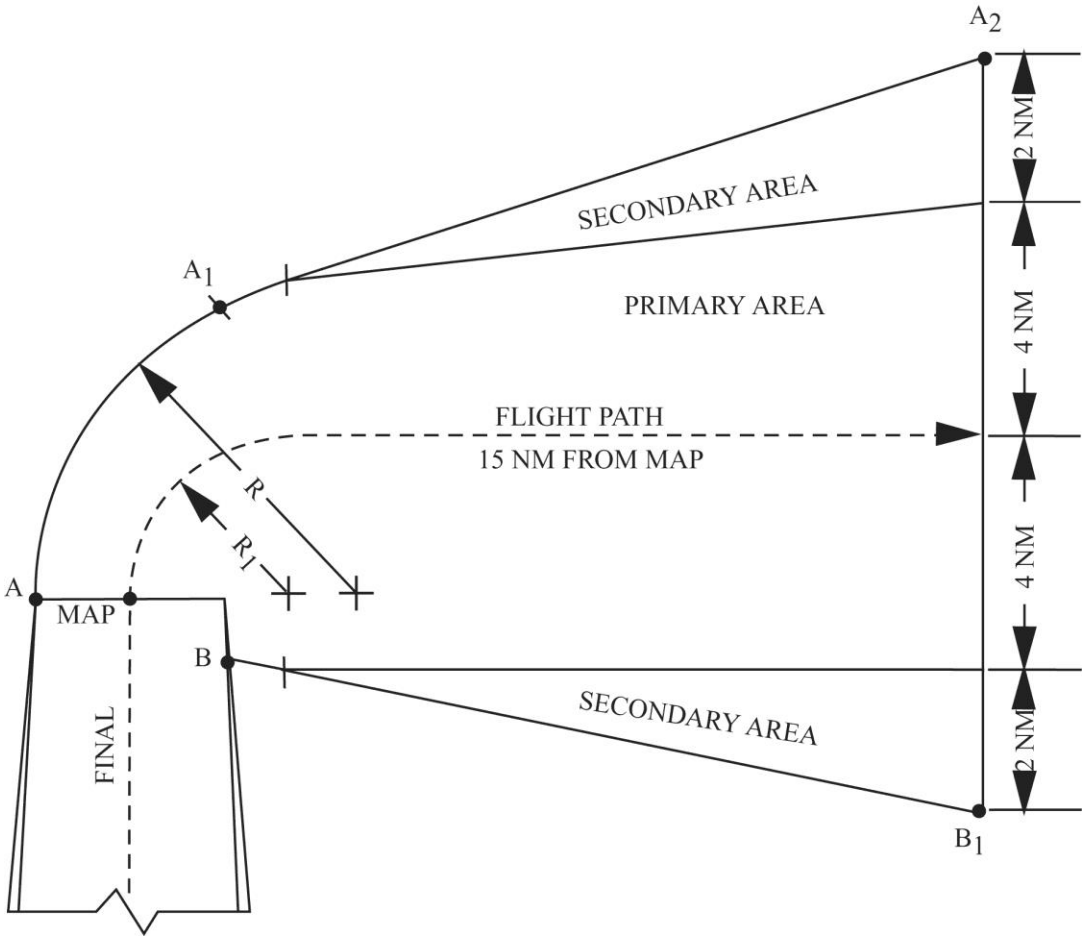
(c) Now connect "A_2" and "B_1" with a straight line.

(d) Draw an arc with the radius (R) from Point "A" to "A_1". ("A_1" is defined as the point where a line from "A_2" becomes tangent to the obstacle clearance "R" radius.) This is the edge of the obstacle clearance area.

(e) Establish Point "B" by measuring backward on the edge of the final approach secondary area a distance of 1 NM or a distance equal to the fix error PRIOR to the FAF, whichever is greater.

(f) Connect Points "A_1" and "A_2", and Points "B" and "B_1" with straight lines.

Figure 2-7-4: Turning Missed Approach Area. 90 Degree Turn or Less. Narrow Final Approach at MAP



(2) **90° Turn or Less**. Wide final approach area at MAP (see Figure 2-7-5). To construct the area:

(a) Draw an arc with the appropriate radius (R_1) from the MAP. This line is then extended outward to a point 15 NM from the MAP, measured along the line. This is the assumed flight path.

(b) Establish Points "A_2" and "B_1" by measuring 6 NM perpendicular to the flight path at the 15 NM point.

(c) Now connect Points "A_2" and "B_1" with a straight line.

(d) Draw an arc with the appropriate radius (R) from Point "A" to "A_1". ("A_1" is defined as the point where a line from "A_2" becomes tangent to the obstacle clearance "R" radius.) This is the edge of the obstacle clearance area.

(e) Establish Point "B" by measuring backward on the edge of the final approach secondary area a distance of 1 NM or a distance equal to the fix error PRIOR to the FAF, whichever is greater.

(f) Connect Points "A_1", and "A_2" and Points "B" and "B_1" with straight lines.

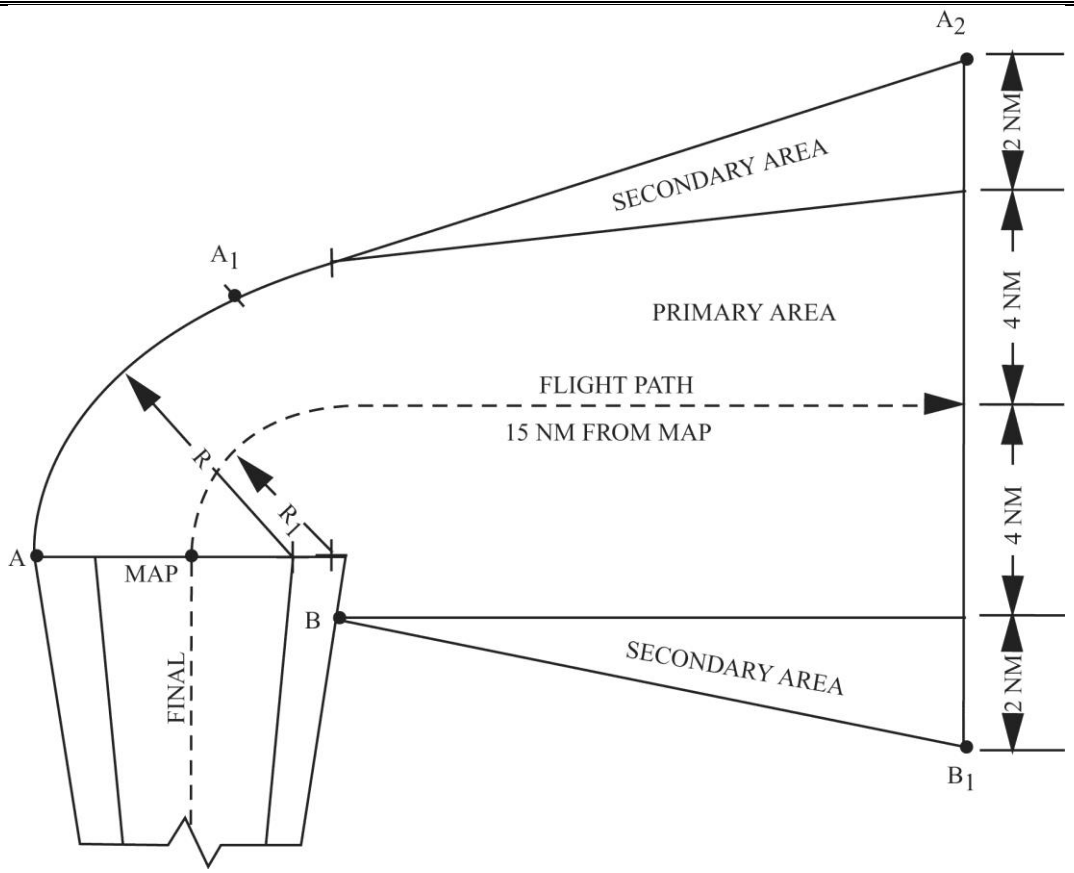


Figure 2-7-5: Turning Missed Approach Area. 90 Degree Turn or Less. Wide Final Approach Area at MAP

(3) **More Than a 90° Turn**. NARROW FINAL approach area at MAP (see Figure 2-7-6). To construct the area:

(a) Draw an arc with the radius (R_1) from the MAP through the required number of degrees and then continue outward to a point 15 NM from the MAP, measured along this line, which is the assumed flight path.

(b) Establish Points "A_2" and "C_1" by measuring 6 NM on each side of the assumed flight path and perpendicular to it at the 15 NM point.

(c) Now connect Points "A_2" and "C_1" with a straight line.

(d) Draw an arc with the radius (R) from Point "A" to Point "A_1" (Figure 2-7-6 uses 135°). ("A_1" is defined as the point where a line from "A_2" becomes tangent to the obstacle clearance "R" radius.) This is the outer edge of the obstacle clearance area.

(e) Locate Point "C" at the inner edge of the final approach secondary area opposite the MAP. (Point "A" and Point "C" will be coincident when the MAP is the facility.)

(f) Connect Points "A_1" and "A_2" and Points "C" and "C_1" with straight lines.

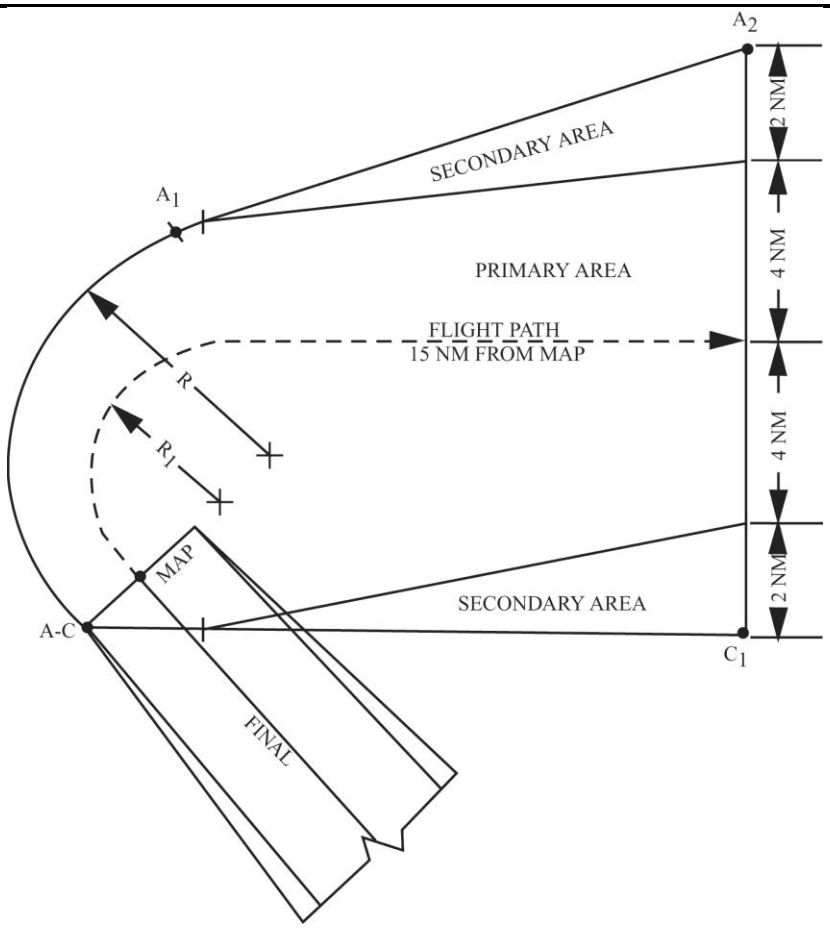


Figure 2-7-6: Turning Missed Approach Area. More Than 90 Degree Turn. Narrow Final Approach at MAP

(4) **More Than 90° Turn.** WIDE FINAL approach area at MAP (see Figure 2-7-7). To construct the area:

(a) Draw the assumed flightpath, which is an arc with the radius (R_1), from the MAP the required number of degrees to the desired flightpath or course.

(b) Establish Points "A_4" and "C_1" by measuring 6 NM on each side of the assumed flight path and perpendicular to it at the 15 NM point.

(c) Connect Points "A_4" and "C_1" with a straight line.

(d) Draw a 90° arc with the appropriate radius (R) from Point "A" to Point "A_1". Note that when the width of the final approach area at the MAP is greater than the appropriate radius (R), the turn is made in two increments when constructing the obstacle clearance area.

(e) Draw an arc with the radius (R) from Point "D" (edge of final approach secondary area opposite MAP) the required number of degrees from Point "A_2" to Point "A_3". (Point "A_3"is defined as the point where a line from "A_4" becomes tangent to the obstacle clearance "R" radius from Point "D"). Compute the number of degrees by subtracting 90° from the total turn magnitude.

(f) Connect Points "A_1" and "A_2" with a straight line.

(g) Locate Point "C" at the inner edge of the final approach secondary area opposite the MAP.

(h) Connect Point "A_3" with Point "A_4" and connect Point "C" with Point "C_1" using straight lines.

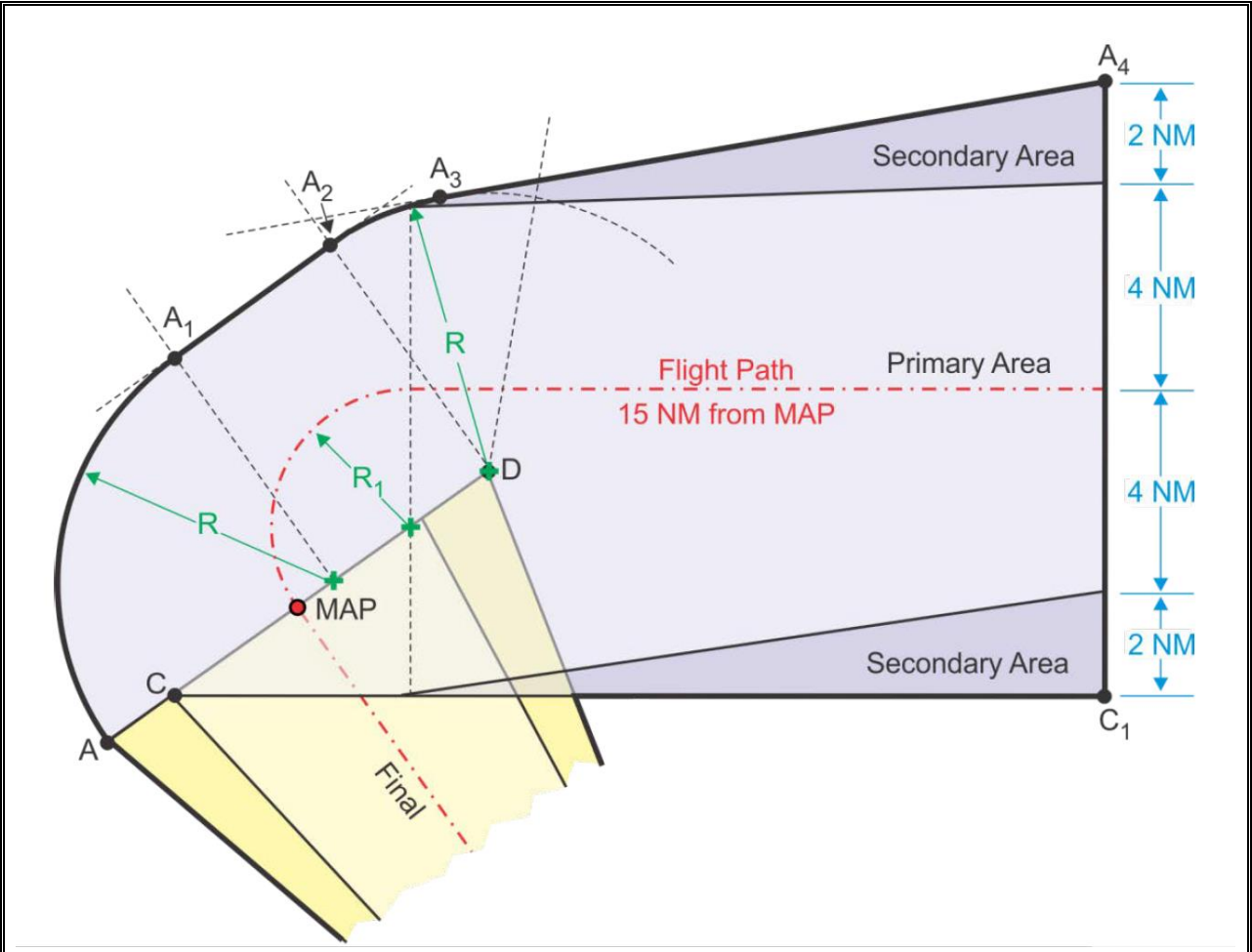


Figure 2-7-7: Turning Missed Approach Area. More Than 90 Degree Turn. Wide Final Approach at MAP

(5) 180° Turn. Narrow final approach area at MAP (see Figure 2-7-8). To construct the area:

(a) Draw an arc with the radius (R_1) from the MAP through 180°, and then continue outward to a point 15 NM from the MAP, measured along this line, which is the assumed flight path.

(b) Establish Points "A_2" and "C_1" by measuring 6 NM on each side of the assumed flight path, and perpendicular to it at the 15 NM point.

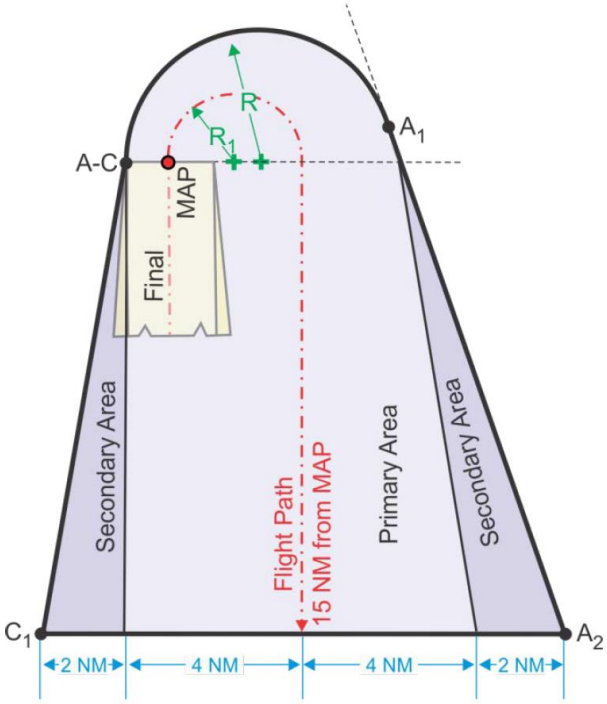
(c) Now connect Point "A_2" and Point "C_1" with a straight line.

(d) Locate Point "C" at the inner edge of the final approach secondary area opposite the MAP. (Point "A" and Point "C" will be coincident when the MAP is the facility.)

(e) Draw an arc with the radius (R) from Point "A" to Point "A_1" (180°). This is the outer edge of the obstacle clearance area.

(f) Connect Points "A_1" and "A_2" and Points "C" and "C_1" by straight lines. (The line "A_1-A_2" joins the arc tangentially.)

Figure 2-7-8: Turning Missed Approach Area. 180 Degree Turn. Narrow Final Approach Area at MAP



(6) 180° Turn. Wide Final Approach area at MAP (see Figure 2-7-9). To construct the area:

(a) Draw the flightpath arc with the radius (R_1) from the MAP and then continue the line outward to a point 15 NM from the MAP, measured along the assumed flightpath.

(b) Establish Points "A_4" and "C_1" by measuring 6 NM on each side of the flight path and perpendicular to it at the 15 NM point.

(c) Now connect Points "A_4" and "C_1" with a straight line.

(d) Draw a 90° arc with the appropriate radius (R) from Point "A" to Point "A_1". Note that when the width of the final approach area at the MAP is greater than the appropriate radius (R), the turn is made in two increments when constructing the obstacle clearance area.

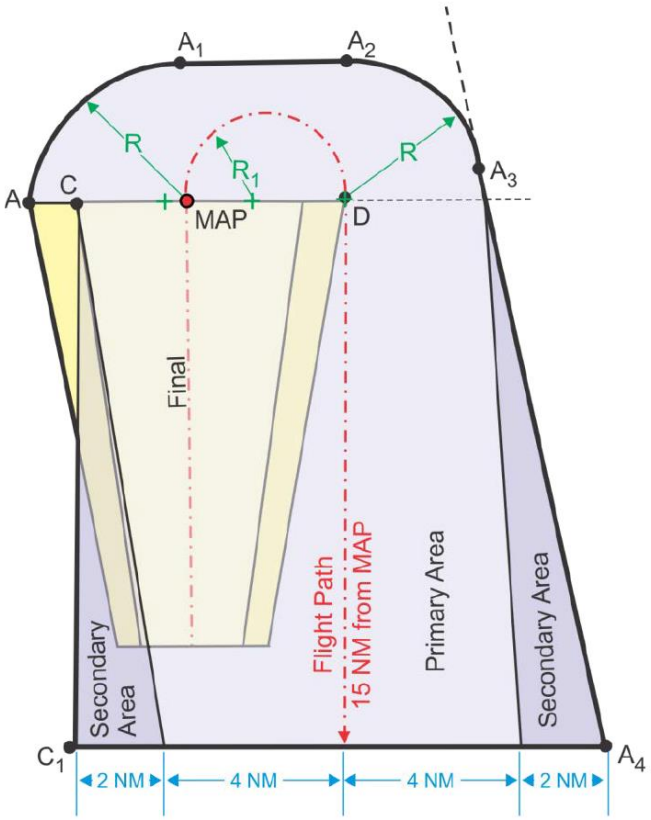
(e) Draw an arc with the radius (R) from Point "D" (edge of final approach secondary area opposite MAP) the required number of degrees from Point "A_2" to Point "A_3". Compute the number of degrees by subtracting 90° from the total turn magnitude.

(f) Connect Points "A_1" and "A_2" with a straight line.

(g) Locate Point "C" at the inner edge of the final approach secondary area opposite the MAP.

(h) Connect Points "A_3" and "A_4" and Points "C" and "C_1" with straight lines. (The line "A_3-A_4" joins the arc tangentially.)

Figure 2-7-9: Turning Missed Approach Area. 180-Degree Turn. Wide Final Approach Area at MAP

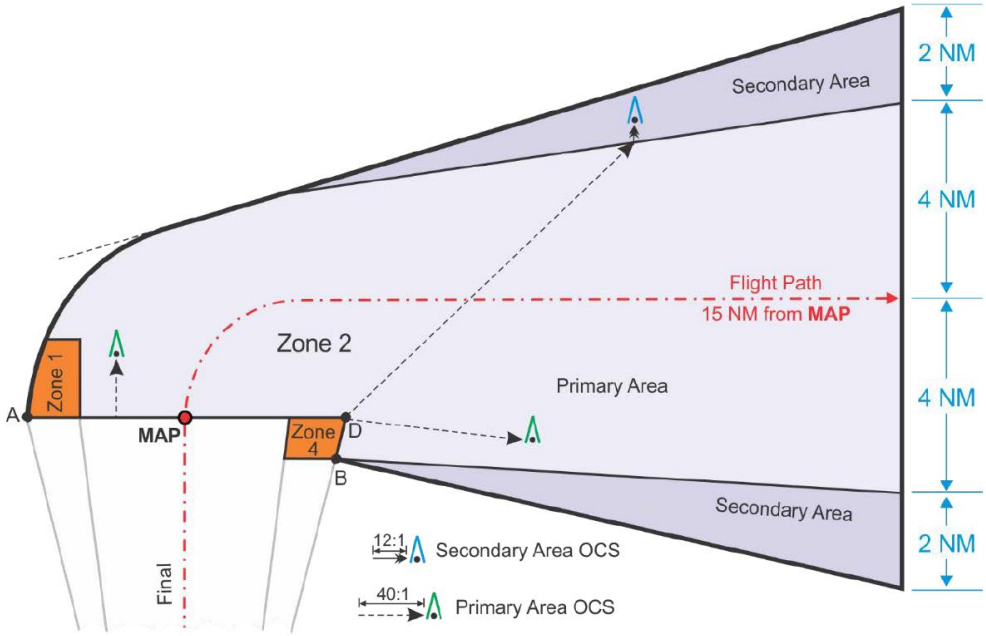


2.7.7 Turning Missed Approach Obstacle Clearance

The methods of determining the height of the 40:1 missed approach surface over obstacles in the turning missed approach area vary with the amount of turn involved. Evaluate the missed approach segment to ensure the 40:1 obstacle clearance surface (OCS) is not penetrated.

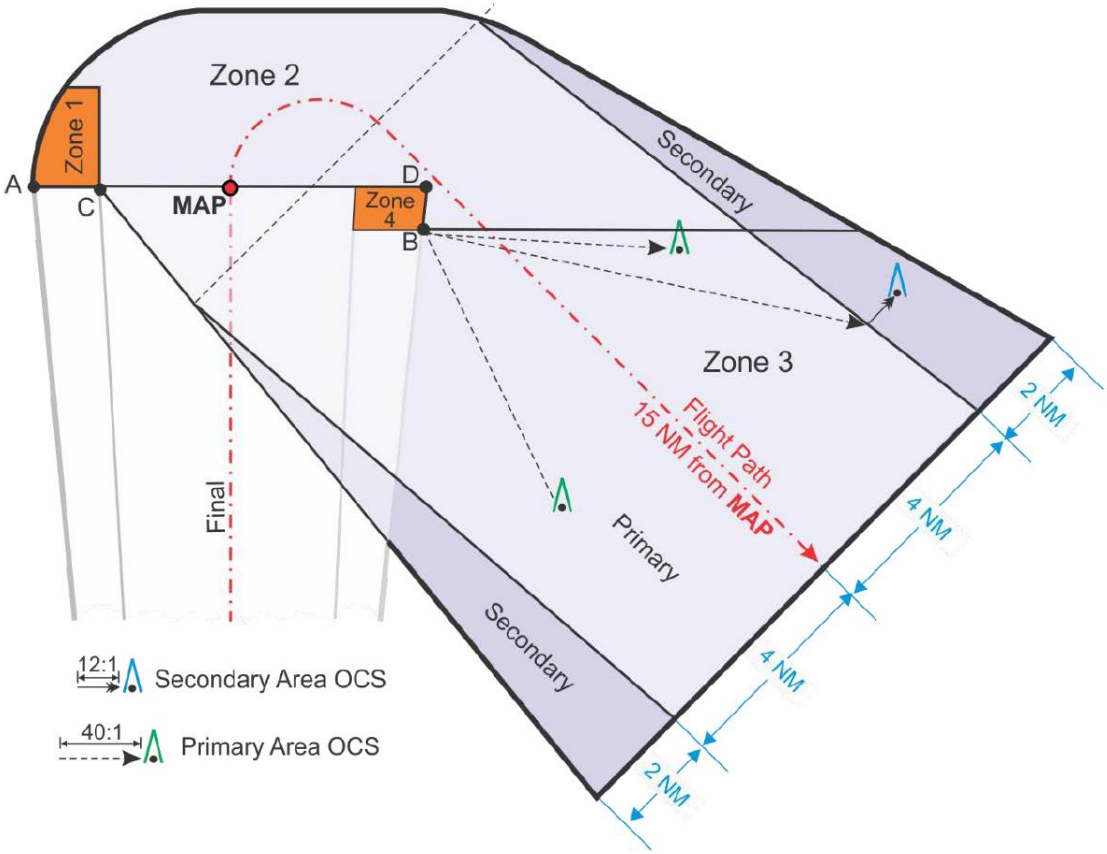
a. **90 degree Turn or Less** (see Figure 2-7-10). The height of the missed approach surface over the MAP is the same as specified in paragraph 2.7.5. Zone 1 is a 1.6 NM continuation of the final approach secondary area. The height of the missed approach surface over an obstacle in zone 1 is equal to the height of the missed approach surface over the MAP plus the secondary rise defined for the final approach segment. Zone 2 is the area in which the height of the missed approach surface over an obstacle must be determined. To do this, first identify line “A-D-B.” To protect for the short turning aircraft point “B” is located by measuring backward on the edge of the final approach area a distance of 1 NM or a distance equal to the fix error prior to the PFAF, whichever is greater. Zone 4 is part of the missed approach equivalent to a portion of the final secondary OEA on the side of the turn between point “B” and the MAP. The height of the missed approach surface over an obstacle in zone 4 is equal to the height of the missed approach surface over the MAP. Obstacles in zones 1 and 4 need not be evaluated by zone 2. The height of the missed approach surface over an obstacle in Zone 2 is determined by measuring the straight-line distance from the obstacle to the nearest point on line "A-D-B" and computing the height based on the 40:1 ratio. The height of the missed approach surface over the MAP is the same as specified in Para 2.7.5. When an obstacle is in a secondary area, measure the straight-line distance from the nearest point on the line "A-D-B" to the point on the inner edge of the secondary area which is nearest the obstacle. Compute the height of the missed approach surface at this point, using the 40:1 ratio. Then apply the 12:1 secondary area ratio from the height of the surface for the remaining distance to the obstacle.

Figure 2-7-10: Turning Missed Approach Obstacle Clearance. 90 Degree Turn or Less



b. **More than 90° Turn** (see Figure 2-7-11). In this case a third zone becomes necessary. Zone 3 is defined by extending a line from Point "B" to the extremity of the missed approach area perpendicular to the FAC. Zone 3 will encompass all of the missed approach area not specifically within Zones 1, 2 and 4. All distance measurements in Zone 3 are made from point "B". The height of the missed approach surface over point “B” for zone 3 computations is equal to the height of the MDA less any RASS and precipitous terrain adjustments. The height of the missed approach surface over an obstacle in Zone 3 is determined by measuring the distance from the obstacle to point "B" and computing the height based on the 40:1 ratio. For an obstacle in the secondary area, use the same measuring method prescribed in Para 2.7.7.a except that the original measuring point shall be point "B".

Figure 2-7-11: Turning Missed Approach Obstacle Clearance. More Than 90 Degree Turn



c. **Secondary Area**. In the secondary area no obstacles may penetrate a 12:1 slope, which extends outward and upward from the 40:1 surface from the inner to the outer boundary lines of the secondary area.

d. **Evaluate** the missed approach segment from the MAP to the clearance limit. Terminate the 40:1 obstacle clearance surface (OCS) at an elevation corresponding to enroute ROC below the missed approach altitude.

(1) If the 40:1 OCS terminates prior to the clearance limit, continue the evaluation using a level OIS at the height that the 40:1 OCS was terminated.

(2) If the clearance limit is reached before the 40:1 OCS terminates, continue a climb-in-hold evaluation at the clearance limit.

e. The preliminary charted missed approach altitude is the highest of the minimum missed approach obstruction altitude, MHA established in accordance with Chapter 18, Para 18.2.4, or lowest airway MEA at the clearance limit. To determine the minimum missed approach obstruction altitude for the missed approach segment, identify the highest obstacle in the primary area; or if applicable, the highest equivalent obstacle in the secondary area. Then add the appropriate ROC (plus adjustments) for holding or enroute to the highest obstacle elevation. Round the total value to the nearest hundred-foot level, provided the ROC is not violated.

f. **Determine** if a climb-in-hold evaluation is required (see Chapter 18, Section 7). If a climb in holding is intended at the clearance limit, a climb-in-hold evaluation is mandatory.

(1) Calculate the elevation of the 40:1 surface at the end of the segment (clearance limit). The 40:1 surface starts at the same elevation as it does for obstacle evaluations. Compute the 40:1 rise from a point on the “A-D-B" line in the shortest distance to the end-of-segment line at the clearance limit.

(2) Compute the ROC surface elevation at the clearance limit by subtracting the appropriate ROC (plus adjustments) from the preliminary charted missed approach altitude.

(3) Compare the ROC surface elevation at the clearance limit with the 40:1 surface elevation.

(a) If the computed 40:1 surface elevation is equal to or greater than the ROC surface elevation, a climb hold evaluation is NOT required, or

(b) If the computed 40:1 surface elevation is less than the ROC surface elevation, a climb-in-hold evaluation is required. Chapter 18 Holding Criteria, Section 7, specifies higher speed groups, and therefore, larger template sizes are usually necessary for the climb-in-hold evaluation. These templates may require an increase in MHA under Para 18.2.4. If this evaluation requires an increase in the MHA, evaluate the new altitude using the higher speed group specified in Chapter 18 Section 7. This sequence of review shall be used until the MHA does not increase, then the 40:1 surface is re-evaluated. If obstacles penetrate the 40:1 surface, take action to eliminate the penetration.

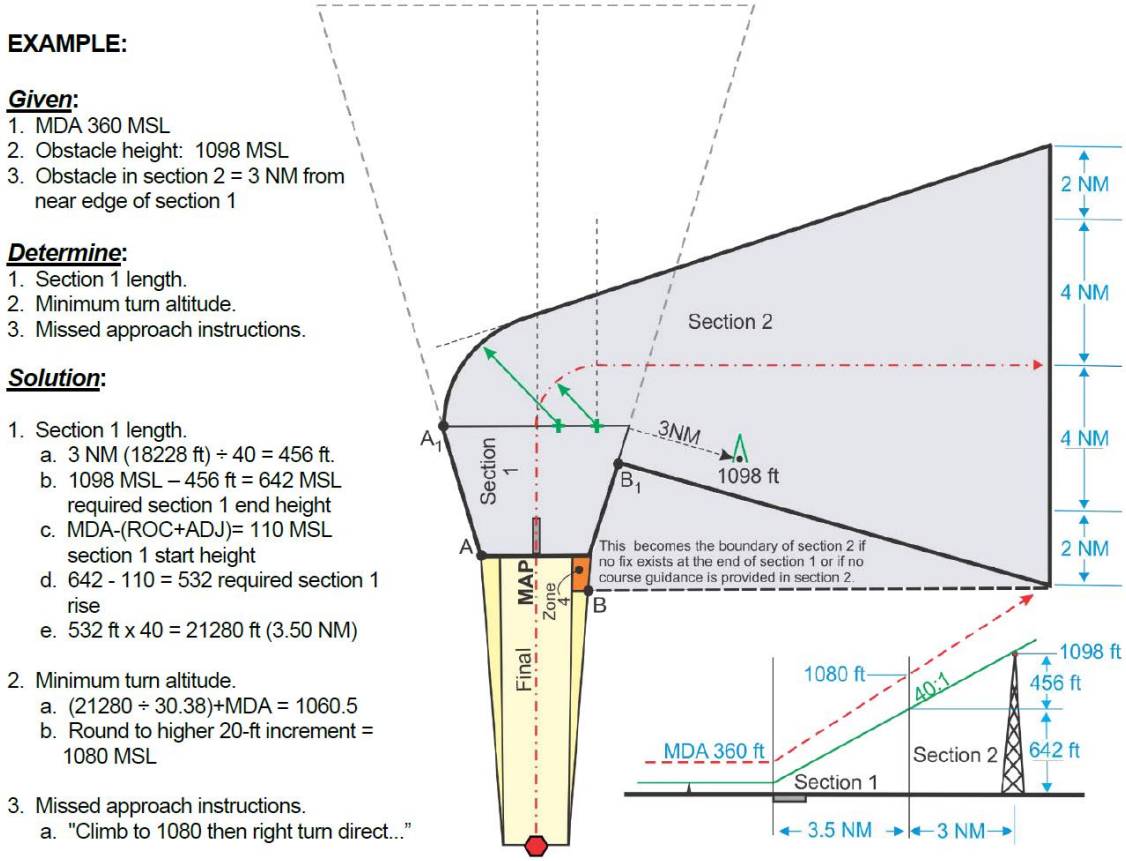
g. The charted missed approach altitude is the higher of the preliminary charted missed approach altitude or the MHA established under Para 2.7.5.c.3.b.

2.7.8 Combination Straight and Turning Missed Approach Area

If a straight climb to a specific altitude followed by a turn is necessary to avoid obstacles, a combination straight and turning missed approach area must be constructed. The straight portion of this missed approach area is Section 1. The portion in which the turn is made is Section 2. Evaluate the missed approach segment to ensure obstacle clearance is provided.

a. **Straight Portion**. Section 1 is a portion of the normal straight missed approach area and is constructed as specified in Para 2.7.4. Obstacle clearance is provided as specified in Para 2.7.5. except that secondary area reductions do not apply. The length of Section 1 is determined as shown in Figure 2-7-12 and relates to the need to climb to a specified altitude prior to commencing the turn. Point A_1 marks the end of Section 1. Point B_1 is one nautical mile from the end of Section 1 (see Figure 2-7-12).

Figure 2-7-12: Combined Missed Approach Area



b. **Turning Portion**. Section 2 is constructed as specified in Para 2.7.6. except that point "A" is replaced by point "A_1" and unless a fix does not exist at the end of section 1, or if positive course guidance is not provided in section 2, point "B" is replaced by a point 1 NM from the end of section 1 (point "B_1") (see Figure 2-7-12). Obstacle clearance requirements in section 2 are the same as those specified in paragraph 2.7.7 with the following exemptions:

(1) Zone 1 is not considered.

(2) The height of the missed approach surface over point "B_1" or "B" for zone 3 computations is equal to the turn altitude less any RASS and precipitous terrain adjustments for final.

(3) Zone 4 may begin at either point "B1" or "B," if either are found prior to the MAP. The height of zone 4 is equal to the height of the OCS at the end of section 1.

c. **Evaluate** the 40:1 surface from the MAP to the clearance limit (end of the missed approach segment). If obstacles penetrate the surface, take action to eliminate the penetration.

d. The preliminary charted missed approach altitude is the lowest of the minimum missed approach obstruction altitude, MHA established in accordance with Chapter 18, Para 18.2.4., or lowest airway MEA at the clearance limit. To determine the minimum missed approach obstruction altitude for the missed approach segment, identify the highest obstacle in the primary area; or if applicable, the highest equivalent obstacle in

the secondary area. Then add the appropriate ROC (plus adjustments) for holding or enroute to the highest obstacle elevation. Round the total value to the next higher hundred-foot level.

e. **Determine** if a climb-in-hold evaluation is required (see Chapter 18, Section 7). If a climb in holding is intended at the clearance limit, a climb-in-hold evaluation is mandatory.

(1) Calculate the elevation in the 40:1 surface at the end of the segment (clearance limit). The 40:1 surface starts at the same elevation as it does for obstacle evaluations. First, compute the 40:1 rise from a point on the line defining the origin of the 40:1 surface at the MAP, in the shortest distance and perpendicular to the end-of-section 1. If there is a remote altimeter setting source (RASS) and the missed approach instructions do not include a parenthetical climb to altitude (see Para 3.2.2. c(5)), then the elevation at the end of section 1 is adjusted by subtracting the altitude difference between the RASS adjustments when two remote altimeter sources are used; or subtracting the RASS adjustment for a part-time altimeter source. The resulting altitude at the end of section 1 must not be lower than the 40:1 surface height at the MAP. Second, compute the 40:1 rise from a point on the nearest edge of section 1, in the shortest distance to the end-of-segment line at the clearance limit. Add the two values together and this is the 40:1 surface height at the end of the segment (clearance limit).

(2) Compute the ROC surface elevation at the clearance limit by subtracting the appropriate ROC (plus adjustments) from the preliminary charted missed approach altitude.

(3) Compare the ROC surface elevation at the clearance limit with the 40:1 surface elevation.

(a) If the computed 40:1 surface elevation is equal to or greater than the ROC surface elevation, a climb-in-hold evaluation is NOT required.

(b) If the computed 40:1 surface elevation is less than the ROC surface elevation, a climb-in-hold evaluation is required. TP 308 Holding Criteria, Para 18.7.2, specifies higher speed groups, and therefore larger template sizes, are usually necessary for the climb-in-hold evaluation. These templates may require an increase in MHA under paragraph 18.2.4. If this evaluation requires an increase in the MHA, evaluate the new altitude using the higher speed group specified in Section 18-7. This sequence of review shall be used until the MHA does not increase, then the 40:1 surface is re-evaluated. If obstacles penetrate the 40:1 surface, take action to eliminate the penetration.

f. The charted missed approach altitude is the higher of the preliminary charted missed approach altitude or the MHA established under Para 2.7.5.c.3.b.

2.7.9 End of Missed Approach

Aircraft shall be assumed to be in the initial approach or enroute environment upon reaching minimum obstacle clearance altitude (MOCA) or minimum enroute altitude (MEA). Thereafter, the initial approach or the enroute obstacle clearance criteria apply. This means that the missed approach altitude must provide sufficient ROC to allow the pilot to hold at the missed approach holding fix (using the appropriate holding template), or must provide sufficient ROC to allow the pilot to proceed enroute. Where the missed approach altitude is below an initial approach altitude or enroute altitude, the 40:1 OCS must be assessed beyond the missed approach holding fix. If a climb in hold is required, it shall be assessed in accordance with

Chapter 18, Holding Criteria. A note indicating that a shuttle climb or climb-in-hold is required prior to proceeding on course shall be included in the missed approach instructions. Example: Shuttle climb to 5000' BPOC.

2.7.10 Missed Approach Climb Gradient

a. Where the OCS is penetrated and the lowest minima is required, a missed approach climb gradient (CG) greater than the standard 200 ft/NM (or 400 ft/NM for COPTER procedures) may be specified.

b. Operations with a minima that requires a climb gradient in excess of 425 feet/NM (600 feet/NM for helicopter-only procedures) requires a Special Authorization. Flight Standards coordination is required for the publication of the restricted IP.

c. For circling minima, CG greater than standard may only be authorized for circling only procedures.

d. When a missed approach CG in excess of standard has been established, the following items must be met:

(1) The (lower) minima associated with the greater than standard CG shall be published along with (higher) minima associated with the standard CG. Where it is not feasible to publish both on the same chart, an alternative is to publish a second chart containing the same type of minima as the first chart that will permit the use of a standard missed approach CG. Should this method be used, the greater than standard CG chart shall make reference to the standard CG chart (e.g. if unable to meet climb gradient, see RNAV (GNSS) Z RWY 05).

(2) The CG shall be clearly published and be specified to an altitude at which the gradient is no longer required.

SECTION 8. TERMINAL AREA FIXES

2.8 Terminal Area Fixes

2.8.1 General

Terminal area fixes include, but are not limited to the FAF, the IF, the IAF, the holding fix, and when possible, a fix to mark the MAP. Each fix is a geographical position on a defined course. Terminal area fixes should be based on similar navigation systems. For example, TACAN, VORTAC, and VOR/DME facilities provide Radial/DME fixes. NDB facilities provide bearings. VOR facilities provide VOR radials. The use of integrated (VHF/NDB) fixes shall be limited to those intersection fixes where no satisfactory alternative exists.

2.8.2 Fixes Formed By Intersection

A geographical position can be determined by the intersection of courses or radials from two stations. One station provides the course the aircraft is flying and the other provides a crossing indication that identifies a point along the course that is being flown. Because all stations have accuracy limitations, the geographical point which is identified is not precise, but may be anywhere within a quadrangle which surrounds the plotted point of intersection. Figure 2-28 illustrates the intersection of an arc and a radial from the same DME facility, and the intersection of two radials or courses from different navigation facilities. The area encompassed by the sides of the quadrangle formed in these ways is referred to in this publication as the "fix displacement area".

2.8.3 Course/Distance Fixes

a. DME fixes. A DME fix is formed by a DME reading on a positive navigational course. The information should be derived from a single facility with collocated azimuth and DME antennas. However, when a unique operational requirement indicates a need for DME information from other than collocated facilities, an individual IAP that specifies DME may be approved, provided the angular divergence between the signal sources at the fix does not exceed 23° (see Figure 2-8-1). For limitation on use of DME with ILS or LOC, see Vol 1, paragraph 9.1.2.

b. Along-Track Distance (ATD) fixes. An ATD fix is an along track position defined as a distance in NM, with reference to the next WP along a specified course.

2.8.4 Fixes Formed By Radar

Where ATC can provide the service, Airport Surveillance Radar (ASR) may be used for any terminal area fix. PAR may be used to form any fix within the radar coverage of the PAR system. Air Route Surveillance Radar (ARSR) may be used for initial approach and intermediate approach fixes. Coordinate with the appropriate ATC facility before establishing a radar fix to ensure the facility agrees to provide the radar fix service.

2.8.5 Fix Displacement Area

The areas portrayed in Figure 2-8-1 extend along the flight course from Point "A" to Point "C". The fix error is a plus-or-minus value, and is represented by the lengths from "A" to "B" and "B" to "C". Each of these lengths is applied differently. The fix error may cause the fix to be

received early (between "A" and "B"). Because the fix may be received early, protection against obstacles must be provided from a line perpendicular to the flight course at point “A".

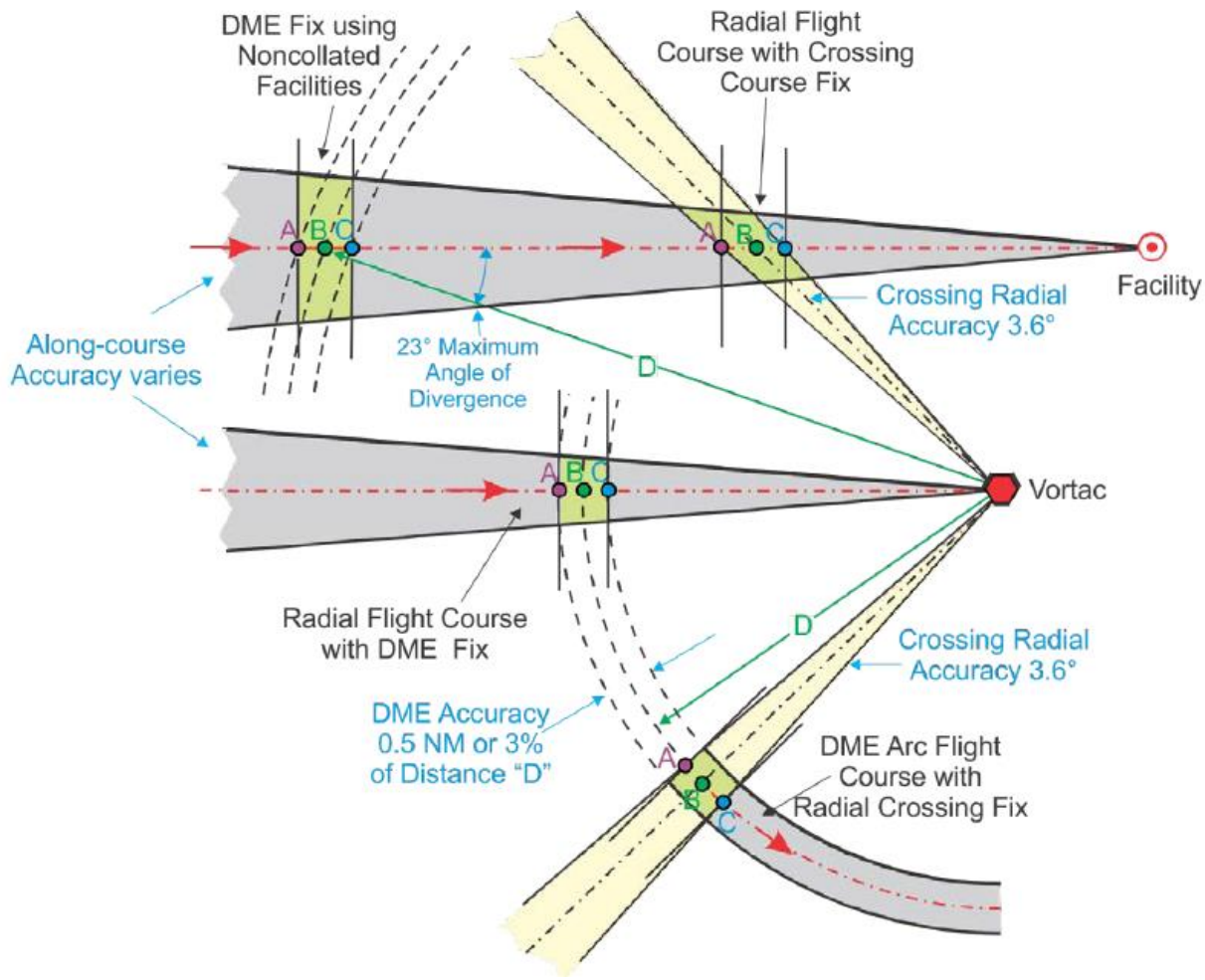


Figure 2-8-1: Intersection Fix Displacement

2.8.6 Intersection Fix Displacement Factors

The intersection fix displacement area is determined by the system use accuracy of the navigation fixing systems (see Figure 2-8-1). The system use accuracy in VOR and TACAN type systems is determined by the combination of ground station error, airborne receiving system error, and flight technical error (FTE). Enroute VOR data have shown that the VOR system accuracy along radial 4.5°, 95 percent of occasions, is a realistic, conservative figure. Thus, in normal use of VOR or TACAN intersections, fix displacement factors may conservatively be assessed as follows:

a. **Along-Course Accuracy.**

(1) VOR/TACAN radials, plus-or-minus 4.5°.

(2) Localizer course, plus-or-minus 1°.

(3) NDB courses or bearings, plus-or-minus 5°.

Note: The plus-or-minus 4.5° (95 percent) VOR/TACAN figure is achieved when the ground station course signal error, the FTE, and the VOR airborne equipment error are controlled to certain normal tolerances. Where it can be shown that any of the three error elements is consistently different from these assumptions (for example, if flight inspection shows a consistently better VOR signal accuracy or stability than the one assumed, or if it can be shown that airborne equipment error is consistently smaller than assumed), VOR fix displacement factors smaller than those shown above may be utilized under Para 141.

b. **Crossing Course Accuracy.**

(1) VOR/TACAN radials, plus-or-minus 3.6°.

(2) Localizer course, plus-or-minus 0.5°.

(3) NDB courses or bearings, plus-or-minus 5°.

Note: The plus-or-minus 3.6° (95 percent) VOR/TACAN figure is achieved when the ground station course signal error and the VOR airborne equipment error are controlled to certain normal tolerances. Since the crossing course is not flown, FTE is not a contributing element. Where it can be shown that either of the error elements is consistently different, VOR displacement factors smaller than those shown above may be utilized in accordance with Para 141.

c. Calculate intersection fix displacement along the track to be flown using formula 2-8-1 and formula 2-8-2 (see figure 2-8-2).

Formula 2-8-1. Fix Displacement Calculations

$$E = \frac{1852 \times D \times \sin(B)}{0.3048 \times \sin(A+B)}$$

Where:

E = Fix displacement on turn side (feet)
A = Angle between along course track and crossing course
B = Crossing course accuracy
D = Distance (NM) from crossing facility to intersection

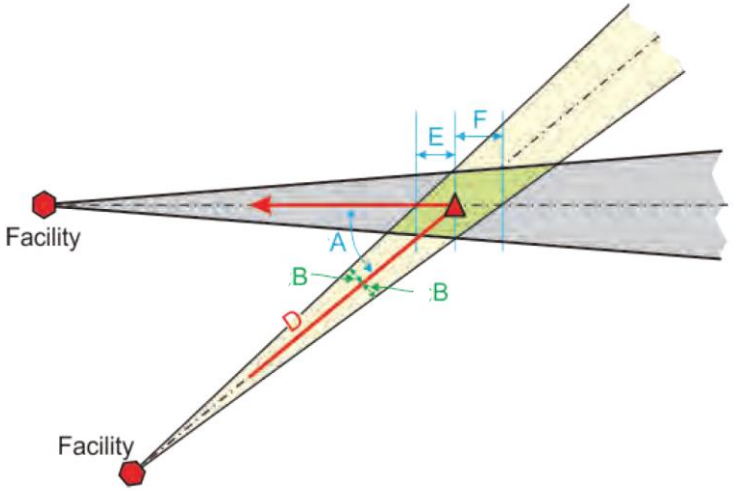
Formula 2-8-2. Fix Displacement Calculations

$$F = \frac{1852 \times D \times \sin(B)}{0.3048 \times \sin(A-B)}$$

Where:

F = Fix displacement opposite of turn side (feet)
A = Angle between along course track and crossing course
B = Crossing course accuracy
D = Distance (NM) from crossing facility to intersection

Figure 2-8-2. Fix Displacement



2.8.7 Other Fix Displacement Factors

a. **Radar**. Plus-or-minus 500 feet or 3 percent of the distance to the antenna, whichever is greater.

b. **DME**. Plus-or-minus 0.5 NM or +/- 3% of the distance to the antenna, whichever is greater.

c. **Overheading a Station**. The fix error involved in station passage is not considered significant in terminal applications. The fix is therefore considered to be at the plotted position of the navigation facility. The use of TACAN station passage as a fix is NOT acceptable for holding fixes or high altitude IAF's.

2.8.8 Satisfactory Fixes

a. **Intermediate, Initial or Feeder Fix**. To be satisfactory as an intermediate or initial or feeder approach fix, the fix error must not be larger than 50 percent of the appropriate segment distance that follows the fix. Measurements are made from the plotted fix position (see Figure 2-8-3).

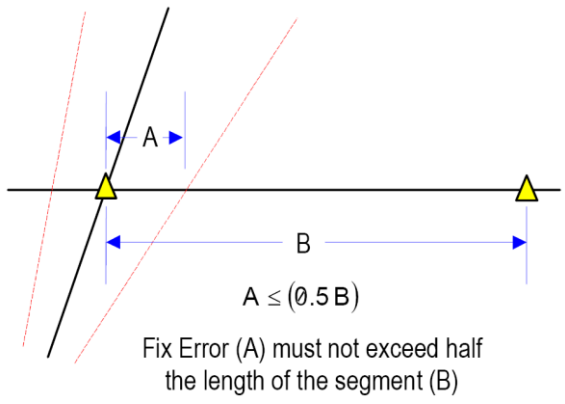


Figure 2-8-3: Intermediate, Initial, or Feeder Approach Fix Errors

Note: B segment from IF to FAF.

b. **Holding Fixes**. Any terminal area fix except overheading a TACAN may be used for holding. The following conditions shall exist when the fix is an intersection formed by courses or radials:

(1) The angle of divergence of the intersecting courses or radials shall not be less than 45°.

(2) If the facility that provides the crossing course, is NOT an NDB, it may be as much as 45 NM from the point of intersection.

(3) If the facility that provides the crossing course is an NDB, it must be within 30 NM of the intersection point.

(4) If distance stated in Para 2.8.8.b.(2) or (3) are exceeded, the minimum angle of divergence of the intersecting courses must be increased at the following rate:

(a) If an NDB facility is involved, 1° for each mile over 30 NM.

(b) If an NDB facility is NOT involved, ½° for each mile over 45 NM.

c. **FAF**. For a fix to be satisfactory for use as a FAF, the fix error should not exceed plus-or-minus 1 NM (see Figures 2-8-3 and 2-8-4). It may be as large as plus-or-minus 2 NM when:

(1) The MAP is marked by overheading an air navigation facility; or

(2) A buffer of equal length to the excessive fix error is provided between the published MAP and the point where the missed approach surface begins. The area between the MAP and the start of the 40:1 surface rise is considered missed approach primary area. When PCG is available, the 12:1 secondary area may begin where the 40:1 surface rise starts (see figure 2-8-5).

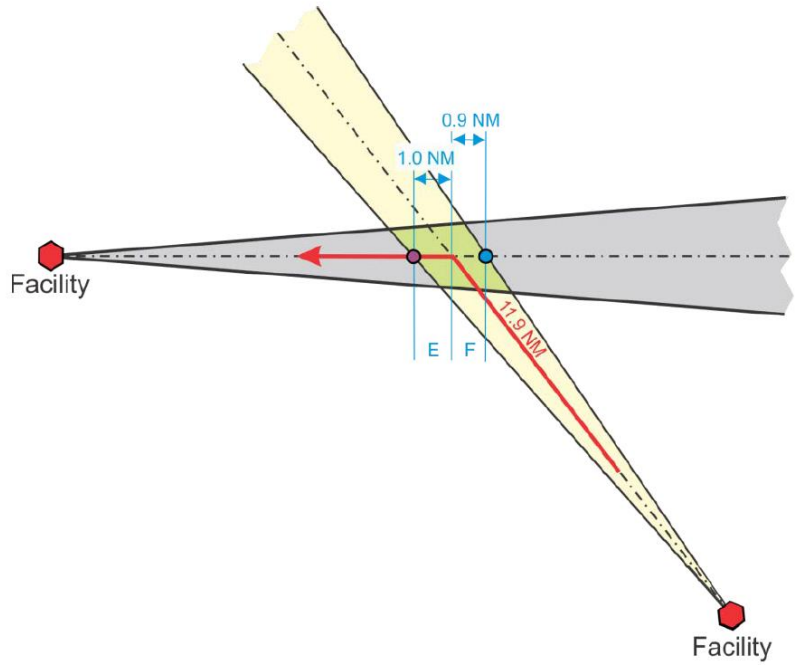


Figure 2-8-4: Measurement of FAF Error

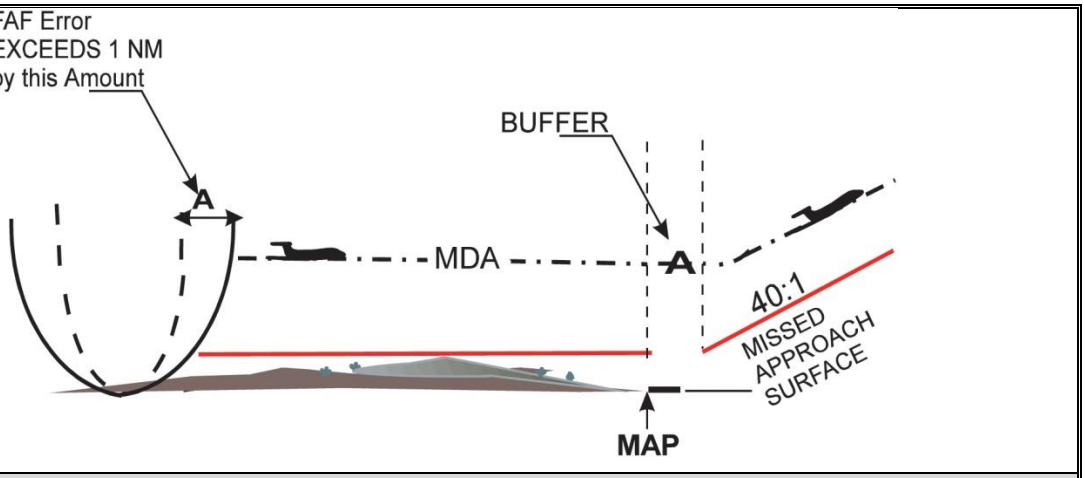


Figure 2-8-5: FAF Error Buffer

2.8.9 Using Fixes for Descent

a. **Distance Available for Descent**. When applying descent gradient criteria applicable to a STAR, feeder or an approach segment (initial, intermediate or final approach), the measuring point is the plotted position of the fix (see Figure 2-8-6) with the lower altitude restriction, and the plotted position of the fix with the higher altitude restriction. Fixes without an altitude restriction are ignored for descent gradient calculations. Calculate using the minimum altitude authorized at each fix for a minimum, mandatory, or block altitude restriction. For maximum altitude restrictions, calculate using the maximum altitude authorized at the fix.

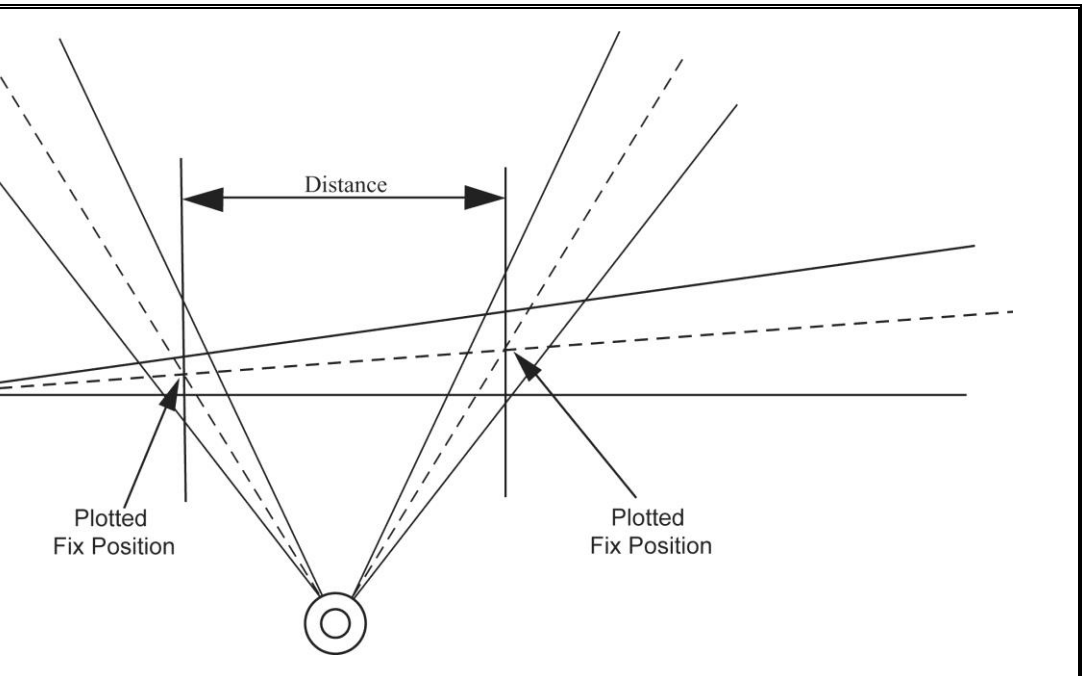


Figure 2-8-6: Distance For Descent Gradient Application

b. **Obstacle Clearance after Passing a Fix**. It is assumed that descent will begin at the earliest point the fix can be received. Full obstacle clearance shall be provided from this

point to the plotted point of the next fix. Therefore, the altitude to which descent is to be made at the fix must provide the same clearance over obstacles in the fix displacement area as it does over those in the approach segment that is being entered (see Figures 2-8-7 and 2-8-8).

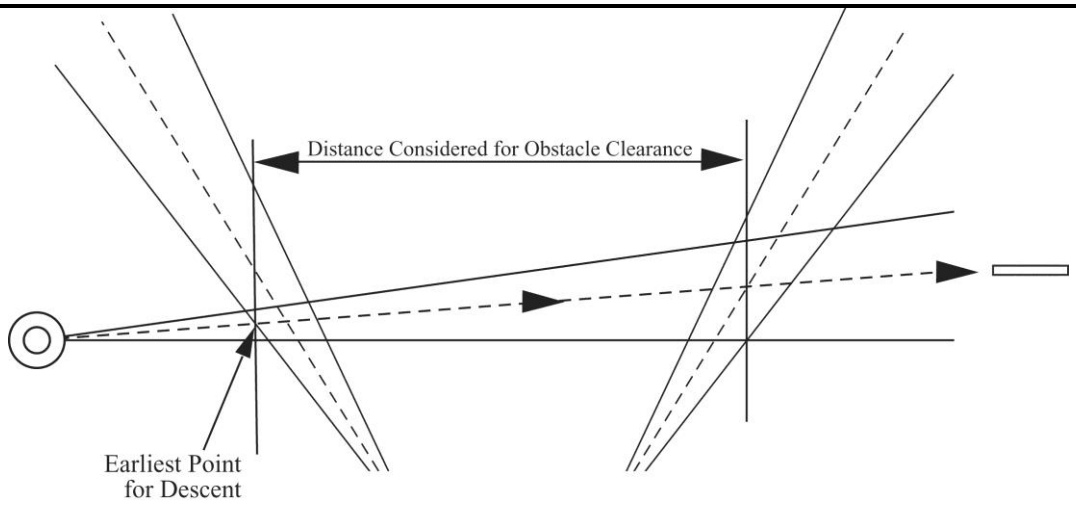
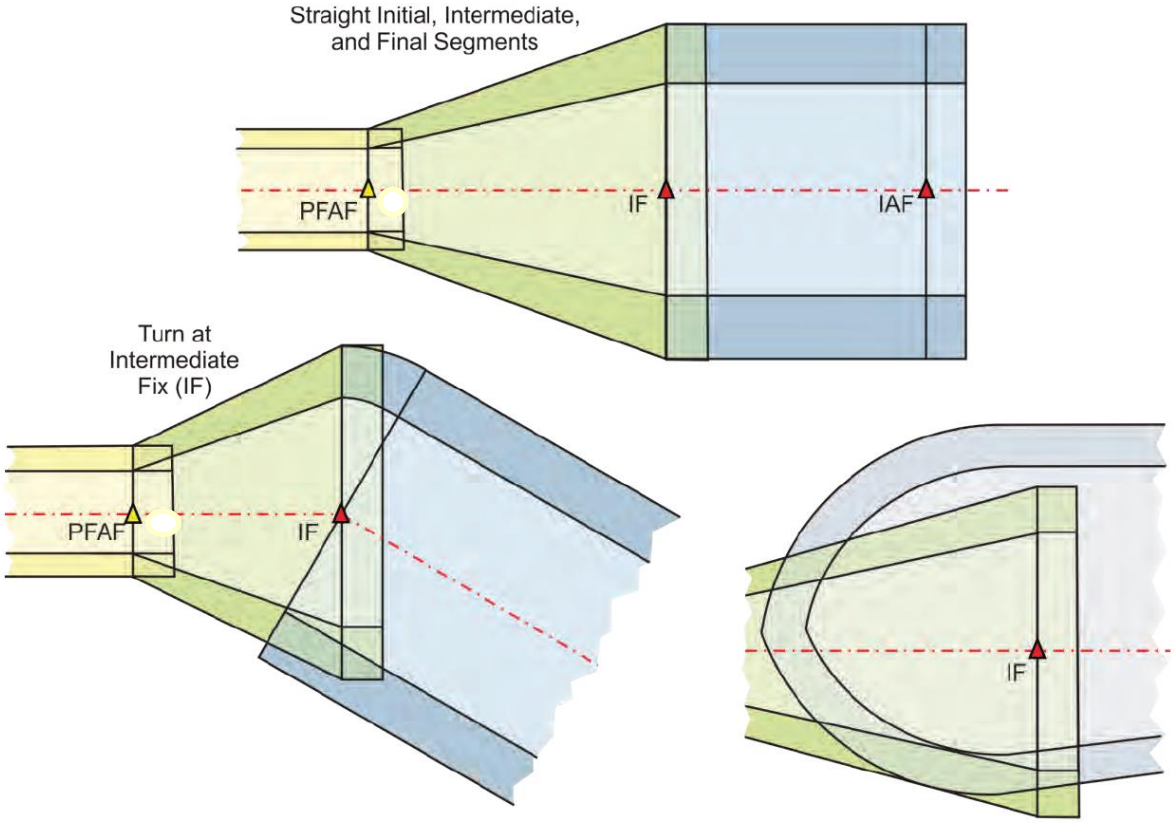


Figure 2-8-7: Obstacle Clearance Area Between Fixes

Figure 2-8-8: Construction of Fix Displacement Area for Obstacle Clearance



c. **Step-down Fixes** (see Figure 2-8-9).

(1) DME or Radar Fixes. Except in the intermediate segment within a procedure turn (see Para 2.4.5), there is no maximum number of step-down fixes in any segment when DME, an RNAV WP, an ATD fix, or radar is used. DME and ATD fixes may be denoted in tenths of a NM. The distance between fixes shall not be less than 1 NM.

(2) Intersection Fixes.

(a) Only one step-down fix is permitted in the final and intermediate segments.

(b) If an intersection fix forms a FAF, IF, or IAF:

(i) The same crossing facility shall be used for the step-down fix(es) within that segment.

(ii) All fixes from the IF to the last step-down fix in final shall be formed using the same crossing facility.

(c) Table 2-8-1 shall be used to determine the number of step-down fixes permitted in the initial segment. The distance between fixes shall not be less than 1 NM.

(3) **Altitude at the Fix**. The minimum altitude at each step-down fix shall be specified in 100-foot increments, except the altitude at the last step-down fix in the final segment may be specified in a 20-foot increment.

(4) **In the Final Segment**:

(a) The altitude at a stepdown fix published in conjunction with vertically-guided minimums (for example, an RNAV with LPV and LNAV minimums or an ILS combined with a LOC) must not exceed the calculated altitude of the glide slope/glidepath at the fix. Calculate the maximum permissible altitude for an SDF by applying formula 2-8-3.

Formula 2-8-3. Maximum SDF Altitude

$$\mathrm{SDF_{max}} = \tan(\theta) \times \mathrm{d} + \mathrm{TCH} + \mathrm{LTP_{elev}}$$

Where:

θ=GPA or VDA published on same procedure
d = distance (feet) from LTP to SDF

TCH = Threshold Crossing Height

$\mathrm{LTP_{elev}}$ = Landing Threshold Point Elevation ASL

(b) A step-down fix shall not be established unless a decrease of at least 60 feet in MDA or a reduction in the visibility minimum is achieved.

(c) The last step-down fix error shall not exceed plus-or-minus 2 NM or the distance to the MAP whichever is less. The fix error for other step-down fixes in final shall not exceed 1 NM.

(d) Minimums shall be published both with and without the last step down fix, except for procedures requiring DME or NDB procedures that use a VOR radial to define the step down fix.

(e) Final Segment RNAV non-vertically guided procedures step-down fixes:

(i) Establish step-down fix locations in 0.10 NM increments from the LTP/FTP.

(ii) The minimum distance between stepdown fixes is 1 NM.

(iii) For step-down fixes published in conjunction with vertically-guided minimums, the published altitude at the fix must be equal to or less than the computed glidepath altitude at the fix

Note: Glidepath altitude is calculated associated with the basis of the PFAF calculation.

(iv) The altitude at any stepdown fix may be established in 20-ft increments and shall be rounded to the next HIGHER 20-ft increment. For example, 2104 becomes 2120.

(v) Where a RASS adjustment is in use, the published stepdown fix altitude must be established no lower than the altitude required for the greatest amount of adjustment (i.e., the published minimum altitude must incorporate the greatest amount of RASS adjustment required).

Note: Step down fix may be lower than one or more circling minima.

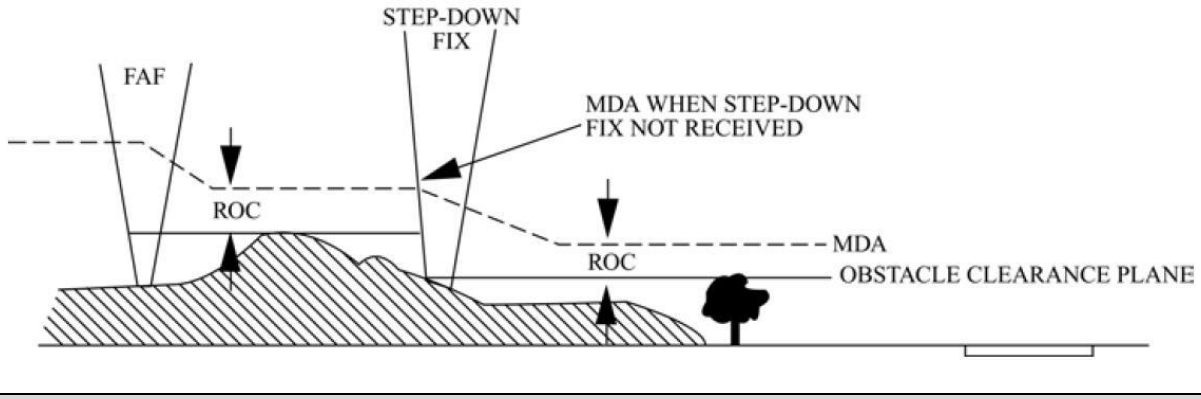


Figure 2-8-9: Final Segment Step down Fix

Length of Segment	Number of Fixes
5 – 10 NM	1 stepdown fix
over 10 – 15 NM	2 stepdown fixes
over 15 NM	3 stepdown fixes

Table 2-8-1: Stepdown Fixes In Initial Segment.

2.8.10 Obstacles Close To a FAF or a Final Approach Segment SDF

Existing obstacles close to a FAF or SDF may be eliminated from consideration if the following conditions are met:

a. The obstacle is in the final approach trapezoid within 1 NM past the point the FAF/SDF can first be received.

b. The obstacle does not penetrate the 7:1 (fixed-wing) or 3.5:1 (helicopter) obstacle identification surface (OIS). The surface begins at the earliest point the fix can be received and extends toward the MAP 1 NM. The beginning surface height is determined by subtracting the final segment ROC (and adjustments from Para 3.2.2, as applicable) from the minimum altitude required at the fix. The surface slopes downward 1 foot vertically for each 7 feet horizontally (fixed-wing) or 1 foot vertically for each 3.5 feet horizontally (helicopter) toward the MAP (see figure 2-8-10).

c. Obstacles eliminated from consideration by application of this paragraph shall be noted on the procedure. The formulas 2-8-4 and 2-8-5 may be used to determine the OIS height at the obstacle or the minimum fix altitude based on applying the surface to an obstacle, which must be eliminated. See figure 2-8-11 and 2-8-12. To determine fix error, see paragraphs 2.8.5, 2.8.6 and 2.8.7.

Formula 2-8-4. OIS Height Calculation

$$OIS_{height} = Fix_{Alt} - ROC - \left(\frac{d}{s}\right)$$

Where:

Fix_{Alt} = Published MSL fix altitude
ROC = Required obstacle clearance plus adjustments
d= Distance from earliest fix reception to obstacle (feet)
s = 7 for fixed-wing, 3.5 for helicopter only

Formula 2-8-5. Minimum Fix Altitude Calculation

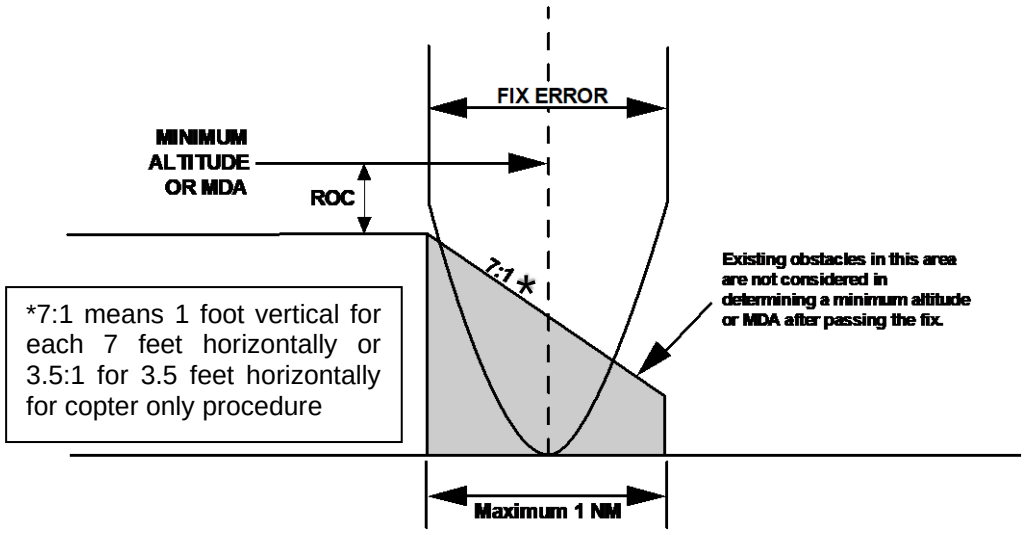
$$MinFix_{Alt} = ObstElev + ROC + \left(\frac{d}{s}\right)$$

Where:

ObstElev = MSL Obstacle elevation
ROC = Required obstacle clearance plus adjustments
d= Distance from earliest fix reception to obstacle (feet)
s = 7 for fixed-wing, 3.5 for helicopter only

Note: Round $\left(\frac{d}{s}\right)$ up to next foot.

Figure 2-8-10: Obstacle Close-In To A Fix



Notes: Obstacles close to a fix (FAF or stepdown) may be eliminated from consideration as an obstacle when the following conditions exist:

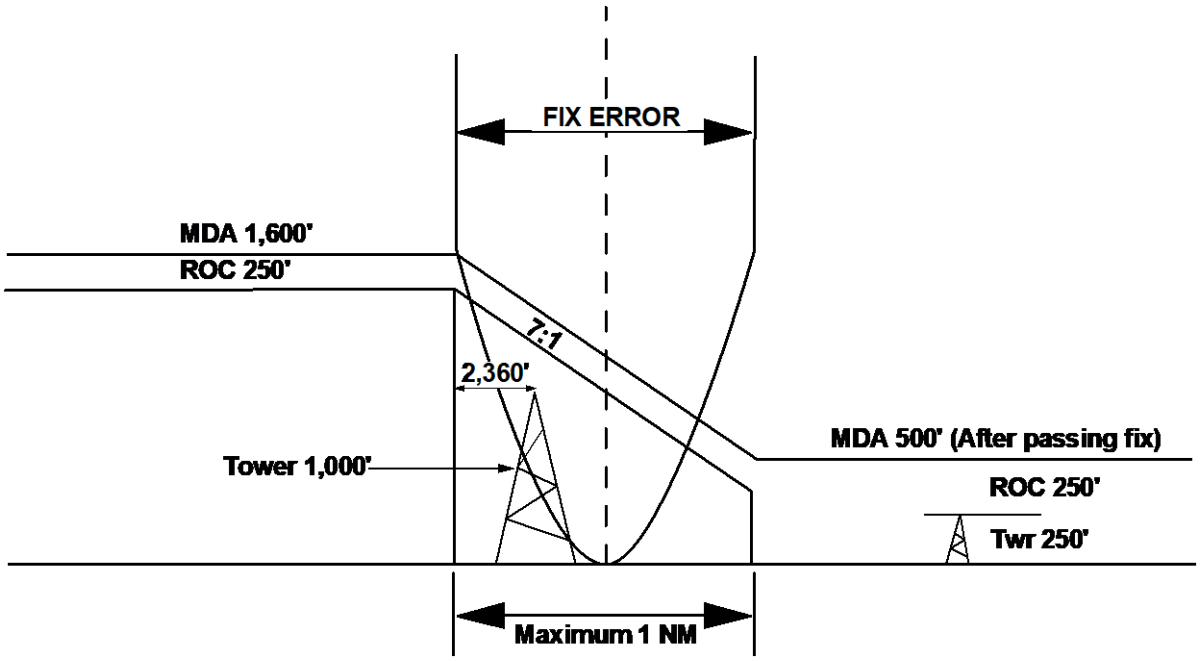
1. Must be located in the final approach area, within 1 NM past the point where the fix can be first received,

2. Obstacle does not penetrate a 7:1 descent gradient (or 3.5:1 copter), which starts at the point where the fix is first received. ,

3. The height at the start of the 7:1 slope (or 3.5:1 copter) is determined by subtracting the ROC from the minimum altitude required, and

4. Any obstacle eliminated because of the 7:1 (or 3.5:1 copter) descent gradient will be noted on the procedure.

5. For helicopter only (COPTER) procedure that are limited to a maximum final airspeed of 70 kt, apply the 3.5:1 and add a note the approach chart indicating the speed restriction.



Height at start of 7:1 Slope = MDA – ROC
= 1,600 – 250 = **1,350'**
Height Loss (ft) of 7:1 slope at d = Dist to Obstacle / 7
= 2,360 / 7 = **337.143' (rounded to 338')**
Height of 7:1 slope at Obstacle = Height at Start – Height Loss
= 1,350 – 338 = **1,012'**

Obstacle does not penetrate 7:1 slope

Figure 2-8-11: Example Of Obstacle Close In To Fix

	Location	**SUMSPOT INTL., AB (CYSS)**	
	Procedure	**RNAV (GNSS) RWY 02**	
	Fix	**BEKIE**	
	Note:	The fix must be located in the final approach area, within 1 mile past the point where the fix can be first received.	
PART I: General		**Primary**	**Secondary**
1	Obstacle #	**WT "A7"**	**WT "B3"**
2	**(MDA)** MDA (before 7:1 slope):	**1740.00**	**1740.00**
3	**(Adjust)** Adjustments (Vol 1, para 3.2.2)	**130.00**	**130.00**
PART II: Obstruction Assessment		**Primary**	**Secondary**
4	Basic ROC (before 7:1) **Basic ROC_P**(Primary)**, Basic ROC_S**(Secondary)	**250.00**	**250.00**
5	**(W_S)** Width of secondary at obstacle (ft)	n/a	**4800.00**
6	**(d_S)** distance (ft) of obstruction in secondary (from edge of primary)	n/a	**3600.00**
7	**(ROC_S)** Secondary ROC at obstacle: $ROC_S = (\text{Basic } ROC_S + \text{adjust}) \times ([W_S - d_S] / W_S)$	n/a	**95.00**
8	**(ROC_P)** Primary ROC (before 7:1): $ROC_P = \text{Basic } ROC_P + \text{Adjust}$	**380.00**	n/a
9	Altitude (ASL) of Primary/Secondary OIS (before 7:1) $ALT_{POIS} = MDA - ROC_P$ $ALT_{SOIS} = MDA - ROC_S$	ALT_{POIS} **1360.00**	ALT_{SOIS} **1645.00**
10	**(d)** Distance (ft) from start of 7:1 Slope to obstacle	**200.00**	**300.00**
11	**(HL)** Height Loss (ft) of 7:1 slope at d HL = d / 7 (Round to next higher foot)	**28.57 (29.00)**	**42.86 (43.00)**
12	**(ALT_{slope})** 7:1 Slope Altitude (ASL) at d $ALT_{slope} = ALT_{POIS} - HL$ (and/or) $ALT_{slope} = ALT_{SOIS} - HL$	**1331.43**	**1602.14**
13	**(ALT_{obs})** Obstruction Altitude (ASL)	**1209.00**	**1248.00**
14	Clearance = $ALT_{slope} - ALT_{obst}$	**122.43**	**354.14**
15	Penetration ? (Negative Value = Penetration)	**No**	**No**
16	Minimum MDA (before 7:1): For obstacle elimination. $ALT_{obs} + HL + ROC_P$ (and/or) $ALT_{obs} + HL + ROC_s$	**1617.57**	**1385.86**
17	Round Value to next 100 foot value	**1700**	**1400**

Figure 2-8-12: 7:1 Slope Worksheet (Example)

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CHAPTER 3.TAKE-OFF AND LANDING MINIMA

SECTION 3-1. GENERAL INFORMATION

3.1 General Information

3.1.1 Application

The minimums specified in this chapter are the lowest that can be approved at any location for the type of navigation facility/system concerned. Category (CAT) II/III visibility minima calculation methods and elements are located in Chapter 13. Non-certified sites are not eligible for visibility credits and are assessed as having a Nil Approach Lighting System (NALS) facility classification.

3.1.2 **Establishment**

Establish the lowest minimums permitted by the criteria contained in this document. Specify minimums for each condition indicated in the procedure; such as straight-in, circling and takeoff, as required. List the following minima elements: DA, decision height (DH), MDA, HAT, HAA, height above landing (HAL), or height above surface (HAS) as appropriate, and RVR and/or visibility. Specify takeoff minimums when required, as visibility only. The height of the MDA or DA above the highest elevation in the touchdown zone (or above the aerodrome elevation for circling approaches) shall be shown on the procedure.

a. Publication. Minima shall be published for each approach category that can be accommodated at the aerodrome. Where the aerodrome landing surface is not adequate, or other restrictions exist which prohibit certain approach categories, "Not Authorized" or "NA" shall be entered in lieu of minima values. Approach Category "E" minima should normally be published only on high altitude procedures, except where special requirements exist for their publication on other procedures.

b. Runway visual range (RVR). Reported RVR values are determined by instruments located alongside of a runway. It represents the horizontal distance a pilot can expect to see down the runway, based on sighting either the high intensity runway lights or the visual contrast of other targets, whichever yields the greater visual range. RVR may be published with straight-in landing minima when:

(1) RVR equipment is installed to the runway in accordance with the applicable standard (ICAO Annex 3 and Manual of Surface Weather Observation). The RVR location must be depicted on the aerodrome chart.

(2) High intensity runway lights standards are installed in accordance with appropriate standards.

(3) Runway markings are installed in accordance with appropriate TP312 or military standards.

c. Approach lighting systems (ALS). Approach lighting systems extend visual cues to the approaching pilot and make the runway environment apparent with less visibility than when such lighting is not available. For this reason, lower straight-in (not applicable to circling) visibility minimums may be established when standard or equivalent approach lighting systems (only for DND) are present.

(1) Standard lighting systems. Table 3-1-1 provides the types of standard approach lighting systems, as well as the operational coverage for each type. Table 3-1-2 provides lighting system classifications.

Table 3-1-1: Standard Lighting Systems

Approach Lighting Systems (ALS)		Lateral (+/-)	Vertical (above horizon)
ALSF-2	Approach Lighting System with Flashing lights for CAT II/III operations	10.0* 15.0#	11.5* 11.0#
SSALR	Simplified Short Approach Lighting System with Runway Alignment Indicator Lights	10.0* 15.0#	11.5* 11.0#
MALSR	Medium Intensity Approach Lighting System with Runway Alignment Indicator Lights	10.0* 15.0#	8.1* 11.0#
HIALS CAT I	High Intensity Approach Lighting System CAT I (Legacy ALS, without sequenced flashing lights)	17.0*	10.0*
SSALS	Simplified Short Approach Lighting System	10.0*	11.5*
MALSF	Medium Intensity Approach Lighting System with Sequenced Flashing Lights	10.0* 15.0#	8.1* 11.0#
MALS	Medium Intensity Approach Lighting System	10.0*	8.1*
ODALS	Omnidirectional Approach Lighting System	180#	10.0#

*Steady-burning #Sequence flash

Note: TP312 contains descriptions of the various lighting systems.

Table 3-1-2: Approach Lighting Systems (ALS)

Facility Classification	Approach Lighting Systems (ALS)	
FALS (Full Approach Lighting System)	ALSF-2	Approach Lighting System with Flashing lights for CAT II/III operations
	SSALR	Simplified Short Approach Lighting System with Runway Alignment Indicator Lights
	MALSR	Medium Intensity Approach Lighting System with Runway Alignment Indicator Lights
	HIALS CAT I	High Intensity Approach Lighting System CAT I (Legacy ALS, without Sequence Flashing lights)
IALS (Intermediate Approach Lighting System)	SSALS	Simplified Short Approach Lighting System High Intensity Approach Lighting System
	MALSF	Medium Intensity Approach Lighting System with Sequenced Flashing Lights
	MALS	Medium Intensity Approach Lighting System
BALS (Basic)	ODALS	Omnidirectional Approach Lighting System High or Medium intensity lights and/or flashing lights
NALS (Nil Approach Lighting System)		No approach lighting or less than 700 feet.

Note: SSALR are required for precision CAT I and ALSF-2 are required for precision CAT II/III.

(2) Operational conditions. In order to apply approach light credit to straight-in landing minimums and publish visibility from the FALS, IALS or BALS column from Table 3-3-1, Table 3-3-3, or Table 3-3-4, the following conditions must exist:

(a) The distance from the MAP/DA to LTP must be less than or equal to 3 SM.

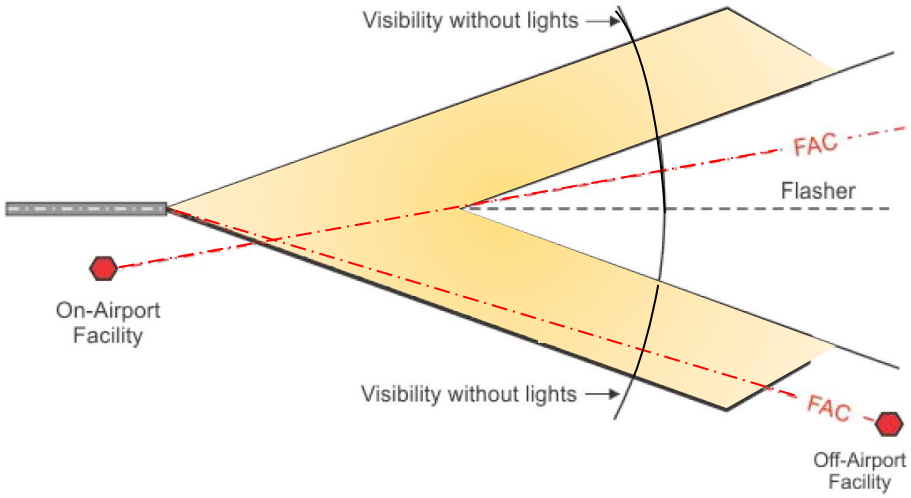
(b) For PA and APV procedures, the TCH must not exceed the upper limit value specified by Table 3-1-3.

(c) The runway must have runway surface marking schemes or both touchdown zone and centerline lights as specified in TP312 or DND Standards as appropriate. Runway marking effectiveness may be degraded when obscured by surface water, snow, ice, or tire marks. The aerodrome/airport operator must notify the procedure sponsor when required markings are removed, or when it is determined the markings are inadequate for reduced visibility credit to ensure that all procedures to the affected runway revert to no-light minimums. Operational TDZ and CL lights may be substituted for removed, deteriorated, or

obscured runway markings to authorize a visibility minimum appropriate for the applicable approach light configuration.

(d) The FAC must place the aircraft within the visual angular coverage of the main beam of the approach lighting system at a distance from the landing threshold equal to the standard visibility required without lights (NALS column). For example, in Figure 3-1-1 the FACs for both the on-airport and off-airport facility transit, the approach light operational areas at the limit of the visibility arc (without lights) and therefore be authorized for light credit (see Table 3-1-1).

Figure 3-1-1. Application of Lateral Coverage Angles



(3) Other lighting systems (only DND). Variations of standard systems, and other systems not included in this chapter, must meet the specified operational conditions in paragraph 3.1.2.c(2) to receive visibility reduction credit.

Table 3-1-3. PA/APV TCH Upper Limits for allowing Approach Lighting Credit

HAT (ft)	Glidepath Angle (degrees)	TCH upper limit (ft)
*200-249	#2.50-3.20	75
	3.20-3.30	70
	3.31-3.40	66
	3.41-3.50	63
	3.51-3.60	59
	3.61-3.70	55
	3.71-3.80	50
	3.81-3.90	47
	3.91-4.00	43
	4.01-4.10	39
	4.11-4.20	35
270-299	#2.50-4.40	75
	4.41-4.50	73
	4.51-4.60	68
	4.61-4.70	64
	4.71-4.80	59
	4.81-4.90	55
	4.91-5.00	51
≥350	#2.50-5.60	75
	5.61-5.70	70
	5.71-5.80	65
	5.81-5.90	60
	5.91-6.00	55
	6.01-6.10	50
	6.11-6.20	45
	6.20-6.30	40
	6.31-6.40	35

HAT (ft)	Glidepath Angle (degrees)	TCH upper limit (ft)
250-269	#2.50-4.10	75
	4.11-4.20	71
	4.21-4.30	67
	4.31-4.40	62
	4.41-4.50	58
	4.51-4.60	54
	4.61-4.70	50
	4.71-4.80	45
	4.81-4.90	41
	4.91-5.00	37
300-349	#2.50-4.90	75
	4.91-5.00	71
	5.01-5.10	66
	5.11-5.20	61
	5.21-5.30	56
	5.31-5.40	52
	5.41-5.50	48
	5.51-5.60	43
	5.61-5.70	39

Note:
*****100 feet – 199 feet HAT for DND PAR only.
Angles less than 3 degrees for DND or ILS systems first installed before January 2019.

SECTION 3-2. ESTABLISHING MINIMUM ALTITUDES/HEIGHTS

3.2 Establishing Minimum Altitudes/Heights

3.2.1 Establish minimum altitudes/heights for each authorized approach category

Minimum Altitudes/heights types are:

a. Decision altitude (DA). A DA is a specified minimum altitude (feet MSL) in a PA or APV instrument approach procedure at which a decision is made to either continue the approach or to initiate a missed approach. Determine the DA using the appropriate criteria and specify in a one-foot increment (for example, 234.10 rounds to 235).

b. Decision height (DH). A DH serves the same purpose as a DA for CAT II ILS, but is expressed as a radio altimeter height above terrain.

c. Height above touchdown (HAT). Calculate by subtracting the TDZE (rounded to the nearest foot) from the DA/MDA. For example, if TDZE is 632.6 and MDA is 1040, then the HAT is 407 (1040 – 633 = 407). The minimum HAT for a PA/APV procedure is specified in Table 3-2-2 unless otherwise specified in the applicable design chapter. The minimum HAT for an NPA is equal to the minimum ROC applicable to the final approach segment primary area as specified in the applicable design chapter (for example, 300 feet for VOR no FAF, 250 feet for VOR/DME and LOC, etc.).

d. Height above airport (HAA). Calculate by subtracting the airport elevation (rounded to the nearest foot) from the CMDA. For example, if airport elevation is 437.4 and CMDA is 920, then the HAA is 483 (920 – 437 = 483). The HAA specified for each aircraft CAT must not be less than those specified in Table 3-2-1.

Table 3-2-1. Minimum Authorized HAA

	CAT				
	A	**B**	**C**	**D**	**E**
HAA (ft)	350	450		550	

e. Radio altimeter (RA). When necessary to establish an RA height, first determine the elevation of the terrain directly beneath the DA point along the FAC. The RA is the difference between the DA and the terrain elevation and is calculated by applying Formula 3-2-1. Determine the distance from LTP to the DA point by applying Formula 3-2-2 (see example in Figure 3-2-1).

Formula 3-2-1. Calculating RA

$$RA = DA - terrain_{elev}$$

Where:

$terrain_{elev}$ = Terrain elevation on the FAC at the DA point.

Formula 3-2-2. DA Point Distance from LTP (feet)

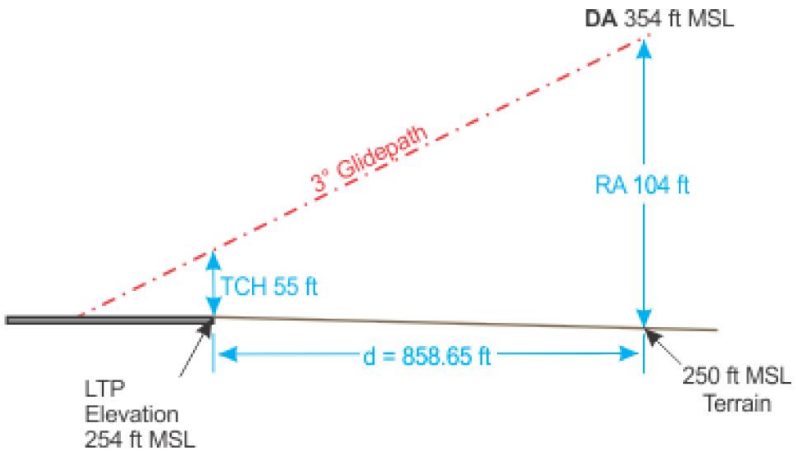
$$d_{LTP} = \frac{DA - (LTP_{elev} + TCH)}{\tan\theta}$$

Where:

LTP_{elev} = LTP elevation

θ = Glidepath angle

Figure 3-2-1. RA Example



f. Minimum descent altitude (MDA). MDA represents the final approach segment minimum altitude for NPA procedures. Each MDA must provide at least the minimum final approach segment (FAS) and missed approach segment (MAS) ROC as specified by the applicable chapter. Express MDAs in 20-foot MSL increments; round upwards when necessary (for example, 820 remains 820, 821 rounds to 840). The MDA must not be higher than the FAF altitude.

g. Circling MDA (CMDA). In addition to the requirements of paragraphs 3.2.1.d and 3.2.1.f, each CMDA must provide the minimum ROC in the circling maneuvering area and must not be lower than the highest straight-in MDA (same CAT) published on the same chart.

Note: When dual minimums are authorized, the CMDA is compared against the straight-in MDA associated with the corresponding minima set (for example, circling with stepdown minimums checked against straight-in with stepdown minimums).

3.2.2 Adjustments to Minimum Altitudes/Heights

The MDA or DA may require an increase under the conditions described below:

a. PA/APV approaches. Determine the minimum HAT based on glidepath angle and aircraft category using Table 3-2-2.

Table 3-2-2. Minimum HAT for PA and APV Approach Procedures

	Aircraft Category				
GPA	**A**	**B**	**C**	**D**	**E**
2.50° - 2.99° [1]	200 [2]				
3.00° - 3.10°	200 [2]				
3.11° - 3.30°	200 [2]		250		**NA[4]**
3.31° - 3.50°	200 [2]		270		**NA[5]**
3.51° - 3.77°	200 [2,3]		300	**NA**	
3.78° - 3.80°	200 [2,3]		**NA**		
3.81° - 4.20°	200 [2,3]	250	**NA**		
4.21° - 5.00°	250	**NA**			
5.01° - 5.70°	300	**NA**			
5.71° - 6.40° Airspeed NTE 80 knots	350	**NA**			

1. DND Only.
2. LNAV/VNAV, RNP AR, and LDA with GS minimum HAT = 250
3. LPV w/GPA > 3.5° = 250
4. DND Only to 250.
5. DND Only to 270.

b. Precipitous terrain. In areas characterized by precipitous terrain (in or outside of designated mountainous areas) consideration must be given to induced altimeter errors and pilot control problems.

(1) Precipitous terrain adjustments must be accomplished using the algorithms in Annex C paragraph 1 for instrument approach procedure segments and level holding associated with a DP.

(a) Precipitous terrain identified in the final segment**.**

1. NPA. Increase ROC values by the result from the algorithms in Annex C.

2. PA and APV. For approaches that permit precipitous terrain in the final segment, increase the HAT by 10 percent of the value determined by evaluation of the final and missed segments; for example, 200-foot HAT increases to 220 feet, 350-foot HAT increases to 385 feet. Do not include adjustments for RASS before determining the precipitous terrain adjustment.

(b) Precipitous terrain identified in initial, intermediate, missed approach OEA (applicable to the missed approach obstruction altitude), and missed approach and departure holding segments. Increase ROC by the result from the algorithms in Annex C. Precipitous terrain adjustments are not applied to the missed approach sloping OCS.

(2) Determination of precipitous terrain should be accomplished using the algorithms in Annex C or other methods for other evaluations such as radar vectoring altitude charts, STAR, feeder routes, TAA, and ATS routes.

c. Remote Altimeter Setting Source (RASS). Not applicable to MSAs, initials, enroute, feeder routes, or segment/areas based on enroute criteria. When the altimeter setting is obtained from a source more than 5 NM from the airport reference point (ARP) for an airport, or the heliport reference point (HRP) for a heliport or the MAP for a Proceed VFR PINSA, a RASS adjustment must be considered. A RASS is not authorized for a remote distance greater than 75 NM or for an elevation differential between the RASS and the landing area that is greater than 6000 feet. To determine which formula applies, evaluate the terrain between the RASS and the airport/heliport/PINSA MAP for adverse atmospheric pressure pattern effect.

Note: When a secondary altimeter source must be specified and either the primary or secondary altimeter source (or both) is considered remote (more than 5 NM from the ARP), establish separate landing minima. If establishing separate minima is impractical, publish a chart note specifying the difference between the MDA/DA for primary and secondary sources.

(1) Where intervening terrain is not characterized by precipitous terrain, use formula 3-2-3 to compute the basic adjustment in feet (see Figure 3-2-2).

Formula 3-2-3. Basic RASS adjustment (no intervening terrain)

$$RASS\ Adjustment\ =\ 2.30\ \times\ D_r +\ 0.14\ \times E_1$$

Where:

D_r = the horizontal distance in nautical miles from the altimeter source to the ARP/HRP*

E_1 = the elevation differential in feet between the elevation of the RASS and the elevation of the airport/heliport/elevation (use heliport or landing area elevation for helicopter PinS approaches; if multiple landing areas are utilized by the approach procedure, use the landing area elevation with the greatest differential to the RASS elevation).

Note: *COPTER PINSA. When annotated “Proceed VFR”: D_r= Horizontal distance from altimeter source to MAP.

Examples:

<u>Airport</u>

D_r = 10.8 NM
E_1 = 1000 - 800 = 200 feet
(2.30×10.8)+(0.14×200)=52.84 feet basic RASS adjustment

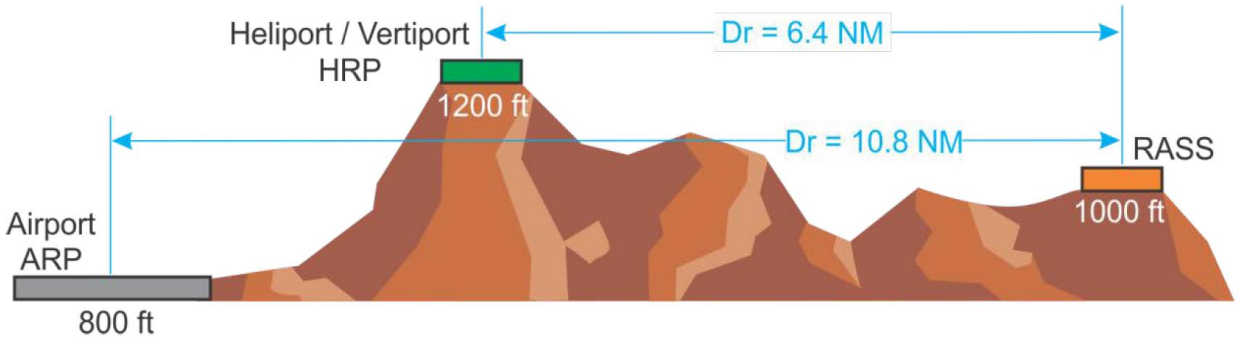
In intermediate segment: 52.84×0.6<200 (no ROC increase)
In PA/APV final segment: DA = 200 + 52.84 = increase DA to 253
In NPA final segment: 1225 (Controlling obs) + 250 ROC + 52.84 = 1540 MDA

Heliport

D_r = 6.4 NM
E_1 = 1200 - 1000 = 200 feet
(2.30×6.4)+(0.14×200)=42.72 feet basic RASS adjustment

In intermediate segment 42.72×0.6<200 (no ROC increase)
In PA/APV final segment: DA = 200 + 42.72 = increase DA to 243
In NPA final segment: 1225 (Controlling obs) + 250 ROC + 42.72 = 1520 MDA

Figure 3-2-2. Basic RASS adjustment (no intervening terrain)



(2) Where intervening is terrain characterized by precipitous terrain, an elevation differential area (EDA) shall be evaluated. The EDA is defined as the area within 5 NM each side of a line connecting the ARP/HRP and the RASS, and includes a circular area enclosed by a 5 NM radius at each end of this line. Use Formula 3-2-4 to compute the basic adjustment in feet (see Figure 3-2-3).

Formula 3-2-4. RASS Adjustment Adverse Terrain

$$RASS\ Adjustment = 2.30 \times D_r + 0.14 \times E_2$$

Where:
D_r = the horizontal distance in nautical miles from the altimeter source to the ARP/HRP*

E_2= the terrain elevation differential in feet between the lowest and the highest terrain elevation points contained within the EDA (see Figure 3-2-3).

Note: *COPTER PINSA. When annotated “Proceed VFR”: D_r = Horizontal distance from altimeter source to MAP.

Examples:

Airport

D_r = 25 NM

E_2 = 5800 - 800 = 5000 feet

(2.30×25)+(0.14×5000)=757.5 feet basic RASS adjustment

In intermediate segment 757.5×0.6=454.5−200 (254.5 feet ROC increase)

In PA/APV final segment: DA = 350 + 757.5 = increase DA to 1108

In NPA final segment: 3052.2 (Controlling obs) + 250 ROC + 757.5 = 4060 MDA

Heliport

D_r = 15 NM

E_2 = 5800 - 800 = 5000 feet

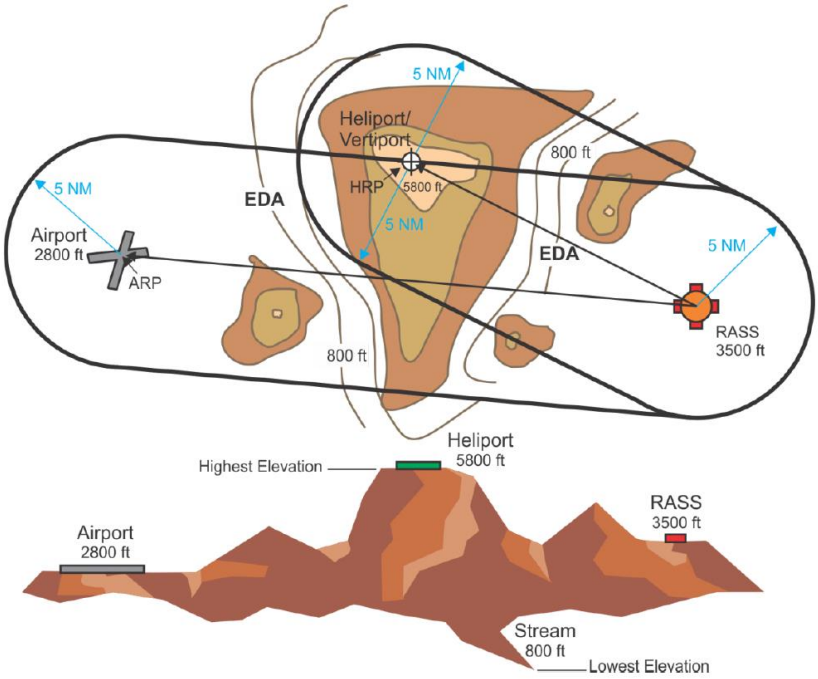
(2.30×15)+(0.14×5000)=734.5 feet basic RASS adjustment

In intermediate segment 734.5×0.6=440.7−200 (240.7 feet ROC increase)

In PA/APV final segment: DA = 294 + 734.5 = increase DA to 1029

In NPA final segment: 6000 (Controlling obs) + 250 ROC + 734.5 = 7000 MDA

Figure 3-2-3. Elevation Differential Area (EDA) Intervening Terrain Influences Atmospheric Pressure Patterns



(3) Final approach segment adjustments.

(a) NPA final segments (including the circling maneuvering area). Increase primary area ROC by the full basic RASS adjustment.

(b) PA/APV final segments. Increase the DA (prior to rounding) by the full basic RASS adjustment.

(c) To determine separate landing minima for a secondary altimeter source, or to determine the increase for a secondary altimeter RASS by chart note:

1. If the primary altimeter source is local (not remote), the MDA/DA adjustment will be the full secondary source RASS adjustment, rounded up to the next publishable increment.

Example:
Secondary altimeter RASS: 72.3 feet
Value for secondary MDA adjustment: 80 feet
Value for secondary DA adjustment: 73 feet

Primary MDA calculation:
1832 (obs. elev.) + 250 (ROC) = 2082 feet (round to 2100 for publication)

Secondary MDA calculation:
2100 (primary MDA) + 80 (secondary RASS adjustment) = 2180

2. If the primary altimeter source is remote, the MDA/DA adjustment from the primary landing minima is the difference between the secondary source RASS adjustment and the primary source RASS adjustment rounded up to the next publishable increment.

Example:

Primary altimeter RASS (remote): 43.7 feet
Secondary altimeter RASS: 72.3 feet
Difference: 72.3 – 43.7 = 28.6 feet
Value for secondary MDA adjustment: 40 feet
Value for secondary DA adjustment: 29 feet

Primary MDA calculation:
1832 (obs. elev.) + 250 (ROC) + 43.7 (RASS) = 2125.7 feet (round to 2140 for publication)

Secondary MDA calculation:
2140 (primary MDA) + 40 (secondary RASS adjustment) = 2180

(4) For the intermediate segment, use 60 per cent of the basic adjustment from Formula 3-2-3 or Formula 3-2-4, and increase the intermediate segment ROC by the amount this value exceeds 200 feet.

Example:

RASS adjustment (100%) = 420 ft
RASS adjustment (60%) = 420 ft x 0.6 = 252 ft
Since 60% value is > 200 ft, then:
Intermediate adjustment = 252 ft – 200 ft = 52 ft

Therefore:

Primary ROC for intermediate segment = 500 ft + 52 ft = 552 ft

(5) When the missed approach design utilizes a turn at altitude prior to the clearance limit and a part-time altimeter source is specified, decrease the turning section OCS starting height by the difference between RASS adjustments for the two remote altimeter sources. Where one altimeter source is local, subtract the full RASS adjustment. Do not decrease these surface starting heights to less than the OCS at the MAP. If this results in an OCS penetration that cannot be resolved by other methods, provide a second climb-to-altitude determined by adding the difference between the RASS adjustments to the climb-to-altitude and rounding to the next higher appropriate increment. This application must not produce a turn altitude above the missed approach clearance-limit altitude.

Example: “MISSED APPROACH: Climb to 6000 (6100 when using Denver Intl altimeter setting) then…”

Note: Combination straight-portion length extension is not required to accommodate the worst-case altimeter source.

(6) Helicopter Point-In-Space Approach (PINSA). When the MAP is more than 5 NM from the PINSA altimeter-setting source, RASS adjustment shall be applied. For application of the RASS formula, define "D_r" as the distance from the altimeter setting source to the MAP, and define "E_1" or "E_2", as specified by Formula 3-2-3 or Formula 3-2-4.

(7) Minimum Reception Altitude (MRA). Where a minimum altitude is dictated by the MRA, the MRA shall be increased by the amount of the RASS adjustment.

(8) When the procedure is based on a remote altimeter source, the procedure shall be annotated.

d. Excessive length, non-precision final approach. When a procedure incorporates a FAF, and the FAF-to-MAP length exceeds 6 NM (plotted positions), increase the final segment primary area ROC five feet for each one-tenth NM over 6 NM.

Exception: If a stepdown fix exists and the remaining segment length is less than 6 NM, the basic ROC may be applied between the stepdown fix and the MAP (see Formula 3-2-5).

Formula 3-2-5. Excessive Length Adjustment

$$Adjustments = 50\ (Length_{final} - 6)$$

Where:

$Length_{final}$ = Horizontal distance (NM) from FAF to MAP (plotted position)

Example:

Distance FAF to MAP = 6.47
Adjustment = 50(6.47- 6) = 23.5
250 ROC + 23.5 = 273.5 adjusted ROC

e. Multiple adjustment sources. When multiple adjustments are required, the resulting MDA/DA will be the sum of the raw values of the adjustments, rounded to the next higher altitude increment for publication.

Example:

For an airport with both remote primary and secondary source, with both precipitous terrain and excessive length of final adjustments:

Primary altimeter RASS (remote): 43.7 feet
Secondary altimeter RASS: 72.3 feet
Difference (72.3 – 43.7): 28.6 feet

Primary MDA

Non-precision approach controlling obstruction elevation 1250.3 MSL

ROC	250 feet
Primary RASS	43.7 feet
Precipitous terrain adjustment	25.1 feet
Excessive length of final adjustment	23.5 feet
	1592.6 MSL
Published rounded value	**1600 MSL**

Secondary MDA

Primary published MDA	1600 MSL
RASS adjustment difference (rounded)	40 feet
Published secondary MDA	**1640 MSL**

SECTION 3-3. VISIBILITY MINIMUMS

3.3 Visibility Minimums

3.3.1 Visibility Minimums Authorization

a. Straight-in visibility minimums are authorized when:

(1) Applicable straight-in alignment standards are met, and

(2) The final approach segment VDA (when applicable) does not exceed tolerances (see paragraphs 2.5.2 and 2.5.4).

b. Circling visibility minimums are authorized when:

(1) Straight-in alignment requirements cannot be met, or

(2) Straight-in alignment requirements are met, but descent angle precludes publication of straight-in minimums (see paragraph 2.5.2.c), or

(3) Published in conjunction with straight-in NPA minimums.

Note: Do not establish circling minimums when PA or APV procedures are established without accompanying straight-in NPA minimums.

3.3.2 Establishing Straight-in Visibility Minimums

Establish as RVR where applicable, otherwise as statute mile (SM) value.

a. Visibility without approach lights. Determine visibility without approach lights as the highest of:

(1) The value specified in the applicable row and the NALS column of Table 3-3-1, Table 3-3-2, Table 3-3-3, or Table 3-3-4 (as applicable) for the type of approach and CAT.

(a) Use Table 3-3-1 for all procedures and CATs except for CAT A and B NPA, CAT II/III ILS, Special Authorization (SA) CAT I/II ILS and helicopter approaches.

(b) Use Table 3-3-3 for CAT A straight-in NPA procedures.

(c) Use Table 3-3-4 for CAT B straight-in NPA approaches.

(2) The MAP-to-LTP distance (NPA only, and only if MAP is located prior to LTP) (see Figure 3-3-1).

(a) Determine the MAP-to-LTP distance in feet.

(b) Regardless of approach CAT for which visibility is being determined, convert the distance to a SM value contained within the NALS column of Table 3-3-1; round upwards when necessary. For example, if the MAP-to-LTP distance is 5121.44 feet (converts to 0.97 SM), select 1 SM from Table 3-3-1 since it is the next value contained on the table greater than 0.97 SM.

(c) For RVR minimums, use the RVR value associated with the SM visibility selected in paragraph 3.3.2.a(2)(b). Use RVR 5000 for 1 SM.

(d) If the MAP-to-LTP distance is greater than 3 SM, then round to the next whole mile increment.

(3) The DA point-to-LTP distance (PA/APV only and only if greater than 3 SM).

(a) Determine the DA point-to-LTP distance in feet by applying Formula 3-2-2.

(b) Convert the distance to a SM value; if not in a whole SM increment, then round upwards to the next whole SM. For example, use 4 SM if the DA point-to-LTP distance is 19694 feet (converts to 3.73 SM).

(4) The minimum visibility based on runway requirements (see paragraph 3.3.2.d).

b. Visibility with approach lights. When authorized approach light credit (see paragraph 3.1.2.c(2)), determine visibility with approach lights as the highest of:

(1) The value specified in the applicable row and column of Table 3-3-1, Table 3-3-2, Table 3-3-3, Table 3-3-4, and Table 3-3-5 (as applicable) for the type approach and CAT.

(a) Use Table 3-3-1 for all procedures and CATs except for CAT A and B NPA, CAT II/III ILS, Special Authorization (SA) CAT I/II ILS and helicopter approaches.

(b) Use Table 3-3-3 for CAT A straight-in NPA procedures. Use Table 3-3-4 for CAT B straight-in NPA approaches.

(c) Use Table 3-3-5 for CAT C/D/E straight-in NPA procedures to runways with FALS after determining the visibility minimums prescribed by Table 3-3-1.

(2) The MAP-to-LTP distance [(NPA only, and only if MAP is located prior to LTP) (see Figure 3-3-1)].

(a) Determine the MAP-to-LTP distance in feet, then subtract 2400 feet for a FALS, 1400 feet for an IALS or 700 feet for BALS.

(b) Convert the distance to a SM value contained within the appropriate ALS column of Table 3-3-1 (regardless of approach CAT for which visibility is being determined); round upwards when necessary. For example, if the MAP-to-LTP distance is 5186.23 feet, and a FALS system is applicable, subtract 2400 feet for the FALS to arrive at 2786.23 feet (converts to 0.53 SM). Then select 5/8 SM from Table 3-3-1 since it is the next incremental value greater than 0.53 SM found on the table.

(c) For RVR minimums, use the RVR value associated with the SM visibility selected in paragraph 3.3.2.b(2)(b). Use RVR 2600 for ½ SM, RVR 3000 for 5/8 SM, and RVR 5000 for 1 SM.

(3) The minimum visibility based on runway requirements (see paragraph 3.3.2.d).

(4) The minimum aerodrome operating visibility for the runway or surface of intended use (i.e. ½ SM or RVOP visibility or LVOP visibility).

Note: Certified Non-Precision runways cannot have visibility minimum lower than ¾ SM.

Table 3-3-1. Minimum Visibility Values, All Procedures/CATs (Except CAT A and B NPA, SA CAT I/II, CAT II/III, and helicopters)

HAT Range			FALS		IALS		BALS		NALS	
			RVR	SM	RVR	SM	RVR	SM	RVR	SM
		200	1800[1,2], 2600	1/2	4000	3/4	4000	3/4	4000	3/4
201	-	210	1800[3], 2600	1/2	4000	3/4	4000	3/4	4000	3/4
211	-	220	1800[3], 2600	1/2	4000	3/4	4000	3/4	4000	3/4
221	-	230	1800[3], 2600	1/2	4000	3/4	4000	3/4	4000	3/4
231	-	240	1800[3], 2600	1/2	4000	3/4	4000	3/4	4000	3/4
241	-	250	1800[3], 2600[4]	1/2[4]	4000	3/4	4000	3/4	4000	3/4
251	-	260	1800[3], 2600[4]	1/2[4]	4000	3/4	4000	3/4	4000	3/4
261	-	280	2000[3], 2600[4]	1/2[4]	4000	3/4	4000	3/4	4500	1
281	-	300	2200[3], 2600[4]	1/2[4]	4000	3/4	4000	3/4	4500	1
301	-	320	2600[4]	1/2[4]	4000	3/4	4000	3/4	4500	1
321	-	340	2600[4]	1/2[4]	4000	3/4	4500	1	5000	1
341	-	360	3000[4]	5/8[4]	4000	3/4	4500	1	5500	1
361	-	380	3500[4]	5/8[4]	4000	3/4	5000	1	5500	1
381	-	400	3500[4]	5/8[4]	4500	1	5000	1	6000	1 1/4
401		420	4000	3/4	5000	1	5500	1	6000	1 1/4
421	-	440	4000	3/4	5000	1	6000	1 1/4		1 1/4
441	-	460	4500	1	5500	1	6000	1 1/4		1 1/2
461	-	480	5000	1	6000	1 1/4		1 1/4		1 1/2
481	-	500	5000	1	6000	1 1/4		1 1/4		1 1/2
501	-	520	5500	1		1 1/4		1 1/2		1 1/2
521	-	540	5500	1		1 1/4		1 1/2		1 1/2
541	-	560	6000	1 1/4		1 1/2		1 1/2		1 3/4
561	-	580		1 1/4		1 1/2		1 1/2		1 3/4
581	-	600		1 1/4		1 1/2		1 3/4		1 3/4
601	-	620		1 1/2		1 1/2		1 3/4		1 3/4
621	-	640		1 1/2		1 1/2		1 3/4		1 3/4
641	-	660		1 1/2		1 3/4		1 3/4		2
661	-	680		1 1/2		1 3/4		1 3/4		2
681	-	700		1 1/2		1 3/4		2		2
701	-	720		1 3/4		1 3/4		2		2
721	-	740		1 3/4		1 3/4		2		2
741	-	760		1 3/4		2		2		2
761	-	800		1 3/4		2		2		2 1/2
801	-	850		2		2		2 1/2		2 1/2
851	-	900		2		2 1/2		2 1/2		2 1/2
901	-	950		2		2 1/2		2 1/2		2 1/2
951	-	1000		2 1/2		2 1/2		2 1/2		3
1001	-	1100		2 1/2		2 1/2		3		3
1101	-	1200		3		3		3		3
1201	-	Above		3		3		3		3

Notes:

1. 1800 RVR permitted for all users of ILS, LPV, and GLS with both touchdown zone lighting and runway centerline lighting.

2. When touchdown zone lighting and runway centerline lighting do not exist, 1800 RVR is still permitted for users with applicable SA (flight director or autopilot or head-up display to DA) when conducting ILS, LPV, and GLS. The following conditions apply:
   a) The runway must be certified precision,
   b) The runway must have a declared landing distance of 5000 feet or greater,
   c) The runway must have high intensity runway lights,
   d) The runway must have RVR A,
   e) The aerodrome must have an RVOP / LVOP, and
   f) The approach procedure must comply with TP 308 criteria.
3. ILS, LPV, or GLS to precision runway with both touchdown zone lighting and runway centerline lighting. If the final approach course is offset, then minimum RVR is 2600.
4. Visibility minimums below ¾ SM are only authorized for certified precision runways.

Table 3-3-2. DND Military Standard Minimums PAR with HAT < 200 feet (all CATs)

ALSF-2 with TDZ and CL			FALS		IALS/BALS		NALS	
RVR	SM	M	RVR	SM	RVR	SM	RVR	SM
1200	-	350	1600	1/4	2600	1/2	2600	1/2

Note: Visibility minimums below ¾ SM are only authorized for DND approved precision runways.

Table 3-3-3. CAT A Straight-in NPA, Authorized RVR/Visibility

HAT (ft)	FALS		IALS/BALS		NALS	
	RVR	SM	RVR	SM	RVR	SM
250-880	2600[1,2]	1/2 [1,2]	4000	3/4	5500	1
881-above	4000	3/4	5500	1		1 1/4

Notes:

1. RVR 4000, 3/4 SM (NDB)
2. Visibility minimums below ¾ SM are only authorized for certified precision runways.

Table 3-3-4. CAT B Straight-in NPA, Authorized RVR/Visibility

HAT (ft)	FALS		IALS/BALS		NALS	
	RVR	SM	RVR	SM	RVR	SM
250-740	2600[1,2]	1/2[1,2]	4000	3/4	5500	1
741-950	4000	3/4	5500	1		1 1/4
951-above	5500	1		1 1/4		1 1/2

Notes:

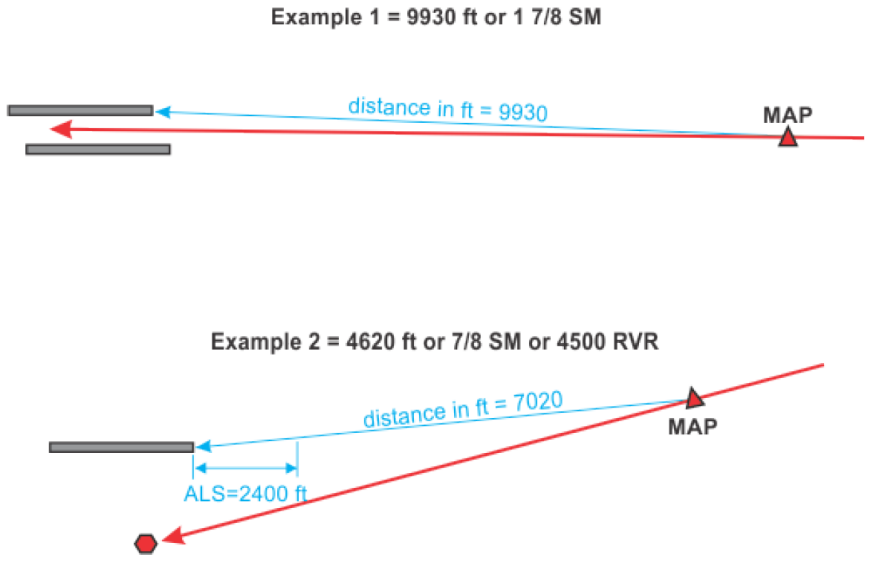
1. RVR 4000, 3/4 SM (NDB)
2. Visibility minimums below ¾ SM are only authorized for certified precision runways.

Table 3-3-5. Minimum Straight-in RVR/Visibility NPA Procedures CAT C/D/E with FALS

Procedure Design			
- Final approach guidance is not NDB, AND - Final Course-RWY C/L offset: ≤ 5°, AND - Final Approach segment ≥ 3 NM, AND - With PFAF procedure, AND - *PFAF to LTP ≤ 8 NM (*If time/distance table is published)		ALL OTHERS	
RVR	**SM**	**RVR**	**SM**
2600[1]	1/2[1]	4000	3/4

Note: 1. Visibility minimums below ¾ SM are only authorized for certified precision runways.

Figure 3-3-1. MAP to LTP Distance Straight-in Aligned



c. Runway Requirements. Table 3-3-6 specifies minimum visibility based on runway characteristics.

Table 3-3-6. Minimum Visibility Based on Runway Characteristics

Runway Characteristics	RVR	SM
Edge lighting is not High or Medium Intensity system	NA	1*

Note: * For night operation only.

d. Approach Lighting System Inoperative (ALS INOP).

When visibility is determined according to paragraph 3.3.2 b (i.e. with FALS or IALS), consideration must be given to cases when the approach light system becomes inoperative. This is accomplished by also determining the visibility according to paragraph 3.3.2 a. When the resulting visibilities differ, both must be charted. In addition, the DH/HAT must meet the minimum requirement for the cases described by table 3-3-7.

Table 3-3-7: Straight-in Minima increase due to Inoperative Component or visual aid

Approach Type	Component INOP	Increase DH/HAT (ft)
ILS, PAR, LPV, GLS	All ALS type	Not lower than 250

3.3.3 Establishing Circling Visibility Minimums

Establish as a statute mile (SM) value. Determine circling visibility as the highest of:

a. The value specified in the applicable row and column of table 3-3-8.

b. The distance from the MAP to the nearest surface authorized for landing by a circling aligned procedure (only if MAP is located prior to the nearest landing surface) (see figure 3-3-4). For procedures meeting straight-in alignment, use the distance from the MAP to the LTP (see figure 3-3-1).

(1) Determine the distance in feet and then convert to SM.

(2) The converted value must be in an incremental value contained within Table 3-3-8; round upwards when necessary. For example, if the MAP distance is 10664.81 feet (2.02 SM), select 2 1/4 SM from Table 3-3-8 since it is the next value contained on the table.

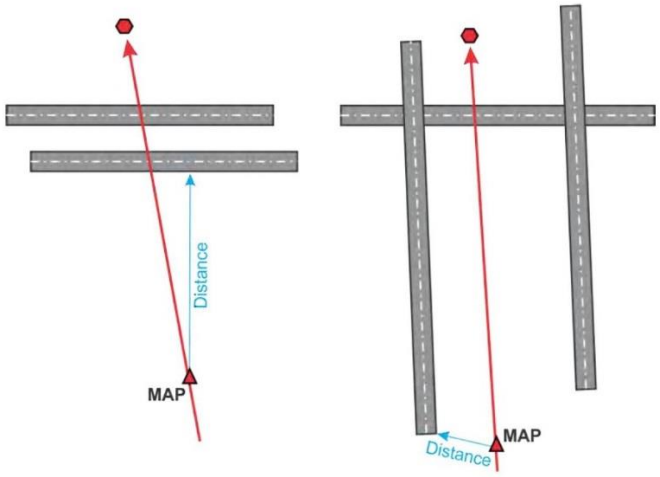
(3) If the MAP distance is greater than 3 SM, then round to the next whole mile increment.

c. The “without approach lights” (see paragraph 3.3.2.a) visibility of the highest straight-in line of minima (same CAT) published on the same chart.

Table 3-3-8. Authorized Circling Visibility Minimums

CAT	A	B	C	D	E
HAA	SM	SM	SM	SM	SM
350 - 449	1				
450 - 549	1	1	1 1/2		
550 - 600	1	1	1 1/2	2	2
601 - 670	1	1	1 3/4	2	2 1/4
671 – 740	1	1	2	2 1/4	2 1/2
741 - 810	1	1	2 1/4	2 1/2	3
811 - 880	1 1/4	1 1/4	2 1/2	3	3
881 - 950	1 1/4	1 1/4	3	3	3
≥ 951	1 1/4	1 1/2	3	3	3

Figure 3-3-4. MAP to Nearest Landing Surface, Circling Aligned



3.3.4 **Reserved**

3.3.5 **Reserved**

SECTION 3-4. ALTERNATE AIRPORT MINIMUMS

3.4 Alternate Airport Minimums

Determining the weather requirements for an alternate is the responsibility of the pilot-in-command based upon criteria detailed in the Canada Air Pilot and A.I.P. Canada. For military procedures, see BGA-100-001/AA-000.

SECTION 3-5. TAKEOFF MINIMUMS

3.5 Takeoff Minimums

All take-off minima shall be determined by applying Vol 1, Chapter 12 of this document to all conventional departure procedures and Standard Instrument Departures (SIDs). The appropriate RNAV criteria shall be applied for all RNAV Departures and SIDs. Published minima are detailed in the Canada Air Pilot and appropriate Military publications.

CHAPTER 4. ON-AIRPORT VOR (NO FAF)

400. General

This chapter is divided into two sections; one for low altitude procedures and one for high altitude teardrop penetration procedures. These criteria apply to procedures based on a VOR facility located on an airport in which no final approach fix (FAF) is established. These procedures must incorporate a procedure or a penetration turn. An ON-AIRPORT facility is one that is located:

a. For Straight-in Approach. Within one mile of the nearest portion of the landing runway.

b. For Circling Approach. Within one mile of the nearest portion of the usable landing surface of the airport.

401—409. Reserved

SECTION 1. LOW ALTITUDE PROCEDURES

410. Feeder Routes

Criteria for feeder routes are contained in Para 2.2.1.

411. Initial Approach Segment

The initial approach fix is received by overheading the navigation facility. The initial approach is a procedure turn. The criteria for the procedure turn areas are contained in Para 2.3.5.

412. Intermediate Approach Segment

This type of procedure has no intermediate segment. Upon completion of the procedure turn, the aircraft is on final approach.

413. Final Approach Segment

The final approach begins where the procedure turn intersects the final approach course inbound.

a. Alignment. The alignment of the final approach course with the runway centreline determines whether a straight-in or circling approach may be established.

(1) Straight-in. The angle of convergence of the final approach course and the extended runway centreline shall not exceed 30 degrees. The final approach course should be aligned to intersect the extended runway centreline 3,000 feet outward from the runway threshold. When an operational advantage can be achieved this point of intersection may be established at any point between the runway threshold and a point 5,200 feet outward from the runway threshold. Also, where an operational advantage can be achieved, a final approach course which does not intersect the runway centreline, or intersects it at a distance greater than 5,200 feet from the threshold, may be established provided such a course lies within 500 feet laterally of the extended runway centreline at a point 3,000 feet outward from the runway threshold. Straight-in category C, D, and E minimums are not authorized when the final approach course intersects the extended runway centreline at an angle greater than 15° and a distance less than 3,000 feet (see Figure 4-38).

(2) Circling Approach. When the final approach course alignment does not meet the criteria for straight-in landing, only a circling approach shall be authorized, and the course alignment should be made to the centre of the landing area. When an

operational advantage can be achieved, the final approach course may be aligned to pass through any portion of the usable landing surface. See Figure 4-39.

b. Area. Figure 4-40 illustrates the final approach primary and secondary areas. The primary area is longitudinally centred on the final approach course, and is 10 miles long. The primary area is 2 miles wide at the facility and expands uniformly to 6 miles at 10 mile from the facility. A secondary area is on each side of the primary area. It is zero miles wide at the facility and expands uniformly to 1.34 miles on each side of the primary area at 10 miles from the facility. When the 5 mile procedure turn is used, only the inner 5 miles of the final approach area need be considered.

c. Obstacle Clearance.

(1) **Straight-in**. The minimum obstacle clearance in the primary area is 300 feet. In the secondary area, 300 feet of obstacle clearance shall be provided at the inner edge, tapering uniformly to zero feet at the outer edge.

(2) **Circling Approach**. In addition to the minimum requirements specified in Para 413.c.(1), obstacle clearance in the circling area shall be as prescribed in Chapter 2, Section 6.

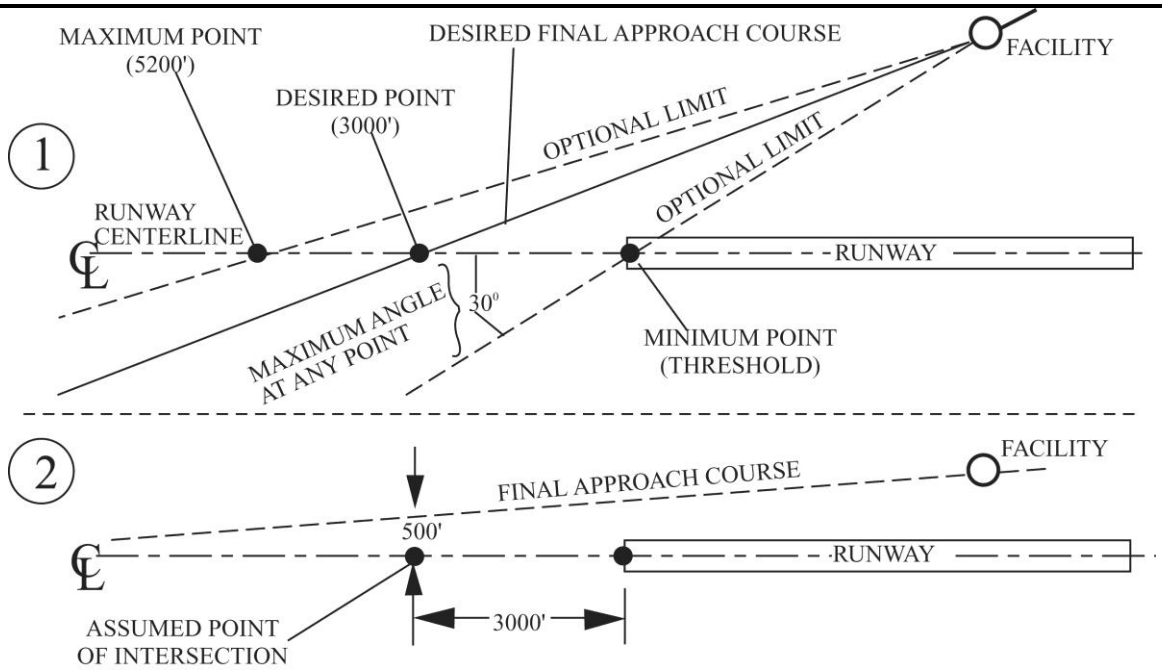
d. Procedure Turn Altitude (Descent Gradient). The procedure turn completion altitude shall be within 1,500 feet of the MDA (1,000 feet with a 5-mile procedure turn), provided the distance from the facility to the point where the final approach course intersects the runway centreline (or the first usable portion of the landing area for "circling only" procedures) does not exceed 2 miles. When this distance exceeds 2 miles, the maximum difference between the procedure turn completion altitude and the MDA shall be reduced at the rate of 25 feet for each one tenth of a mile in excess of 2 miles. See Figure 4-41.

Note: For those procedures in which the final approach does NOT intersect the extended runway centreline within 5,200 feet of the runway threshold (see Para 413.a.(1)) the assumed point of intersection for computing the distance from the facility shall be 3,000 feet from the runway threshold. See Figure 4-38.

e. Use of Step-down Fix. Use of the step-down fix (Para 288.c) is permitted provided the distance from the facility to the step-down fix does not exceed 4 miles. The descent gradient between PT completion altitude and stepdown altitude shall not exceed 150 ft/NM. The descent gradient will be computed based upon the difference in PT completion altitude minus stepdown fix altitude, divided by the specified PT distance, minus the facility to stepdown fix distance. Obstacle clearance may be reduced to 250 feet from the stepdown fix to the MAP/FEP. See Figure 4-42, Para 2.5.2.

f. Minimum Descent Altitude. Criteria for determining the MDA are contained in Chapter 3.

Figure 4-1 TO 4-37: Reserved



Note: Note: Straight-in category C, D, and E minimums are not authorized when the final approach course intersects the extended runway centerline at an angle greater than 15° and a distance less than 3,000 feet.

Figure 4-38: Alignment Options For Final Approach Course. On-Airport VOR, No FAF, Straight-In Approach Procedure. Para 413.a.(1).

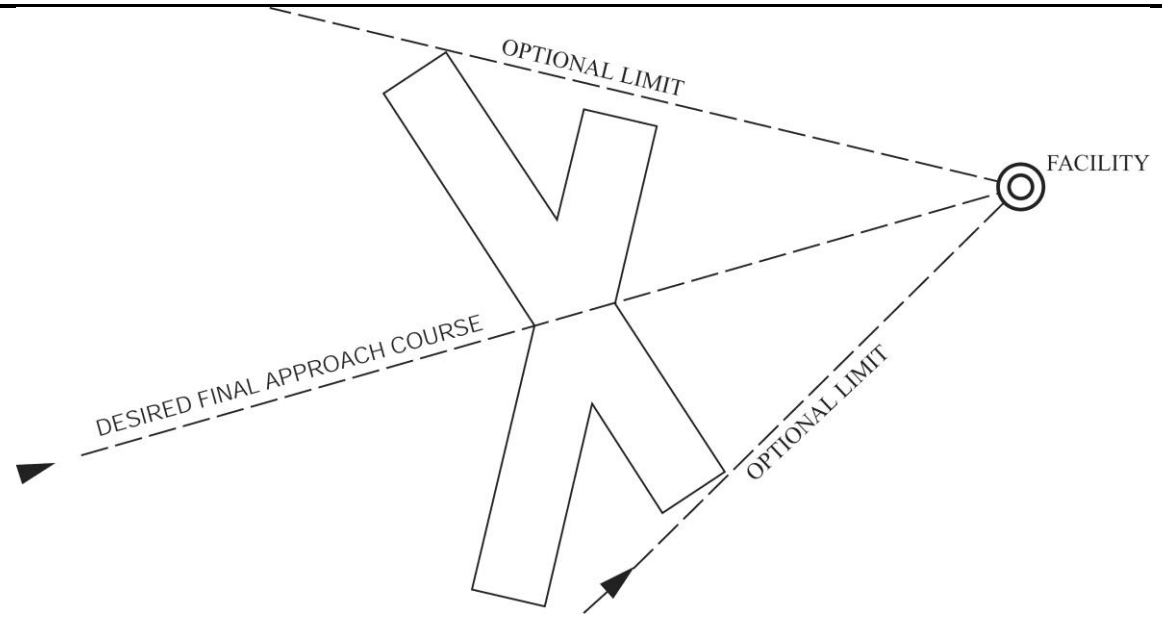


Figure 4-39: Alignment Options For Final Approach Course. On Airport VOR, No FAF, Circling Approach Procedure. Para 413.a.(2).

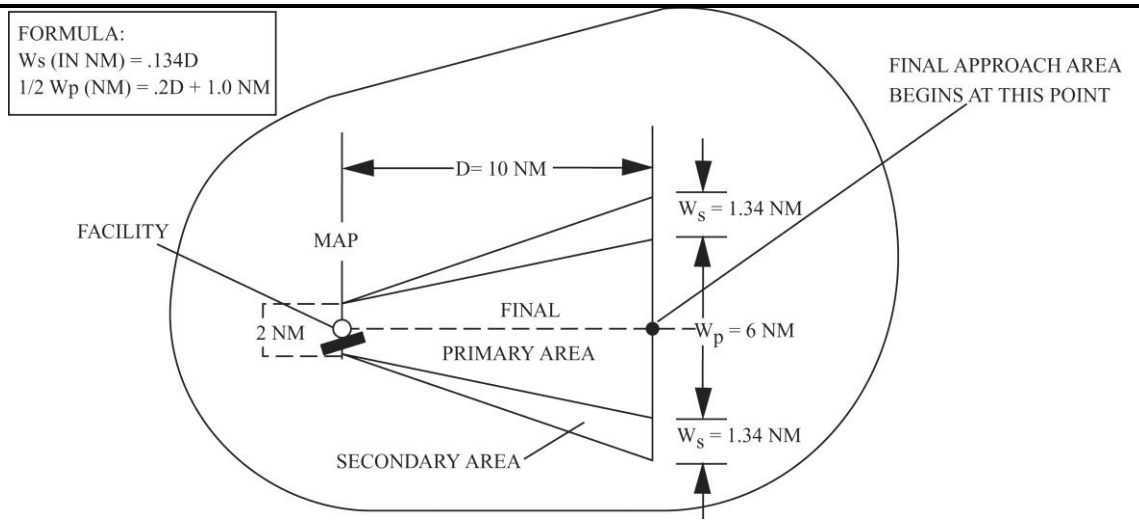


Figure 4-40: Final Approach Primary And Secondary Areas. On-Airport VOR, No FAF. Para 413.b.

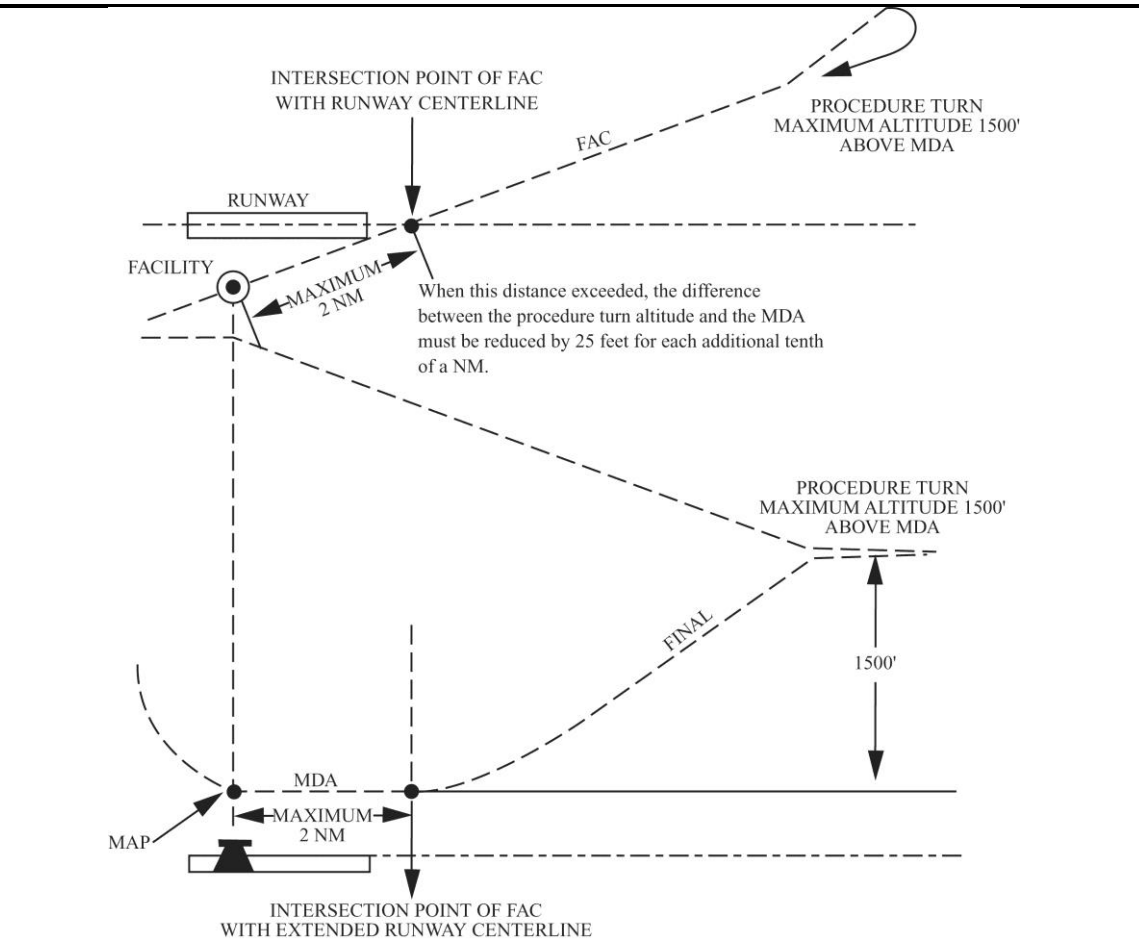


Figure 4-41: Procedure Turn Altitude. On-Airport VOR, No FAF. Para 413.d.

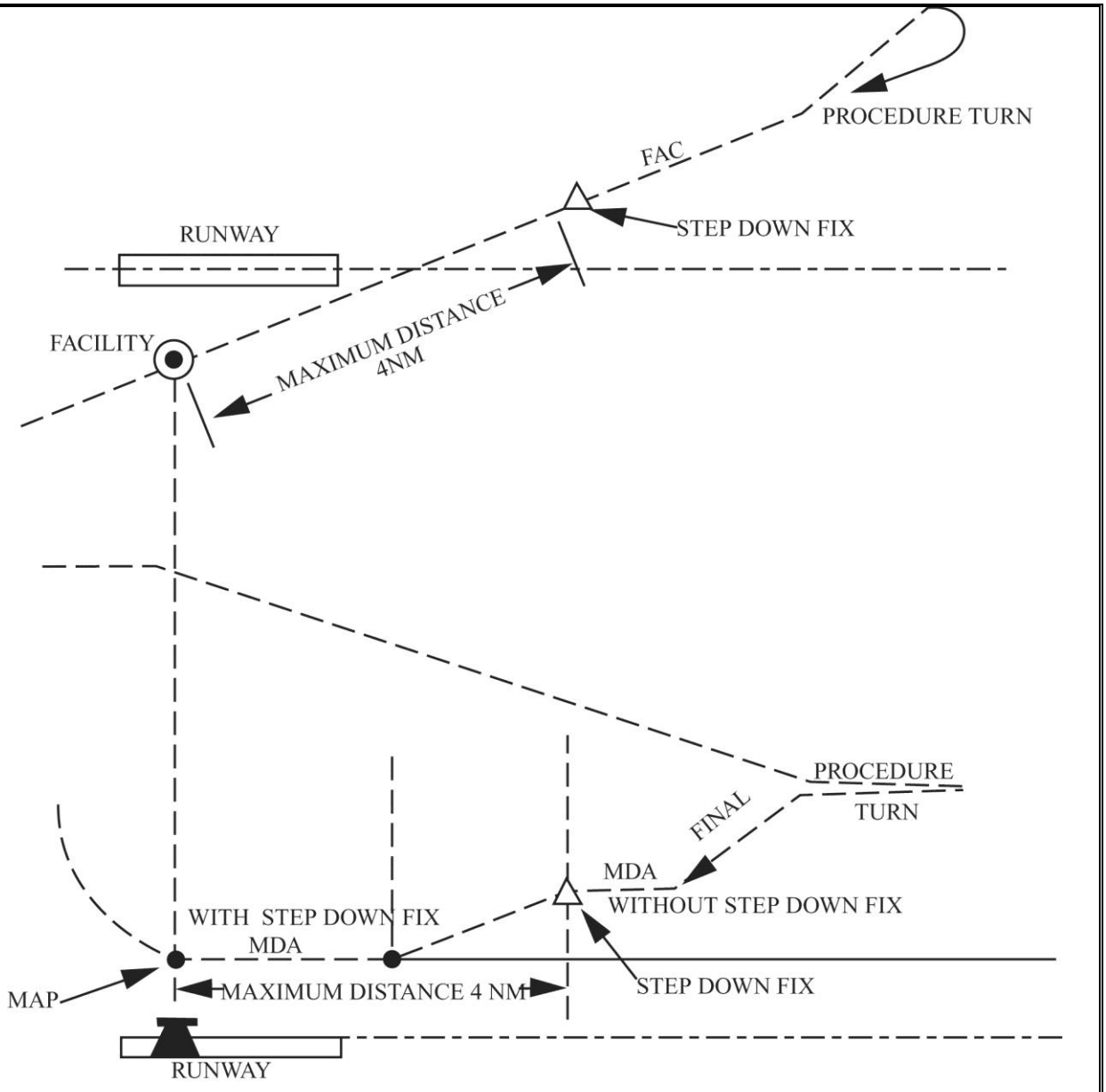


Figure 4-42: Use Of Step-Down Fix. On-Airport VOR, No FAF. Para 413.e.

414. Missed Approach Segment

Criteria for the missed approach segment are contained in Chapter 2, Section 7. The missed approach point is the facility. See Figure 4-42. The missed approach surface shall commence over the facility at the required height. See Para 2.7.5.

415—419. Reserved

SECTION 2. HIGH ALTITUDE TEARDROP PENETRATIONS

420. Feeder Routes

Criteria for feeder routes are contained in Para 2.2.1.

421. Initial Approach Segment

The initial approach fix is received by overheading the navigation facility. The initial approach is a teardrop penetration turn. The criteria for the penetration turn are contained in Para 2.3.6.

422. Intermediate Approach Segment

This procedure has no intermediate segment. Upon completion of the penetration turn, the aircraft is on final approach.

423. Final Approach Segment

An aircraft is considered to be on final approach upon completion of the penetration turn. However, the final approach segment begins on the final approach course 10 miles from the facility. That portion of the penetration procedure prior to the 10-mile point is treated as the initial approach segment. See Figure 4-6.

a. Alignment. Same as low altitude (Para 413.a).

b. Area. Figure 4-6 illustrates the final approach primary and secondary areas. The primary area is longitudinally centred on the final approach course, and is 10 miles long. The primary area is 2 miles wide at the facility, and expands uniformly to 8 miles at a point 10 miles from the facility. A secondary area is on each side of the primary area. It is zero miles wide at the facility, and expands uniformly to 2 miles each side of the primary area at a point 10 miles from the facility.

c. Obstacle Clearance.

(1) **Straight-in**. The minimum obstacle clearance in the primary area is 500 feet. In the secondary area, 500 feet of obstacle clearance shall be provided at the inner edge, tapering uniformly to zero feet at the outer edge.

(2) **Circling Approach**. In addition to the minimum requirements specified in Para 423.c.(1), obstacle clearance in the circling area shall be as prescribed in Chapter 2, Section 6.

d. Penetration Turn Altitude (Descent Gradient). The penetration turn completion altitude shall be at least 1,000 feet, but not more than 4,000 feet, above the MDA on final approach.

e. Use of Step-down Fix. The use of the step-down fix is permitted provided the distance from the facility to the step-down fix does not exceed 10 miles. See Para 2.8.9.c.

f. Minimum Descent Altitude. In addition to the normal obstacle clearance requirement of the final approach segment (see Para 423.c), the MDA specified shall provide at least 500 feet of clearance over obstacles in the portion of the initial approach segment between the final approach segment and the point where the assumed penetration turn track intercepts the inbound course. See Figure 4-43.

424. Missed Approach Segment

Criteria for the missed approach segment are contained in Chapter 2, Section 7. The missed approach point is the facility. See Figure 4-43. The missed approach surface shall commence over the facility at the required height. See Para 2.7.5.

425—499. Reserved

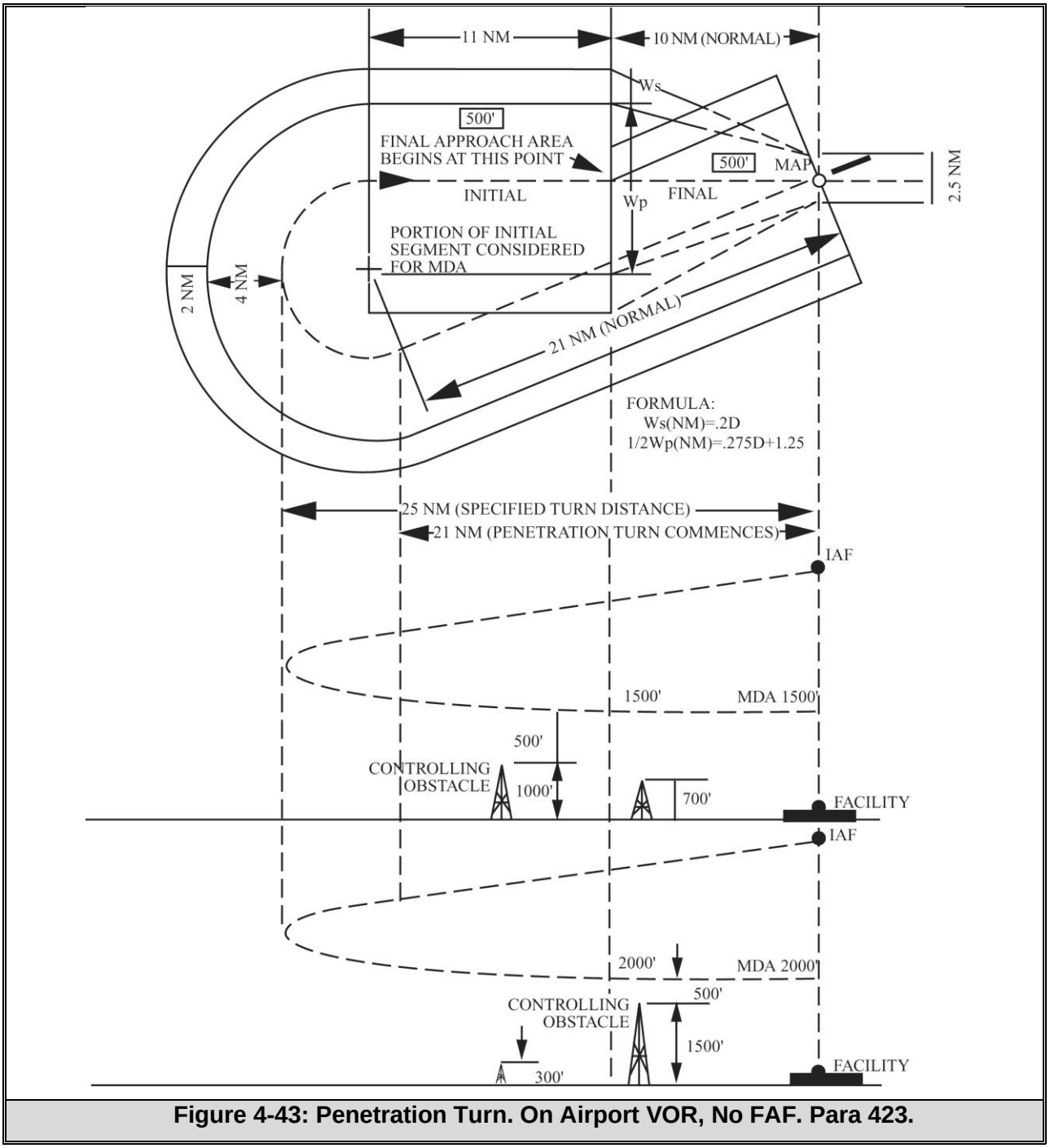


Figure 4-43: Penetration Turn. On Airport VOR, No FAF. Para 423.

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CHAPTER 5.TACAN, VOR/DME AND VOR WITH FAF

500. General

This chapter applies to approach procedures based on VOR, VOR/DME, VORTAC or TACAN facilities in which a final approach fix (FAF) is established. The chapter is divided into two sections; Section 1 for VOR procedures that do not use DME as the primary method for establishing fixes, and Section 2 for VOR/DME and TACAN procedures, which use collocated, frequency, paired DME as the sole method of establishing fixes. When both the VOR and TACAN azimuth elements of a VORTAC station will support it, a single procedure, identified as a VOR/DME or TACAN shall be published. Such a procedure may be flown using either a VOR/DME or TACAN airborne receiver and shall satisfy TACAN terminal area fix requirements. See Para 2.8.7.c.

501—509. Reserved

SECTION 1. VOR WITH FAF

510. Feeder Routes

Criteria for feeder routes are contained in Para 2.2.1.

511. Initial Approach Segment

Criteria for the initial approach segment are contained in Chapter 2, Section 3. (see Figures 5-44a, 5-44b and 5–45.)

512. Intermediate Approach Segment

Criteria for the intermediate approach segment are contained in Chapter 2, Section 4. (see Figures 5–44a, 5-44b and 5–45.)

513. Final Approach Segment

The final approach may be made either FROM or TOWARD the facility. The final approach segment begins at the final approach fix and ends at the runway or missed approach point, whichever is encountered last.

a. Alignment. The alignment of the final approach course with the runway centreline determines whether a straight-in or circling-only approach may be established. The alignment criteria differ depending on whether the facility is OFF or ON the airport. See definitions in Para 400.

(1) Off-airport Facility.

(a) **Straight-in**. The angle of convergence of the final approach course and the extended runway centreline shall not exceed 30 degrees. The final approach course should be aligned to intersect the runway centreline at the runway threshold. However, when an operational advantage can be achieved, the point of intersection may be established to as much as 3,000 feet outward along extended RWY centerline from the runway threshold. (see Figure 5–46.)

(b) **Circling Approach**. When the final approach course alignment does not meet the criteria for a straight-in landing, only a circling approach shall be authorized, and the course alignment should be made to the centre of the landing area. When an operational advantage can be achieved, the final approach course may be aligned to any portion of the usable landing surface. (see Figure 5–47.)

(2) On-airport Facility.

(a) **Straight-in**. The angle of convergence of the final approach course and the extended runway centreline shall not exceed 30 degrees. The final approach course should be aligned to intersect the extended runway centreline 3,000 feet outward from the runway threshold. When an operational advantage can be achieved, this point of intersection may be established at any point between the threshold and a point 5,200 feet outward from the threshold. Also, where an operational advantage can be achieved a final approach course which does not intersect the runway centreline, or which intersects it at a distance greater than 5,200 feet from the threshold, may be established, provided that such a course lies within 500 feet laterally of the extended runway centreline at a point 3,000 feet outward from the runway threshold. (see Figure 5–48.)

(b) **Circling Approach**. When the final approach course alignment does not meet the criteria for a straight-in landing, only a circling approach shall be authorized, and the course alignment should be made to the centre of the landing area. When an operational advantage can be achieved, the final approach course may be aligned to any portion of the usable landing surface. (see Figure 5–49.)

b. Area. The area considered for obstacle clearance in the final approach segment starts at the final approach fix and ends at the runway or missed approach point, whichever is encountered last. It is a portion of a 30 nautical mile long trapezoid (see Figure 5–50), which is made up of primary and secondary areas. The primary area is centred longitudinally on the final approach course. It is 2 nautical miles wide at the facility, and expands uniformly to 5 nautical miles wide at 30 nautical miles from the facility. A secondary area is on each side of the primary area. It is zero miles wide at the facility and expands uniformly to 1 nautical mile on each side of the primary area at 30 nautical miles from the facility. Final approaches may be made to airports, which are a maximum of 30 nautical miles from the facility. (see Figure 5–51.) The OPTIMUM length of the final approach segment is 5 nautical miles. The MAXIMUM length is 10 nautical miles. The MINIMUM length of the final approach segment shall provide adequate distance for an aircraft to make the required descent, and to regain course alignment when a turn is required over the facility. Table 5–14 shall be used to determine the minimum length needed to regain the course.

c. Obstacle Clearance.

(1) **Straight-in Landing**. The minimum obstacle clearance in the primary area is 250 feet. In the secondary area 250 feet of obstacle clearance shall be provided at the inner edge, tapering uniformly to zero feet at the outer edge (see Figure 5-51a). Allowance for adjustments should be considered as specified in Para 3.2.2.

(2) **Circling Approach**. In addition to the minimum requirements specified in Para 513.c.(1) above, obstacle clearance in the circling area shall be as prescribed in Chapter 2, Section 6.

d. Descent Gradient. Para 2.5.2 applies.

e. Use of Fixes. Criteria for the use of radio fixes are contained in Chapter 2, Section 8. Where a procedure is based on a procedure turn and an on-airport facility is the procedure turn fix, the distance from the facility to the FAF shall not exceed 4 miles.

f. Minimum Descent Altitudes. Criteria for determining the MDA are contained in Chapter 3, Section 3-2.

514. Missed Approach Segment

Criteria for the missed approach segment are contained in Chapter 2, Section 7. For VOR procedures, the missed approach point and surface shall be established as follows:

a. Off-airport Facilities.

(1) **Straight-in**. The missed approach point is a point on the final approach course, which is not farther from the final approach fix than the runway threshold. (see Figure 5-52.) The missed approach surface shall commence over the missed approach point at the required height. (See Para 2.7.5.)

(2) **Circling Approach**. The missed approach point is a point on the final approach course, which is not farther from the final approach fix than the first usable portion of the landing area. The missed approach surface shall commence over the missed approach point at the required height. (See Para 2.7.5.)

b. On-airport Facilities. The missed approach point is a point on the final approach course, which is not farther from the final approach fix than the facility. The missed approach surface shall commence over the missed approach point at the required height. (See Para 2.7.5.)

515—519. Reserved

SECTION 2. TACAN AND VOR/DME

520. Feeder Routes

Criteria for feeder routes are contained in Para 2.2.1.

521. Initial Approach Segment

Due to the fixing capability of TACAN and VOR/DME a procedure turn initial approach may not be required. Criteria for initial approach segments are contained in Chapter 2, Section 3.

522. Intermediate Approach Segment

Criteria for the intermediate segment are contained in Chapter 2, Section 4.

523. Final Approach Segment

TACAN and VOR/DME final approaches may be based either on arcs or radials. The final approach begins at a final approach fix and ends at the missed approach point. The missed approach point is always marked with a fix.

a. Radial Final Approach. Criteria for the radial final approach are specified in Para 513.

b. Arc Final Approach. The final approach arc shall be a continuation of the intermediate arc. It shall be specified in nautical miles and tenths thereof. Arcs closer than 7 miles (15 miles for high altitude procedures) and farther than 30 miles from the facility shall not be used for final approach. No turns are permitted over the final approach fix.

(1) **Alignment**. For Straight-in approaches, the final approach arc shall pass through the runway threshold when the angle of convergence of the runway centreline and the tangent of the arc does not exceed 15 degrees. When the angle exceeds 15 degrees the final approach arc shall be aligned to pass through the centre of the airport and only circling minimums shall be authorized. (see Figure 5–53.)

(2) **Area**. The area considered for obstacle clearance in the arc final approach segments starts at the final approach fix and ends at the runway or missed approach point, whichever is encountered last. It should not be more than 5 miles long. It shall be divided into primary and secondary areas. The primary area is 8 miles wide, and extends 4 miles on either side of the arc. A secondary area is on each side of the primary area. The secondary areas are 2 miles wide on each side of the primary area. (see Figure 5–54.)

(3) **Obstacle Clearance**. The minimum obstacle clearance in the primary area is 500 feet. In the secondary area, 500 feet of obstacle clearance shall be provided at the inner edge, tapering uniformly to zero feet at the outer edge (see Figure 5-54a). Allowance for adjustments should be considered as specified in Para 3.2.2.

(4) **Descent Gradient**. Criteria for descents are specified in Para 2.5.2.

(5) **Use of Fixes**. Fixes along an arc are restricted to those formed by radials from the VORTAC facility which provides the DME signal. Criteria for such fixes are contained in Chapter 2, Section 8.

(6) **Minimum Descent Altitude**. Straight-in MDAs shall not be specified lower than circling for arc procedures. Criteria for determining the circling MDA are contained in Chapter 3, Section 3-2.

524. Missed Approach Segment

Criteria for the missed approach segment are contained in Chapter 2, Section 7. The missed approach point shall be a radial/DME fix. The missed approach surface shall commence over the fix and at the required height. (Also see Para 514.)

Note: The arc missed approach course may be a continuation of the final approach arc.

525—599. Reserved

Figure 5-1 TO 5-44: Reserved

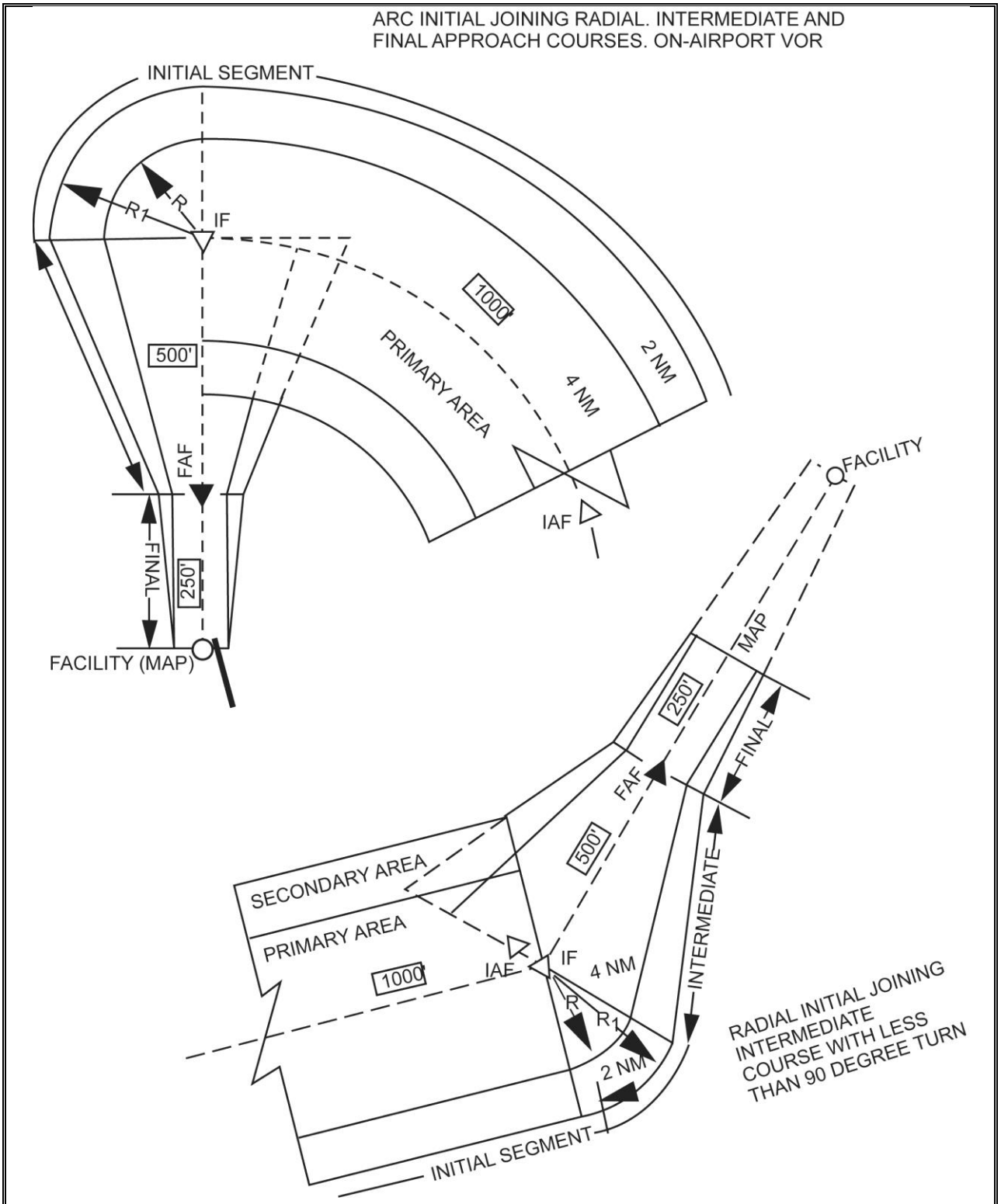


Figure 5-44a: Typical Low Alt Approach Segments. VOR with FAF. Para 511 & 512.

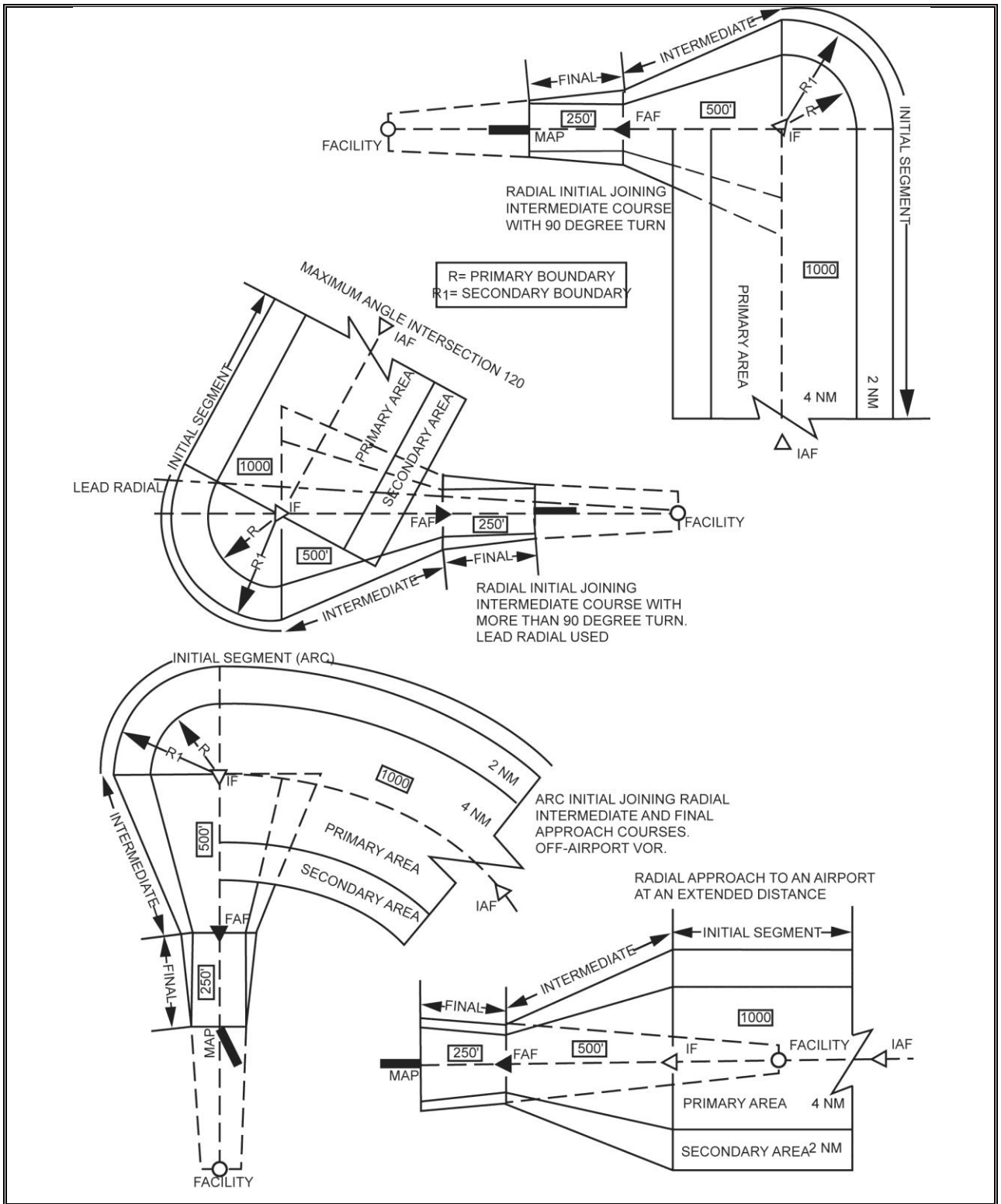


Figure 5-44b: Typical Low Alt Approach Segments. VOR with FAF. Para 511 & 512.

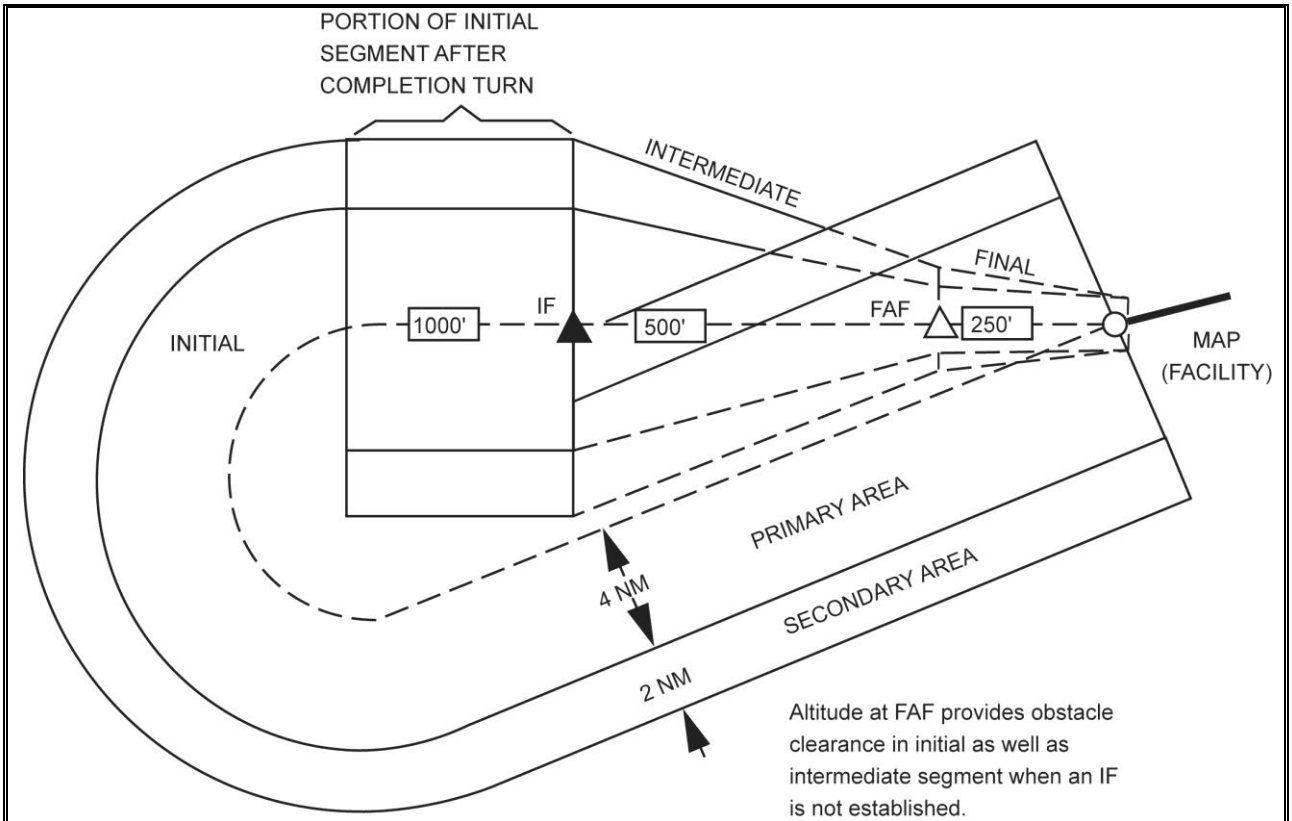


Figure 5-45: Typical High Altitude Segments. VOR with FAF. Para 511 & 512.

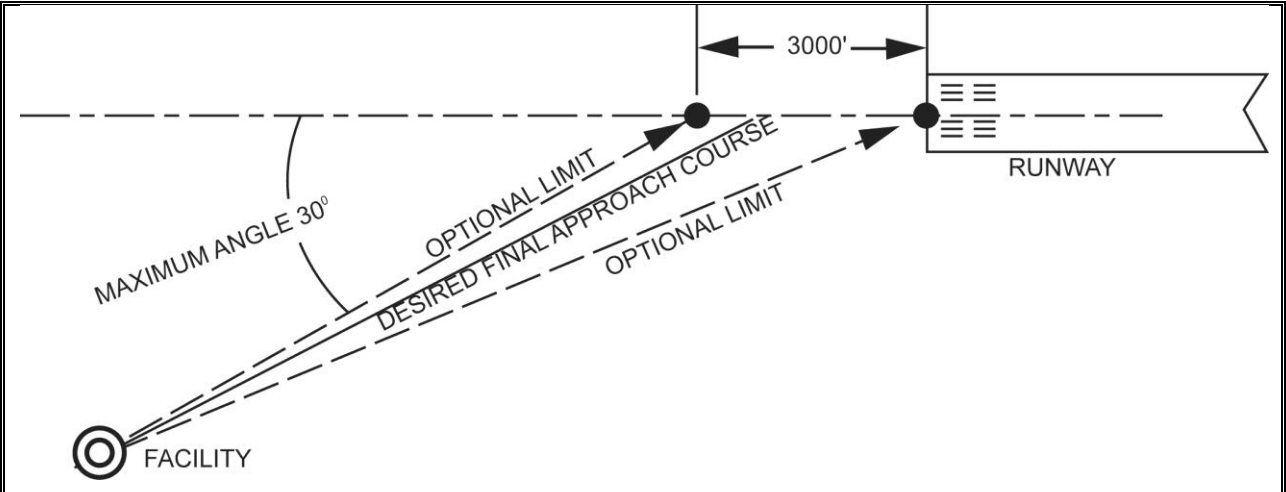


Figure 5-46: Alignment Options For Final Approach Course. Off-airport VOR with FAF. Straight-in approach. Off-airport Para 513.1.(1)(a).

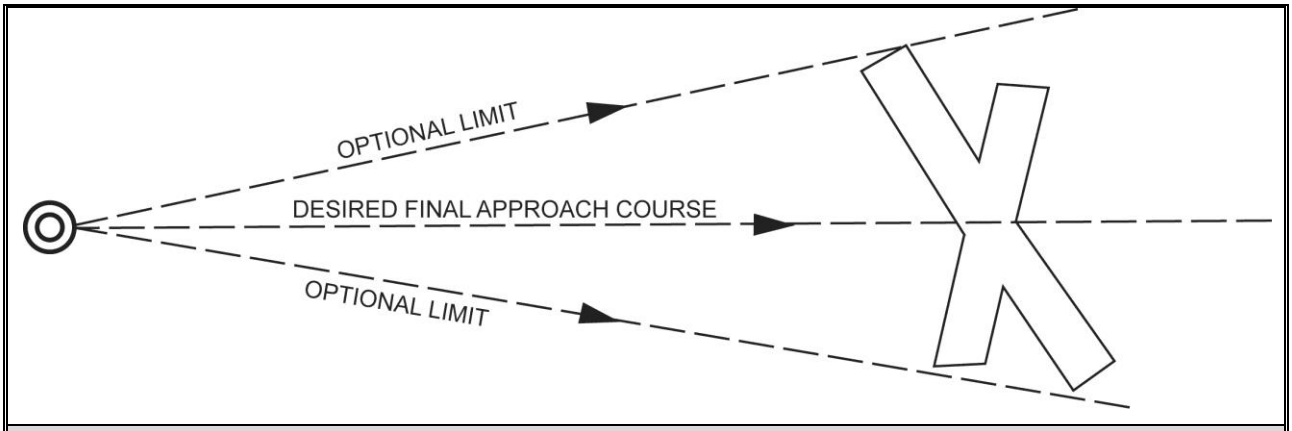


Figure 5-47: Alignment Options For Final Approach Course. Off-airport VOR with FAF. Circling Approach. Para 513.a.(1)(b).

Tables 5–1 TO 5–13: Reserved

Approach Category	Magnitude of Turn over the FAF (Degrees)		
	10° or less	20°	30°
A	1.0	1.5	2.0
B	1.5	2.0	2.5
C	2.0	2.5	3.0
D	2.5	3.0	3.5
E	3.0	3.5	4.0

Note: This table may be interpolated. If turns of more than 30° are required, or if the minimum lengths specified in the table are not available, straight-in minima are not authorized and only the circling OCA/H should be published See Figure 5-51 for typical straight-in final approach areas.

Table 5-14: Minimum Length Of Final Approach Segment - VOR (NM). Para 513.b.

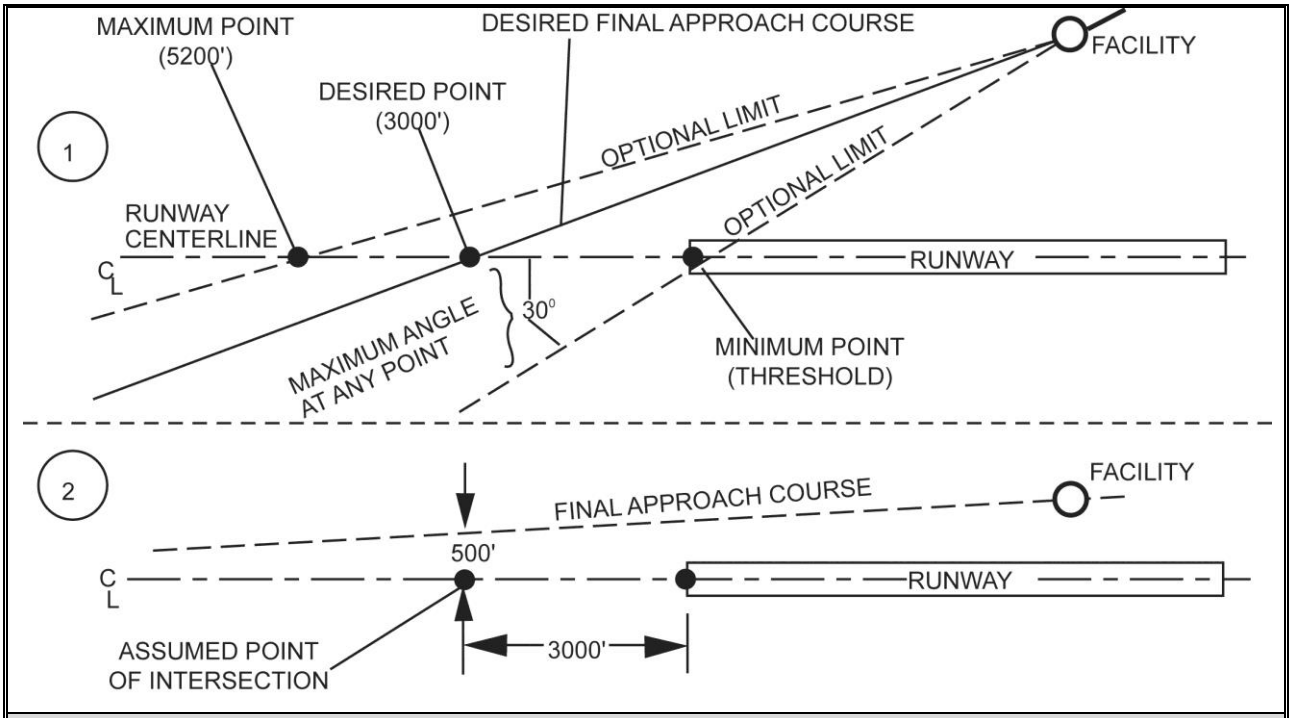


Figure 5-48: Alignment Options For Final Approach Course. On-Airport VOR, with FAF, Straight-In Approach Procedure. Para 513.a.(2)(a).

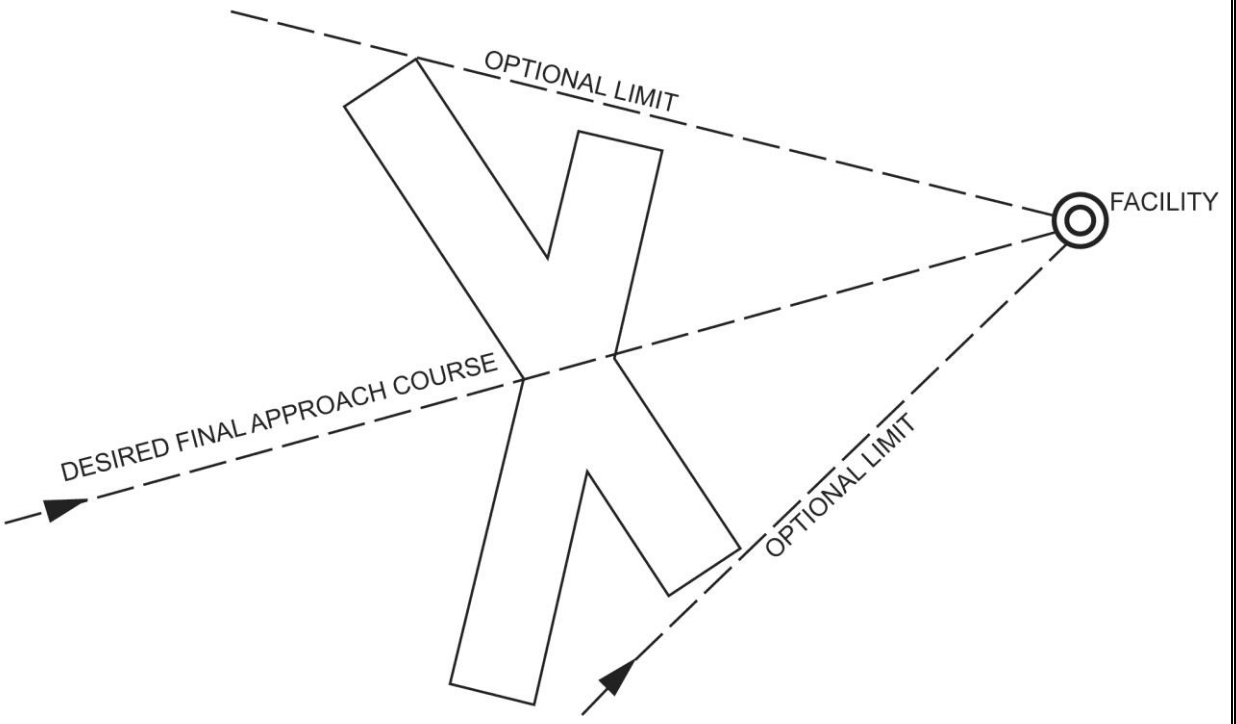


Figure 5-49: Alignment Options For Final Approach Course. On Airport VOR with FAF, Circling Approach Procedure. Para 513.a.(2)(b).

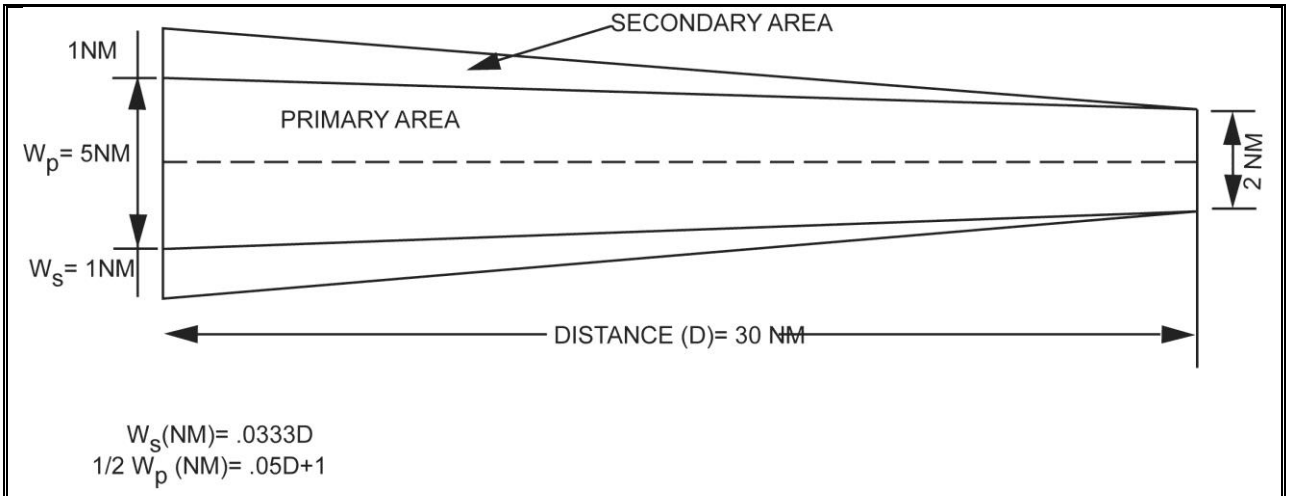


Figure 5-50: Final Approach Trapezoid. VOR with FAF. Para 513.b.

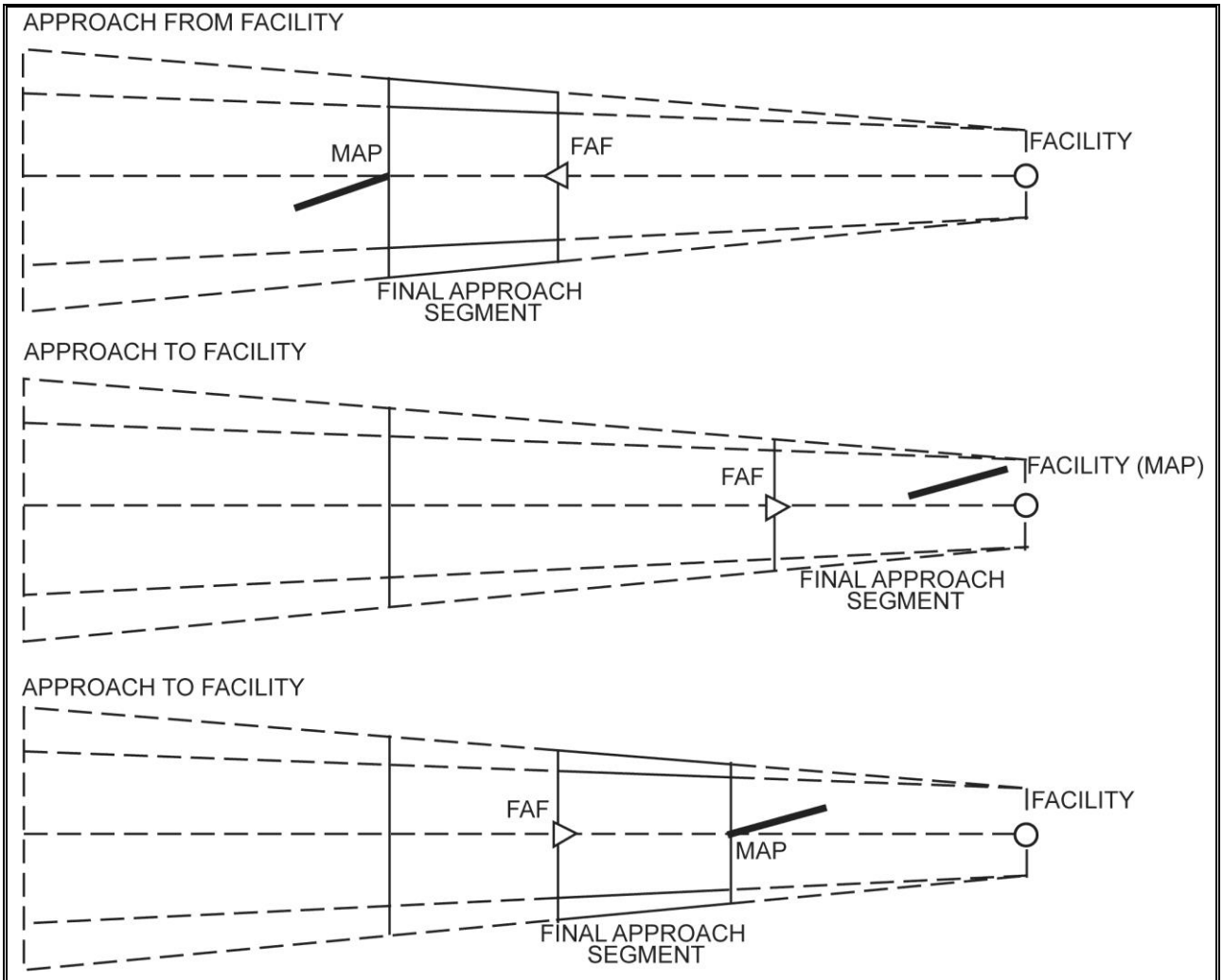
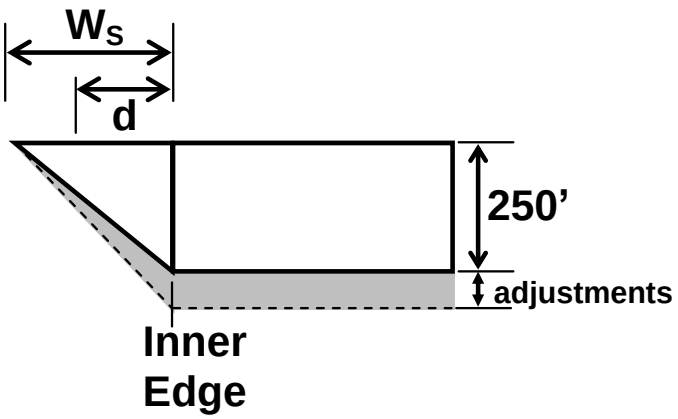


Figure 5-51: Typical Straight -In Final Approach. VOR with FAF. Para 513.b.



Secondary ROC = $(250 + adj) \times \frac{(W_S - d)}{W_S}$

Where:
d = distance from inner edge to obstacle (ft)
W_S = Width of secondary area (ft)
adj = adjustments (ft) as per para 3.2.2.

Figure 5- 51a: Minimum Obstacle Clearance. Para 513.c(1).

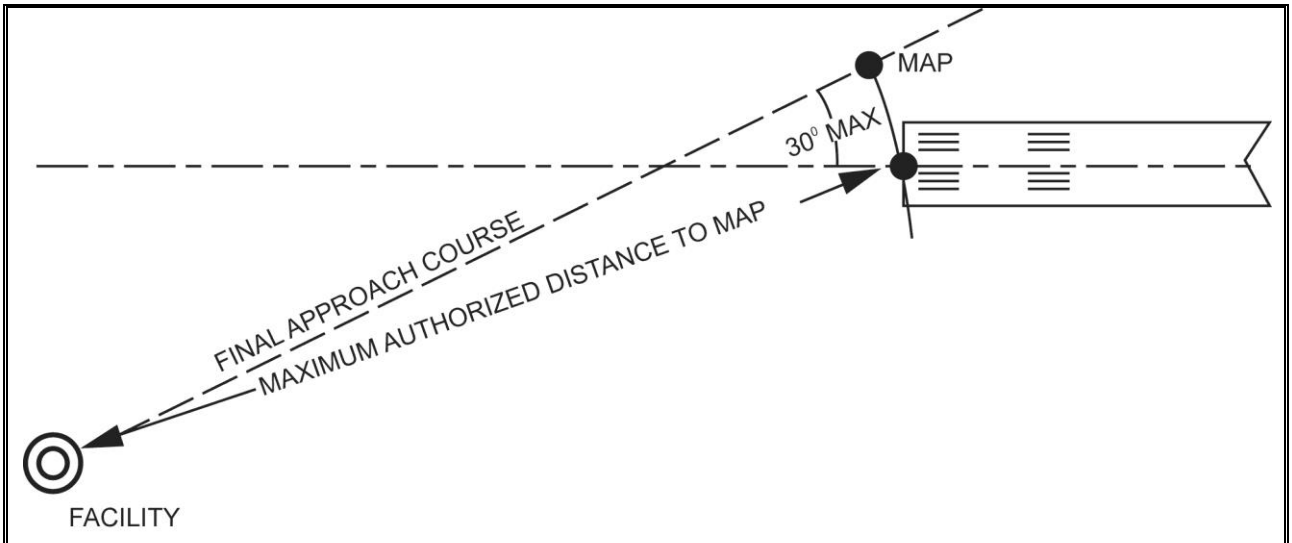


Figure 5-52: Missed Approach Point. Off-Airport VOR with FAF. Para 514.a.(1).

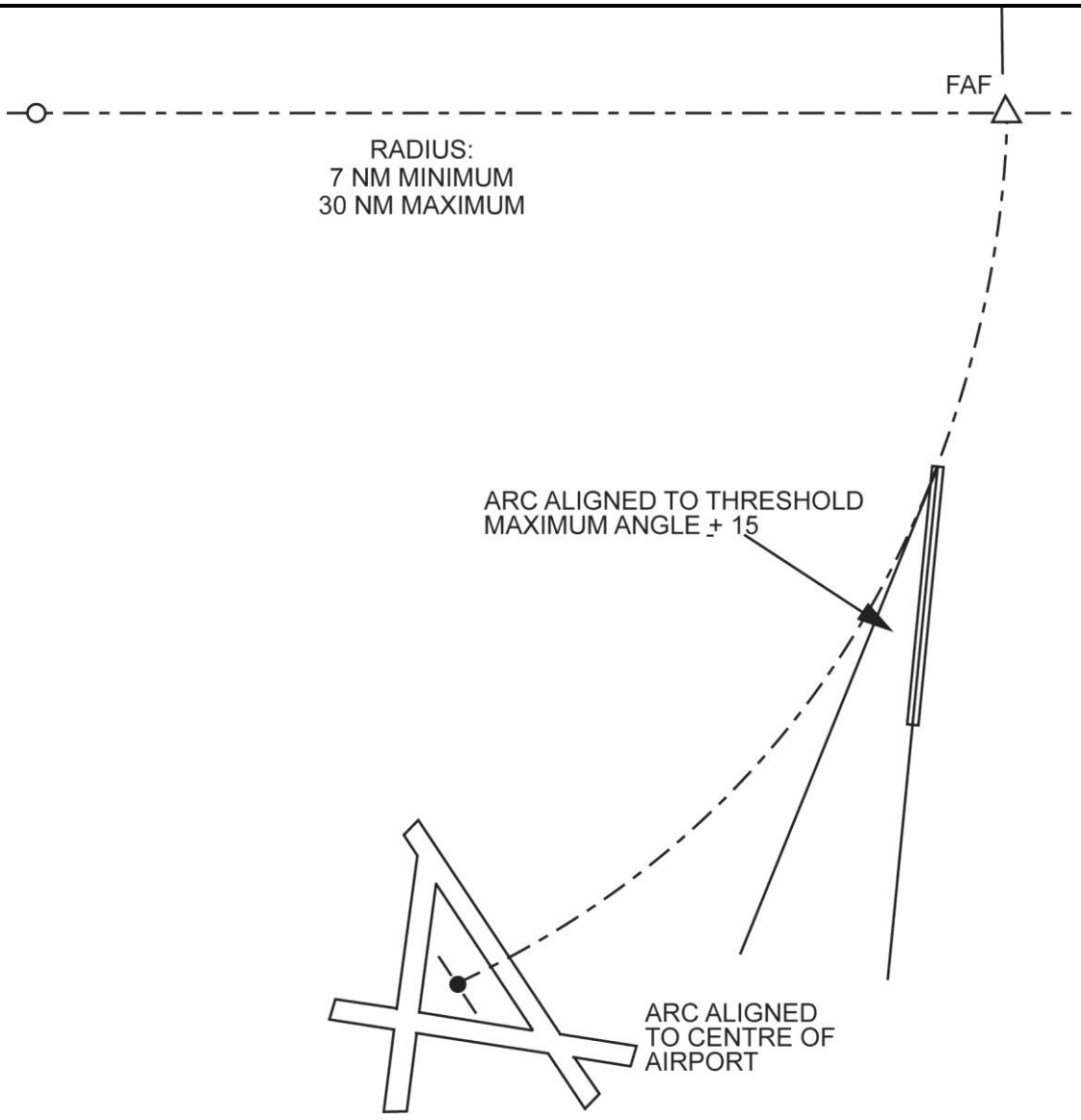


Figure 5-53: Arc Final Approach Alignment. Arc Aligned To Threshold. TACAN or VOR/DME. Para 523.b.(1).

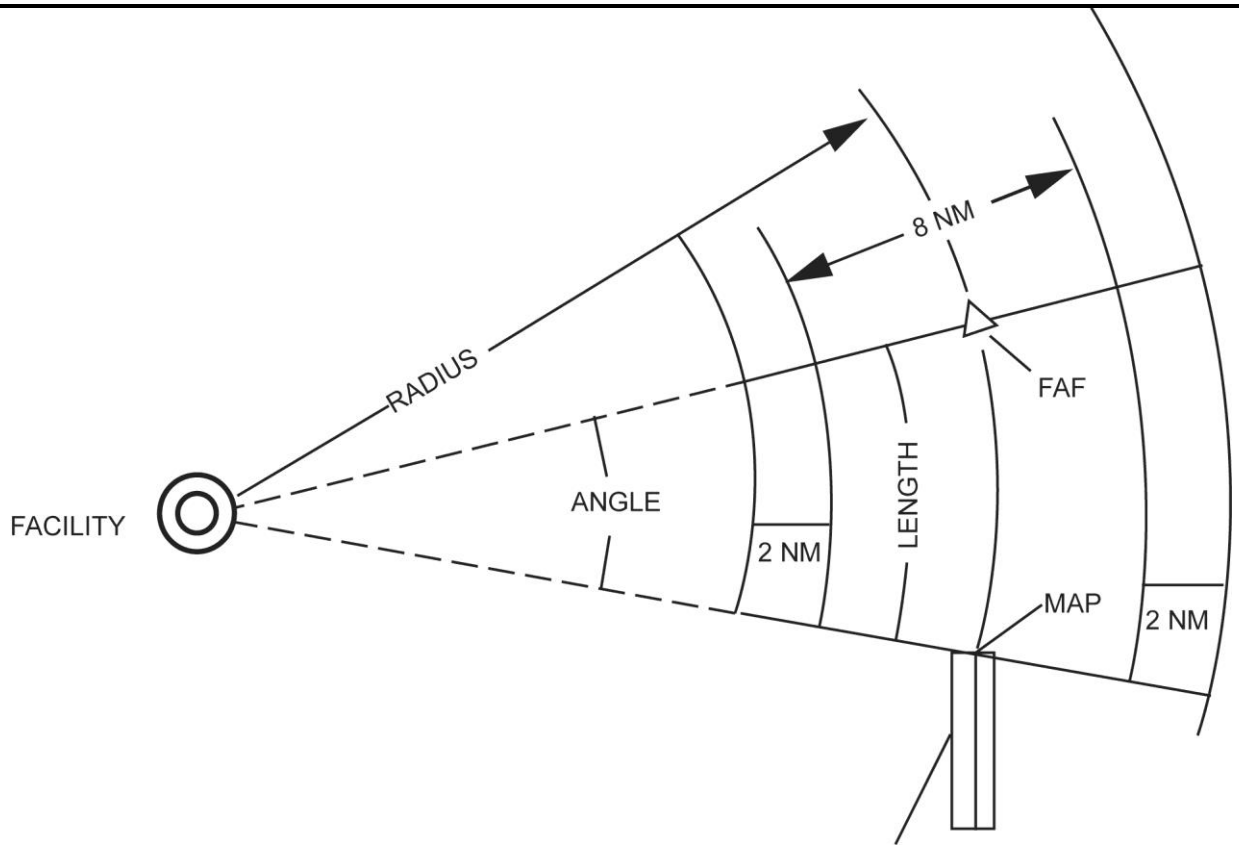
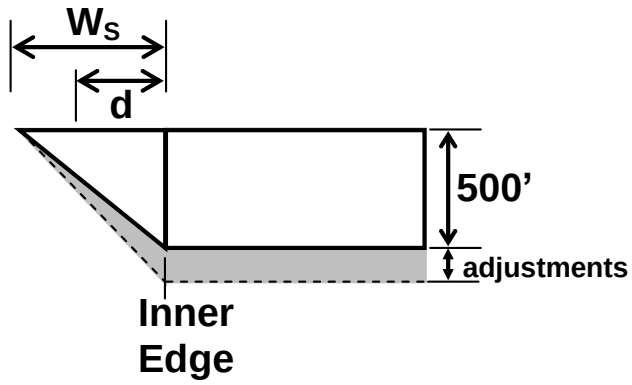


Figure 5-54: Arc Final Approach Area. TACAN or VOR/DME. Para 523.b.(2).



Secondary ROC = $(500 + adj) \times \frac{(W_S - d)}{W_S}$

Where:
- d = distance from inner edge to obstacle (ft)
- W_S = Width of secondary area (ft)
- adj = adjustments (ft) as per para 3.2.2.

Figure 5- 54a: Minimum Obstacle Clearance. Para 523.b(3).

CHAPTER 6. NDB PROCEDURES ON-AIRPORT FACILITY, NO FAF

600. General

This chapter is divided into two sections: one for low altitude procedures and one for high altitude teardrop penetration procedures. These criteria apply to NDB procedures based on a facility located on the airport in which no final approach fix is established. These procedures must incorporate a procedure turn or a penetration turn. An on-airport facility is one that is located:

a. For Straight-in Approach. Within 1 mile of any portion of the landing runway.

b. For Circling Approach. Within 1 mile of any portion of the usable landing surface on the airport.

601—609. Reserved

SECTION 1. LOW ALTITUDE PROCEDURES

610. Feeder Routes

Criteria for feeder routes are contained in Para 2.2.1.

611. Initial Approach Segment

The initial approach fix is received by overheading the navigation facility. The initial approach is a procedure turn. Criteria for the procedure turn areas are contained in Para 2.3.5.

612. Intermediate Approach Segment

This type of procedure has no intermediate segment. Upon completion of the procedure turn the aircraft is on final approach.

613. Final Approach Segment

The final approach begins where the procedure turn intersects the final approach course.

a. Alignment. The alignment of the final approach course with the runway centreline determines whether a straight-in or circling-only approach may be established.

(1) Straight-in. The angle of convergence of the final approach course and the extended runway centreline shall not exceed 30 degrees. The final approach course should be aligned to intersect the extended runway centreline 3,000 feet outward from the runway threshold. When an operational advantage can be achieved, this point of intersection may be established at any point between the runway threshold and a point 5,200 feet outward from the runway threshold. Also, where an operational advantage can be achieved a final approach course which does not intersect the runway centreline, or intersects it at a distance greater than 5,200 feet from the threshold, may be established provided that such course lies within 500 feet laterally of the extended runway centreline at a point 3,000 feet outward from the runway threshold. Straight-in category C, D, and E minimums are not authorized when the final approach course intersects the extended runway centerline at an angle greater than 15° and a distance less than 3,000 feet. (See Figure 6-55.)

(2) Circling Approach. When the final approach course alignment does not meet the criteria for straight-in landing, only a circling approach shall be authorized, and the course alignment should be made to the centre of the landing area. When an operational advantage can be achieved, the final approach course may be aligned to pass through any portion of the usable landing surface. (See Figure 6-56.)

b. Area. Figure 6-57 illustrates the final approach primary and secondary areas. The primary area is longitudinally centred on the final approach course, and is 10 miles long. The primary area is 2.5 miles wide at the facility, and expands uniformly to 6 miles wide at 10 miles from the facility. A secondary area is on each side of the primary area. It is zero miles wide at the facility, and expands uniformly to 1.34 miles on each side of the primary area at 10 miles from the facility. When the 5-mile procedure turn is used, only the inner 5 miles of the final approach area need be considered.

c. Obstacle Clearance.

(1) Straight-in. The minimum obstacle clearance in the primary area is 350 feet. In the secondary area, 350 feet of obstacle clearance shall be provided at the inner edge, tapering uniformly to zero feet at the outer edge. To determine ROC in the secondary area, see Figure 6-57a.

(2) Circling Approach. In addition to the minimum requirements specified in Para 613.c.(1), obstacle clearance in the circling area shall be as prescribed in Chapter 2, Section 6.

d. Procedure Turn Altitude (Descent Gradient). The procedure turn completion altitude shall be within 1,500 feet of the MDA (1,000 feet with a 5-mile procedure turn), provided the distance from the facility to the point where the final approach course intersects the runway centreline (or the first usable portion of the landing area for "circling only" procedures) does not exceed 2 miles. When this distance exceeds 2 miles, the maximum difference between the procedure turn completion altitude and the MDA shall be reduced at the rate of 25 feet for each one-tenth of a mile in excess of 2 miles. (see Figure 6-58.)

Note: For those procedures in which the final approach course does not intersect the extended runway centreline within 5,200 feet of the runway threshold (Para 613.a.(1)), the assumed point of intersection for computing distance from the facility shall be 3,000 feet from the runway threshold. (See Figure 6-55.)

e. Use of Step-down Fix. Use of the step-down fix (Para 2.8.9.c) is permitted provided the distance from the facility to the step-down fix does not exceed 4 miles. The descent gradient between PT completion altitude and stepdown fix altitude shall not exceed 150 ft/NM. The descent gradient will be computed based upon the difference in PT completion altitude minus stepdown fix altitude, divided by the specified PT distance, minus the facility to stepdown fix distance. Obstacle clearance may be reduced to 300 feet from the stepdown fix to the MAP/FEP (see Figure 6-59, and Paras 2.5.1, 2.5.2, and 2.5.3).

f. Minimum Descent Altitude. Criteria for determining the MDA are contained in Chapter 3, Section 3-2.

614. Missed Approach Segment

Criteria for the missed approach segment are contained in Chapter 2, Section 7. The missed approach point is the facility. (see Figure 6-59. The missed approach surface shall commence over the facility at the required height. (See Para 2.7.5.)

615—619. Reserved

SECTION 2. HIGH ALTITUDE TEARDROP PENETRATIONS

620. Feeder Routes

Criteria for feeder routes are contained in Para 2.2.1.

621. Initial Approach Segment

The initial approach fix is received by overheading the navigation facility. The initial approach is a teardrop penetration turn. The criteria for the penetration turn are contained in Para 2.3.6.

622. Intermediate Approach Segment

The procedure has no intermediate segment. Upon completion of the penetration turn, the aircraft is on final approach.

623. Final Approach Segment

An aircraft is considered to be on final approach upon completion of the penetration turn. However, the final approach segment begins on the final approach course 10 miles from the facility. That portion of the penetration procedure prior to the 10-mile point is treated as the initial approach segment. (see Figure 6-60.)

a. Alignment. Same as low altitude criteria. (See Para 613.a.)

b. Area. Figure 6-60 illustrates the final approach primary and secondary areas. The primary area is longitudinally centred on the final approach course, and is 10 miles long. The primary area is 2.5 miles wide at the facility, and expands uniformly to 8 miles at 10 miles from the facility. A secondary area is on each side of the primary area. It is zero miles wide at the facility and expands uniformly to 2 miles each side of the primary area at 10 miles from the facility.

c. Obstacle Clearance.

(1) Straight-in. The minimum obstacle clearance in the primary area is 500 feet. In the secondary area, 500 feet of obstacle clearance shall be provided at the inner edge, tapering to zero feet at the outer edge. The minimum required obstacle clearance at any given point in the secondary area is shown in, Figure 2-4-2.

(2) Circling Approach. In addition to the minimum requirements specified in Para 623.c.(1), obstacle clearance in the circling area shall be as prescribed in Chapter 2, Section 6.

d. Penetration Turn Altitude (Descent Gradient). The penetration turn completion altitude shall be at least 1,000 feet, but not more than 4,000 feet above the MDA on final approach.

e. Use of a Step-down Fix. Use of a step-down fix (see Para 2.8.9.c) is permitted, provided the distance from the facility to the step-down fix does not exceed 10 miles.

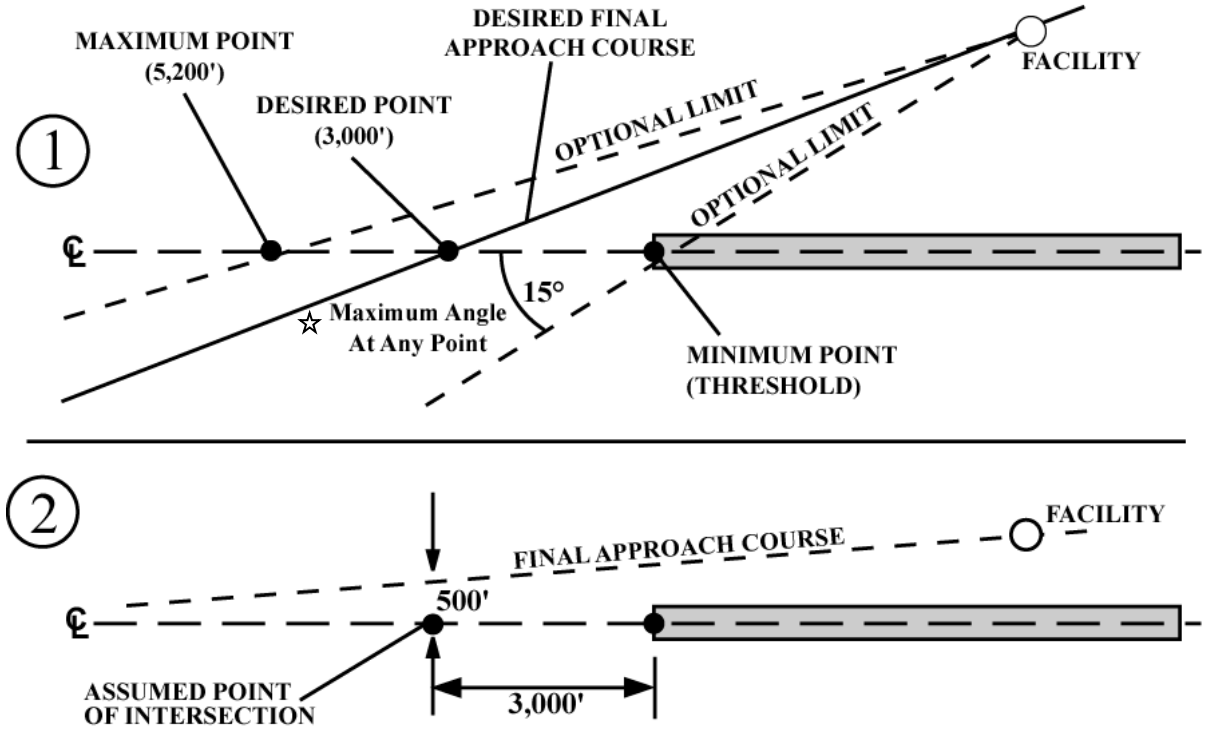
f. Minimum Descent Altitude. In addition to the normal obstacle clearance requirements of the final approach segment (see Para 623.c), the MDA specified shall provide at least 1000 feet of clearance over obstacles in that portion of the initial approach segment between the final approach segment and the point where the assumed penetration turn track intercepts the inbound course. (See Figure 6-60.)

624. Missed Approach Segment

Criteria for the missed approach segment are contained in Chapter 2, Section 7. The missed approach point is the facility. (See Figure 6-60.) The missed approach surface shall commence over the facility at the required height. (See Para 2.7.5.)

625—699. Reserved

Figure 6-1 TO 6-54: Reserved



☆**Supplementary Note:** In diagram (1), the "Maximum Angle At Any Point" for CAT A & B is 30 degrees, and for CAT C, D & E is 15 degrees (Para 613.a.)

Figure 6-55: Alignment Options For Final Approach Course. On-Airport NDB, No FAF, Straight-In Procedure. Para 613.a.(1).

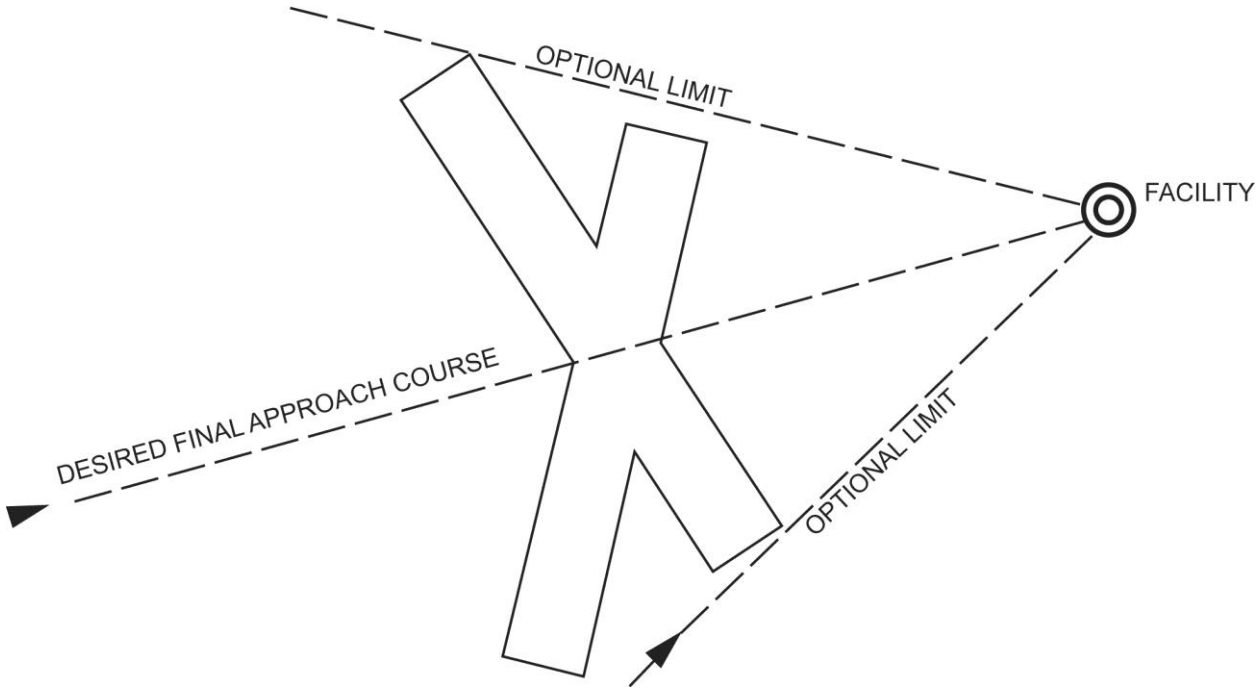


Figure 6-56: Alignment Options For Final Approach Course. On Airport NDB, No FAF, Circling Approach. Para 613.a.(2)

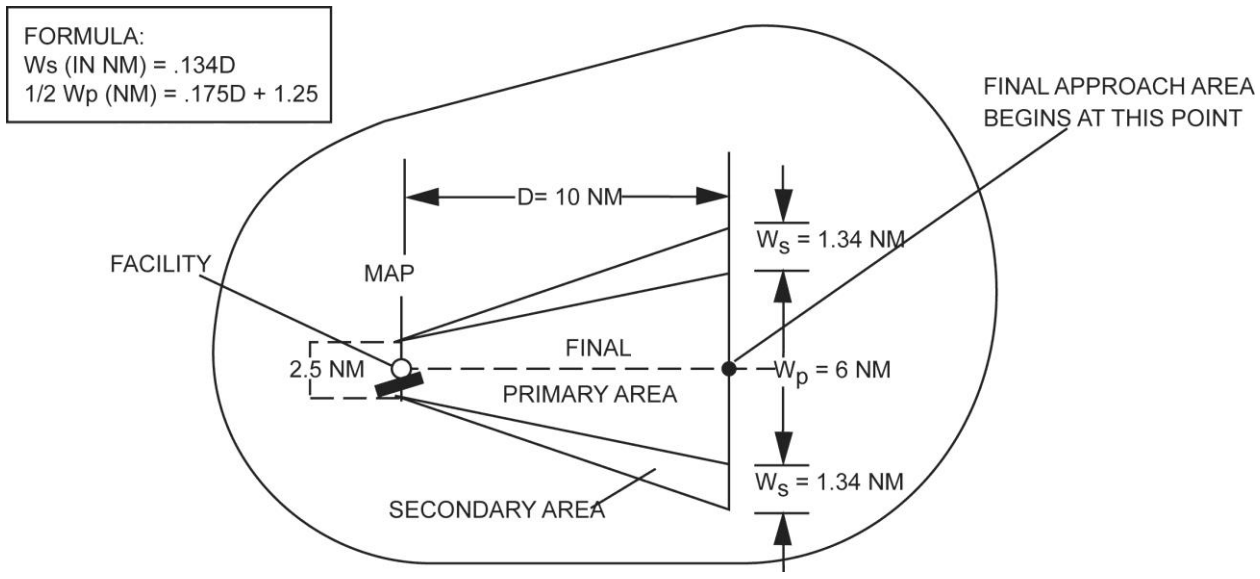
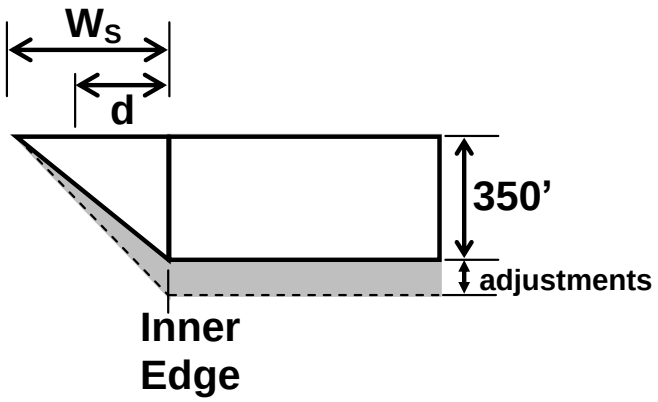


Figure 6-57: Final Approach Primary And Secondary Areas. On-Airport NDB, No FAF. Para 613.b.



Secondary ROC $= (350 + adj) \times \frac{(W_S - d)}{W_S}$

Where:
- d = distance from inner edge to obstacle (ft)
- W_S = Width of secondary area (ft)
- adj = adjustments (ft) as per para 3.2.2.

Figure 6-57a: Secondary ROC. Para 613.c.

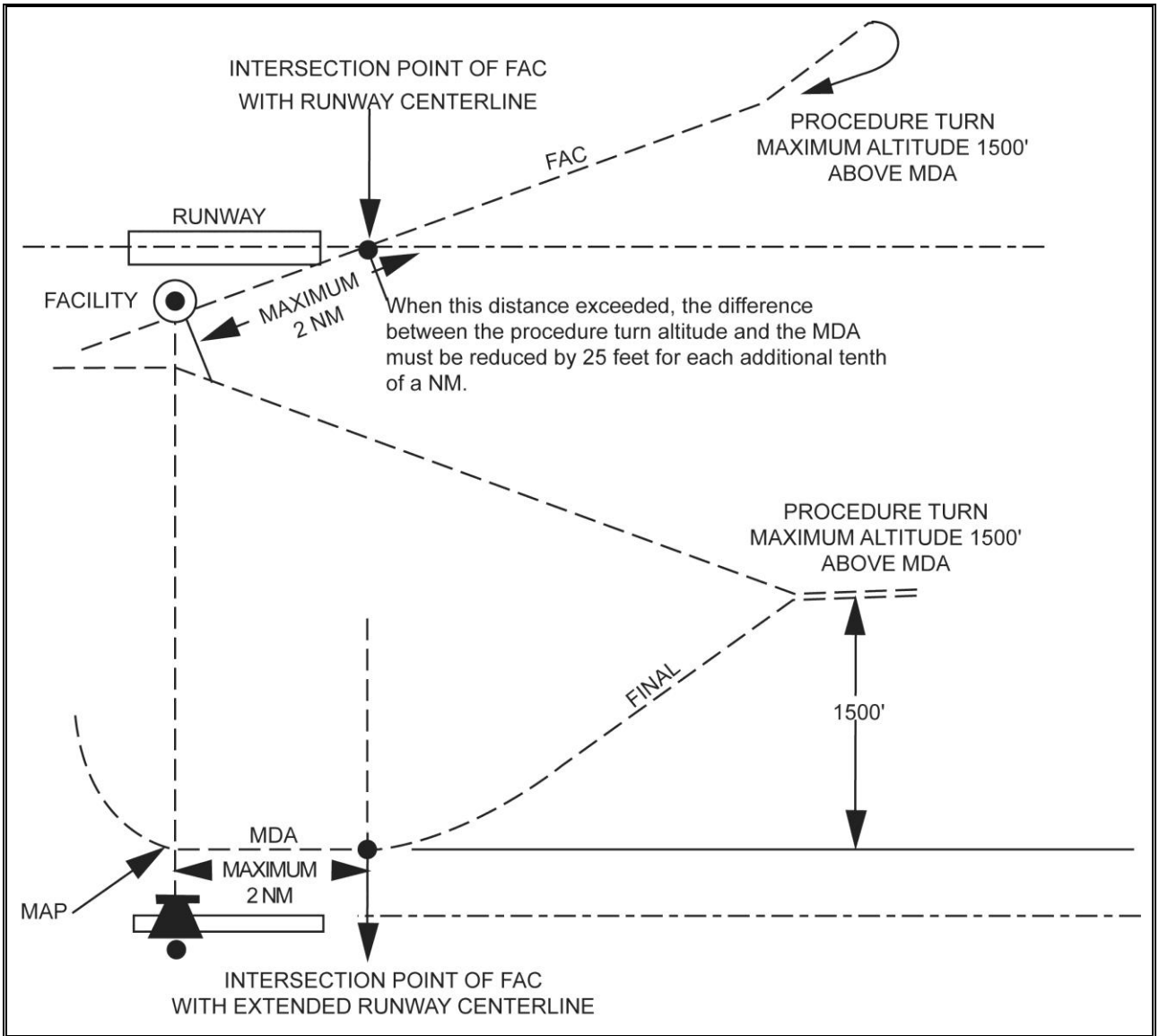


Figure 6-58: Procedure Turn Altitude. On-Airport NDB, No FAF. Para 613.d.

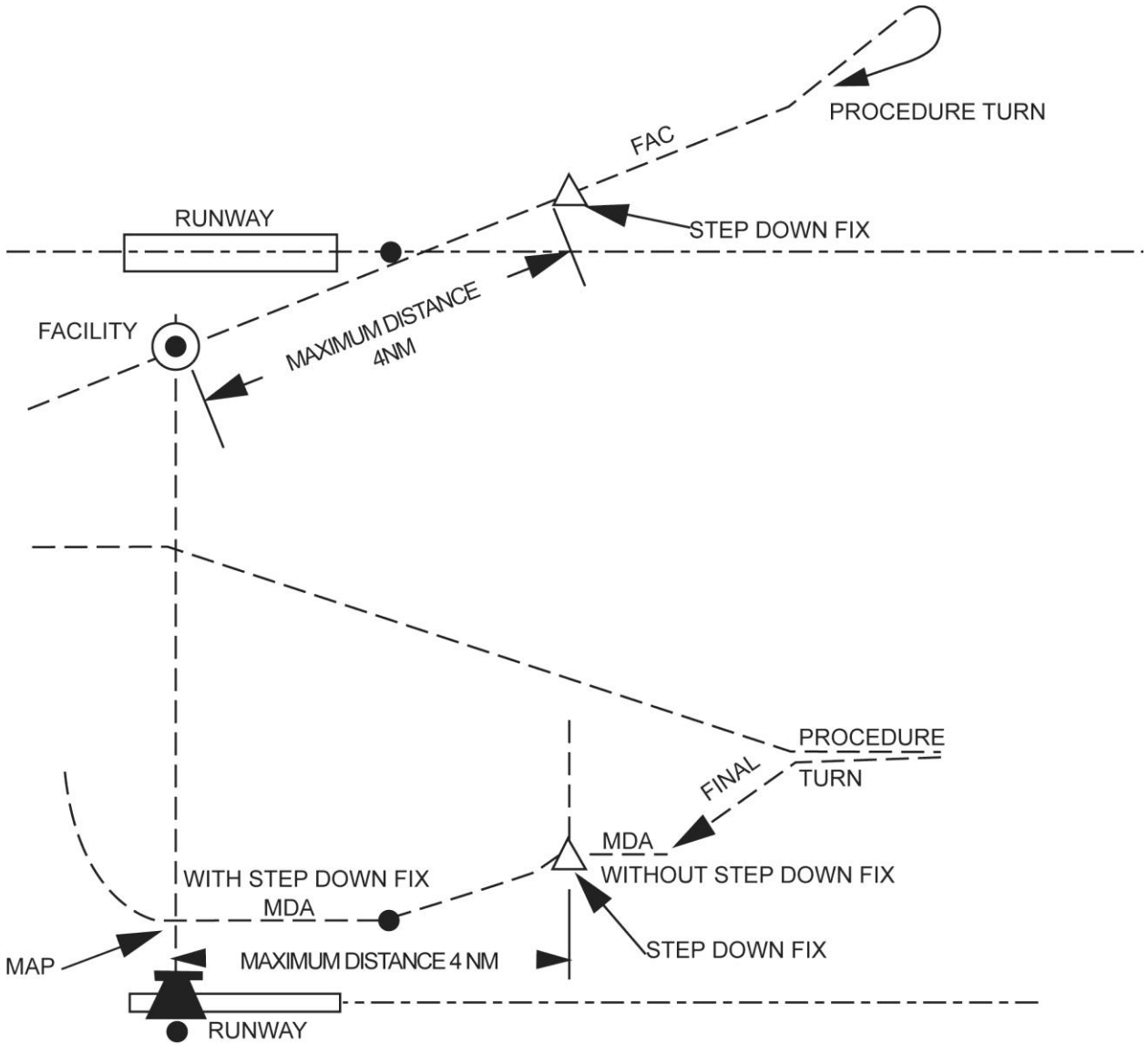


Figure 6-59: Use Of Step-Down Fix. On-Airport NDB, No FAF. Para 613.e.

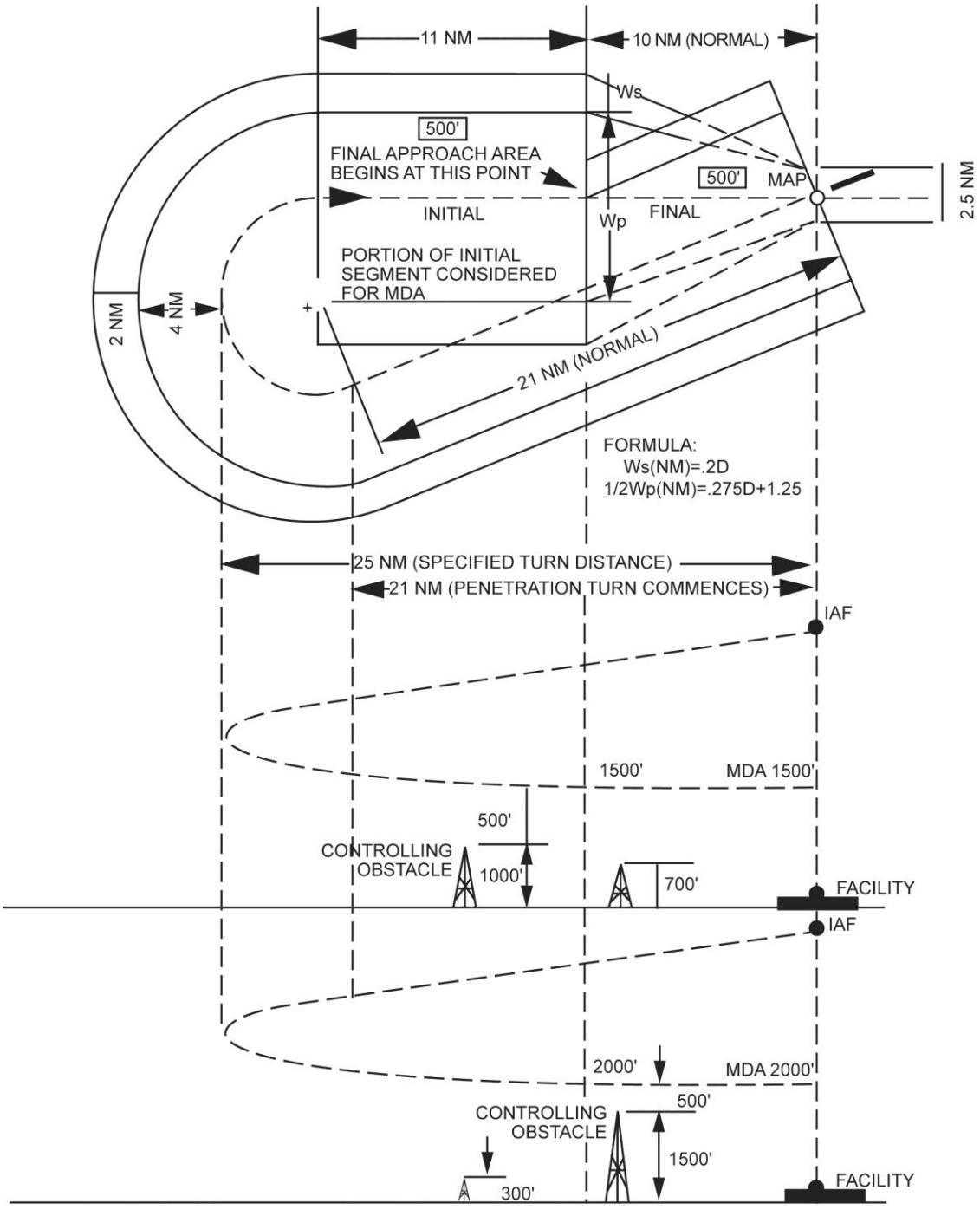


Figure 6-60: Penetration Turn. On Airport VOR, No FAF. Para 623.

CHAPTER 7. NDB WITH FAF

700. General

This chapter prescribes criteria for NDB procedures that incorporate a final approach fix. NDB procedures shall be based only on facilities that transmit a continuous carrier.

701—709. Reserved

SECTION 1. NDB WITH FAF

710. Feeder Routes

Criteria for feeder routes are contained in Para 2.2.1.

711. Initial Approach Segment

Criteria for the initial approach are contained in Chapter 2, Section 3.

712. Intermediate Approach Segment

Criteria for the intermediate approach segment are contained in Chapter 2, Section 4.

713. Final Approach Segment

The final approach may be made either FROM or TOWARD the facility. The final approach segment begins at the final approach fix and ends at the runway or missed approach point, whichever is encountered last.

Note: Criteria for the establishment of arc final approaches are specified in Para 523.b.

a. The alignment of the final approach course with the runway centreline determines whether a straight-in or circling-only approach may be established. The alignment criteria differ depending on whether the facility is OFF or ON the airport. See definition in Para 400.

(1) Off-airport Facility.

(a) **Straight-in**. The angle of convergence of the final approach course and the extended runway centreline shall not exceed 30 degrees. The final approach course should be aligned to intersect the runway centreline at the runway threshold. However, when an operational advantage can be achieved, the point of intersection may be established anywhere from the runway threshold to as much as 3,000 feet outward from the runway threshold. (See Figure 7-61.)

(b) **Circling Approach**. When the final approach course alignment does not meet the criteria for straight-in landing, only a circling approach shall be authorized, and the alignment should be made to the centre of the landing area. When an operational advantage can be achieved, the final approach course may be aligned to any portion of the usable landing surface. (See Figure 7-62.)

(2) On-airport Facility.

(a) **Straight-in**. The angle of convergence between the final approach course and the extended runway centreline shall not exceed 30 degrees. The final approach course should be aligned to intersect the extended runway centreline 3,000 feet outward from the runway threshold. When an operational advantage can be achieved, this point of intersection may be established at any point between the runway threshold and a point 5,200 feet outward from the runway threshold. Also, where an operational advantage can be achieved, a final approach course which does not intersect the runway centreline, or which intersects it at a distance greater than 5,200 feet from the threshold, may be established provided such a course lies within 500 feet laterally of the extended runway centreline at a point 3,000 feet outward from the runway threshold (See Figure 7-63).

(b) **Circling Approach**. When the final approach course alignment does not meet the criteria for a straight-in landing, only a circling approach shall be authorized, and the course alignment should be made to the centre of the landing area. When an operational advantage can be achieved, the final approach course may be aligned to any portion of the usable landing surface. (See Figure 7-64).

b. Area. The area considered for obstacle clearance in the final approach segment starts at the final approach fix and ends at the runway or missed approach point, whichever is encountered last. It is a portion of a 15 nautical mile long trapezoid (see Figure 7-65), which is made up of primary and secondary areas. The primary area is centred longitudinally on the final approach course. It is 2.5 nautical miles wide at the facility and expands uniformly to 5 nautical miles at 15 nautical miles from the facility. A secondary area is on each side of the primary area. It is zero miles wide at the facility, and expands uniformly to 1 nautical mile each side of the primary area at 15 nautical miles from the facility. Final approaches may be made to airports which are a maximum of 15 nautical miles from the facility. The **OPTIMUM** length of the final approach segment is 5 nautical miles. The **MAXIMUM** length is 10 nautical miles. The **MINIMUM** length of the final approach segment shall provide adequate distance for an aircraft to make the required descent, and to regain course alignment when a turn is required over the facility. Table 7-15 shall be used to determine the minimum length needed to regain the course.

c. Obstacle Clearance.

(1) **Straight-in**. The minimum obstacle clearance in the primary area is 300 feet. In the secondary area, 300 feet of obstacle clearance shall be provided at the inner edge, tapering uniformly to zero feet at the outer edge (see Figure 7-66a). Allowance for adjustments should be considered as specified in Para 3.2.2.

(2) **Circling Approach**. In addition to the minimum requirements specified in Para 713.c.(1), obstacle clearance in the circling area shall be as prescribed in Chapter 2, Section 6.

d. Descent Gradient. Para 2.5.2. applies

e. Use of Fixes. Criteria for the use of radio fixes are contained in Chapter 2, Section 8. Where a procedure is based on a procedure turn and an on-airport facility is the procedure turn fix, the distance from the facility to the FAF shall not exceed 4 nautical miles.

f. Minimum Descent Altitude. Criteria for determining the MDA are contained in Chapter 3, Section 3-2.

714. Missed Approach Segment

Criteria for the missed approach segment are contained in Chapter 2, Section 7. The missed approach point and surface shall be established as follows:

a. Off-airport Facilities.

(1) **Straight-in**. The missed approach point is a point on the final approach course which is not farther from the FAF than the runway threshold. The missed approach surface shall commence over the missed approach point at the required height. (See Para 2.7.5 and Figure 7-67.)

(2) **Circling Approach**. The missed approach point is a point on the final approach course which is not farther from the final approach fix than the first usable portion of the landing area. The missed approach surface shall commence over the missed approach point at the required height. (See Para 2.7.5.)

b. On-airport Facilities. The missed approach point is a point on the final approach course which is not farther from the final approach fix than the facility. The missed approach surface shall commence over the missed approach point at the required height. (See Para 2.7.5.)

715—799. Reserved

Table 7-1 TO 7-14 : Reserved

Approach Category	Magnitude of Turn over the FAF (Degrees)		
	10° or less	20°	30°
A	1.0	1.5	2.0
B	1.5	2.0	2.5
C	2.0	2.5	3.0
D	2.5	3.0	3.5
E	3.0	3.5	4.0

Note: This table may be interpolated. If turns of more than 30° are required, or if the minimum lengths specified in the table are not available, straight-in minima are not authorized and only the circling OCA/H should be published. See Figure 7-66 for typical final approach areas.

Table 7-15: Minimum Length Of Final Approach Segment — NDB (NM). Para 713.b.

Figure 7-1 TO 7-60: Reserved

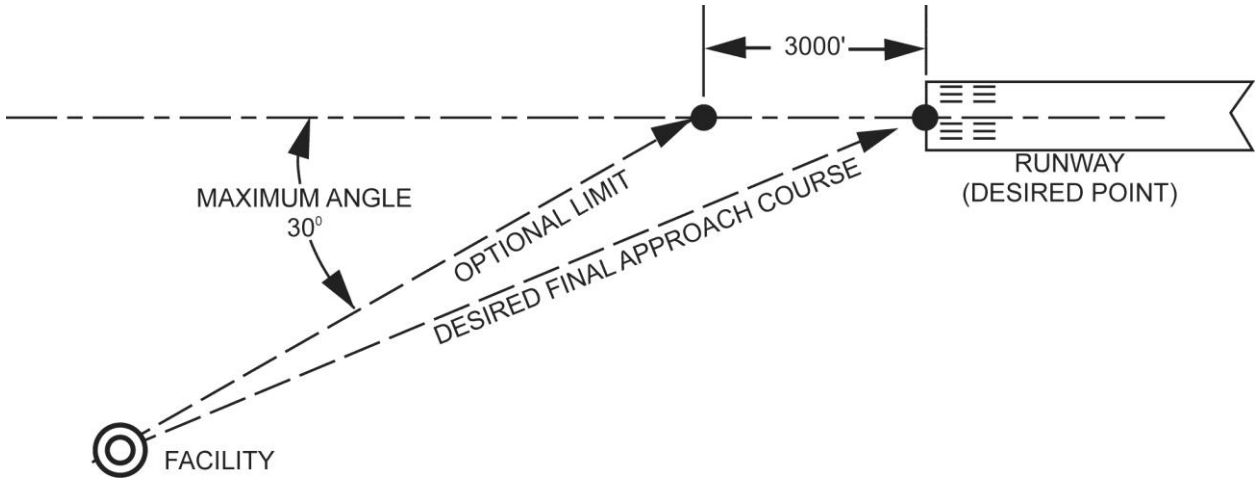


Figure 7-61: Alignment Options For Final Approach Course. Off-Airport NDB with FAF. Straight-In Approach. Para 713.a.(1)(a).

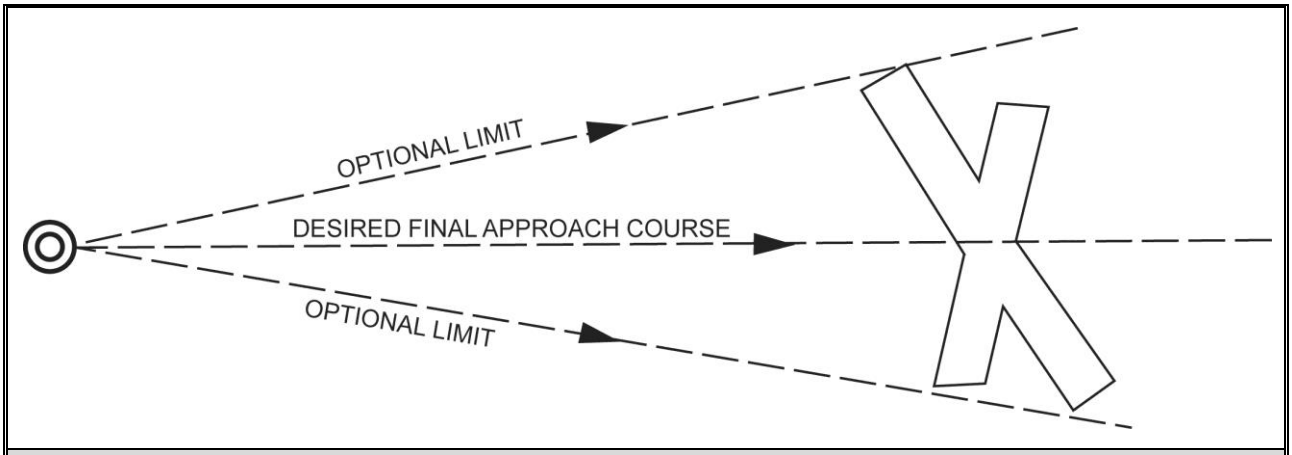


Figure 7-62: Alignment Options For Final Approach Course. Off-Airport NDB with FAF. Circling Approach. Para 713.a.(1)(b).

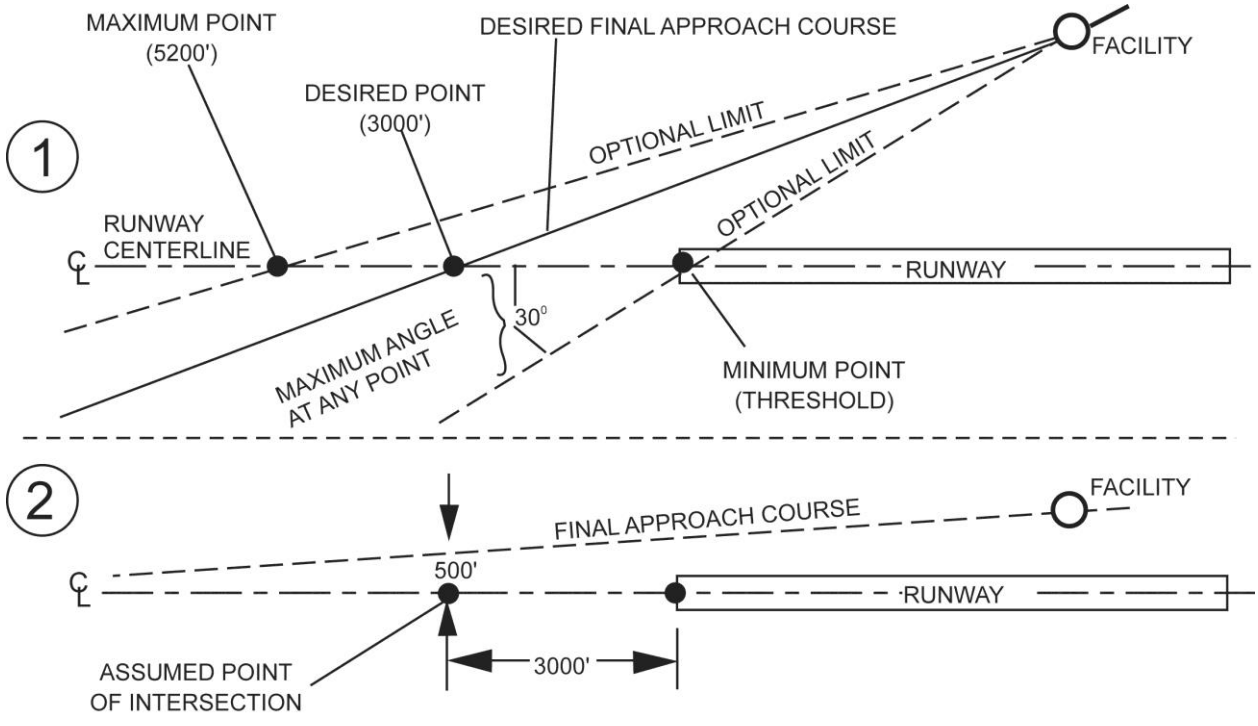


Figure 7-63: Alignment Options For Final Approach Course. On-Airport NDB. Para 713.a.(2)(a).

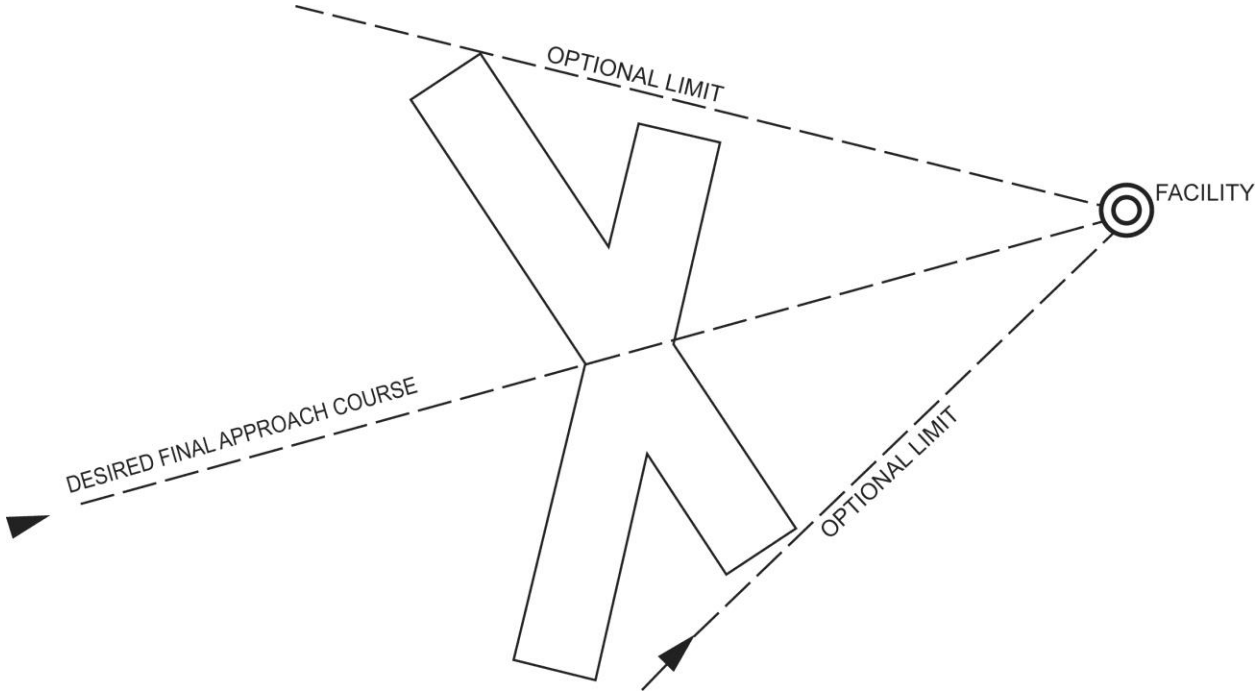


Figure 7-64: Alignment Options For Final Approach Course. On Airport NDB with FAF, Circling Approach. Para 713.a.(2)(b).

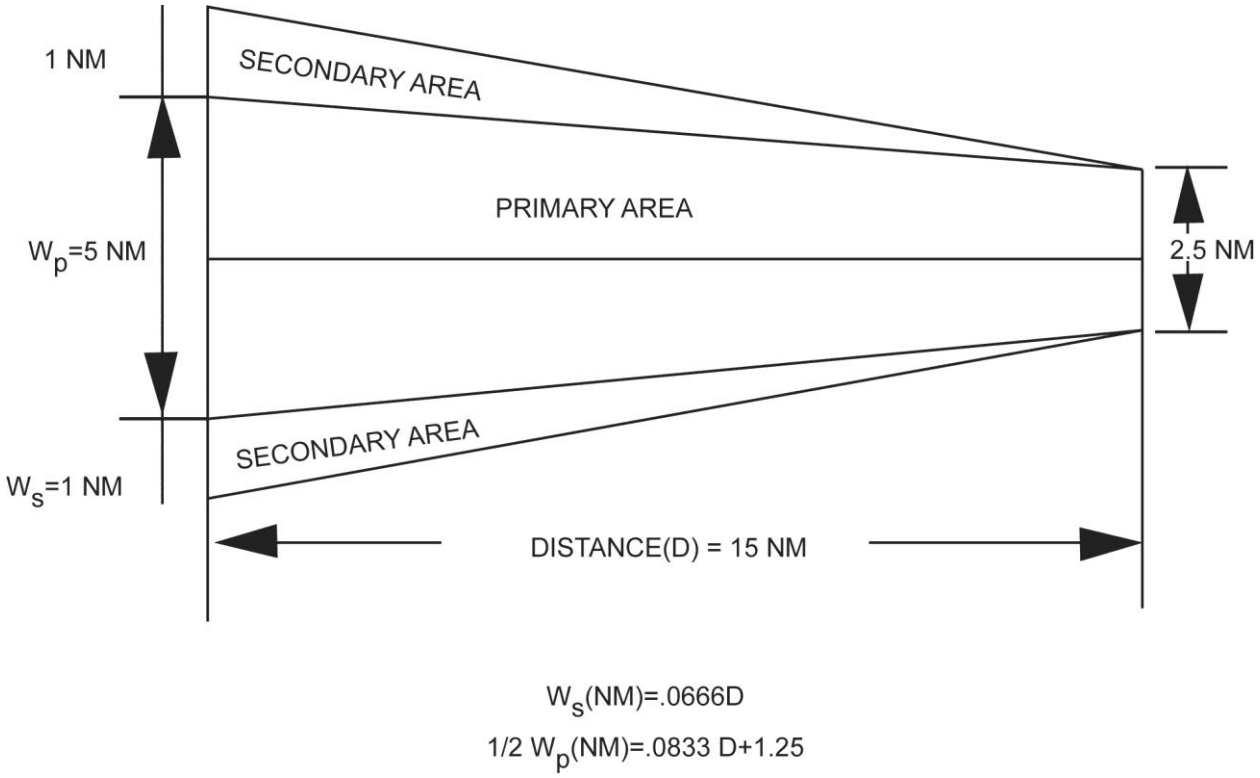
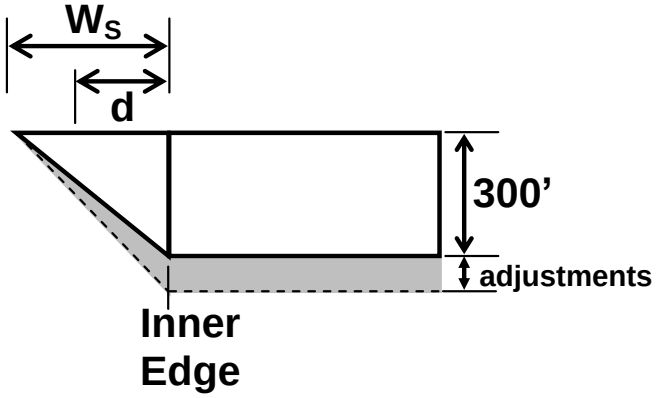


Figure 7-65: Final Approach Trapezoid. NDB with FAF. Para 713.b.



Secondary ROC $= (300 + adj) \times \frac{(W_S - d)}{W_S}$

Where:
- d = distance from inner edge to obstacle (ft)
- W_S = Width of secondary area (ft)
- adj = adjustments (ft) as per para 3.2.2.

Figure 7-66a: Minimum Obstacle Clearance. Para 713.c.

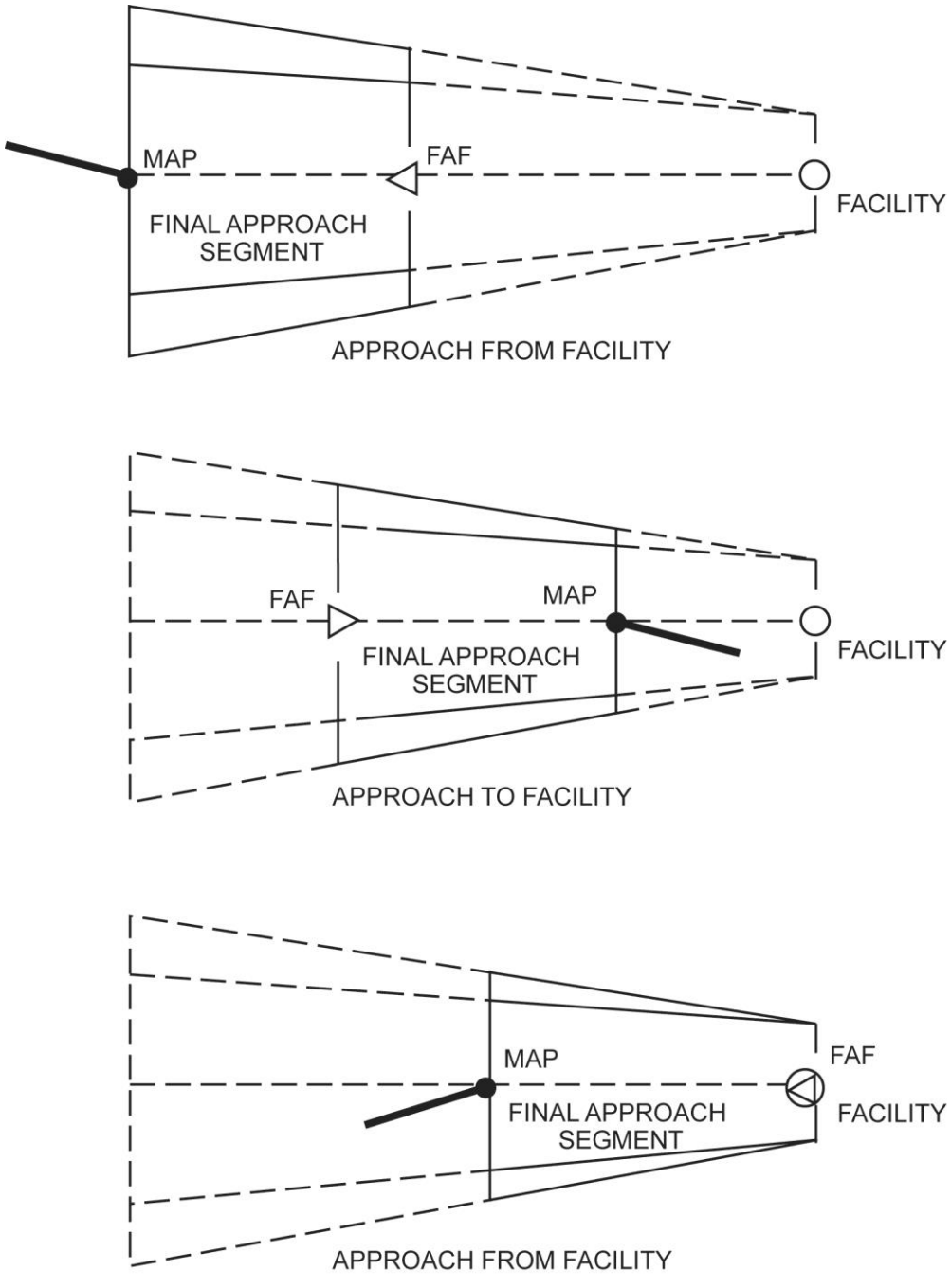


Figure 7-66: Typical Final Approach Areas. NDB with FAF. Para 713.b.

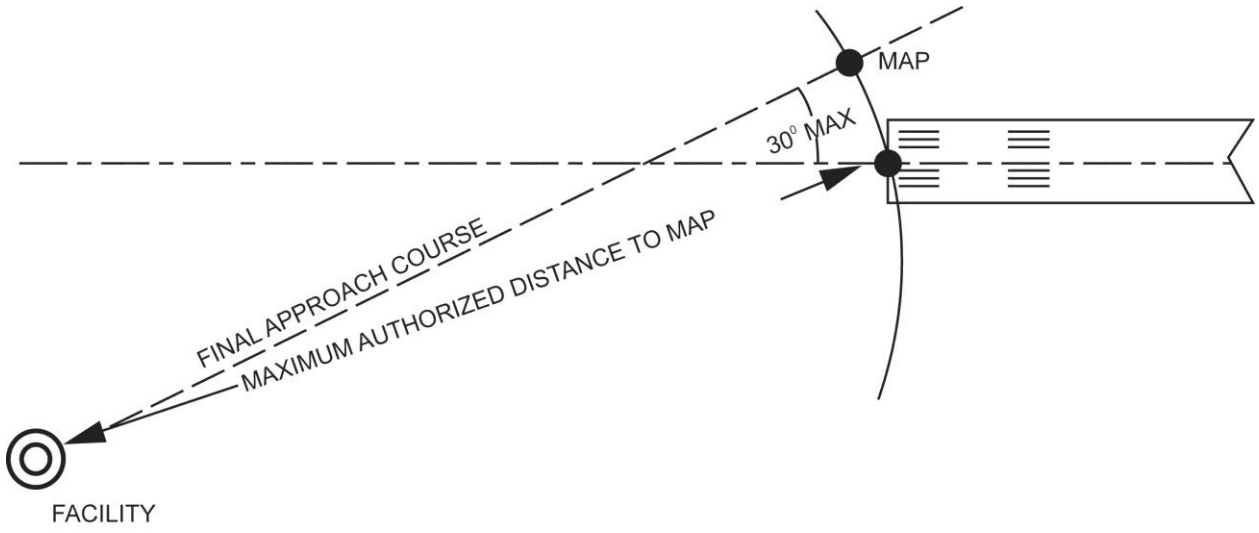


Figure 7-67: Missed Approach Point. Off-Airport NDB with FAF. Para 714.a.(1).

CHAPTER 8. RESERVED

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CHAPTER 9. LOCALIZER (LOC) AND LOCALIZER TYPE DIRECTIONAL AIDS (LDA)

SECTION 9-1. GENERAL INFORMATION AND CRITERIA

9.1. General Information and Criteria

9.1.1. Feeder Routes, Initial Approach, and Intermediate Segments

Apply criteria in sections 2-2 thru 2-4. When a LOC is associated with an ILS procedure, apply paragraph 13.1.3.

9.1.2. Final Segment

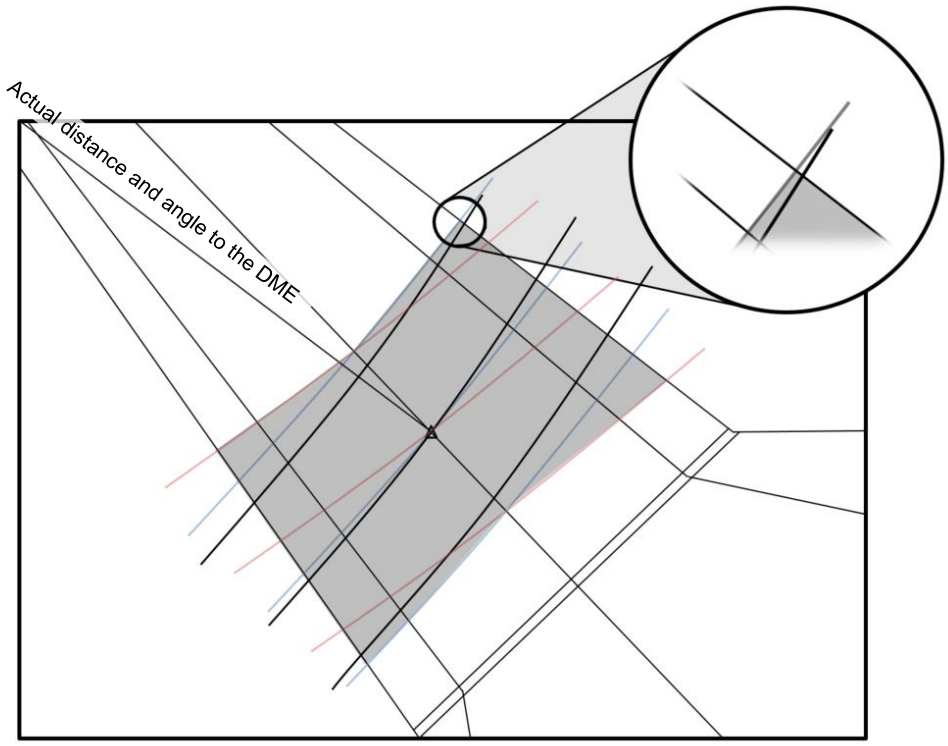
a. FAF. The procedure must include a FAF located within 10 NM of the LTP/FTP.

(1) If the FAF is a DME fix, then the distance from the DME facility to the FAF must not exceed 16.66 NM.

(2) If the FAF is formed by DME from a facility that isn't collocated with the LOC/LDA, then the angular divergence between the DME and LOC/LDA signal sources at the FAF must not exceed six degrees (DND 23 degrees).

(3) Exception: DME angular divergence exceeding 6 degrees may be used provided that the fix displacement area that results from the actual distance and angle to the DME facility is wholly contained within the fix displacement area that results from the 16.66 NM and 6° reference case (grey shaded area) (see Figure 9-1-1-A).

Figure 9-1-1-A. Fix Displacements – Reference Case vs. Exception Case



b. Alignment. Localizers aligned within three degrees of the RCL are identified as localizers. If the alignment exceeds three degrees, they will be identified as LDA facilities. An LDA procedure must meet the final approach alignment criteria for VOR on-airport facilities (see paragraph 513 and figure 5-48). Procedures developed utilizing localizers that are offset from the runway centreline up to and including 3 degrees shall have an operational note published identifying the number of degrees of offset. Procedures developed utilizing localizers that are offset more than 3 degrees shall have an operational note published indicating that the procedure is not aligned with the runway.

c. Where no usable glide slope is available, a localizer-only (front or back course) approach may be approved, provided the approach is made on a localizer from a final approach fix located within 10 nautical miles of the runway threshold. Back course procedures shall not be based on courses that exceed 6 degrees in width and shall not be approved for offset localizers. Back course procedures must be aligned within 3 degrees of the runway alignment.

9.1.3. Area

Figure 9-1-1-B illustrates the final approach primary and transitional areas out to 50200 feet from LTP/FTP. For LDA procedures, the final approach area commences at the fix or facility. Extend the boundaries symmetrically beyond 50200 feet when necessary. Apply formula 9-1-1 and formula 9-1-2 to determine the area widths. Only that portion of the final approach area that is between the earliest point the FAF can be received and the LTP/FTP need be considered as the final approach segment for obstacle clearance purposes. The optimum length of the final approach segment is 5 NM. The minimum length of the final approach segment must be sufficient to provide adequate distance for an aircraft to make the required descent. The area must be centered on the FAC.

Formula 9-1-1. Primary Area Half Width Formula

$$\frac{1}{2}W_P = 0.10752 \times (d - 200) + 700$$

Where:

d = Distance (feet) from LTP/FTP measured along FAC

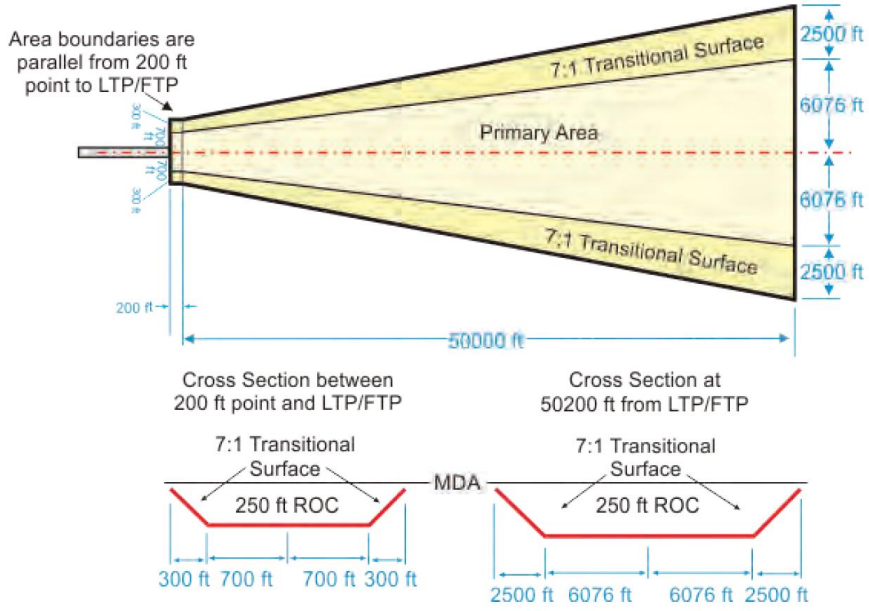
Formula 9-1-2. Perpendicular Width from RCL to Edge of Transitional Surface

$$\text{Transitional Sfc} = 0.15152 \times (d - 200) + 1000$$

Where:

d = Distance (feet) from LTP/FTP measured along FAC

Figure 9-1-1-B. Final Approach Area



9.1.4. Obstacle Clearance

The minimum ROC in the final area is 250 feet plus adjustments as specified in paragraph 3.2.2. In addition, the MDA established for the final approach area must assure that no obstacles penetrate the 7:1 transitional surfaces.

9.1.5. Vertical Descent Angle

Apply criteria in paragraphs 2.5.2 and 2.5.4.

9.1.6. Minimum Descent Altitude

The lowest altitude on final approach is specified as an MDA. Apply criteria in Chapter 3, Section 3-2.

9.1.7. Missed Approach Segment

Apply criteria in section 2-7. The MAP is on the FAC not farther from the FAF than the LTP/FTP (first usable portion of the landing area for circling approach), and must be at least 3000 feet from the LOC/LDA facility. The missed approach surface must commence over the MAP at the required height (see paragraph 2.7.5). When a LOC (stand alone or associated with an ILS) has an RNAV-based missed approach, apply the LP missed approach criteria specified in Volume 2.

CHAPTER 10. RADAR APPROACH PROCEDURES AND VECTORING CHARTS

SECTION 1. GENERAL INFORMATION

10.1. General Information

This chapter applies to radar approach procedures and vectoring charts utilizing ground-based radar or other approved surveillance systems (such as satellite-based).

10.1.1. Precision Approach Radar (PAR)

Precision Approach Radar is a system that graphically displays lateral course, glidepath, and distance from touchdown information of sufficient accuracy, continuity, and integrity to provide precision approach capability to a runway/landing area.

10.1.2. Surveillance Radar or System

Surveillance radar is a system that displays position (direction and distance) information with suitable accuracy, continuity, and integrity to safely provide radar vectoring capability for departures, arrivals, en route operations and approaches to an airport.

a. Within this chapter, the term “single sensor” applies to configurations authorized to use 3-NM lateral separation, and the term “multi-sensor” applies to those that require 5 NM. Where both single sensor and multi-sensor separation standards apply, either establish a separate procedure/chart for each sensor configuration, or establish one procedure/chart to accommodate the larger standard.

Note: Within 60 NM of the antenna, single sensor separation applies to full time reinforced Mono pulse Secondary Surveillance Radar (MSSR) systems.

b. ATC surveillance system: Authorized technology for the purpose of providing a source of surveillance in an ATS system formally approved by Transport Canada with specific lateral separation (for example MLAT).

c. FUSION describes adaptations based on the input of all available surveillance sources such as ASR, ARSR, automatic dependent surveillance – broadcast (ADS-B), authorized ATC surveillance system (multi-lateration (MLAT)) and any future surveillance source, into the display of a single tracked target for air traffic control separation services.

(1) When the aircraft target symbol can be used for 3-NM separation, minimum lateral obstacle clearance is 3 NM.

(2) When the aircraft target symbol can be used for 5-NM separation (Increased Separation Required (ISR) is displayed), minimum lateral obstacle clearance is 5 NM.

d. ADS-B. Apply paragraph 10.1.2 (c), except not authorized for conducting ASR approaches.

10.1.3. Minimum Vectoring Altitude Charts (MVAC)

See section 3 of this chapter for MVAC construction. Minimum vectoring altitude charts do not require flight inspection certification. During the lifecycle of the MVAC, it must be monitored for changes affecting the MVAC. These changes are to include but are not limited to: updated obstacle data,

change in criteria and change in surveillance radar or system. The MVAC must also be periodically reviewed (at least every 5 years) to determine if corrections are required.

SECTION 2. RADAR APPROACHES

10.2. Radar Approaches

PAR procedures may be established where coverage and alignment tolerances are met.

10.2.1. Feeder Routes and Initial Approach Segments

Feeder and initial segments do not need to be established when navigation guidance and obstacle clearance are provided by Air Traffic Control radar vectors, during the transition from the enroute to the terminal phase of flight.

a. Feeder/Initial Segments based on Routes. When operationally required, establish feeder routes and/or initial segments based on conventional navigation, Area Navigation (RNAV), or radar routes.

(1) **Conventional/RNAV Feeder/Initial**. Develop in accordance with TP308/GPH209 Volume 1, chapter 2 or Volume 2 as appropriate.

(2) **Radar Feeder/Initial**. The route/segment begins at an established fix that permits positive radar identification and ends at the appropriate termination fix for the segment. Display the course centerline on a radar video map display.

(a) **Alignment**. Design feeder/initial and initial/initial segment intersections with the smallest amount of course change necessary for the procedure. The maximum allowable course change between segments is 90 degrees.

(b) **Area**. The Obstacle Evaluation Area (OEA) begins at the applicable radar fix displacement prior to the route/segment start fix and extends to the segment termination fix. Primary area half-width is equal to the minimum lateral clearance applicable to the radar adaptation (e.g. 3 NM if the aircraft is less than 40 NM from the antenna, see paragraph 10.1.2). There is no secondary area. The primary area has no specified maximum or minimum length; however, the segment must be long enough to permit the required altitude loss without exceeding the maximum authorized descent gradient.

Note: When the minimum lateral clearance changes within a segment (e.g. 5 NM to 3 NM), the OEA half-width also changes without the need to “splay” or “taper”. For example, when transitioning from a Multi-sensor to Single Sensor configuration, the lateral clearance changes from 5 NM to 3 NM. Likewise lateral clearance changes from 5 NM to 3 NM when the distance to the sensor reduces to less than 40 NM and the configuration qualifies for 3 NM clearance at that point (see paragraph 10.1.2).

(c) **Obstacle Clearance**. Apply the Volume 1, chapter 2 standard applicable to the segment.

(d) **Descent Angle**. Apply Volume 1, chapter 2 standard applicable to the segment.

(e) **Altitude Selection**. Apply Volume 1, chapter 2 standard applicable to the segment. Do not publish fix altitudes higher than the minimum required for obstacle clearance or airspace to achieve an “optimum” descent gradient.

10.2.2. Intermediate Approach Segment.

Establish an intermediate segment when necessary (e.g., ATC radar vectors not available or MVA too high to support desired FAF/PFAF altitude). The intermediate segment begins at the intermediate fix and extends to the PFAF. When there is a preceding conventional / RNAV route segment, the applicable conventional/RNAV intermediate segment standards apply, except as specified in paragraph 10.2.2b(2).

a. Alignment. The intermediate course is an extension of the final approach course (no course change permitted at the PFAF).

b. Area.

(1) **Radar Intermediate**. When radar is used for course guidance (route or vector), the OEA begins at the applicable radar fix displacement prior to the Intermediate Fix (IF) and extends to the PFAF. Primary area half-width is equal to the minimum lateral clearance applicable to the radar adaptation (e.g. 3 NM if the A/C is less than 40 NM from the antenna and 5 NM if the A/C is 40 NM or more from the antenna, see paragraph 10.1.2) until reaching a point 2 NM prior to the PFAF, then tapers to the width of the PAR Final Approach segment (FAS) primary OEA when abeam the PFAF. There are no intermediate secondary areas. See figure 10-2-1.

Note: When the minimum lateral clearance changes within a segment (e.g. 5 NM to 3 NM), the OEA half-width also changes without the need to “splay” or “taper”.

(2) **Non-Radar Intermediate**. When conventional/RNAV navigation is used for course guidance, apply the intermediate OEA criteria from the applicable TP308/GPH209 volume with the following exceptions:

(a) **Connection to PAR Final**. Connect the outer edges of the intermediate primary area abeam the IF to the outer edges precision “X” Obstacle Clearance Surface (OCS) and the intermediate secondary area to the precision “Y” OCS abeam the PFAF.

(3) **Length**. The intermediate segment length is normally 6 NM. The MINIMUM length varies based on course guidance but must always accommodate the required altitude loss. The maximum length is 15 NM.

(a) For conventional/RNAV and radar route course guidance, apply Volume 1, chapter 2 for ASR approaches and Volume 1, chapter 13 for PAR approaches. Radar intermediate segments may not be less than 2 NM.

c. Obstacle Clearance. Apply 500 ft ROC over the highest obstacle in the area. Volume 1, chapter 3 RASS adjustments apply. For conventional/RNAV course guidance, apply secondary area ROC criteria from the applicable TP308/GPH209 Volume.

d. Descent gradient. Apply Volume 1, Chapter 2.

10.2.3. PAR Final Approach Segment (FAS).

a. Inoperative/unused Components. Failure of the azimuth component renders the entire PAR system inoperative. When the glide slope feature becomes inoperative, the PAR reverts to a non-precision approach system. In this case, obstacle clearance shall be as specified in Vol. 1, Chapter 9 for localizer approaches.

The missed approach instructions are the same, and the radar missed approach point is identifiable on the PAR scope. NPA minimums are established according to TP308/GPH209, Volume 1, Chapter 3 and are documented as applicable.

b. General. Apply the current basic vertically guided final segment general criteria applicable to Instrument Landing System (ILS) for Glidepath Angle (GPA), Threshold Crossing Height (TCH), Precise Final Approach Fix (PFAF), Vertical guidance surface (VGS), and Precision Obstacle Free Zone (POFZ).

(1) Use the highest applicable MVA to determine the PFAF distance to LTP/coordinates when there is no preceding segment.

(2) ILS Height Above Touchdown/Threshold (HAT/HATh) and Decision Altitude (DA) standards apply (to include Volume 1, chapter 3 adjustments), except the minimum HAT/HATh may be 100 ft for helicopter approaches when the OCS is clear.

Note: Adjusting TCH to reduce/eliminate OCS penetrations is not applicable to PAR FAS evaluations.

c. Obstacle Evaluation Area (OEA)/Obstacle Clearance Surface (OCS). Apply current ILS FAS criteria for alignment, OCS slope, width, height, and OEA/OCS evaluation except the OEA extends to the PFAF (no radar fix tolerance applied). Also, where the PFAF must be located more than 50200 ft from the RWT coordinates, the OEA continues to splay to the PFAF or until reaching the minimum lateral clearance applicable to the radar adaptation.

10.2.4. Missed Approach Segment (MAS).

a. PAR. Apply the Volume 1, chapter 13 Category (CAT) I ILS missed approach criteria to approaches with HAT/HATh values greater than or equal to 200 ft. Apply CAT II missed approach criteria for approaches with HAT/HATh values lower than 200 ft.

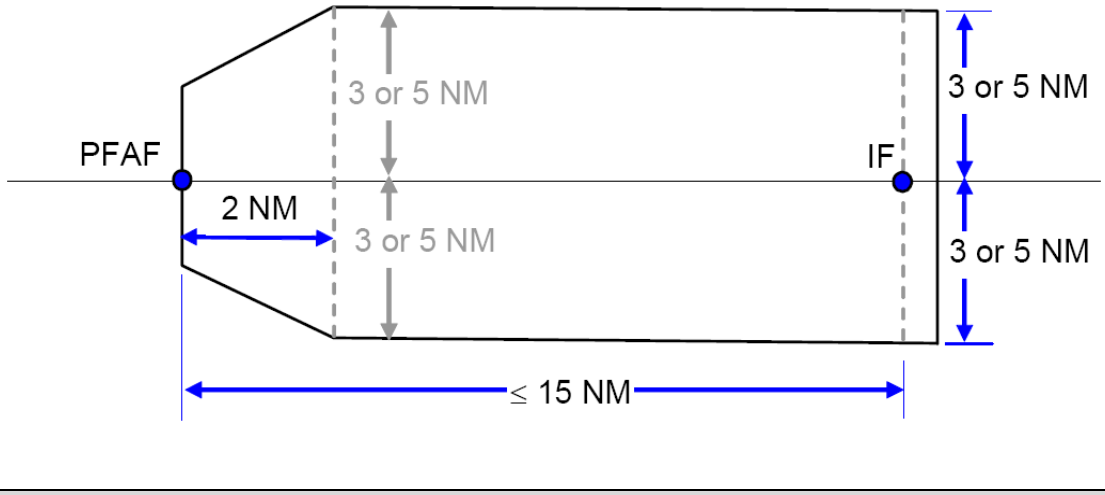


Figure 10-2-1: Intermediate Segment Area

SECTION 3. MINIMUM VECTORING ALTITUDE CHARTS

10.3. MINIMUM VECTORING ALTITUDE CHARTS (MVAC)

An MVAC is used by air traffic facilities when providing terminal service. An MVAC may also be used by en route facilities in selected areas where the MIA chart does not meet operational needs. An MVAC specifies the lowest MSL altitude at or above the floor of controlled airspace that provides at least the minimum ROC over obstacles. The MVAC may be used in lieu of feeder, initial, and intermediate approach segment(s) for radar approaches.

a. Apply the vertical and horizontal obstacle accuracy standards in Annex E.

b. MVACs must be developed to provide either 3-NM lateral separation minima or more and 5-NM lateral separation minima or more from obstacles and authorized ATC surveillance system lateral separation. The MVAC(s) must depict obstacle clearances outward to the lateral limits of the associated airspace and an appropriate buffer outside its lateral dimensions.

c. Define sector boundaries by any combination of bearings, point-to-point lines, arcs, and/or circles relative to a specified point or points; such as a radar antenna, NAVAID, fix, latitude/longitude coordinate, etc (see figures 10-3-1 and 10-3-2).

10.3.1. Chart Preparation

MVACs are developed for areas where there are numerous minimum vectoring altitudes due to variable terrain features or man-made obstacles. The responsible ATC facility shall determine whether MVACs are required. Procedure design specialists shall establish the minimum altitudes by ensuring all MVACs meet the obstacle requirements outlined within this section.

Figure 10-3-1. MVAC (Example 1)

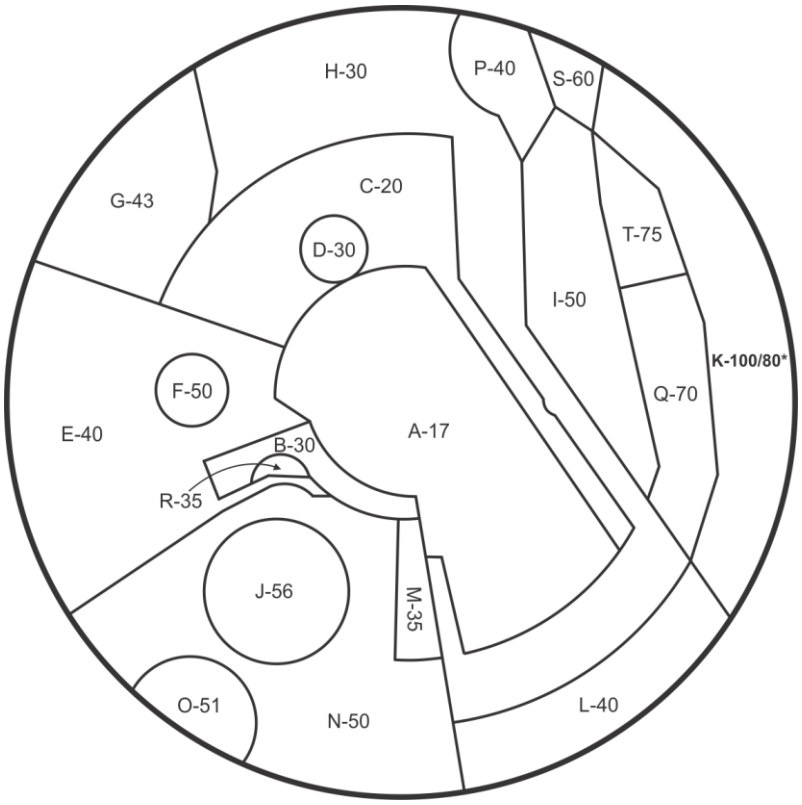
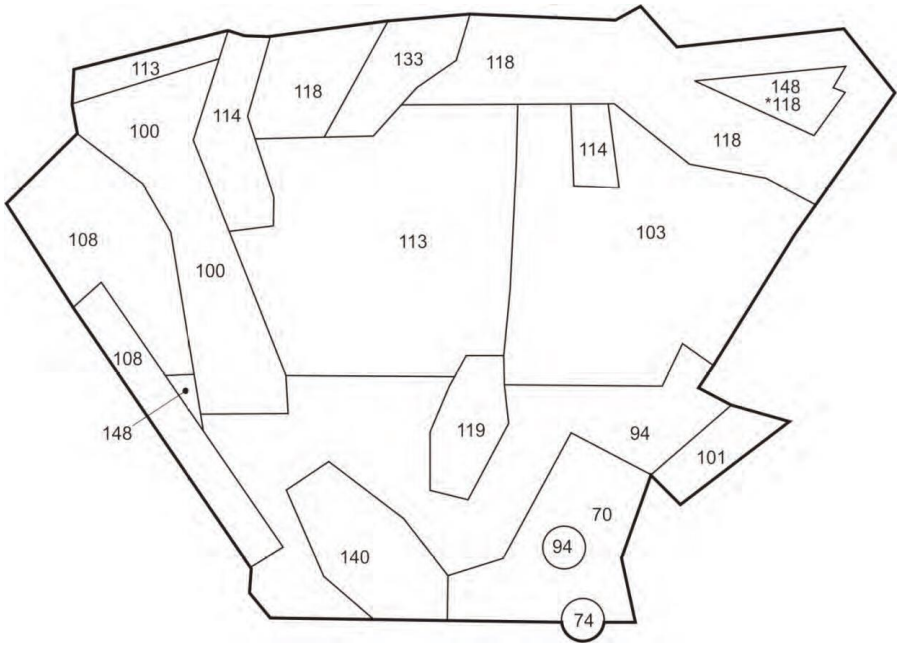


Figure 10-3-2. MVAC (Example 2)



10.3.2. Sectors

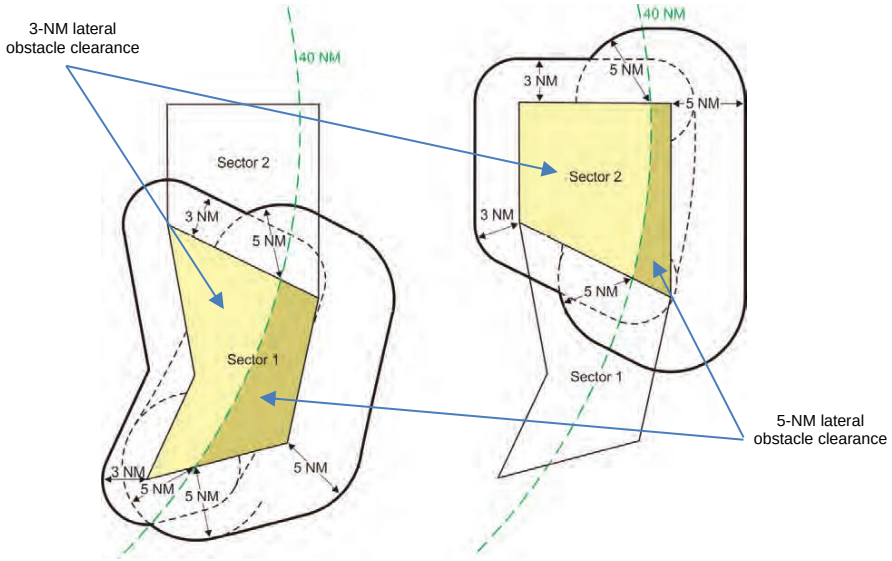
The area considered for obstacle clearance shall be based upon the maximum range of the applicable radar and the area of coverage provided by the surveillance system(s). This area may be subdivided into sectors to gain relief from obstacles that are clear of the area in which flight is to be conducted. There is no limit on the size, shape or orientation of the sectors; however, they must be designed with consideration to aircraft maneuvering ability, obstacle clearance requirements and air traffic flow requirements. Where small contiguous sectors with different altitudes do not serve an operational need, consider combining them. Rapidly rising terrain, although possibly not a factor in identifying prominent obstacles, may trigger activation of ground proximity warning devices onboard aircraft due to an aircraft descending to a MVA in these areas. Procedure designers should consider this when establishing sectors and MVAs with a view to eliminating this possibility during the development of MVA charts.

a. OEA. Adjacent sectors share common boundaries; however, each sector OEA is stand-alone and evaluated separately. The sector OEA includes the volume of airspace contained within its defined boundaries. Each sector includes a buffer equal to the minimum required lateral clearance for the applicable radar configuration/adaptation and ATC surveillance system.

(1) **Single sensor configuration.** An OEA buffer expands outward at least 3 NM from those portions of the boundary within 40 NM of the radar antenna and at least 5 NM outward from those portions of the boundary equal to or greater than 40 NM from the radar antenna. When a contiguous sector crosses 40 NM from the radar antenna, the sector is effectively divided into sub-sectors at the 40 NM arc and normal OEA/buffers applied to each, except buffers expanding into the sector may be truncated at the boundary. The highest altitude from each sub-sector applies (see figure 10-3-3 and figure 10-3-4).

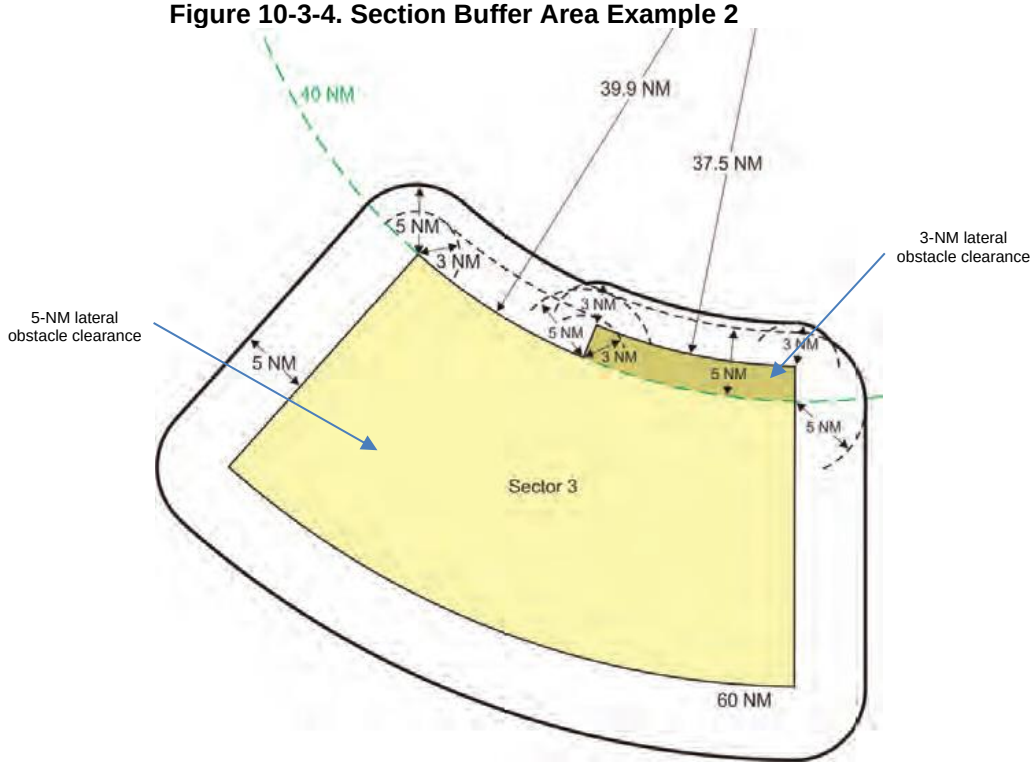
Note: For full time reinforced MSSR systems use 60 NM instead of 40 NM in all instances within the above paragraph.

Figure 10-3-3. Sector Buffer Areas Example 1



Note: Construction for Single Sensor, w/out reinforced MSSR or Construction for sections with 3 NM and 5 NM (shaded darker area) lateral separation.

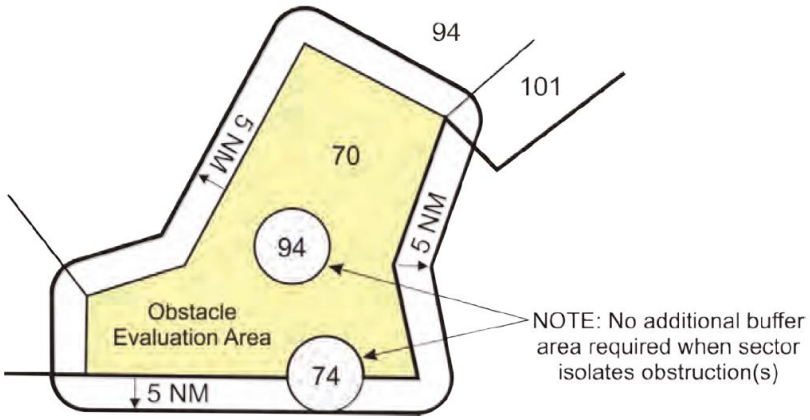
Figure 10-3-4. Section Buffer Area Example 2



Note: Construction for sector crossing 40 NM Single Sensor (w/out reinforced MSSR) or Construction for sections with 3 NM (shaded darker area) and 5 NM lateral separation.

(2) **Multi-sensor configuration.** The OEA includes a buffer extending at least 5 NM outward from the boundary, regardless of distance to radar antenna or MVAC center (see figure 10-3-5).

Figure 10-3-5. Sector Buffer Areas Example 3

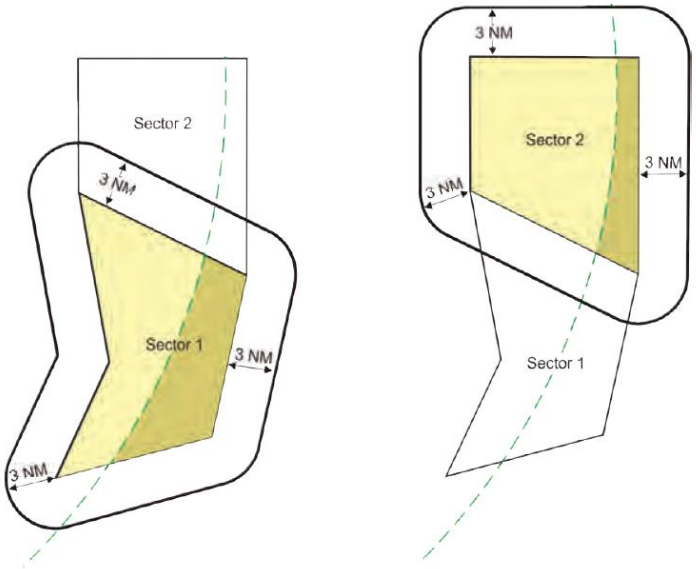


Note: Construction for sector with 5 NM lateral separation and sector isolated obstruction(s).

(3) FUSION adaptation:

(a) The OEA includes a buffer extending at least 3 NM outward from the boundary, regardless of distance to radar antenna or MVAC center for the 3-NM separation minima chart (see figure 10-3-6).

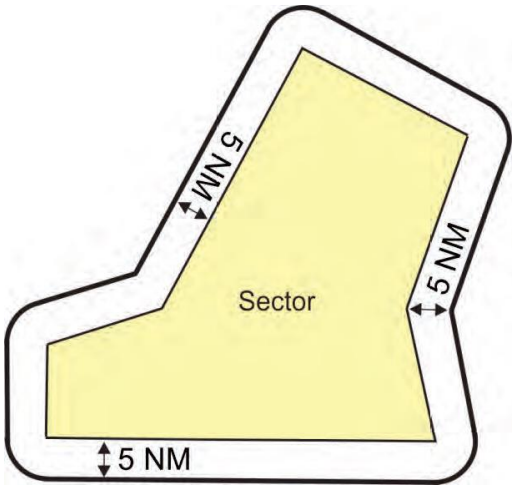
Figure 10-3-6. Sector Buffer Areas Example 4



Note: Construction for sector with 3 NM lateral separation.

(b) The OEA includes a buffer extending at least 5 NM outward from the boundary, regardless of distance to radar antenna or MVAC center for the 5-NM minima separation chart (see figure 10-3-7).

Figure 10-3-7. Sector Buffer Areas Example 5



Note: Construction for sector with 5 NM lateral separation.

(4) **ATC surveillance system.** The OEA includes a buffer extending at least 3 NM or 5 NM outward from the boundary based on authorized (by Transport Canada) ATC surveillance system approved lateral separation (see figure 10-3-6 and 10-3-7).

b. Isolating obstacles. Any obstacle may be isolated to lower the MVA in one or more standard sectors. The OEA buffers of neighboring sectors still apply in the isolation area, but exclude the specific feature being isolated (all other obstacles must be considered). Truncate an isolation area at the sector boundary when it expands into a sector requiring a higher MVA. The dimensions of the isolation area otherwise depend on the feature type and whether single sensor configuration, multi-sensor configuration, a FUSION adaptation or authorized ATC surveillance system applies.

(1) Point feature (antennas, towers, high-rise buildings, etc). The isolation area is based on a radius centered on the feature that provides at least the minimum lateral clearance applicable to the radar configuration/adaptation (see paragraph 10.1.2). Apply Annex E, section 2.11, Obstacle Data. Isolation areas for multiple point features (such as antenna or wind farms, etc) may be combined; however the minimum required lateral clearance must be provided from each feature and the MVA must equal the highest required for any individual feature.

(a) Single sensor configuration. The isolation area boundary is a 3-NM radius when the feature is 35 NM or less from the radar antenna, and a 5-NM radius when the feature is more than 35 NM from the radar antenna (see figure 10-3-8). When operationally advantageous, the boundary may be reduced to less than 5 NM for those portions of the isolation area within 40 NM from the antenna, but not less than the minimum required lateral clearance (see figure 10-3-9).

Note: For full time reinforced MSSR systems use a 3-NM radius when the feature is 55 NM or less from antenna (instead of 35 NM). Boundaries may also be reduced to less than 5 NM for those portions of an isolation area within 60 NM of these system antennas (instead of 40 NM).

(b) Multi-sensor configuration. Isolation area boundary is a 5 NM radius, regardless of distance from radar antenna.

(c) FUSION adaptation.

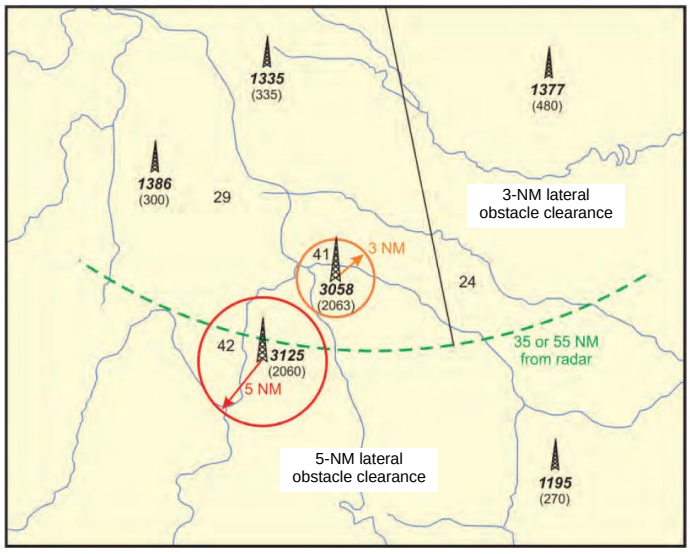
1. The isolation area boundary is a 3-NM radius, regardless of distance from radar antenna for the 3-NM minima separation chart (see figure 10-3-6).

2. The isolation area boundary is a 5-NM radius, regardless of distance from radar antenna for the 5-NM minima separation chart (see figure 10-3-7).

(d) ATC surveillance system.

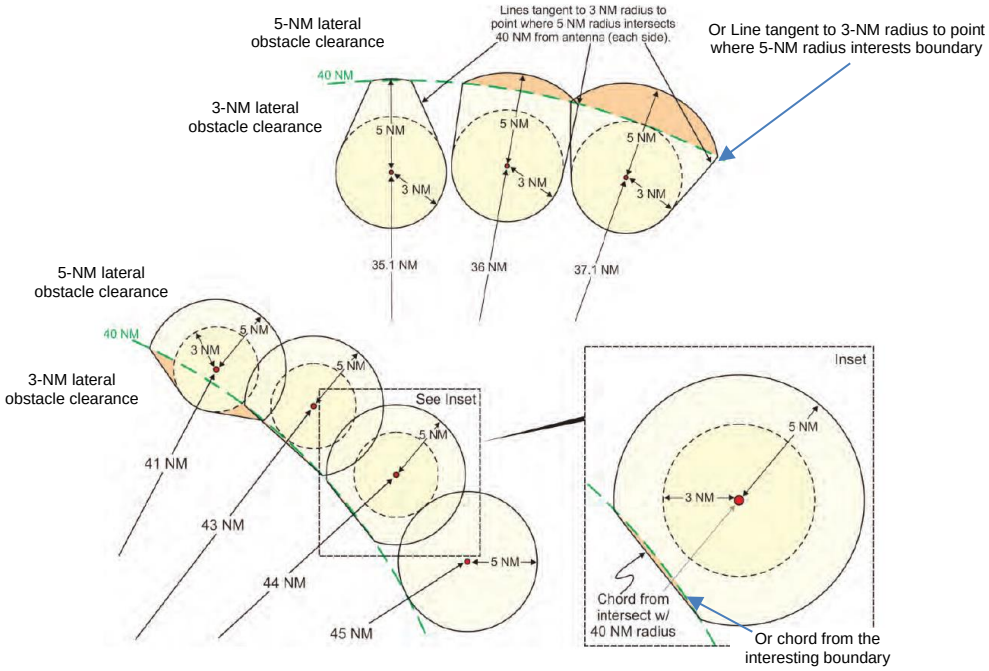
The isolation area boundary is a 3-NM or 5-NM radius from the feature, based on the ATC surveillance system approved lateral separation. When the feature is within 5-NM of the boundary between areas where 3-NM lateral obstacle clearance apply and 5-NM lateral obstacle clearance apply, construct the isolation area as described in figure 10-3-8. Isolation areas for multiple point features (such as antenna or wind farms, etc.) may be combined, however the minimum required lateral clearance must be provided from each feature and the MVA must equal the highest required for any individual feature.

Figure 10-3-8. Isolation Area, Point Feature, Example 1



Note: Construction of isolation area boundary is a 3-NM or 5-NM radius from the feature**.**

Figure 10-3-9. Isolation Area, Point Feature, Example 2

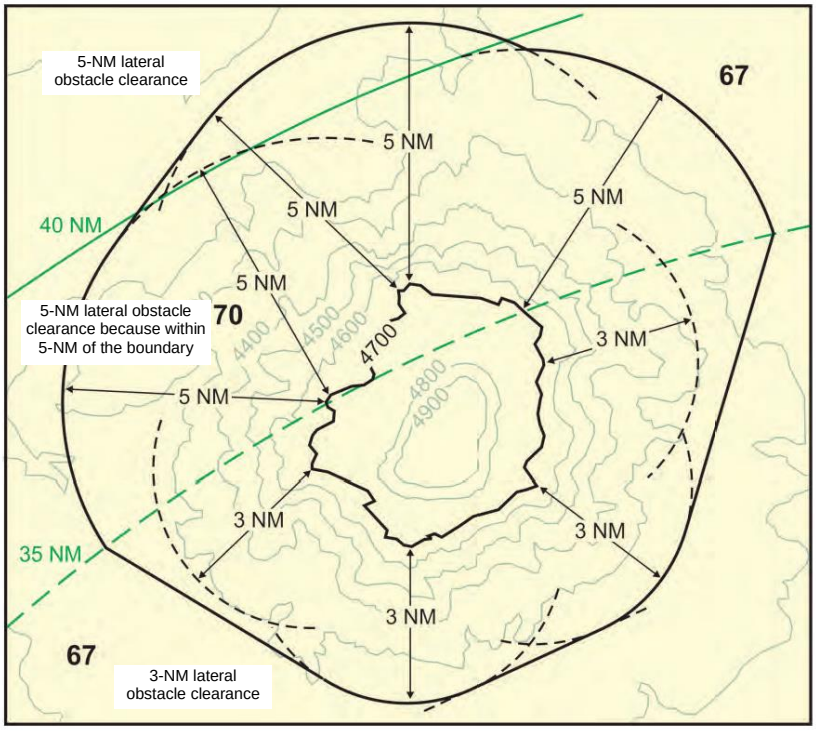


Note: Construction of isolation area boundary when the feature is within 5-NM of the boundary between areas where 3-NM lateral obstacle clearance apply or construction > 35 NM from Radar (Single Sensor, w/out reinforced MSSR).

(2) Zone feature (for example, distinct terrain, topographical contours, etc.). When determining the sector boundary, first define the dimensions of the feature to be isolated (for example, mountain from 4700-foot contour and above).

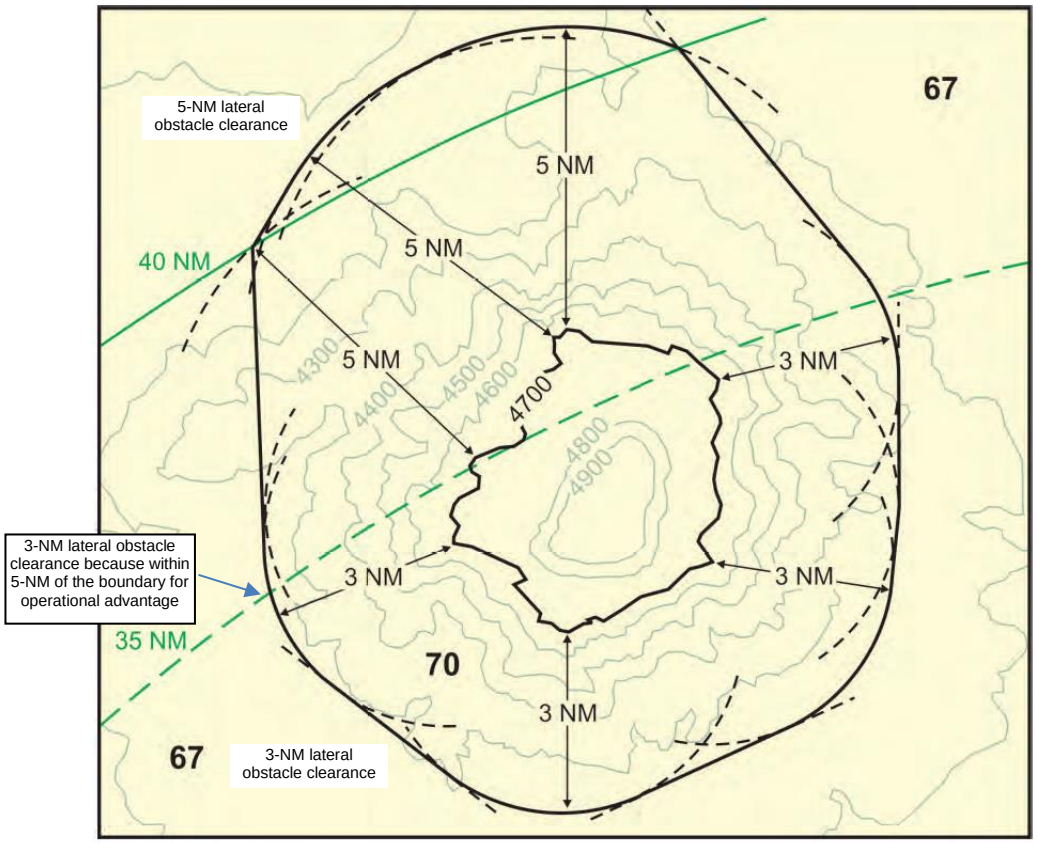
(a) Single sensor configuration. Establish the isolation area boundary 3 NM from the feature for points 35 NM or less from the radar antenna and 5 NM from the feature for points more than 35 NM from the radar antenna. When operationally advantageous, the boundary may be reduced to less than 5 NM for those portions of the isolation area within 40 NM from the antenna, but not less than the minimum required lateral clearance (see figure 10-3-10 and figure 10-3-11).

Figure 10-3-10. Isolation Area, Zone Feature, Example 3



Note: Construction when Isolation Area Crosses Boundary of 3-NM and 5-NM Lateral Obstacle Clearance or Construction for **> 35 NM from Radar (Single Sensor, w/out reinforced MSSR)**.

Figure 10-3-11. Isolation Area, Zone Feature, Example 4



Note: When operationally advantageous, the boundary may be reduced to less than 5 NM for those portions of the isolation area but not less than the minimum required lateral clearance when Isolation Area Crosses Boundary of 3-NM and 5-NM Lateral Obstacle Clearance or Construction for **> 35 NM from Radar (Single Sensor, w/out reinforced MSSR)**.

(b) Multi-sensor configuration. Isolation area boundary is 5 NM from the feature, regardless of distance from radar antenna.

(c) FUSION adaptation.

1. The isolation area boundary is a 3-NM radius from the feature, regardless of distance from radar antenna for the 3-NM minima separation chart.

2. The isolation area boundary is a 5-NM radius from the feature, regardless of distance from radar antenna for the 5-NM minima separation chart.

(d) ATC surveillance system.

The isolation area boundary is a 3-NM or 5-NM radius from the feature, based on the ATC surveillance system approved lateral separation. When the feature is within 5-NM of the boundary between areas where 3-NM lateral obstacle clearance apply and 5-NM lateral obstacle clearance apply, construct the isolation area as described in figure 10-3-10 and 10-3-11.

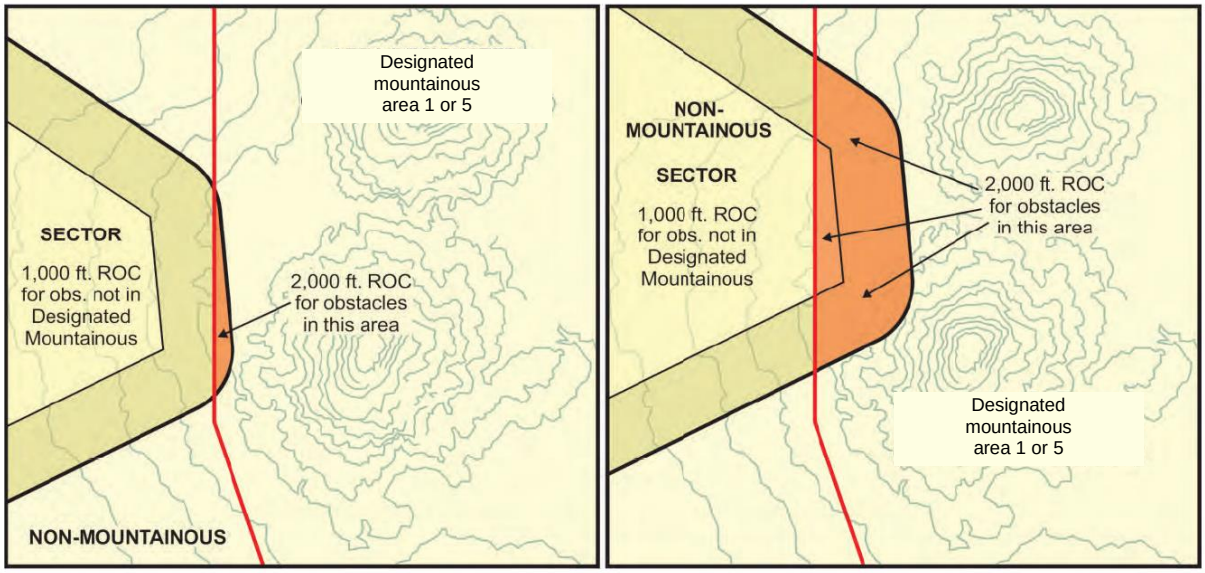
10.3.3. Obstacle Clearance

a. Obstacle Clearance Reductions: Where lower MVAs are required in designated mountainous areas to achieve compatibility with terminal routes or to permit vectoring to an instrument approach procedure, obstacle clearances may be reduced to not less than 1000 feet when precipitous terrain is not a factor.

b. Obstacle clearance shall be provided over all obstacles within sector/buffer area. Normally, 1000 feet of obstacle clearance is provided in non-mountainous areas and 1500 feet or 2000 feet, as appropriate, in areas designated as mountainous in the Designated Airspace Handbook. When a sector/buffer area overlies both non-mountainous and mountainous areas, consider revising sector boundaries. Otherwise, apply the appropriate ROC based on the location of the obstacle.

Figure 10-3-12. Sector/Buffer Overlying Both Mountainous and Non-Mountainous Areas

Example 1 **Example 2**



Note: Extension of the sector/buffer can be applied the same way into designated mountainous area 2, 3, and 4 for 1500 feet.

10.3.4. Altitude Selection

a. Specify sector altitudes (to include isolation areas) rounded to the next higher 100-foot increment that provides ROC over all obstacles (including the controlling obstacle) within the OEA.

b. All MVAs shall be contained within controlled airspace. Do not consider sector buffer areas for controlled airspace evaluations. Table 10-3-1 illustrates the calculation steps for determining the MVAs.

Table 10-3-1: Uncorrected Minimum Vectoring Altitude Computations

A.	**MVA Required for Terrain Obstacle Clearance (uncorrected)**	**Sector**
1.	Controlling Obstacle Height (MSL)	
2.	Required Obstacle Clearance *(1000' (1500' or 2000' mountainous Area))*	+
3.	Required Altitude based on Obstacle Clearance	=
B.	**MVA Required for Airspace (uncorrected)**	
1.	Floor of Controlled Airspace *(AGL)(if MSL, Skip 1&2)*	
2.	Highest Terrain in Sector	+
3.	Required Altitude Based on Airspace Floor	=
C.	**Required for Cold Temperature Correction**	
1.	Required altitude based on obstacle clearance (A3)	
2.	Cold temperature correction value (Formula 10-3-1)	+
3.	Required altitude based on cold temperature correction	=
D.	**Selected Altitude**	
1.	Uncorrected altitude – A3 or B3 (whichever is higher)	
2.	Cold temperature corrected altitude – B3 or C3 (whichever is higher)	

Note: Items within these calculation steps are to be left un-rounded. Once D1 and D2 have been determined, they are to be rounded as per paragraph 10.3.4.

c. **Cold Temperature Correction.** In addition to an uncorrected altitude (highest of A3 or B3), a cold temperature corrected altitude (or altitudes) shall be determined for each MVA sector to enable air traffic control in the provision of vectors during cold temperature operations. Corrected altitudes shall be determined by adding the correction value calculated using formula 10-3-1 to the basic altitude required for obstacle clearance. No correction is required for temperatures warmer than 0ºC.

Note: The lowest temperature promulgated by Environment Canada.

i. To minimize operational impact, cold temperature corrected altitudes may be determined for a set of temperature bands from which air traffic control can provide vectoring service in a tactical manner based on the actual occurring temperature. The banding interval should not span less than 10ºC and should be as large as possible. In all cases, the range of temperature bands provided shall cover all temperatures down to the minimum temperature recorded for the site. See table 10-3-2 for an example of MVAs based on temperature bands that use a 10ºC span.

ii. For sites where a simplified solution is preferred, a reduced number of altitudes may be provided based on a set of months and the minimum temperature recorded for the site within those applicable months. See table 10-3-3 for an example.

Table 10-3-2: MVA – Example 1

Aerodrome elevation: 912 feet Minimum temperature: -31.7ºC			
Aerodrome Temperature	**MVA Sector #1 (ft)**	**MVA Sector #2 (ft)**	**MVA Sector #3* (ft)**
>0°C	2600	3000	3600
0°C >-10°C	2700	3200	
-10°C >-20°C	2800	3300	
-20°C >-30°C		3400	
-30°C >-40°C	2900	3500	

Note: *Sector #3 illustrates a scenario in which the MVAs are raised to 3600 ft to ensure they remain in controlled airspace. For all temperature bands, this altitude is greater than the basic altitude required for obstacle clearance plus the applicable correction value accounting for cold temperature.

Table 10-3-3: MVA – Example 2

Aerodrome elevation: 912 feet Minimum monthly temperature			
May: -5.0ºC June: -0.6ºC July: 5.0ºC August: 1.5ºC September: -2.8ºC		October: -11.1ºC November: -18.3ºC December: -26.9ºC **January: -31.7ºC** February: -29.5ºC March: -24.8ºC April: -12.2ºC	
Month	**MVA Sector #1**	**MVA Sector #2**	**MVA Sector #3***
May to September	2700 (ft)	3100 (ft)	3600 (ft)
October to April	2900 (ft)	3400 (ft)	

Formula 10-3-1. Cold Temperature Correction

$$\text{Correction} = \text{H} \times \left(\frac{15 - \text{t}_\text{o}}{273 + \text{t}_\text{o} - 0.5 \times \text{L}_\text{o} \times (\text{H} + \text{H}_{ss})}\right)$$

H: height above the altimeter setting source
t_o: $t_{aerodrome}$ + L_o x $h_{aerodrome}$, aerodrome temperature adjusted to sea level
L_o: 0.00198ºC per foot
H_{ss}: altimeter setting source elevation
$t_{aerodrome}$: aerodrome temperature
$h_{aerodrome}$: aerodrome elevation

Example: Aerodrome elevation is 912’ ASL

Minimum temperature is -31.7ºC

Altimeter source is the aerodrome

Required altitude based on obstacle clearance 2944’ ASL

t_o = -31.7 + (0.00198 x 912) = -29.89424

H = 2944 – 912 = 2032

$$\text{Correction} = \ 2032 \ \times \left(\frac{15 - (-29.89424)}{273 + \ (-29.89424) - 0.5 \ \times \ 0.00198 \times (2032 + 912)}\right)$$

$$\text{Correction} = \ 2032 \ \times \left(\frac{44.89424}{240.1912}\right)$$

$$\text{Correction} = \ 2032 \ \times 0.186910428$$

$$\text{Correction} = \ 379.8019897$$

Cold temperature corrected altitude: (uncorrected altitude + correction = Sector MVA)

2944 ft + 379.8019897 ft = 3323.8019897 ft

3400 ft ASL (rounded as per paragraph 10.3.4.)

CHAPTER 11. HELICOPTER PROCEDURES

SECTION 1. ADMINISTRATION

1100. General

This chapter contains criteria for application to “helicopter only” procedures. These criteria are based on the premise that helicopters are approach Category A aircraft with special maneuvering characteristics. The intent, therefore, is to provide a relief from those portions of other chapters that are more restrictive than the criteria specified herein. However, any criteria contained elsewhere in other chapters of this document may be applied to helicopter only procedures when an operational advantage may be gained.

a. Identification of Inapplicable Criteria. Criteria contained elsewhere in TP308 applies to helicopter procedures, except as detailed in this chapter. Circling approach and high altitude penetration criteria do not apply to helicopter procedures.

b. Use of Existing Facilities. Helicopter-only procedures based on existing facilities may be developed using criteria contained in this chapter.

1101. Terminology And Abbreviations

The following terms are peculiar to helicopter procedures and are defined as follows:

a. HAL. Height above landing area elevation.

b. Height Above the Surface (HAS). The height of the MDA above the highest terrain/obstacle within a 5,200-foot radius of the MAP in Point in Space procedures.

c. Landing Area. As used in helicopter operations, refers to the portion of the heliport or airport runway used, or intended to be used for the landing and take-off of helicopters.

d. Landing Area Boundary (LAB). The beginning of the landing area of the heliport or runway.

e. Point in Space Approach (PINSA). An instrument approach procedure to a point in space, identified as a Missed Approach Point, which is not associated with a specific landing area within 2,600 feet of the MAP.

f. Touchdown Zone (TZ). As used in helicopter procedures, is identical to the landing area.

g. Touchdown Zone Elevation (TDZE). As used in helicopter procedures, is the highest elevation in the landing area.

1102. RESERVED

1103. Type Of Procedure

HELICOPTER ONLY PROCEDURES are designed to meet low altitude straight-in requirements ONLY.

1104. Facilities For Which Criteria Are Not Provided

This chapter does not include criteria for procedures predicated on VHF/UHF DF, area navigation (RNAV), airborne radar approach (ARA) or microwave landing system (MLS). Procedures utilizing VHF/UHF DF may be developed in accordance with the appropriate chapters of this document. Criteria for RNAV, ARA, and MLS with high glide path angle or selectable glide path angle capability will be developed at a later date.

1105. Procedure Identification

Identify helicopter-only procedures using the term “COPTER,” the type of facility or system providing final approach course guidance, and:

a. For approaches to runways. The abbreviation RWY, and the runway number; e.g., COPTER ILS or LOC RWY 17; COPTER RNAV (GPS) RWY 31.

b. For approaches to heliports and a point-in-space. The magnetic final approach course value and degree symbol; e.g., COPTER ILS or LOC 014°; COPTER TACAN O97°, COPTER RNAV (GPS) 010°.

c. For approaches based on an ARC final. The word ARC will be used, and will be followed by a sequential number; e.g., COPTER VOR/DME ARC 1.

d. For separate procedures at the same location. Use the same type of facility and same final approach course, add an alpha suffix starting in reverse alphabetical order; COPTER ILS or LOC Z RWY 28L (first procedure), COPTER ILS or LOC Y RWY 28L (second procedure), COPTER ILS or LOC X RWY 28L (third procedure), etc.

SECTION 2. APPLICATION

1106. General Criteria

These criteria are based on the unique manoeuvring capability of the helicopter at airspeeds not exceeding 90 knots.

1107. Point In Space Approach

Where the centre of the landing area is not within 2,600’ of the MAP, an approach procedure to a point in space may be developed using any of the facilities for which criteria are provided in this chapter. In such procedures the point in space and the missed approach point are identical and upon arrival at this point, helicopters must proceed under visual flight rules (or special VFR in control zone as applicable) to a landing area or conduct the specified missed approach procedure. The MAP must be within 10 NM of the landing area. The published procedure shall be noted to this effect and also should identify available landing areas in the vicinity by noting the course and distance from the MAP to each selected landing area. Point in space approach procedures will not contain alternate minima.

1108. Approach Categories

When helicopters use instrument flight procedures designed for fixed wing aircraft, approach Category “A” approach minima shall apply.

1109. Procedure Construction

Volume 1, Para 2.1.9, applies except for the reference to circling approach.

1110. Descent Gradient

The descent gradient criteria specified in other chapters of this document do not apply. The **OPTIMUM** descent gradient in all segments of helicopter approach procedures is 400 feet per nautical mile. Where a higher descent gradient is necessary, the recommended **MAXIMUM** is 600 feet per nautical mile. However, where an operational requirement exists a gradient of as much as 800 feet per nautical mile may be authorized provided the gradient used is depicted on approach charts. See special procedure turn criteria in Vol 1, Para 1112.

1111. Initial Approach Segments Based On Straight Courses And Arcs With Positive Course Guidance

Volume 1, Para 2.3.3, is changed as follows:

a. Alignment.

(1) Courses. The two-mile lead radial specified in Para 2.33.a.(1) is reduced to 1 NM (see Figure 2–3-1).

(2) Arcs. The MINIMUM arc radius specified in Para 2.3.3.a.(2) is reduced to 4 NM. The 2-mile lead radial may be reduced to 1 NM (see Figure 2–4-1).

1112. Initial Approach Based On Procedure Turn

Volume 1, Para 2.3.5., applies except for all of subparagraph d. and the number 300 in subparagraph e.(1), which is changed to 600. Since helicopters operate at approach Category A speeds, the 5 NM procedure turn will normally be used (see Figure 11-105). However, the larger 10 and 15 NM areas may be used if considered necessary.

Descent Gradient. Because the actual length of the track will vary with environmental conditions and pilot technique it is not practical to specify a descent gradient solely in feet per mile for the procedure turn. Instead the descent gradient is controlled by requiring the procedure turn completion altitude to be as close as possible to the final approach fix altitude. The difference between the procedure turn completion altitude and the altitude over the final approach fix shall not be greater than those shown in Table 11–23.

1113. Intermediate Approach Segment Based On Straight Courses

Volume 1, Para 2.4.3, is changed as follows:

a. Alignment. The provisions of Volume 1, Para 2.4.3.a, apply with the exception that the intermediate course shall not differ from the final approach course by more than 60 degrees.

b. Area.

(1) Length. The OPTIMUM length of the intermediate approach segment is 2 NM. The **MINIMUM** length is 1 mile and the recommended **MAXIMUM** is 5 NM. A distance greater than 5 NM should not be used unless an operational requirement justifies the greater distance. When the angle at which the initial approach course joins the intermediate course exceeds 30 degrees (see Figure 2–3-1), the **MINIMUM** length of the intermediate course is as shown in Table 11–24.

1114. Intermediate Approach Segment Based On An Arc

Volume 1, Para 2.4.4, is changed as follows: Arcs with a radius of less than 4 NM or more than 30 NM from the navigation facility shall not be used.

a. Area.

(1) Length. The OPTIMUM length of the intermediate approach segment is 2 NM. The **MINIMUM** length is 1 NM and the recommended **MAXIMUM** is 5 NM. A distance greater than 5 NM should not be used unless an operational requirement justifies the greater distance. When the angle at which the initial approach course joins the intermediate course exceeds 30 degrees (see Figure 2–3), the **MINIMUM** length of the intermediate course is as shown in Table 11–24.

1115. Intermediate Segment Within A Procedure Turn Segment

Volume 1, Para 2.4.5, is changed as follows: The normal procedure turn distance is 5 NM from the fix or from the facility. This produces an intermediate segment 5 NM long. The portion of the intermediate segment considered for obstacle clearance will always have the same length as the procedure turn distance. A distance greater than 5 NM should not be used unless an operational requirement justifies the greater distance (see Figure 2–4-5, Volume 1, Para 2.4.5).

1116. Final Approach

Volume 1, Para 2.5.1, applies except that the word runway is understood to include landing area and the reference to circling approach does not apply. The final approach course in precision approach procedures shall be aligned as indicated in Paras 1152 and 1159. For non-precision procedures final approach course alignment shall be as follows:

a. Approaches to a Landing Area. The final approach course should be aligned so as to pass through the landing area. Where an operational advantage can be achieved, a final approach course which does not pass through the landing area may be established, provided such a course lies within 2,600 feet of the centre of the landing area at the MAP.

b. Point in Space Approaches. The final approach course should be aligned to provide for the most effective operational use of the procedure consistent with safety.

1117. Missed Approach Point (MAP)

Volume 1, Para 2.7.3, is changed to state that the specified distance may not be more than the distance from the final approach fix to a point not more than 2,600 feet from the centre of the landing area. The MAP may be located more than 2,600 feet from the landing area, provided the MINIMUM visibility agrees with the increased distance; e.g., MAP 3,800 feet from the landing area, basic visibility is ¾ mile (see Figure 11-108). For point in space approaches the MAP is on the final approach course at the end of the final approach area.

1118. Straight Missed Approach Area

Volume 1, Para 2.7.4, applies with the exception that the length of the primary and secondary missed approach area is reduced from 15 NM to 7.5 NM and will have the width of the appropriate airway at termination.

1119. Straight Missed Approach Obstacle Clearance

Volume 1, Para 2.7.5, applies except that the slope of the missed approach surface is changed from 40:1 to 20:1 and the secondary area slope is changed from 12:1 to 4:1.

1120. Turning Missed Approach Area

The provisions of Volume 1, Para 2.7.6, apply with the exception that when applying missed approach criteria shown in Figures 2–19 through 2–24, and Table 2–7-1, change all flight path lengths to 7.5 NM, missed approach surface slope to 20:1, secondary slopes to 4:1, obstacle clearance radius (R) to 1.3 NM and flight path radius (R_1) to 4,000 feet (0.66 NM). The area width will expand uniformly to the appropriate airway width.

Note: “TDZE” or airport elevation” is changed to “landing area elevation”.

1121. Turning Missed Approach Obstacle Clearance

All missed approach areas described in Volume 1, Para 2.7.7, and depicted in Figures 2–25 and 2–26 will be adjusted for helicopter operation using the values shown in Volume 1, Para 1120. The area width will expand uniformly to the appropriate airway width.

1122. Combination Straight And Turning Missed Approach

Volume 1, Para 2.7.8, applies except that the values shown in Para 1120, shall be used and point B is relocated to a position abeam the MAP. The area width will expand uniformly to the appropriate airway width (see Figure 11-106).

1123. Holding Alignment

The provisions of Volume 1, Para 18.9.2, apply with the exception that when the final approach fix is a facility, the inbound holding course shall not differ from the final approach course by more than 90 degrees.

1124. Holding Area

Volume 1, Para 18.11.2 Copter holding published on copter charts is based on pattern number four.

SECTION 3. TAKE-OFF AND LANDING MINIMA

1125. Application

The minima specified in this section apply to Helicopter Only procedures.

1126. Altitudes

Apply Volume 1 Chapter 3, Section 3-2, except do not establish a CMDA for helicopter only procedures.

1127. Visibility

Apply Volume 1 Chapter 3, Section 3-3, except as follows:

a. Non-precision approaches.

(1) Approach to runway. The minimum visibility may be one-half the computed straight-in value from Table 3-3-3, but not less than ¼ SM/1200 RVR.

(2) Approach to an IFR heliport (landing area within 2600 feet of MAP). The minimum visibility required prior to applying credit for lights may not be less than the visibility associated with the HAL, as specified in Table 11-25. Do not apply paragraph 3.3.2

b. Precision and APV approaches.

(1) Approach to runway. The minimum visibility may be one-half the computed value specified in Table 3-3-1, but not less than ¼ SM/1200 RVR.

(2) Approach to an IFR heliport (landing area within 2600 feet of MAP). The minimum visibility required prior to applying credit for lights may not be less than the visibility associated with the HAL, as specified in Table 11-25. Do not apply paragraph 3.3.2

c. Point in Space Approaches. The minimum visibility shall be 1 SM. Table 11–25 does not apply.

1128. Visibility Credit

Where visibility credit for lighting facilities is allowed for fixed wing operations, the same type credit should be considered for helicopter operations. The approving authority will grant credit on an individual case basis until such time as a standard for helicopter approach light systems is established.

1129. Take-Off Minima

Helicopter take-off minima will be in accordance with the appropriate civil or military regulations as applicable.

SECTION 4. ON-HELIPORT VOR, NO FAF

1130. General

Volume 1, Para 400, does not apply. These criteria apply to procedures based on a VOR facility located within 2,600 feet of the centre of the landing area in which no final approach fix is established. These procedures must incorporate a procedure turn.

1131. Initial And Intermediate Segments

These criteria are contained in Section 2 of this chapter.

1132. Final Approach Segment

Volume 1, Para 413, does not apply except as noted below. The final approach begins where the procedure turn intersects the final approach course inbound.

a. Alignment. Volume 1, Para 1116 applies.

b. Area. The primary area is longitudinally centred on the final approach course. The minimum length is 5 NM. This may be extended if an operational requirement exists. The primary area is 2 NM wide at the facility, and expands uniformly to 4 NM wide at 5 NM from the facility. A secondary area is on each side of the primary area. It is zero NM wide at the facility and expands uniformly to .67 NM on each side of the primary area at 5 NM from the facility (see Figure 11–107).

c. Obstacle Clearance. Volume 1, Para 413.c.(1), applies.

d. Procedure Turn Altitude. The procedure turn completion altitude shall be in accordance with Table 11–23.

e. Use of Step-down Fix. Volume 1, Para 413.e, applies except that 4 NM is changed to 2.5 NM.

f. Minimum Descent Altitude. Criteria for determining MDA are contained in Section 3 of this chapter and Chapter 3.

SECTION 5. TACAN, VOR/DME, AND VOR WITH FAF

1133. Final Approach Segment

Volume 1, Para 513, does not apply except as noted below.

a. Alignment. Volume 1, Paras 1116.a and b, apply.

b. Area. Volume 1, Para 513.b, applies except that portion which refers to the minimum length of the final approach segment. The minimum length of the final approach segment is shown in Table 11–26.

c. Obstacle Clearance. Volume 1, Para 513.c.(1), applies.

1134. Reserved

1135. Missed Approach Point

The identification of the MAP in Volume 1, Para 514, is changed as follows: The missed approach point is a point on the final approach course which is not farther that 2,600 feet from the centre of the landing area (see Figure 11–108). For point in space approaches the MAP is on the final approach course at the end of the final approach area.

1136. Arc Final Approach Segment Radius

Volume 1, Para 523.b, does not apply. The final approach arc shall be a continuation of the intermediate arc. It shall be specified in NM and tenths thereof. The minimum arc radius on final approach is 4 NM.

1137. Arc Final Approach Segment Alignment

Volume 1, Para 523.b.(1), does not apply. The final approach arc should be aligned so as to pass through the landing area. Where an operational advantage can be achieved, a final approach course, which does not pass through the landing area may be established provided the arc lies 2,600 feet of the landing area at the MAP.

1138. Reserved

SECTION 6. ON-HELIPORT NDB, NO FAF

1139. General

Volume 1, Para 600, does not apply. These criteria apply to procedures based on an NDB facility located within 2,600 feet of the centre of the landing area in which no final approach fix is established. These procedures must incorporate a procedure turn.

1140. Final Approach Segment

Volume 1, Para 613, does not apply except as noted below. The final approach begins where the procedure turn intersects the final approach course inbound.

a. Alignment. Volume 1, Para 1116.a, applies.

b. Area. The primary area is longitudinally centred on the final approach course. The minimum length is 5 NM. This may be extended if an operational requirement exists. The primary area is 2.5 NM wide at the facility, and expands uniformly to 4.25 NM wide at 5 NM from the facility. A secondary area is on each side of the primary area. It is zero NM wide at the facility, and expands uniformly to .67 NM wide on each side of the primary area at 5 NM from the facility. Figure 11–109 illustrates the primary and secondary areas.

c. Obstacle Clearance. Volume 1, Para 613.c.(1), applies.

d. Procedure Turn Altitude (Descent Gradient). The procedure turn completion altitude shall be in accordance with Table 11–23.

e. Use of Step-down Fix. Volume 1, Para 613.e, applies except that 4 NM is changed to 2.5 NM.

f. Minimum Descent Altitude. Criteria for determining the MDA are contained in Section 3 of this chapter and Chapter 3.

SECTION 7. NDB PROCEDURES WITH FAF

1141. General

These criteria apply to procedures based on an NDB facility that incorporates a final approach fix.

1142. Final Approach Segment

Volume 1, Para 713, does not apply except as noted below:

a. Alignment. Volume 1, Paras 1116.a and b, apply.

b. Area. Volume 1, Para 713.b, applies except that portion which refers to the minimum length of the final approach segment. The minimum length is specified in Table 11–26.

c. Obstacle Clearance. Volume 1, Para 713.c.(1), applies.

1143. Missed Approach Point

The identification of the MAP in Volume 1, Para 714, is changed as follows: The missed approach point is a point on the final approach course which is not farther than 2,600 feet from the centre of the landing area (see Figure 11–108). For point in space approaches, the MAP is on the final approach course at the end of the final approach area.

SECTION 8. RESERVED

1144—1149. Reserved

SECTION 9. ILS PROCEDURES

1150. General

These criteria apply to the present design of instrument landing systems (on airport) only.

1151. Intermediate Approach Segment

Volume 1, Chapter 14, applies with the exception that Table 11–27 specifies the minimum length of the intermediate segment based on the angle of intersection of the initial approach course with the localizer course.

1152. Final Approach Segment

Volume 1, Chapter 13, Section 13-2 applies except that glide slope intersection need not occur prior to the FAF normally used for fixed operations.

a. The **optimum length** of the final approach course is 3.0 NM. The minimum length is 2.0 NM. A distance in excess of 4.0 NM should not be used unless a special operational requirement exists.

b. **Final Approach Termination**. The final approach shall terminate at a landing point (runway) or at a hover point between the Decision Height and the GPI. Where required, visual hover/taxi routes will be provided to the terminal area.

1153. Missed Approach Area

Normally existing missed approach criteria described in Volume1, Chapter 13, Section 13-3, will be utilized for helicopter operations. However, if an operational advantage can be gained, the areas described in Volume 1, Para 1168 through 1171, may be substituted.

1154. Reserved

1155. Localizer

a. **Alignment**. Volume 1, Para 902, applies except that alignment shall be as specified in Para 1116.a and b.

b. **Area**. Volume 1, Para 903, applies except that portion which refers to the minimum length of the final approach segment. The minimum length of the final approach segment is shown in Table 11–26.

c. **Missed Approach Point**. The identification of the MAP in Volume 1, Para 907, is changed as follows: The missed approach point is a point on the final approach course which is not farther than 2,600 feet from the landing area (see Figure 11–108). For point-in-space approaches, the MAP is on the final approach course at the end of the final.

SECTION 10. PRECISION APPROACH RADAR (PAR)

1156. Intermediate Approach Segment

Volume 1, Para 1014, applies with the exception that Table 11–27, specifies the MINIMUM length of the intermediate segment based on the angle of intersection of the initial approach course with the intermediate course.

1157. Reserved

1158. Final Approach Segment

The provisions of Volume 1, Paras 1020.b.(1) and (2), do not apply. The minimum distance from the glide slope intercept point to the GPI is 2 NM.

1159. Final Approach Alignment

Volume 1, Para 1020.a, applies with the exception that a final approach course shall be aligned to a landing area. Where required, visual hover/taxi routes shall be established leading to terminal areas.

1160. Final Approach Area

a. Length. The final approach area is 25,000 feet long, measured outward along the final approach course from the GPI. Where operationally required for other procedural considerations or for existing obstacles, the length may be increased or decreased symmetrically, except when glide slope usability would be impaired or restricted (see Figure 11–110).

b. Width. The final approach area is centred on the final approach course. The area has a total width of 500 feet at the GPI and expands uniformly to a total width of 8,000 feet at a point 25,000 feet outward from the GPI. The widths are further uniformly expanded or reduced where a different length is required as in Volume 1, Para 160.a above (see Figure 11-110). The width either side of the centreline at a given distance “D” from the point of beginning can be found by using the formula:

Formula 11-10-1: Half width

$$250 + 0.15D = \tfrac{1}{2} \text{ width.}$$

1161. Reserved

1162. Final Approach Obstacle Clearance Surface

Volume 1, Para 1021, does not apply. The final approach obstacle clearance surface is divided into two sections.

a. Section 1. This section originates at the GPI and extends for a distance of 775 feet in the direction of the FAF. It is a level plane, the elevation of which is equal to the elevation of the GPI.

b. Section 2. This section originates 775 feet outward from the GPI. It connects with Section 1 at the elevation of the GPI. The gradient of this section varies with the glide path angle used.

(1) To identify the glide slope angle and associated final approach surface gradient to clear obstacles in Section 2:

(a) Determine the distance “D” from the GPI to the controlling obstacle and the height of the controlling obstacle above the GPI.

(b) Enter these values in the formula:

$$\text{TAN ANGLE} = \frac{\text{Obstacle Height}}{\text{D - 775}}$$

(c) Covert the tangent angle. This is the angle of the section 2 approach surface gradient measured at the height of the GPI.

(d) The minimum glide slope angle required is found in Table 11–28 (Values may be interpolated).

1163. Transitional Surfaces

Volume 1, Para 1022, does not apply. Transitional surfaces for PAR are inclined planes with a slope of 4:1, which extend outward and upward from the edges of the final approach surfaces. They start at the height of the applicable final approach surface, and are perpendicular to the final approach course. They extend laterally 600 feet at the GPI and expand uniformly to a width of 1,500 feet at 25,000 feet from the GPI.

Note: The distance to the outer edge of the 4:1 transitional surface from the final approach course centreline is: ½W = 0.186D + 850. To determine the width of the transitional area, subtract the final approach primary area width found in Para 160.b.

1164. Obstacle Clearance

No obstacle may penetrate the applicable final approach surface specified in Para 1162 or the transitional surfaces specified in Para 1163. Obstacle clearance requirements greater than 500 feet need not be applied unless required in the interest of safety due to precipitous terrain or radar system peculiarities (see Figure 11–111).

Note: Provided the surface is free of obstacles, the terrain within Section 1 and 2 may rise at a gradient of 75:1 without adverse effect on minima. The 75:1 gradient begins at the GPI and extends until it meets the Section 2 obstacle clearance gradient (see Figure 11-111a). This is intended to allow for terrain undulations only, Any vegetation or non-frangible man-made obstructions within this area must be treated in accordance with Para 1162.

1165. Glide Slope Landing Area

Required obstacle clearance is specified in Para 1164. In addition, consideration requirements shall be given to the following in the selection of the glide slope angle:

a. Angles greater than 6 degrees shall not be established without authorization of the approving authority. The angle selected should be no greater than that required to provide obstacle clearance.

b. Angles selected should be increased to the next higher tenth of a degree, e.g., 4.71 degrees becomes 4.8; 4.69 degrees becomes 4.7.

1166. Relocation Of The Glide Slope

The GPI shall normally be located at the arrival edge of the landing area. If obstacle clearance requirements cannot be satisfied, or if operational advantages will result, the GPI may be moved into the landing area provided sufficient landing area is available forward of the displaced or relocated GPI.

1167. Adjustment Of DH

An adjustment is required whenever the angle to be used exceeds 3.8 degrees (see Table 11–29). This adjustment is necessary to provide ample deceleration between the DH point and the landing area.

1168. Missed Approach Obstacle Clearance

No obstacle may penetrate a 20:1 missed approach surface that overlies the missed approach areas illustrated in Figures 11–113, 11–114, and 11–115. The missed approach surface originates at the GPI. However, to gain relief from existing obstacles in the missed approach area the point at which the surface originates may be relocated as far backward from the GPI as a point on the final approach course that is directly below the MAP. In such cases the surface originates at a height below the DH as specified in Table 11–30 (see Figure 11–112).

When penetration of the 20:1 surface originating at the GPI occurs, an upward adjustment to the DH equal to the maximum penetration of the surface should be considered.

1169. Straight Missed Approach Area

The straight missed approach (maximum of 15 degrees turn from final approach course) area starts at the MAP and extends to 7.5 NM.

a. Primary Area. This area is divided into three sections.

(1) Section 1A is a continuation of the final approach area. It starts at the MAP and ends at the GPI. It has the same width as the final approach area at the MAP.

(2) Section 1B is centered on the missed approach course. It begins at the GPI and extends to a point 1 mile from the MAP outward along the missed approach course. It has a beginning width the same as the final approach area at the MAP and expands uniformly to 4,000 feet at 1 mile from the MAP.

(3) Section 2 is centered on the continuation of the Section 1 course. It begins 1 mile from the MAP and ends 7.5 NM from the MAP. It has a beginning width of 4,000 feet expanding uniformly to a width equal to that of an initial approach area at 7.5 NM from the MAP.

b. Secondary Area. The secondary area begins at the MAP, where it has the same width as the final approach secondary area. In Section 1A the width remains constant from the MAP to the GPI, after which it increases uniformly to the appropriate airway width at 7.5 NM from the MAP (see Figure 11–113).

1170. Turning Missed Approach Area

Where turns of more than 15 degrees are required in a missed approach procedure, they shall commence at an altitude that is at least 400 feet above the elevation of the landing area rounded to the nearest foot. Such turns are assumed to commence at the point where Section 2 begins. The turning flight track radius shall be 4,000 feet (0.66 NM).

a. Primary Area. The outer boundary of the Section 2 primary area shall be drawn with a 1.3 mile radius. The inner boundary shall commence at the beginning of Section 1B. The outer and inner boundary shall flare to the width of an initial approach area 7.5 NM from the MAP.

b. Secondary Area. Secondary areas for reduction of obstacle clearance are identified with Section 2. The secondary areas begin after completion of the turn. They are zero NM wide at the point of beginning and increase uniformly to the appropriate airway at the end of Section 2. Positive course guidance is required to reduce obstacle clearance in the secondary area (see Figure 11–114).

1171. Combination Straight And Turning Missed Approach Area

If a straight climb to an altitude greater than 400 feet is necessary prior to commencing a missed approach turn, a combination straight and turning missed approach area must be constructed. The straight portion of this missed approach area is divided into Section 1 and 2a. The portion in which the turn is made is Section 2b.

a. Straight Portion. Sections 1 and 2a correspond respectively to Section 1 and 2 of normal straight missed approach area and are constructed as specified in Volume 1, Para 1169, except that Section 2a has no secondary areas. Obstacle clearance is provided as specified in Volume 1, Para 1169. The length of Section 2a is determined as shown in Figure 11–115, and relates to the need to climb to a specified altitude prior to commencing the turn. The line A'–B' marks the end of Section 2a. Point C' is 5,300 feet from the end of Section 2a.

b. Turning Portion. Section 2b is constructed as specified in Volume 1, Para 1169, except that it begins at the end of Section 2a instead of the end of Section 1. As illustrated in Figure 11-115, to determine the height which must be attained before commencing the missed approach turn, first identify the controlling obstacle on the side of Section 2a to which the turn is to be made. Then measure the distance from this obstacle to the nearest edge of the Section 2a area. Using this distance, determine the height of the 20:1 slope at the edge of Section 2a. This height plus 250 feet (rounded off to the next higher 20-foot increment) is the height at which the turn should be started. Obstacle clearance requirements in Section 2b are the same as those specified in Volume 1, Para 1164, except that Section 2b is expanded to start at Point C if no fix exists at the end of Section 2a or if no course guidance is provide in Section 2 (see Figure 11–115).

Note: The missed approach areas expand uniformly to the appropriate airway width.

SECTION 11. AIRPORT SURVEILLANCE RADAR (ASR)

1172. Initial Approach Segment

Alignment. The initial approach course, or courses, shall be selected to coincide with air traffic flow requirements. The angle at which the initial approach course joins the intermediate course shall not exceed 120 degrees.

1173. Intermediate Approach Segment

Area. The width of the intermediate segment is 3 miles either side of the course at the intermediate fix. It tapers to the width of the final approach area at the final approach fix. There are no secondary areas. The length of the intermediate segment shall not exceed 15 miles. The minimum length of the intermediate segment depends on the angle at which the initial approach course intercepts the intermediate course, and is specified in Table 10–20. The MAXIMUM angle of interception shall be 120 degrees. Table 11–24 is used to determine the required minimum length of the intermediate segment.

1174. Final Approach Segment

The final approach begins at the final approach fix, which is a radar fix and ends at the runway or missed approach point, whichever is encountered last.

a. Area. The area considered for obstacle clearance begins at the final approach fix and ends at the runway or missed approach point, whichever is encountered last, and is centered on the final approach course. The minimum length of the final approach area shall be 3 miles. The maximum length should not exceed 6 miles (see Figure 11-11-1). The width of the primary area (W_p) is based on a formula that provides 2 miles of width at the radar antenna, increasing to 6 miles of width at a distance (D) of 20 miles from the radar antenna. The formula is ½ W_p = 0.1D + 1 mile. There are no secondary areas (see Figure 11–11-2).

b. Obstacle Clearance. Straight-in. A minimum of 250 feet of clearance shall be provided over all obstacles in the final approach area, except that where a prominent obstacle which is displayed as a permanent echo on the radar scopes exists it need not be considered for obstacle clearance after the aircraft is observed to have passed the obstacle. Allowance for precipitous terrain as specified in Para 3.2.2. should be made.

Figure 11-11-1: Typical ASR Approach Segments

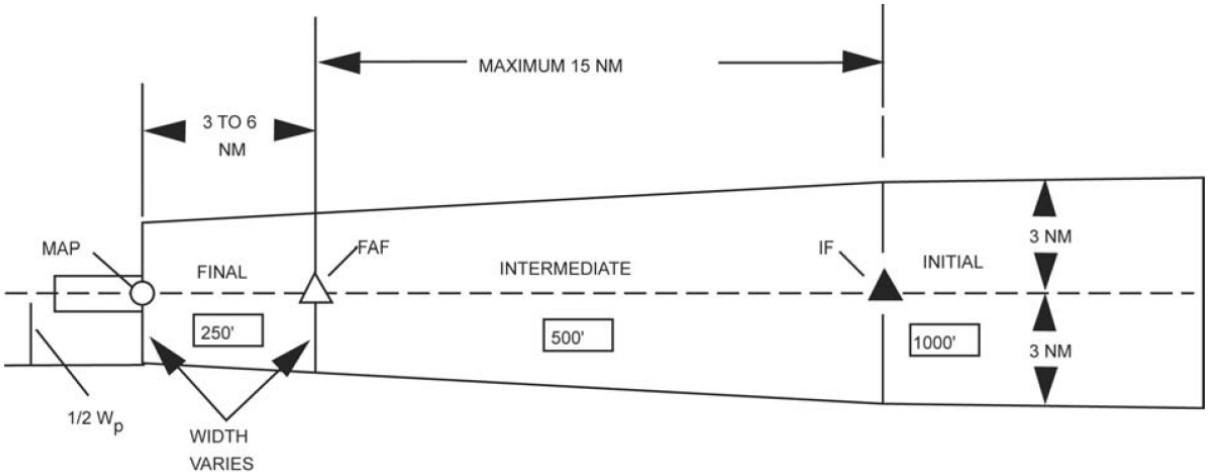
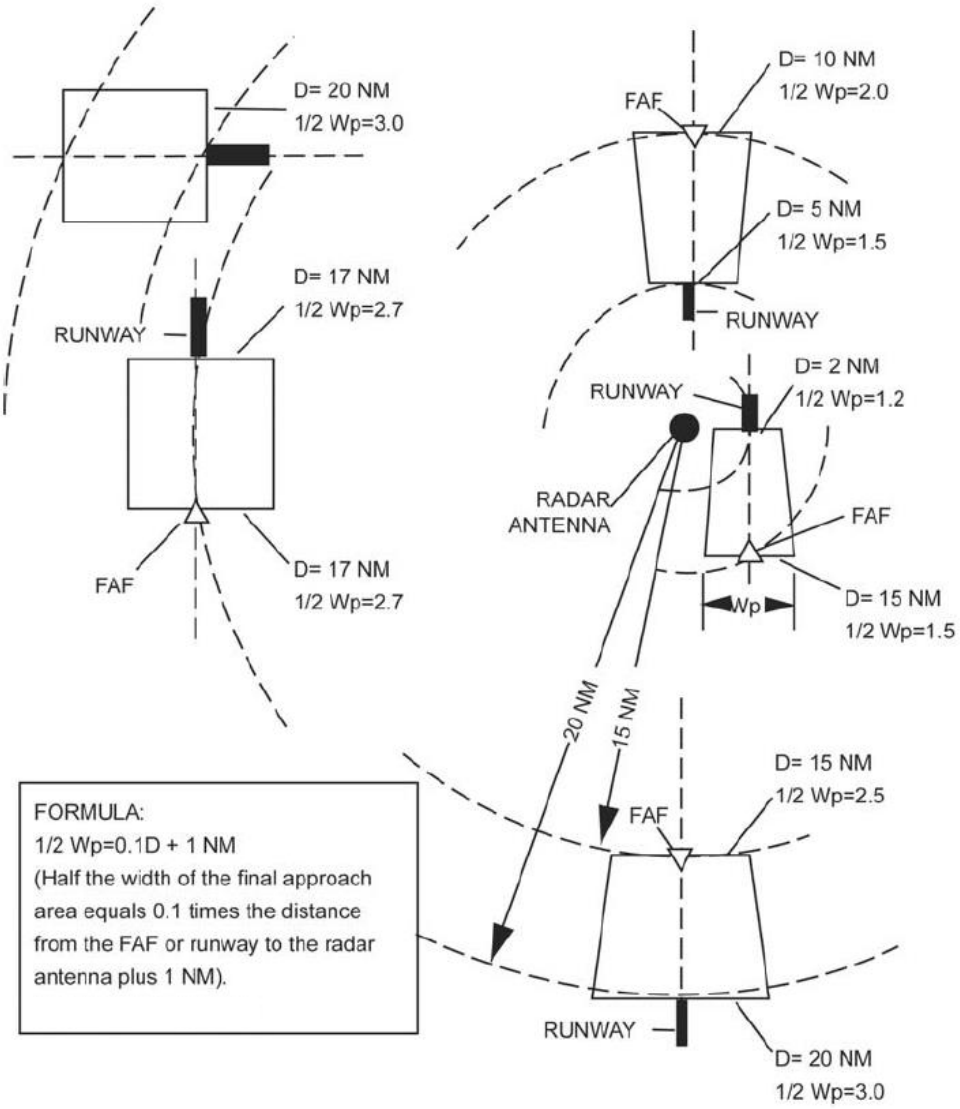


Figure 11-11-2: Examples Of ASR Final Approach Area Dimensions.



c. Alignment. Volume 1, Paras 1116.a and b, apply.

1175. Missed Approach Point

The criteria for the missed approach segment are contained in Chapter 2, Section 7. The missed approach point is a point on the final approach course that is not farther than 2,600 feet from the centre of the landing area (see Figure 11–108). For point in space approaches the MAP is on the final approach course at the end of the final approach area.

1176—1199. Reserved

Table 11-1 To 11-22: Reserved.

Type Procedure Turn	Altitude Difference
15 NM PT from FAF	Within 6,000 ft of alt over FAF
10 NM PT from FAF	Within 4,000 ft of alt over FAF
5 NM PT from FAF	Within 2,000 ft of alt over FAF
15 NM PT, no FAF	Not Authorized
10 NM PT, no FAF	Within 4,000 ft of MDA on Final
5 NM PT, no FAF	Within 2,000 ft of MDA on Final

Table 11-23: Procedure Turn Completion Altitude Differential. Para 112.

Angle (Degrees)	Minimum Length (NM)
30	1.0
60	2.0
90	3.0
120	4.0
Note: This Table may be interpolated	

Table 11-24: Minimum Intermediate Course Length (Not applicable to PAR or ILS). Para 1113.

HAL	250 – 600 ft	601 – 800 ft	More than 800 ft
Visibility (SM) Minima	½ SM	¾ SM	1 SM

Table 11-25: Effect Of HAL On Visibility Minima. Para 1127.

Magnitude of Turn Over the Facility	Minimum Length (NM)
30°	1.0
60°	2.0
90°	3.0
Note: This Table may be interpolated	

Table 11-26: Minimum Length Of Final Approach Segment (NM). Para 1142.b.

Angle (Degrees)	Minimum Length (NM)
30°	1.0
60°	2.0
90°	3.0
Note: This Table may be interpolated	

Table 11-27: Intermediate Segment Angle Of Intercept vs Segment Length. Para 1151 & 1156

Glide Slope Angle (Degrees)	Less Than 3°	3°	4°	5°	6°	7°	8°	12°
Section 2 obstacle clearance surface gradient (degrees)	NA	1.65	2.51	3.37	4.23	5.09	5.95	9.39
Note: This Table may be interpolated								

Table 11-28: Final Approach Glide Slope – Surface Slope Angles. Para 1162.b.

GS Angle (Degrees)	Up to 3.80	3.81 to 5.70	Over 5.70
Minimum DH (Feet)	100	150	200

Table 11-29: Minimum DH – GS Angle Relationship. Para 1167.

GS Angle (Degrees)	3	6	9
Dist. below DH point (Feet)	100	150	200
Note: This Table may be interpolated			

Table 11-30: Beginning Point Of Missed Approach Surface. Para 1168.

Figure 11-1 TO 1-104: Reserved

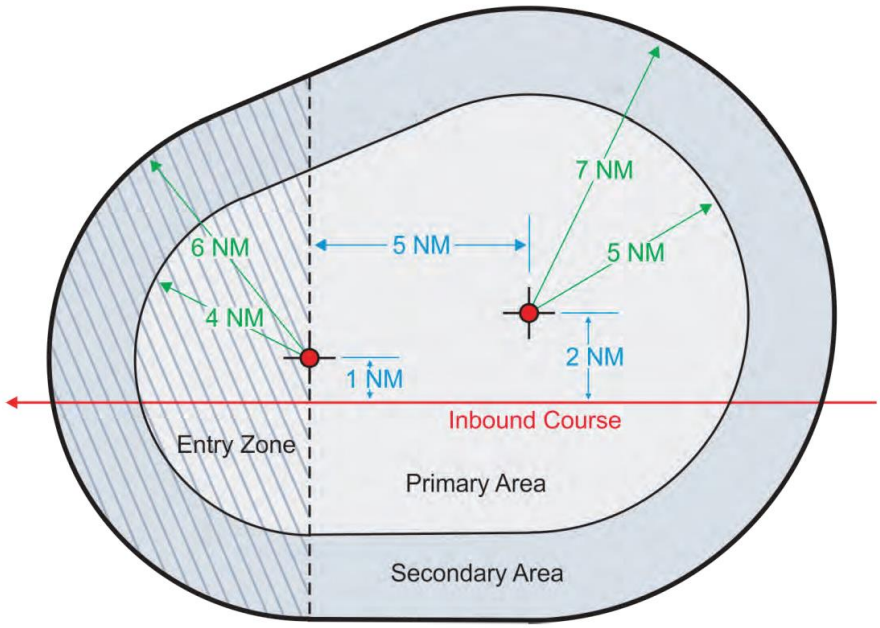
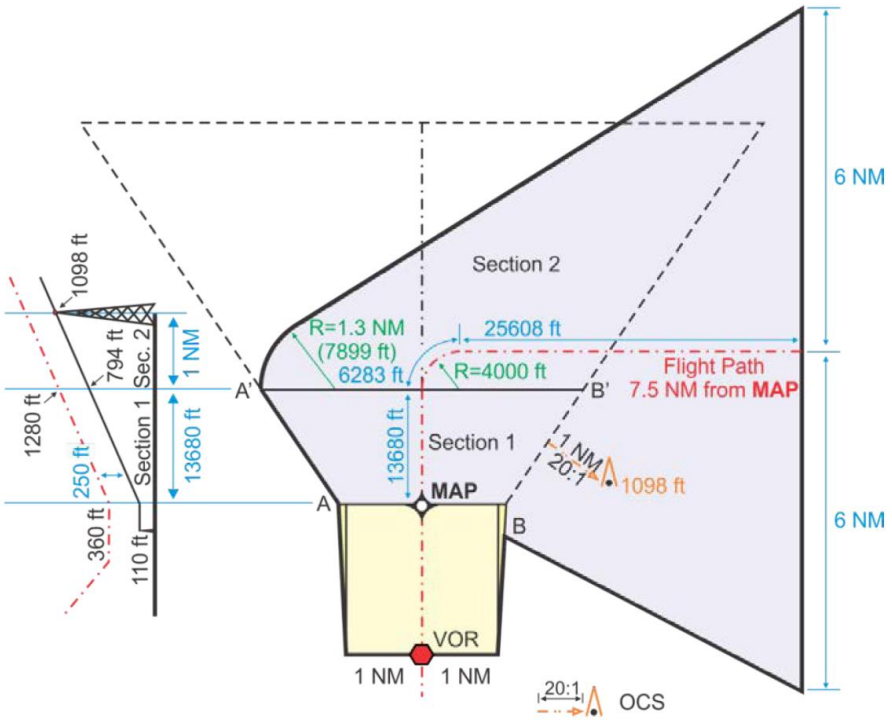


Figure 11-105: Helicopter Procedure Turn Area. Para 1112.



Example:

Given:

1.MDA is 360 feet MSL based on obstacles in the approach area
2.1098 feet MSL obstacle is 1 NM from the near edge of section 1

Determine:

1.Section 1 length
2.Minimum turn altitude
3.Missed approach instructions

Solution:

1.Section 1 length

a. $\frac{1\ NM}{20\ feet} = \frac{1852}{20 \times 0.3048} \approx 304\ ft$

b.1098 feet - 304 feet = 794 feet MSL, required section 1 end height
c. MDA – (ROC + Adjustments) = 110 feet MSL, section 1 start height
d. 794 feet – 110 feet = 684 feet, required section 1 rise
e. 684 feet x 20 = 13680 feet, required length of section 1

2.Minimum turn altitude

a. $\frac{13680}{15.19} + MDA = 1261\ ft$
b. Round to next higher 20-foot increment = 1280 feet MSL

3.Missed approach instructions “Climb to 1280 then turn right direct…”

Figure 11-106: Combination Missed Approach Area. Para 1122.

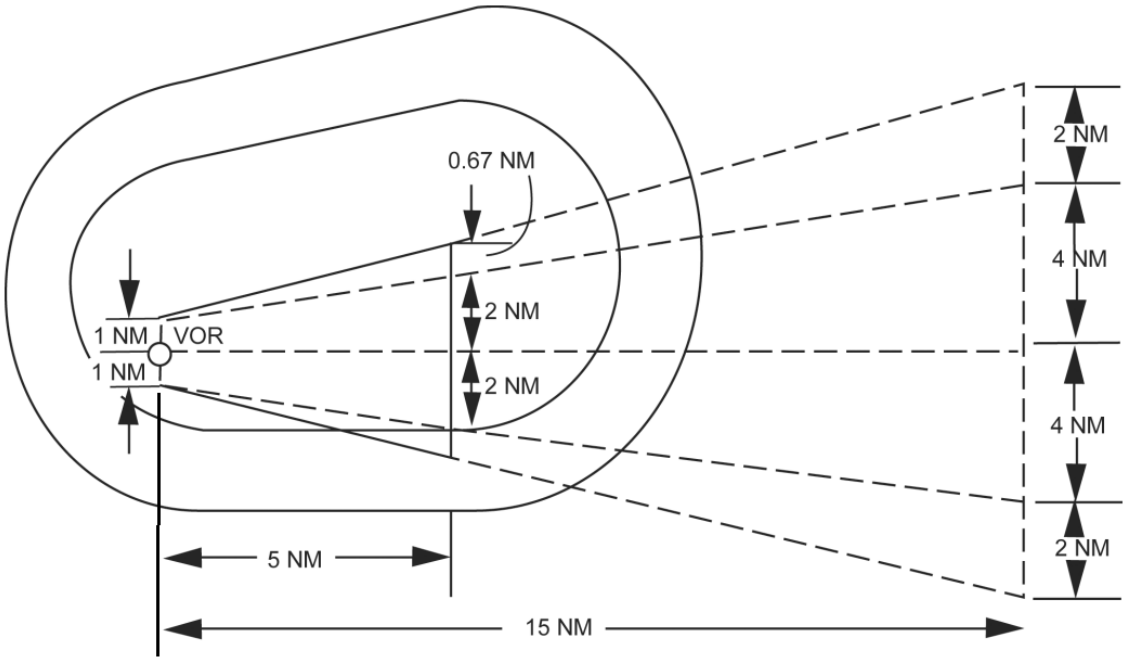


Figure 11-107: Final Approach Primary And Secondary Area. On Heliport VOR, No FAF. Para 32.b and Fig 1-110.

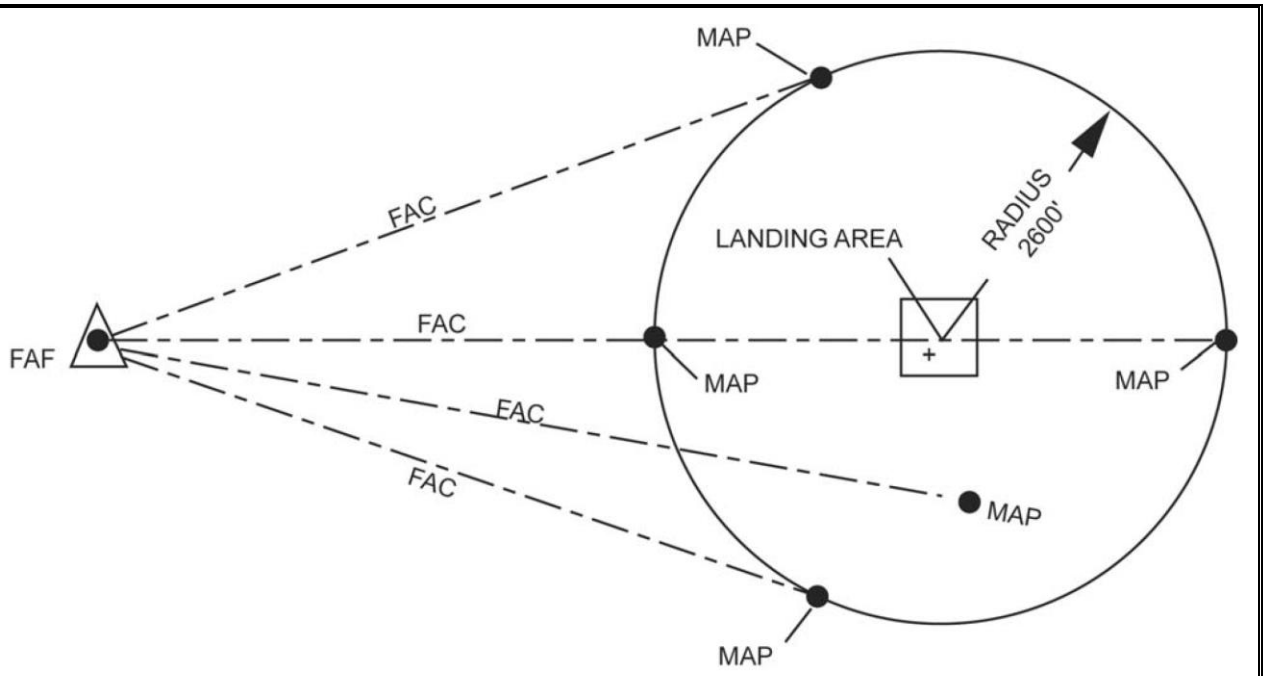


Figure 11-108: Missed Approach Points. Off-Heliport VOR with FAF. Para 1135.

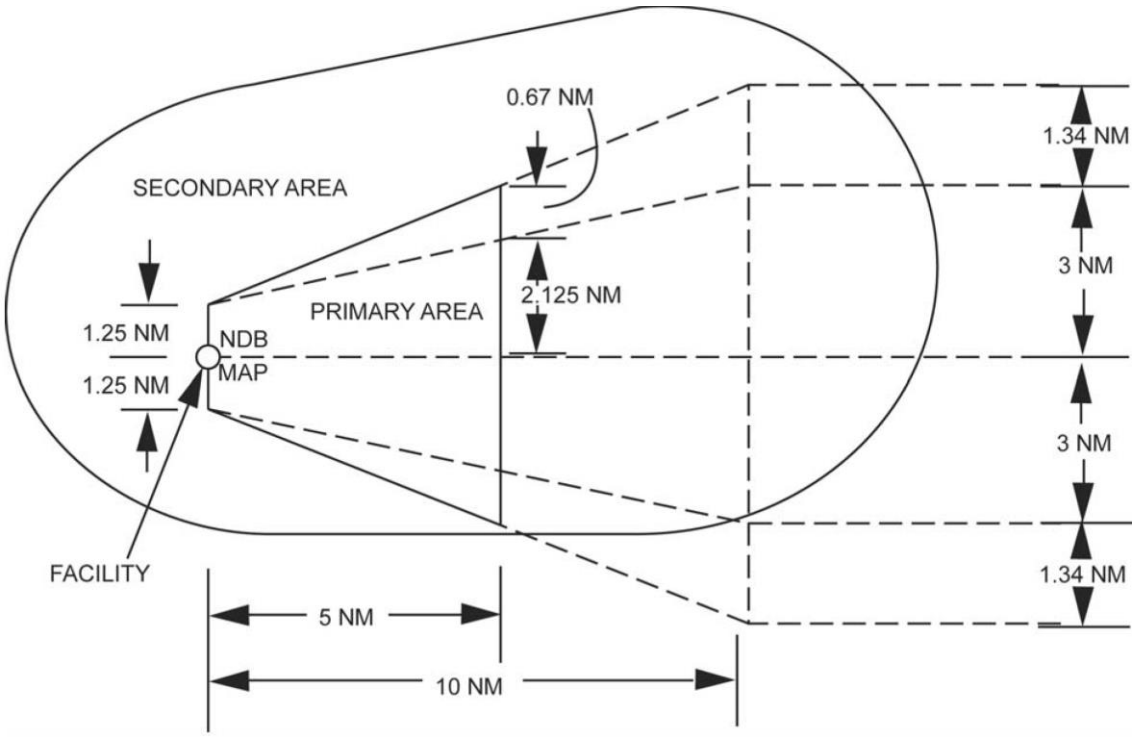


Figure 11-109: Final Approach Primary And Secondary Areas. On-Heliport NDB, no FAF. Para 1140.

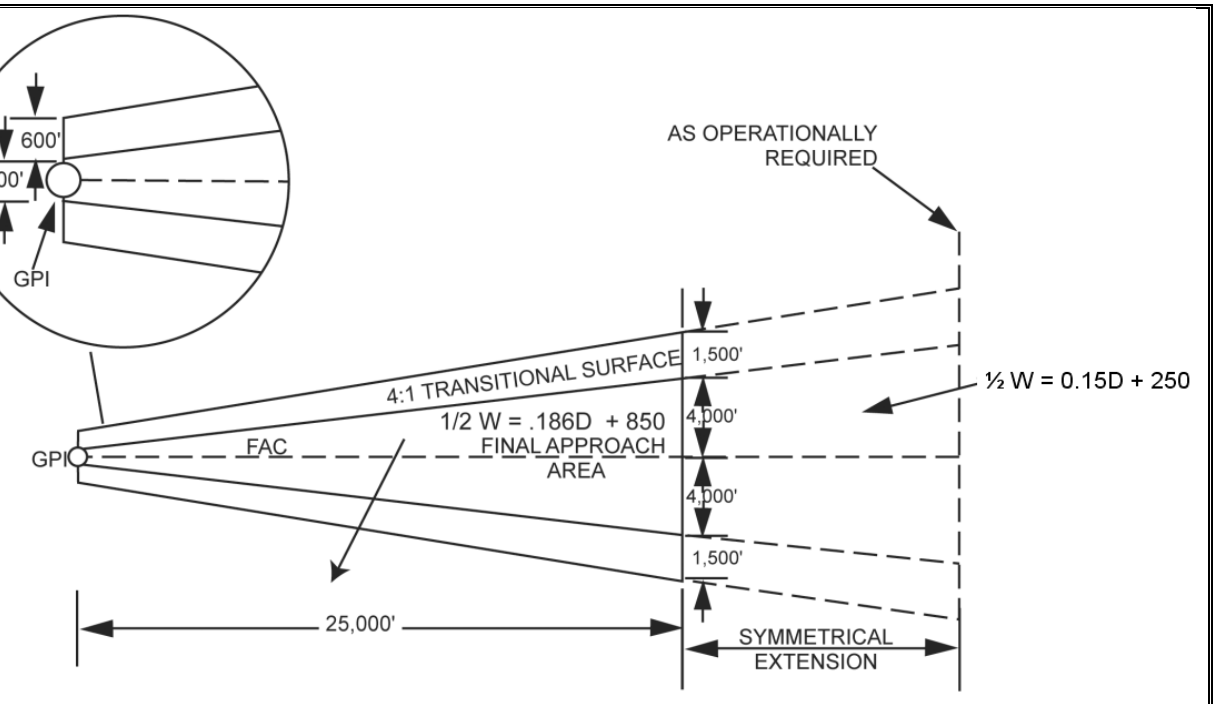


Figure 11-110: PAR Final Approach Area. Para 1159 and 1160.

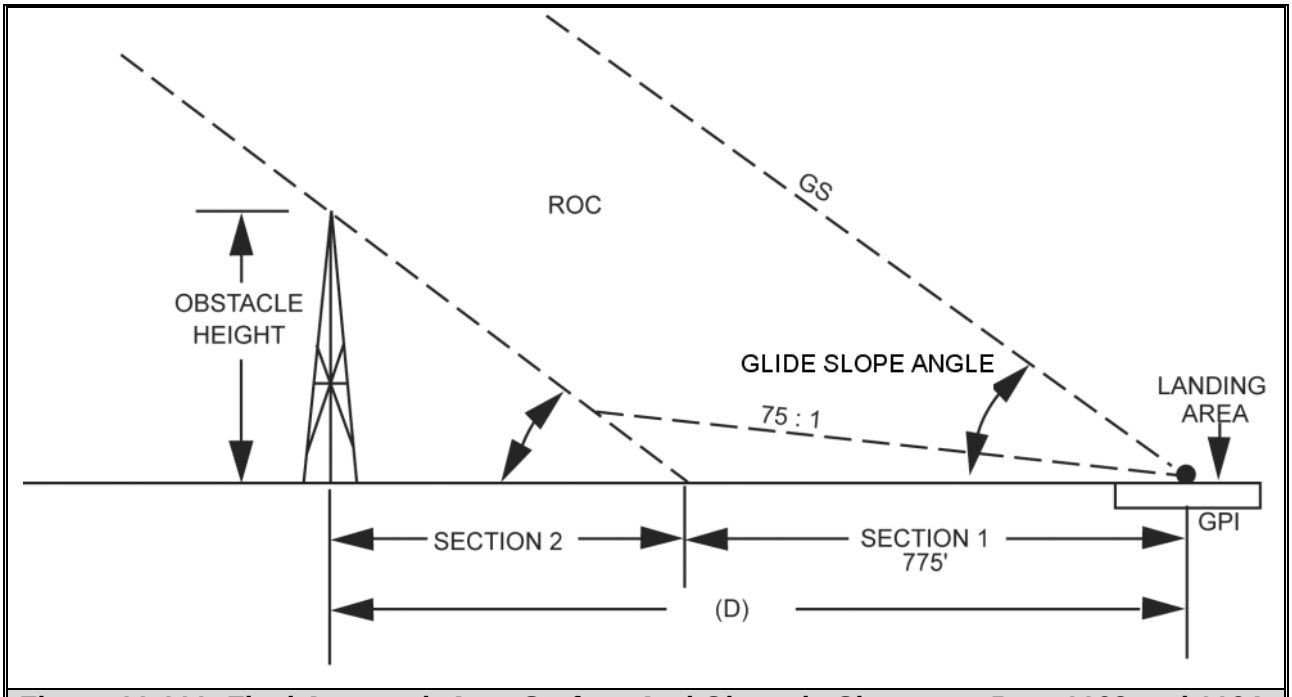


Figure 11-111: Final Approach Area Surface And Obstacle Clearance. Para 1162 and 1164.

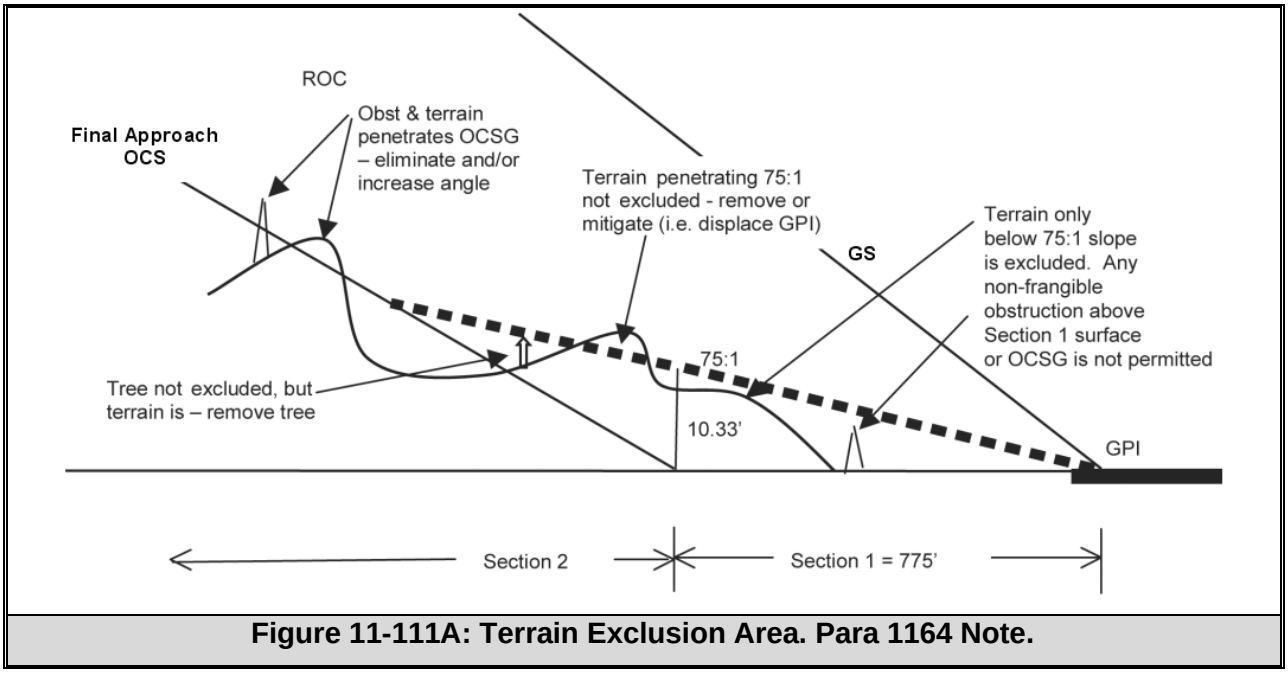


Figure 11-111A: Terrain Exclusion Area. Para 1164 Note.

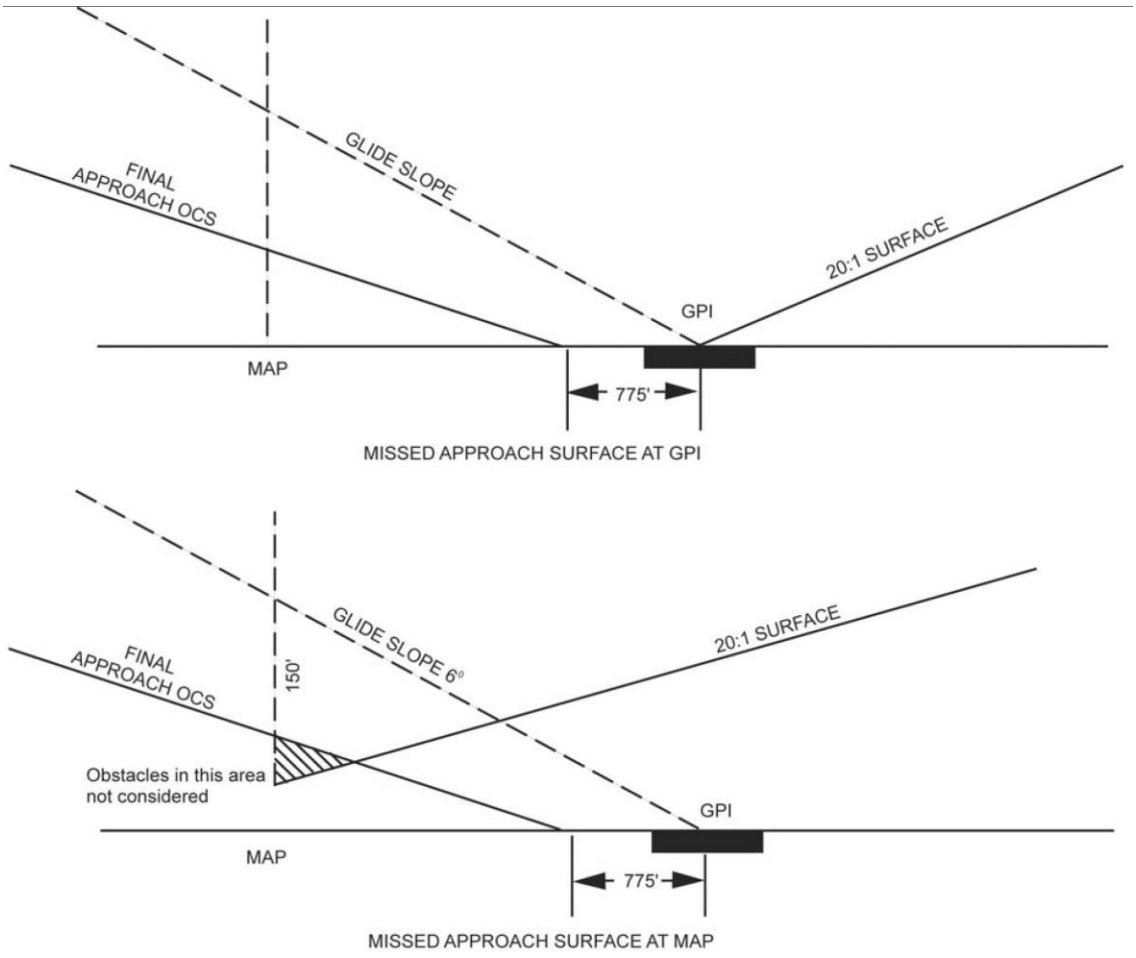


Figure 11-112: Missed Approach Surface Options. Para 1168.

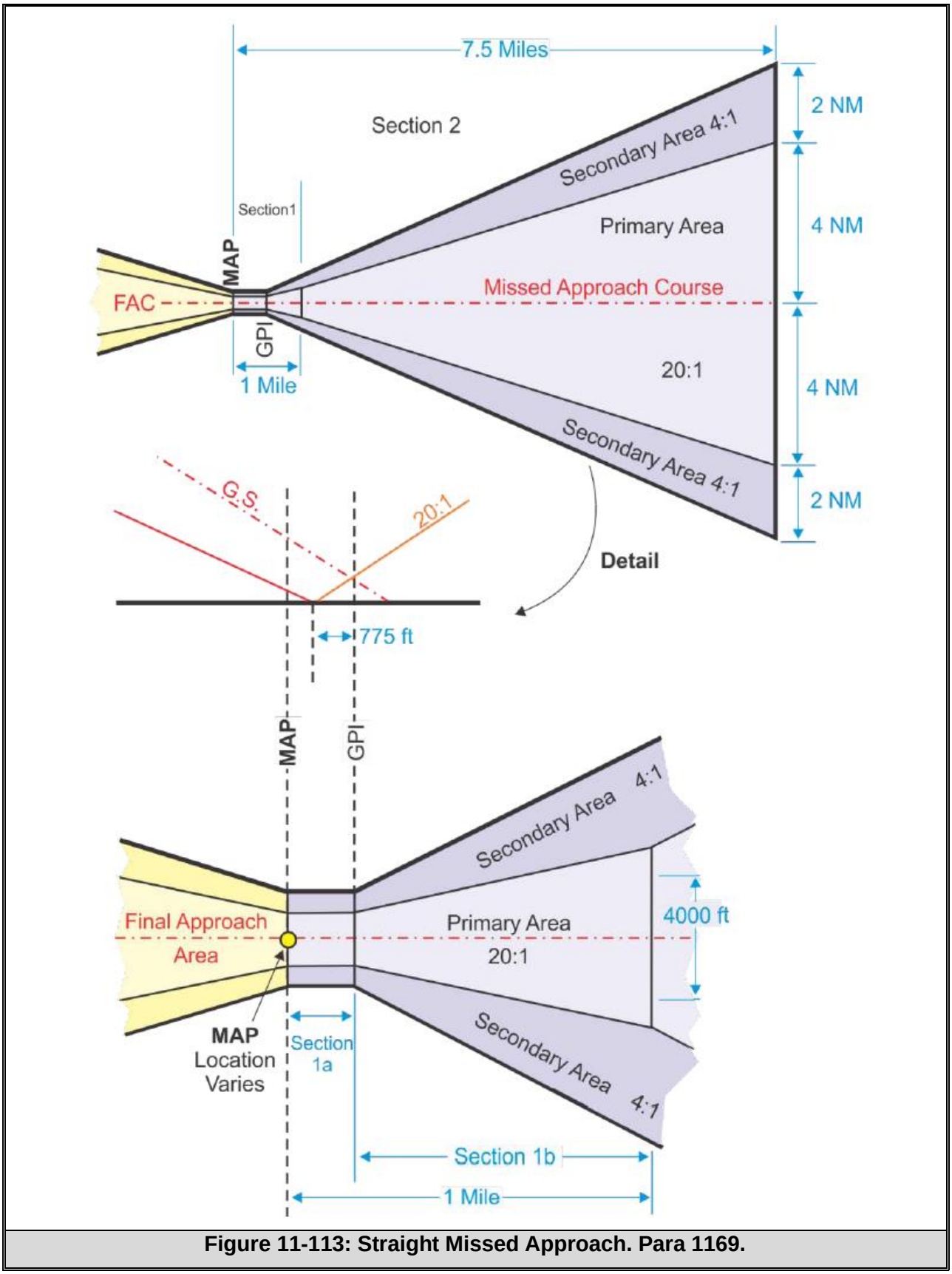


Figure 11-113: Straight Missed Approach. Para 1169.

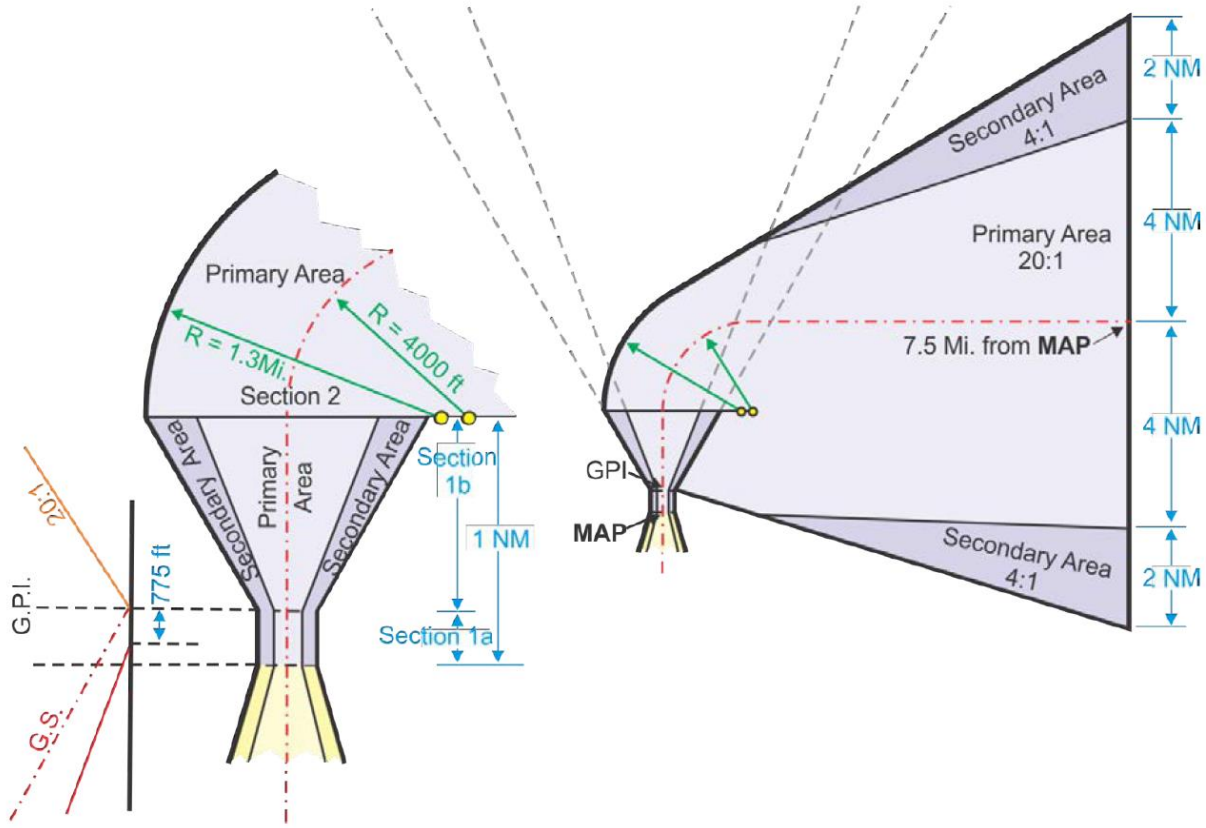
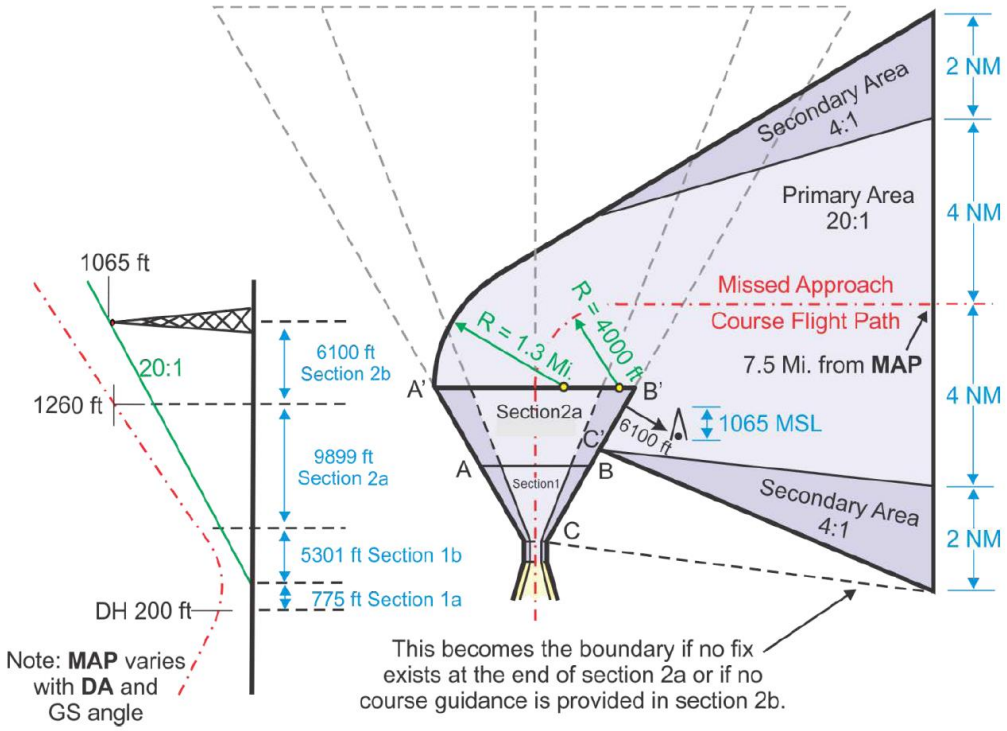


Figure 11-114: Turning Missed Approach Area. Para 1170.



Example:

Given:

1. DA/DH is 200 feet
2. Obstacle height: 1065 MSL
3. Obstacle in section 2 = 6100 feet from the near edge of section 2a
4. Missed approach surface begins at GPI

Determine:

1. Distance from DA point to end of section 2a
2. Minimum turn altitude
3. Missed approach instructions

Solution:

1. Distance from DA point to end of section 2a
   a. $\frac{6100}{20} = 305\ ft$
   b. 1065 - 305 = 760 MSL, required section 2a end OCS height
   c. 760 – 0 (20:1 origin height) = 760 feet of total rise in sections 1 and 2a
   d. 760 × 20 = 15200 feet, distance from 20:1 origin to end of section 2a
   e. 15200 + 775 (distance from DA point to 20:1 origin) = 15975 feet

2. Minimum turn altitude
   a. $\frac{15975}{15.19} + DA = 1251.68\ ft$
   b. Round to next higher 20-foot increment = 1260 MSL

3. Missed approach instructions “Climb to 1260 then turn right…”

Figure 11-115: Combination Straight And Turning Missed Approach. Para 1171.

CHAPTER 12. DEPARTURE CRITERIA

SECTION 1. GENERAL CRITERIA

12.1. General Criteria.

12.1.1. General.

a. These criteria specify the obstacle clearance requirements to be applied to diverse departure, departures routes and Visual Climb Over Airport (VCOA). Criteria for RNAV equipped aircraft are provided in TP308 Volume 2.

b. There are two types of Departure Procedures (DPs); those developed to assist pilots in obstruction avoidance [referred to as obstacle departure procedure (ODP)] and those developed to communicate air traffic control (ATC) clearances [referred to as standard instrument departure (SID)].

12.1.2. Departure Criteria Application.

Evaluate runways for IFR departure operations by applying criteria in the sequence listed below.

a. Perform a diverse departure assessment and where the Obstacle Clearance Surfaces (OCS) is penetrated, development of an obstacle departure procedure (ODP) is mandatory.

b. Develop departure routes as necessary.

c. Develop a Visual Climb Over Airport (VCOA) procedure where obstacles require the publication of a climb gradients greater than 200 ft/NM (see section 4).

d. At locations served by radar, air traffic control may request development of diverse vector areas to aid in radar vectoring departure traffic (see section 5).

12.1.3. Departure OCS Application.

a. Evaluate the 40:1 departure OCS originating at the departure end of runway (DER) threshold at DER elevation (see figure 12-1-1). If a clearway exists, then evaluate a 40:1 departure OCS originating at the end of the clearway at an elevation determined by application of formula 12-1-1. See figure 12-1-2 for application of OCS when a clearway is present.

Note: A clearway is present when the Take-Off Distance Available (TODA) exceeds the Take-Off Run Available (TORA). When TODA exceeds TORA, the airport will declare and publish these values within the applicable Airport Operations Manual.

b. Departure operations are unrestricted if the OCS is clear. Objects which penetrate the OCS are obstacles and shall be considered in the departure procedure by specifying a flight path which will safely avoid the obstacle(s) or by specifying a climb gradient greater than 200 feet per NM that will provide 24% of required obstacle clearance (ROC) for each NM of the flight path.

c. Do not publish a CG to a height of 200 feet or less above the OCS start elevation, instead, publish a note identifying the obstacles(s) type, MSL elevation and location relative to DER. These obstacles are commonly referred as “low, close-in-obstacles”.

Formula 12-1-1. OCS Start Elevation (OCS_{Start}) (Runways with Clearway)

$$OCS_{Start} = \frac{TODA - TORA}{80} + DER_{elev}$$

Where:

DER_{elev} = DER elevation

Figure 12-1-1. OCS Starting Elevation

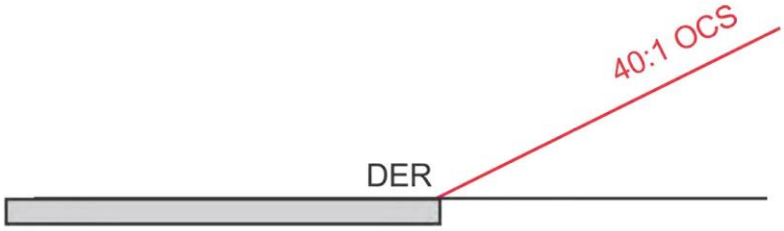
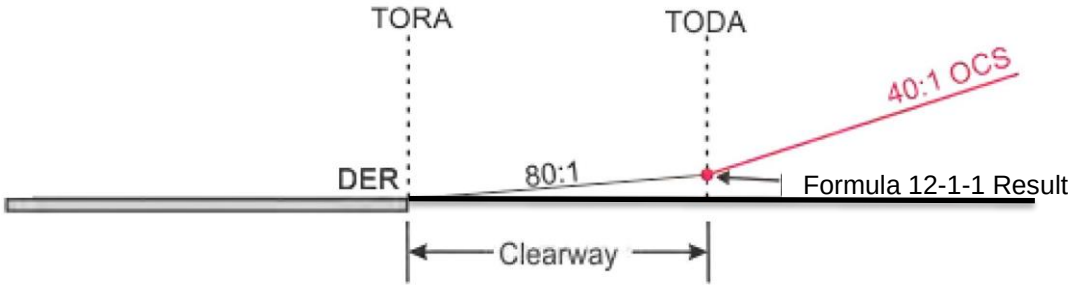


Figure 12-1-2. OCS Starting Elevation With Clearway



d. **Calculating OCS height**. The OCS height is based on the distance measured from the OCS origin along the shortest distance to an obstacle within the segment. See paragraph 12-1-6b(3) for measuring obstacles located within the ICA.

(1) Primary area. The OCS slope is 40:1. Use formula 12-1-2 to calculate the OCS elevation.

Formula 12-1-2. Primary OCS Elevation (h_{OCS})

$$h_{OCS} = \frac{d}{40} + e$$

Where:

d = shortest distance (feet) from OCS origin to obstacle
e = OCS origin elevation

(2) Secondary area. (Applicable only when positive course guidance (PCG) is identified.) The OCS slope is 12:1. The secondary OCS elevation is the sum of the 40:1 OCS rise in the primary area to a point the obstacle is perpendicular to the departure course, and the secondary OCS rise from the edge of the primary OCS to the obstacle (see figure 12-1-3). Use formula 12-1-3 to calculate the secondary OCS elevation.

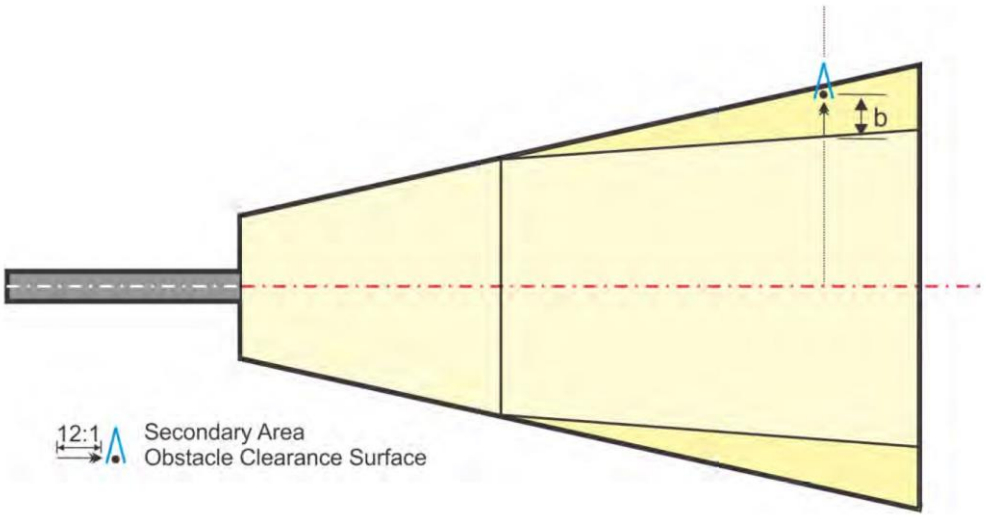
Formula 12-1-3. Secondary OCS Elevation ($h_{SECONDARY}$)

$$h_{SECONDARY} = h_{OCS} + \frac{b}{12}$$

Where:

h_{OCS} = primary OCS height
b = distance (feet) from edge of primary, perpendicular to the course line

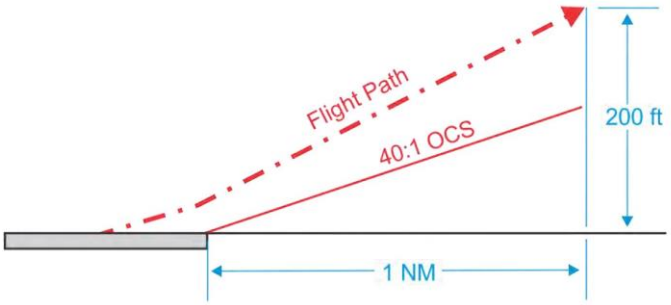
Figure 12-1-3. Secondary OCS



12.1.4. Climb Gradients.

Departure procedure obstacle clearance is based on a minimum climb gradient performance of 200 ft/NM (see figure 12-1-4).

Figure 12-1-4. Standard Climb Gradient



a. Calculating climb gradients to clear obstacles. The maximum Climb gradient is 500 ft/NM for departure procedure. Calculate climb gradients using formula 12-1-4.

Formula 12-1-4. Standard/Military Option Climb Gradient

Standard Formula	**Military Option***
$CG = \frac{O-E}{0.76 \times D}$	$CG = \frac{(48 \times D + O) - E}{D}$

Where:

O = Obstacle MSL elevation
E = OCS start elevation
D = Distance (NM) OCS origin to obstacle

* For use by military aircraft only. Not for civil use.

b. **Calculating the CG termination altitude.** When the aircraft achieves an altitude that provides the required obstacle clearance, the CG restriction may be lifted. This altitude is called the "climb to" altitude (A). Calculate the climb to altitude using formula 12-1-5.

Formula 12-1-5. Climb to Altitude (*A*)

$$A = E + (CG \times D)$$

Where:

E = Climb gradient starting elevation (MSL)
D = Distance (NM) from OCS origin to point where altitude is required

Example: $1221 + (352 \times 3.1) = 2312.20$ *round to* 2400

c. **Climb gradients to altitudes for other than obstacles**. Calculate the climb gradient to the stated “climb to” altitude using formula 12-1-6.

Formula 12-1-6. Climb to Altitude for Other than Obstacles

$$CG = \frac{A - E}{D}$$

Where:

A = Climb to altitude (CG termination altitude)
E = Climb gradient starting elevation (MSL)
D = Distance (NM) from OCS origin to point where altitude is required

Example: $CG = \frac{3000-1221}{5} = 355.8\, round\ to\ 356\ ft/NM$

Note: The climb gradient must be equal to or greater than the gradient required for obstacles along the route of flight.

d. Reserved.

Formula 12-1-7. Reserved

e. Reserved.

12.1.5. Reserved.

12.1.6. Initial Climb Area (ICA).

The ICA is an area centered on the runway centerline extended used to evaluate obstacle clearance during the climb to 400 feet above DER rounded to the nearest foot, with a minimum climb gradient 200 ft/NM.

a. ICA terms.

(1) ICA baseline (ICAB). The ICAB is a line extending perpendicular to the runway centerline (RCL) ± 500 ft at DER. If a clearway is present, the ICAB is a line perpendicular to the extended RCL at the clearway end. It is the origin of the ICA (see figure 12-1-5).

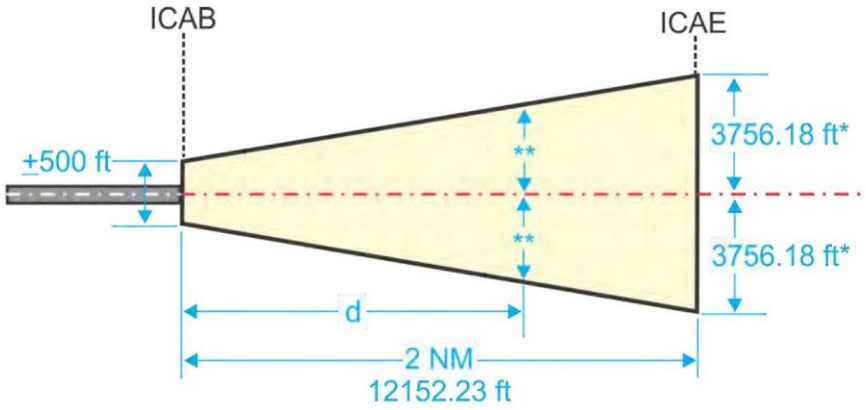
(2) ICA end-line (ICAE). The ICAE is a line at the end of the ICA perpendicular to the RCL extended. The splay of 15 degrees and length of the ICA determine its width (see figure 12-1-5).

b. Area.

(1) Length. The ICA length is normally 2 NM, measured from the ICAB to the ICAE along RCL extended. It may be less than 2 NM in length for early turns by publishing a climb gradient. The ICA may be extended beyond 2 NM to maximum length of 10 NM. A specified altitude (typically 400 feet above DER) or the interception of PCG route must identify the ICAE.

(2) Width. The ICA origin is 1000 feet (± 500 perpendicular RCL) wide at its origin. The area splays outward at a rate of 15 degrees relative to the departure course (normally RCL extended).

Figure 12-1-5. Initial Climb Area



(3) OCS. The OCS originates at the ICAB, at the OCS start elevation (see paragraph 12-1-3). Apply the OCS by measuring along the RCL from the ICAB to a point where the obstacle is perpendicular to the RCL and evaluate per paragraph 12-1-3. The MSL elevation of the ICAE is calculated using formula 12-1-8.

Formula 12-1-8. ICAE Elevation ($ICAE_{elev}$)

$$ICAE_{elev} = a + \left(\frac{b}{c}\right)$$

Where:

a = OCS start elevation
b = ICA length (feet)
c = OCS slope (standard 40:1)

SECTION 2. DIVERSE DEPARTURE ASSESSMENT

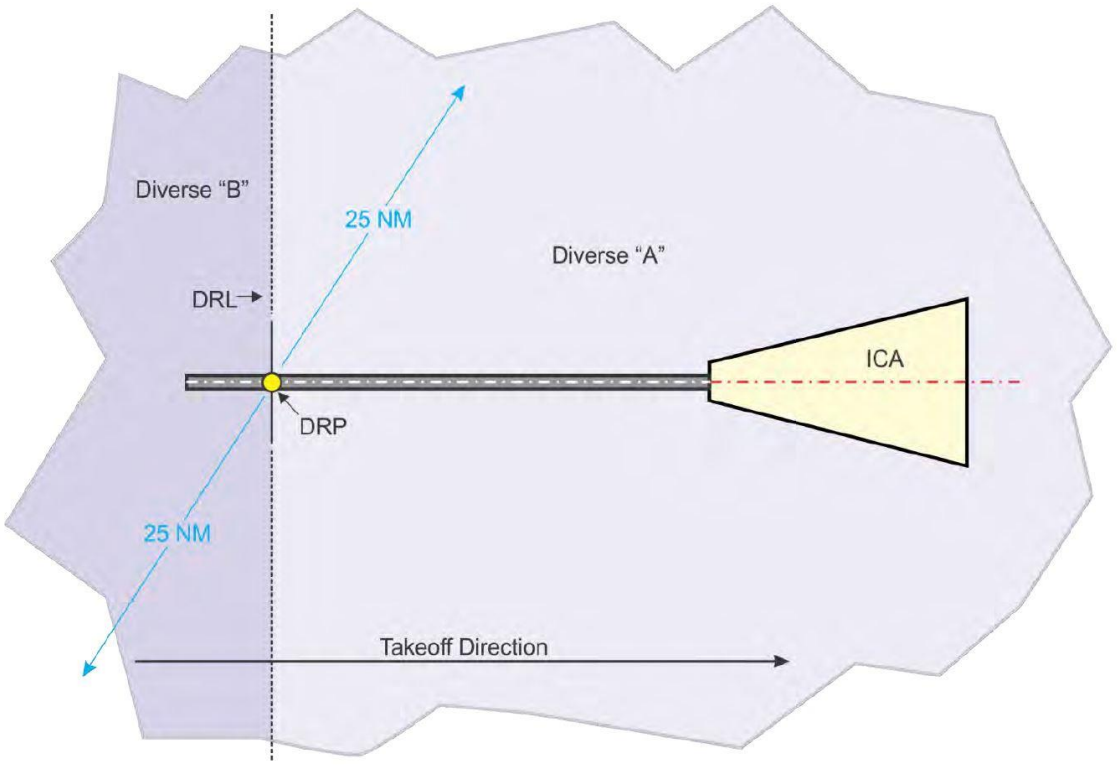
12.2. Diverse Departure Assessment

12.2.1. General.

Assess diverse “A” and “B” areas to a distance of 25 NM. Extend the assessment to a distance of 46 NM if any part of the assessment area includes mountainous areas. See figure 12-2-1.

a. Area. The diverse departure assessment covers three areas.

Figure 12-2-1. Diverse Departure Assessment Areas



(1) ICA. Assess the ICA under paragraph 12-1-6 using a 40:1 OCS slope. See figure 12-2-1.

(2) Diverse "A" area. Diverse “A” consists of all area on the DER side of the departure reference line (DRL), excluding the ICA. The DRL is a line perpendicular to the RCL that passes through the departure reference point (DRP) which is established on RCL 2000 feet from the start end of the runway. Calculate the elevation of the OCS at any given location in the diverse "A" by applying formula 12-2-1. Measure the distance from the obstacle to the closest point on the centerline of the runway between the DRP and ICAB, or the closest point on ICA boundary lines as appropriate (see figure 12-2-2). The beginning OCS elevation is equal to the MSL elevation of the ICAE.

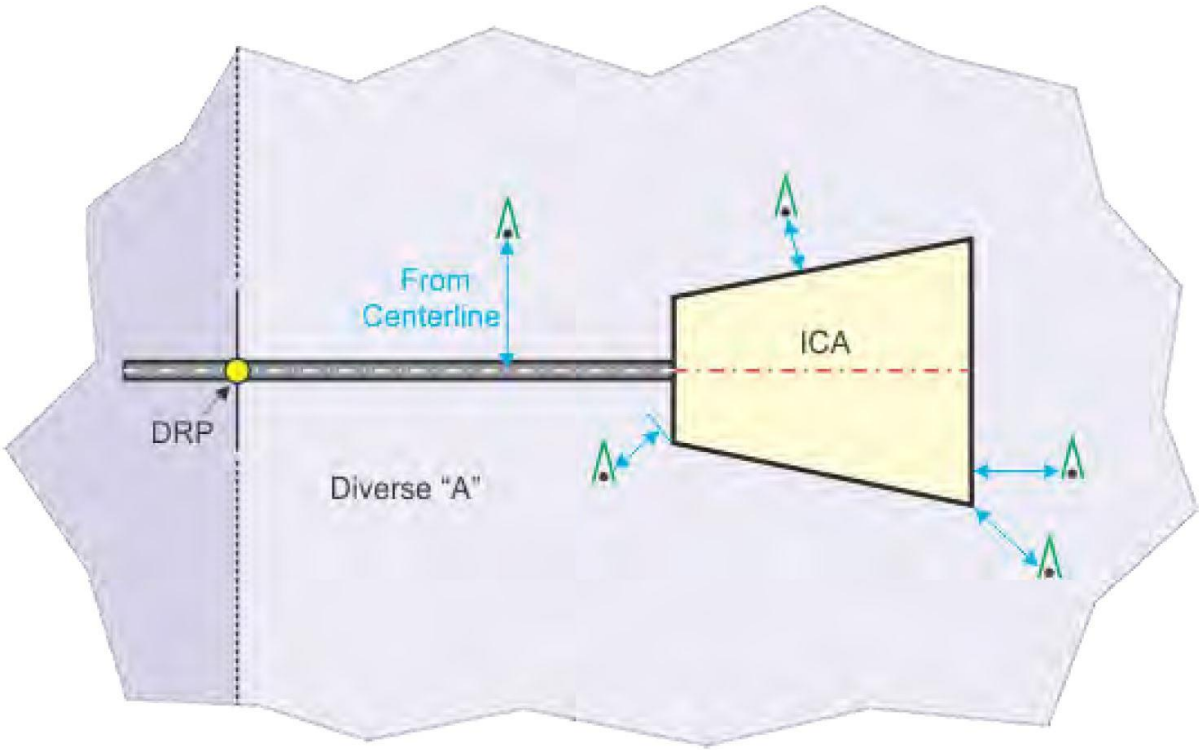
Formula 12-2-1. OCS Height Diverse "A" Area

$$h = a + \frac{d}{40}$$

Where:

h = OCS MSL elevation at obstacle
d = distance (feet) from obstacle to closest point
a = ICAE MSL elevation

Figure 12-2-2. Diverse "A" Area Evaluation



(3) Diverse "B" area. All areas on the start end of runway side of the DRL (see figure 12-2-1). Evaluate obstacles in the Diverse "B" area by measuring the distance in feet from the obstacle to the DRP (see figure 12-2-3). Calculate the OCS MSL elevation at the obstacle using formula 12-2-2.

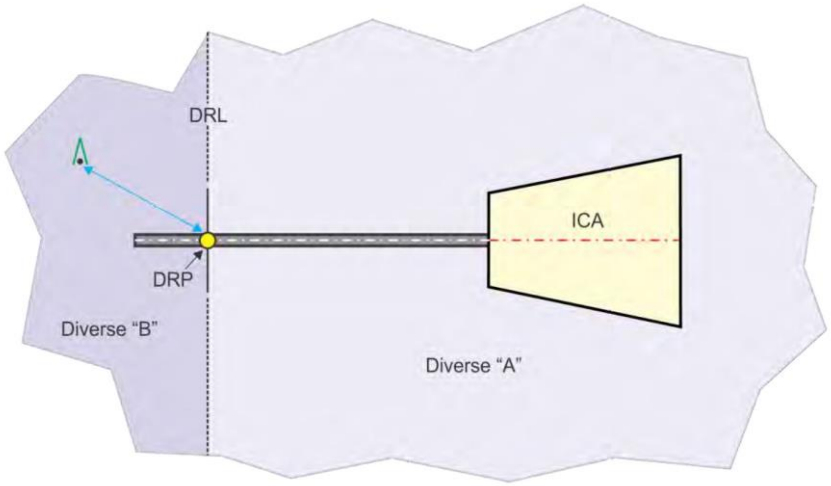
Formula 12-2-2. OCS Height Diverse "B" Area

$$\boldsymbol{h = \frac{d}{40} + (b + 400)}$$

Where:

h = OCS MSL elevation at obstacle
d = distance (feet) from obstacle to DRP
b = Airport MSL elevation

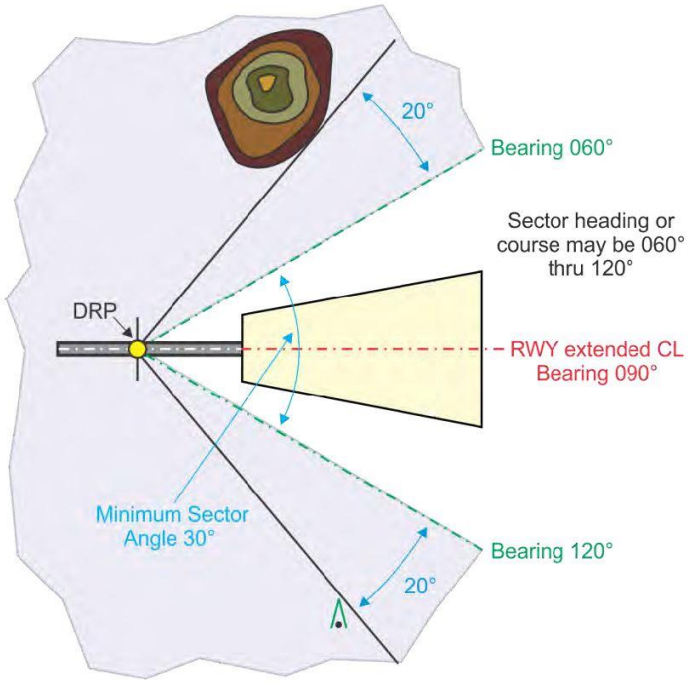
Figure 12-2-3. Diverse "B" Area



12.2.2. Departure Sectors.

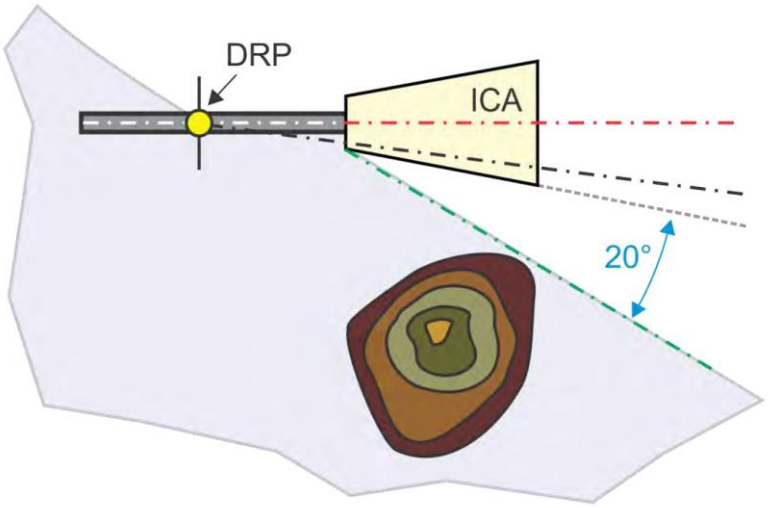
Where OCS penetrations prevent unrestricted diverse departure, consider constructing sectors within the diverse areas where departure flight is prohibited. Departure instructions must assure the aircraft will maneuver clear of the prohibited sector boundaries. Separate sector boundaries from obstacles via a buffer established by a 20-degree splay from the DRP. The minimum angle between sector boundaries is 30 degrees. The ICA must be protected at all times. See figure 12-2-4.

Figure 12-2-4. Minimum Sector Area



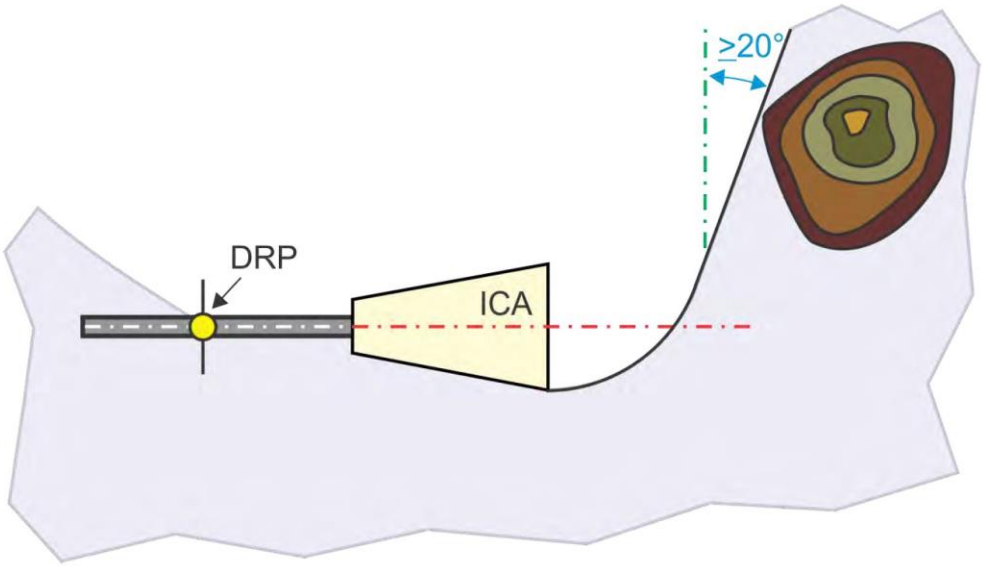
a. Boundary based on the ICA. When the 20-degree splay from the DRP cuts across the ICA, construct a line 20 degrees relative to the side of the ICA. To protect the ICA, no obstacle may lie inside this line. See figure 12-2-5.

Figure 12-2-5. Boundary Based on ICA



b. Outer boundary involving a turn. Locate the turn point on runway centerline (extended) and establish the ICAE. Construct the outer boundary from the ICAE, using table 12-3-2 for selection of the outer boundary radius. Construct a line from the obstacle tangent to the outer boundary radius. Establish the outer boundary buffer 20 degrees from this line on the maneuvering side. Begin the 20-degree buffer at the tangent point where the obstacle line intercepts the arc. See figure 12-2-6.

Figure 12-2-6. Outer Boundary



c. Defining sector boundaries. Construct boundaries to define each sector. Sector boundaries originate at the DRP, or are defined tangentially from the outer boundary radius (see figure 12-2-7). Define and publish sector boundaries by reference to aircraft magnetic headings. Sector “headings” must be equivalent to the magnetic bearing of the sector boundaries from their origins.

12.2.3. Sector Limitations.

a. The maximum turn from the takeoff runway in any one direction is 180 degrees relative to takeoff runway heading (see figure 12-2-7). Figure 12-2-8 shows a sector of 360 degrees clockwise, 270 degrees could be assigned; however, the maximum turn to the right is a heading not in excess of the reciprocal of the takeoff runway heading.

Figure 12-2-7. Sector Limitations

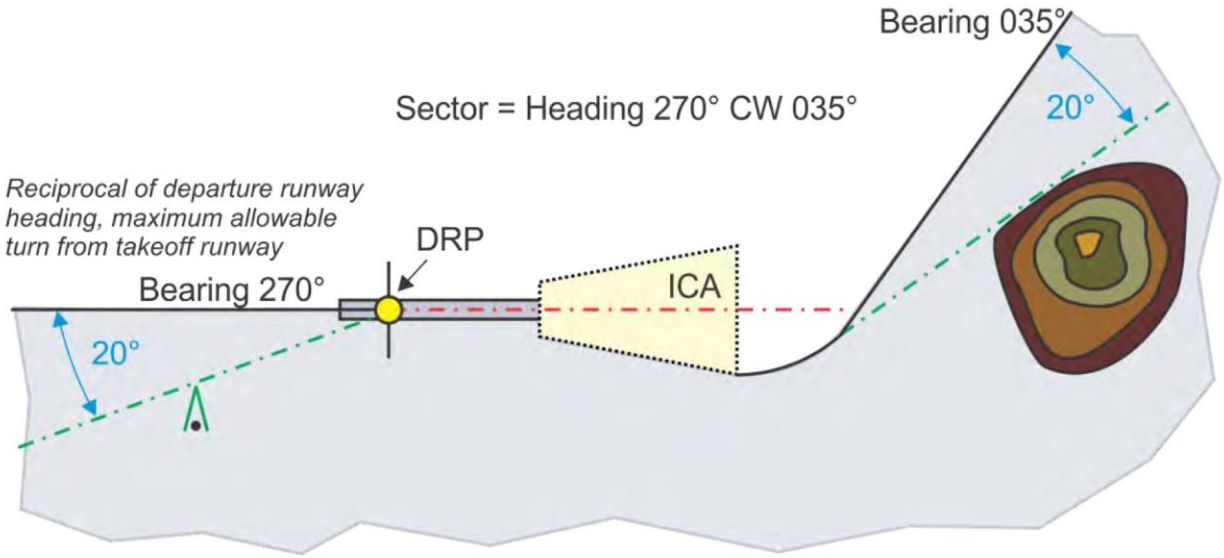
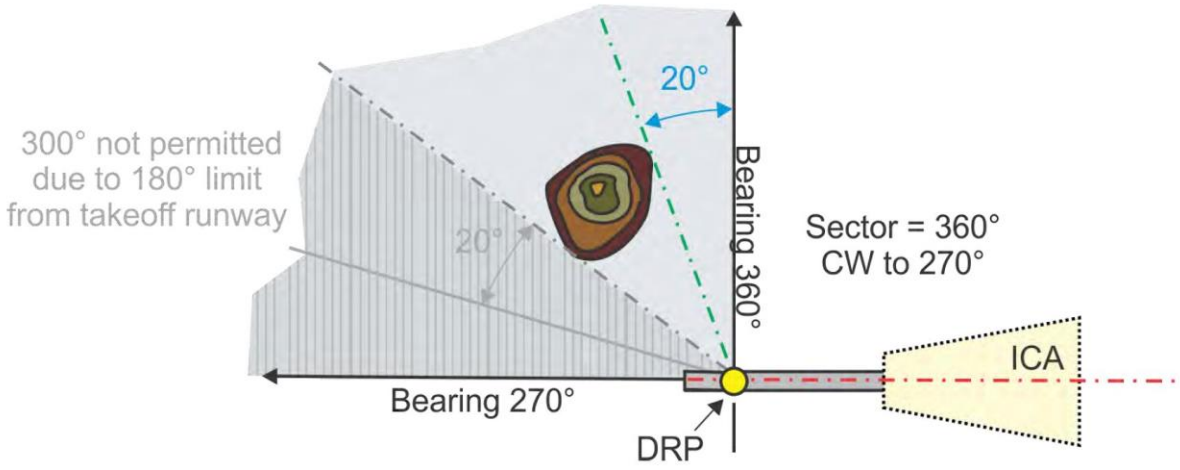
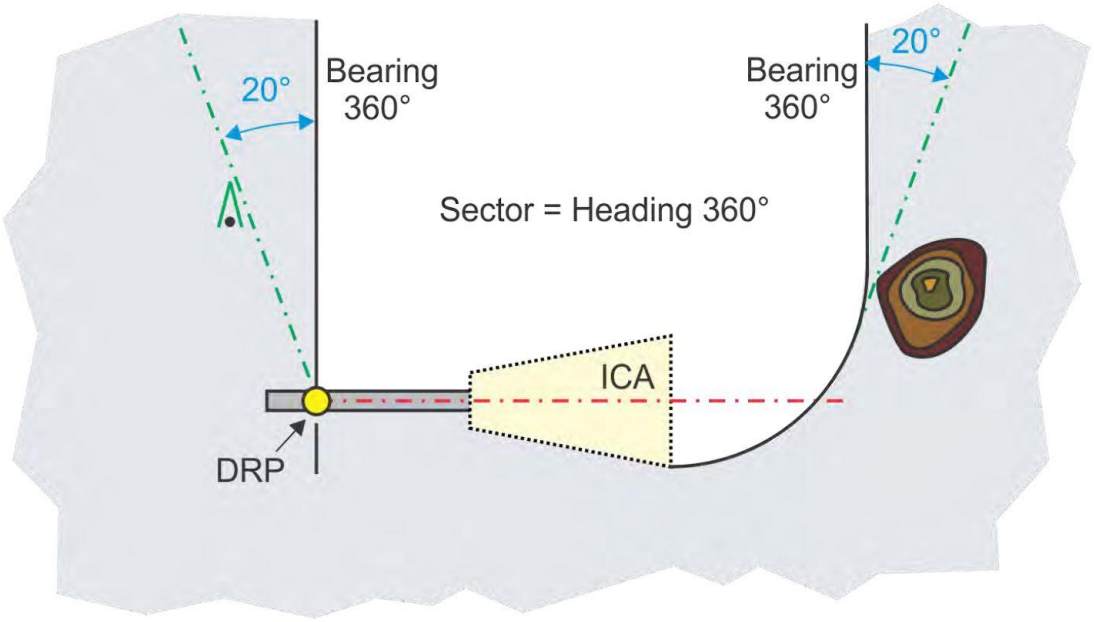


Figure 12-2-8. Maximum Heading Limitation



b. Assign a single heading for a sector which has parallel boundaries. The heading must parallel the boundaries. Figure 12-2-9 shows heading 360 degrees as the only heading allowable.

Figure 12-2-9. Parallel Boundaries



c. Do not establish a sector if the boundaries converge.

Example: In figure 12-2-9, if the bearing from the DRP had been .001 degrees or greater or the outer bearing 359 degrees or less, the sector could not be established.

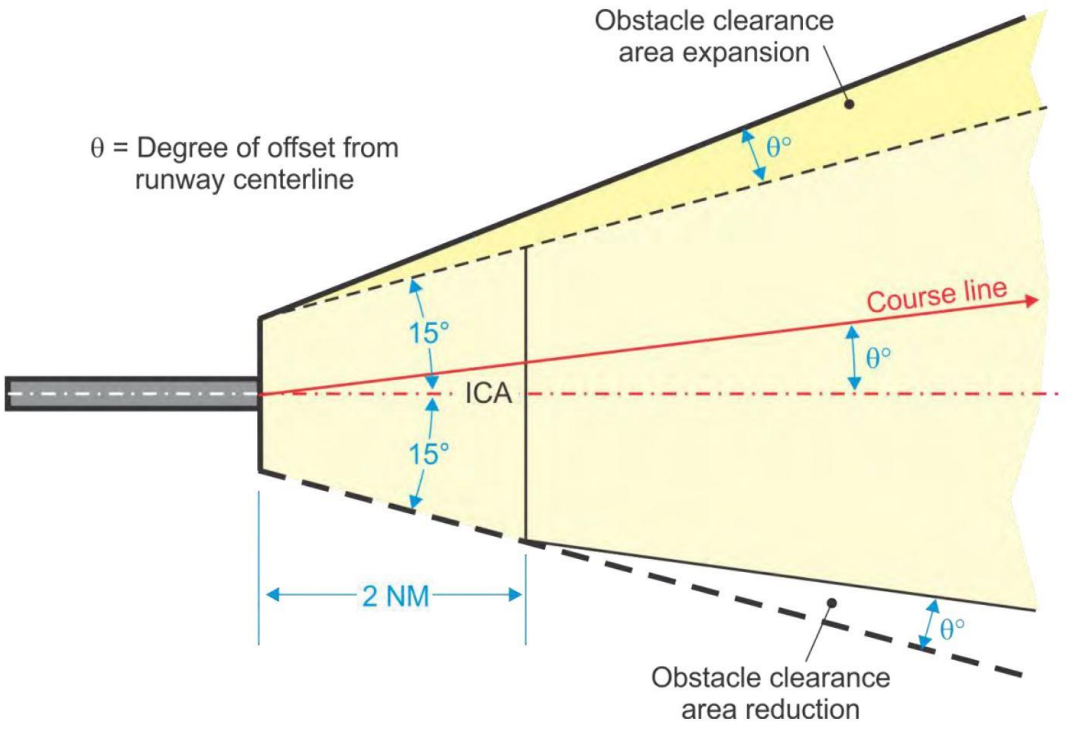
SECTION 3. DEPARTURE ROUTES

12.3. Departure Routes

12.3.1. Straight Route Departure Segments.

Straight departures are aligned within 15 degrees of the runway centerline. The ICA is aligned along the runway centerline for at least 2 NM (see paragraph 12-1-6). If a turn at the DER is desired, expand the obstacle clearance area in the direction of the turn an amount equal to the departure course degree of offset from runway centerline (see figure 12-3-1). Reduce the obstacle clearance area following the ICA on the side opposite the turn an amount equal to the expansion on the opposite side.

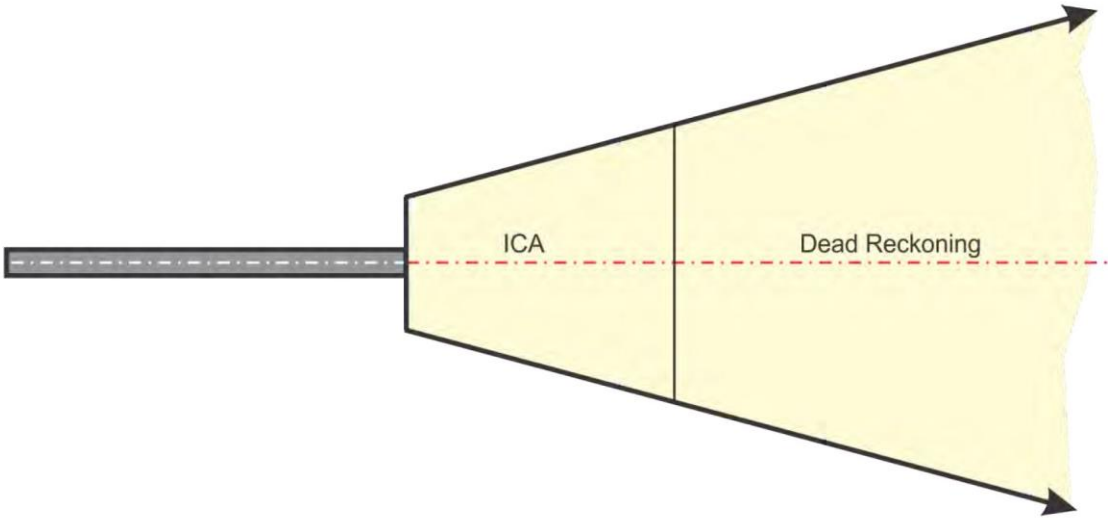
Figure 12-3-1. Turn ≤ 15 degrees at DER



12.3.2. DR Departure.

The boundary lines of the departure obstacle evaluation area (OEA) splay outwards 15 degrees relative to the departure course from the end of the ICA (see figures 12-3-1 and 12-3-2). Limit the DR segment to a maximum distance of 10 NM from DER.

Figure 12-3-2. Dead Reckoning



12.3.3. Positive Course Guidance (PCG) Departure, 15 Degrees or less.

Apply the values from table 12-3-1 to formulas 12-3-1 and 12-3-2 to calculate the obstruction primary area half width (½WP), and the width of the secondary area (WS). Refer to table 12-3-1 for the values of k_P, D, A, and k_S.

Formula 12-3-1. Half Width of the Primary Area

$$\frac{1}{2}W_P = k_P \times D + A$$

Formula 12-3-2. Width of the Secondary Area

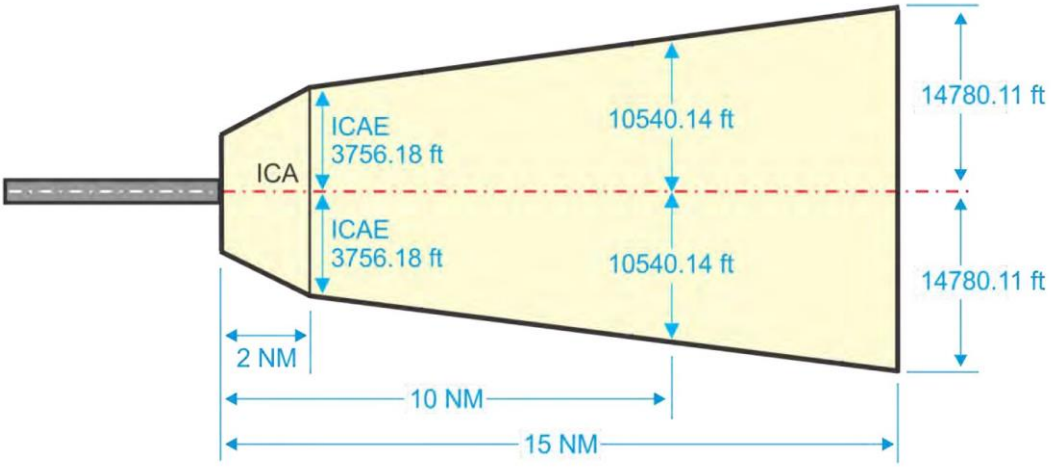
$$W_S = k_S \times D$$

Table 12-3-1. Obstruction Area Values

½ Width	k_P	k_S	D	A
Dep DR	0.267949	none	Distance (feet) from DER	500 feet
Localizer	0.139562	none	Distance (feet) from ICAE	3756.18 feet
NDB	0.0833	0.0666	Distance (NM) from facility	1.25 NM
VOR / TACAN	0.05	0.0333	Distance (NM) from facility	1 NM

a. Localizer guidance. The OEA begins at the ICAE. The maximum length of the segment is 15 NM from DER. Evaluate in accordance with paragraph 12-3-1. If necessary, calculate the required minimum climb gradient using formula 12-1-4 where D is the shortest distance to the ICAB. See figure 12-3-3.

Figure 12-3-3. Localizer Area



b. **NDB guidance.** Evaluate in accordance with paragraph 12-3-1. If necessary, calculate the required minimum climb gradient using formula 12-1-4. Figures 12-3-4, 12-3-5, and 12-3-6 illustrate possible facility area configurations.

c. **VOR/TACAN guidance.** Evaluate in accordance with paragraph 12-3-1. If necessary, calculate the required minimum climb gradient using formula 12-1-4. Figures 12-3-4, 12-3-5, and 12-3-6 illustrate possible facility area configurations.

Figure 12-3-4. Facility Area and DR Area Relationship

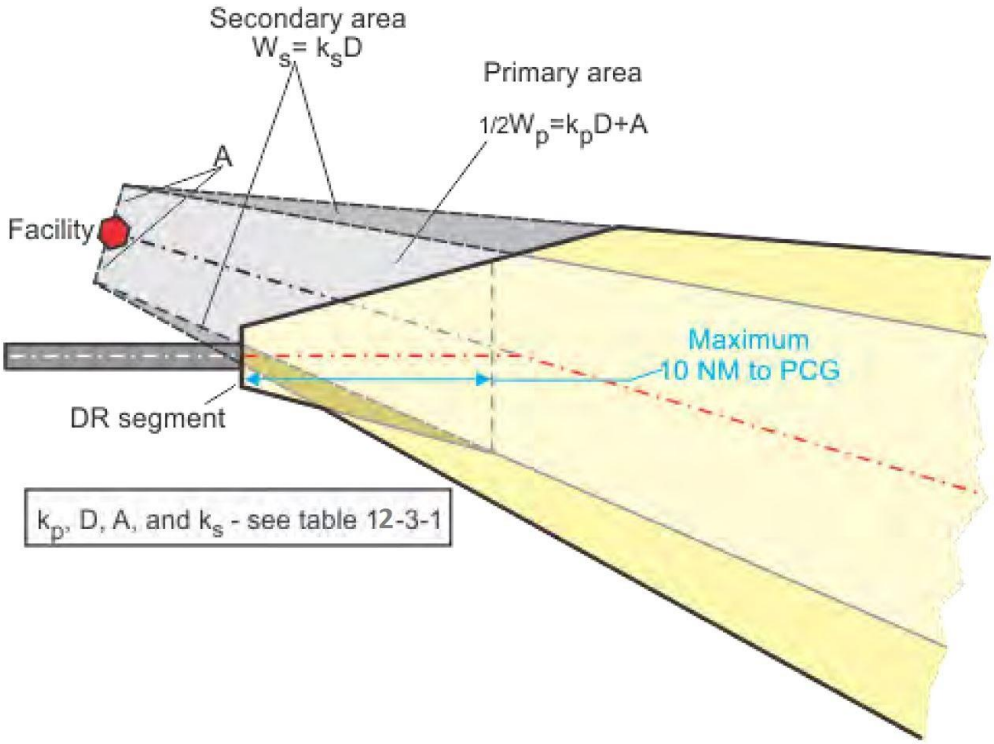
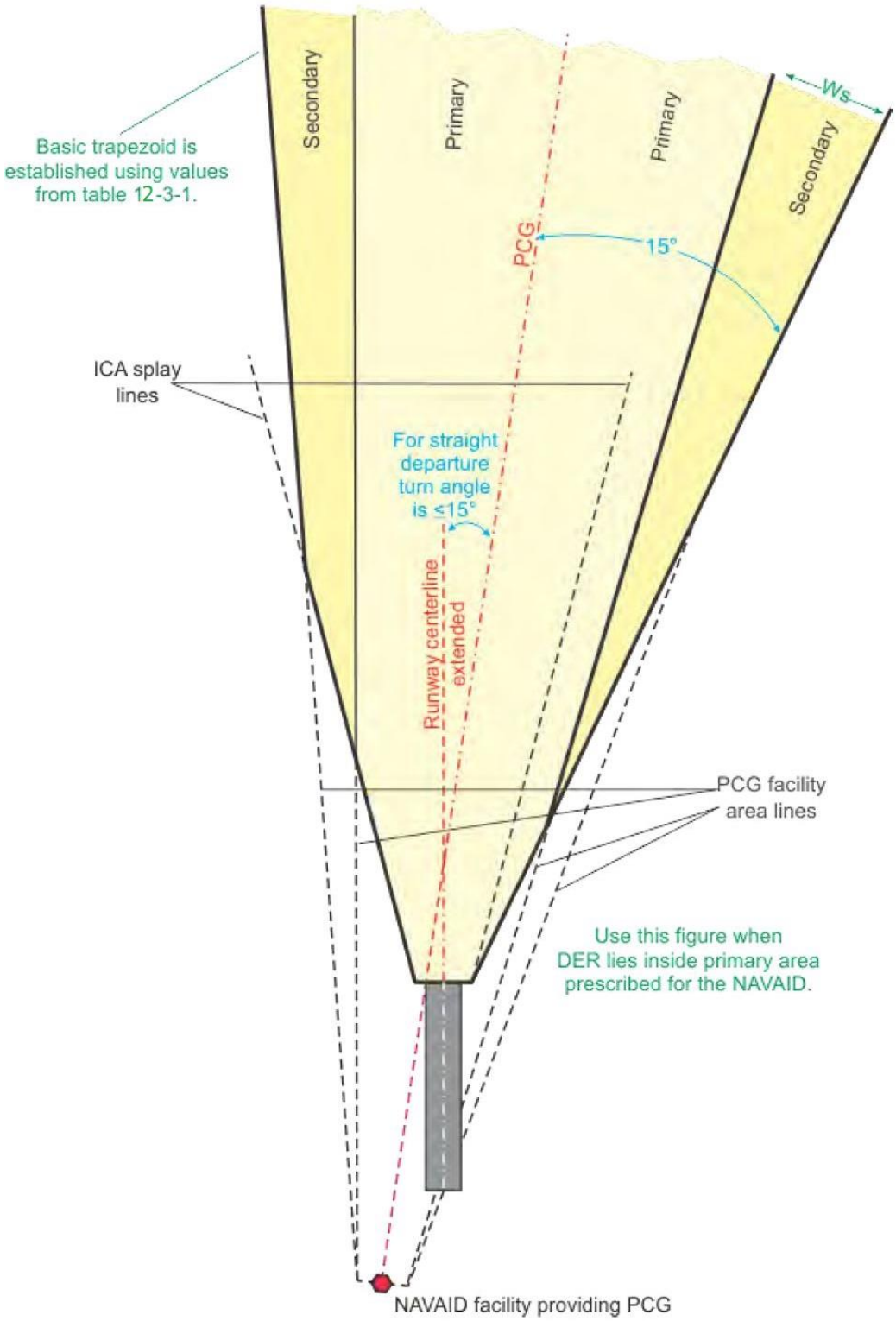
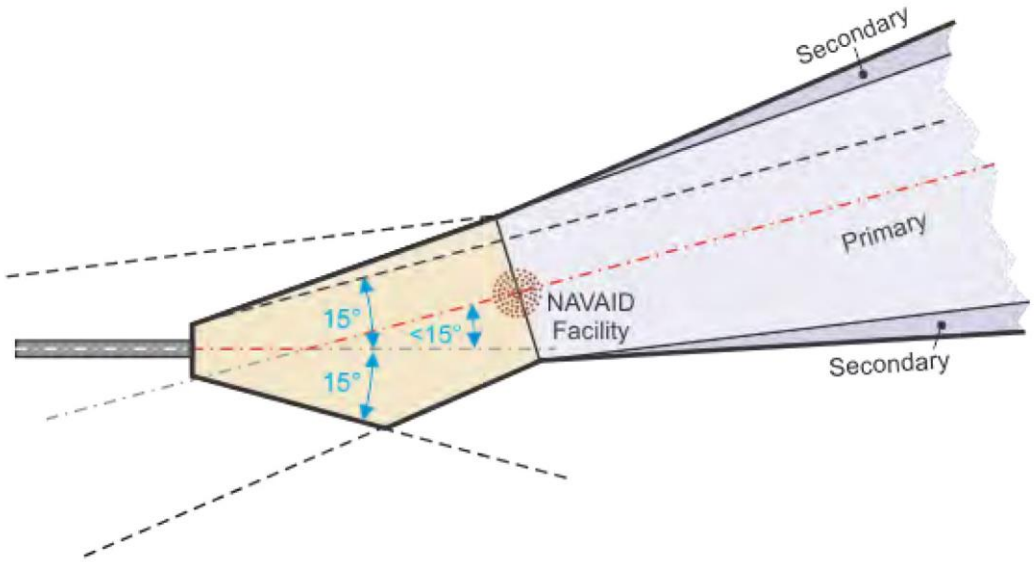


Figure 12-3-5. DER within Primary Area Facility



d. Secondary area obstructions. Secondary areas may be constructed and employed where PCG is provided.

Figure 12-3-6. Facility Area Relationship



12.3.4. Turning Segment Construction.

Construct turning segments when the course change is more than 15 degrees. Establish an ICA. For outer boundary radius use table 12-3-2 and apply paragraphs 12-3-4a through 12-3-4d, as appropriate. Use next higher airspeed in table 12-3-2 if specific speed is not given.

a. Turns below 10000 feet MSL. Use 250 KIAS unless a speed restriction other than 250 KIAS is noted on the procedure for that turn. Use 200 KIAS for a minimum speed for CAT C and 230 KIAS for CAT D aircraft.

b. **Turns at 10000 feet and above.** Use 310 KIAS unless a speed restriction not less than 250 KIAS above 10000 through 15000 feet is noted on the procedure for that turn. Above 15000 feet, speed reduction below 310 KIAS is not permitted.

c. When speeds greater than 250 KIAS are authorized below 10000 feet MSL and speeds greater than 310 KIAS are authorized at or above 10000 feet MSL, use the appropriate speed in table 12-3-2.

d. Ensure speed restriction is depicted.

Table 12-3-2, Outer Boundary Radius

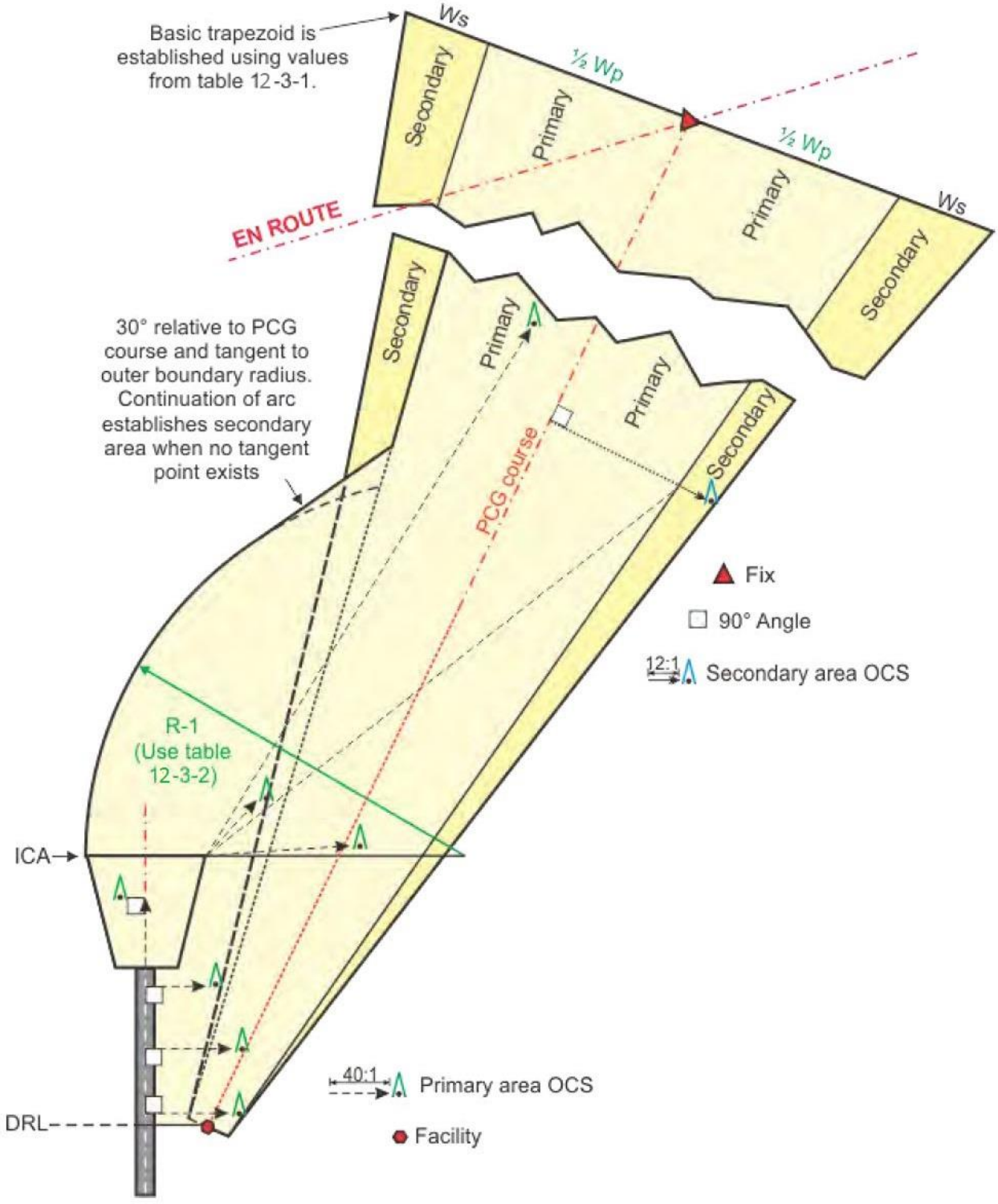
Primary Area Outer Boundary radius (R1)				
Aircraft Speeds (KIAS)	90	120	150	175
Turn radii:				
Below 10000 feet MSL	0.9	1.4	1.9	2.4
10000 feet MSL and above	1.4	2.0	2.7	3.3
Aircraft Speeds	180	210	240	250
Turn radii:				
Below 10000 feet MSL	2.5	3.2	3.9	4.2
10000 feet MSL and above	3.4	4.3	5.2	5.5
Aircraft speeds	270	300	310	350
Turn radii:				
Below 10000 feet MSL	4.7	5.6	6.0	7.3
10000 feet MSL and above	6.2	7.3	7.7	9.3

Note: Speeds include 60-knot omni directional winds below 10000 feet MSL; 90-knot omni winds at 10000 feet and above; bank angle 23 degrees.

12.3.5. Turn to PCG.

Extend the ICA boundaries as necessary to intersect the boundaries appropriate to the PCG provided. Where the ICA outer boundary will not intersect the PCG boundary, construct an outer boundary radius from the outer edge of the ICA to intersect the PCG boundary. For the radius length, use table 12-3-2 or the width of the end of ICA, whichever is longer (see figure 12-3-7). Specify a course, not aligned with the runway centerline, to intersect a PCG course. The amount of turn is not restricted.

Figure 12-3-7. ICA Joining PCG Area



SECTION 4. VISUAL CLIMB OVER AIRPORT (VCOA)

12.4. Visual Climb Over Airport (VCOA)

12.4.1. General.

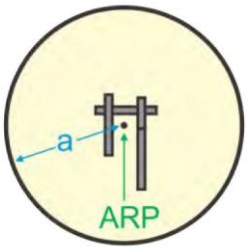
The VCOA is used where aircraft performance cannot meet the specified climb gradient and allows the pilots to depart visually on an IFR clearance. On departure, the aircraft is maneuvered visually, in order to avoid obstacles until it reaches the specified climb-to altitude over the aerodrome. From this point onward, the pilot can revert back to onboard instrumentation and may now continue to safely climb at the minimum standard climb gradient. VCOA is not authorised for departures from heliports.

Supplementary Note: It is possible that VCOA operations may be deemed impractical or even a detriment to the overall performance of certain high traffic density aerodromes. Should this be the case and the aerodrome has 24 hr control tower service in Class B, C or D controlled airspace, then the aerodrome may be exempt from the requirement to build a VCOA. A note stating the above shall be required in the design documentation.

12.4.2. Basic Area.

a. Construct a visual climb area (VCA) over the airport using Aerodrome Reference Point (ARP) as the center of a circle (see figure 12-4-1). Use R1 in table 12-4-1 plus the distance the ARP to the most distant runway end as the radius for the circle.

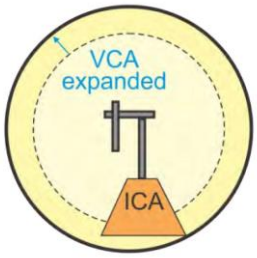
Figure 12-4-1. VCA



a = R1 (table 12-4-1) plus the distance from ARP to most distant DER

b. Select 250 KIAS as the standard airspeed and apply the appropriate MSL altitude to determine the R1 value. Use other airspeeds in table 12-4-1, if specified on the procedure, using the appropriate radius for the selected airspeed. Altitude must equal or exceed field elevation. The VCA must encompass the area of the ICA from the departure runway(s). Expand the VCA radius if necessary to include the ICA (see figure 12-4-2).

Figure 12-4-2. VCA Expanded



The VCA must completely encompass the ICA.

Table 12-4-1. Radius Values (R1)

Altitudes MSL (climb to)	Up to 2,000 feet	2,001 to 5,000 feet	5,001 to 10,000 feet	10,001 and above
Speed KIAS	(NM)	(NM)	(NM)	(NM)
90	2.0	2.0	2.0	2.0
120	2.0	2.0	2.0	2.0
180	2.0	2.0	2.5	3.4
210	2.1	2.5	3.2	4.3
250	2.8	3.4	4.2	5.5
310	4.2	4.9	6.0	7.7
350	5.2	6.0	7.3	9.3

Note: Table 12-4-1 speeds include 30-knot tail winds up to 2000 feet MSL, 45-knot tail winds up to 5000 feet MSL, and 60-knot tail winds at 10000 feet MSL; bank angle: 23 degrees.

12.4.3. VCOA Assessment.

a. Diverse VCOA.

(1) Identify the highest obstacle within the VCA. This is the preliminary height of the VCA level surface.

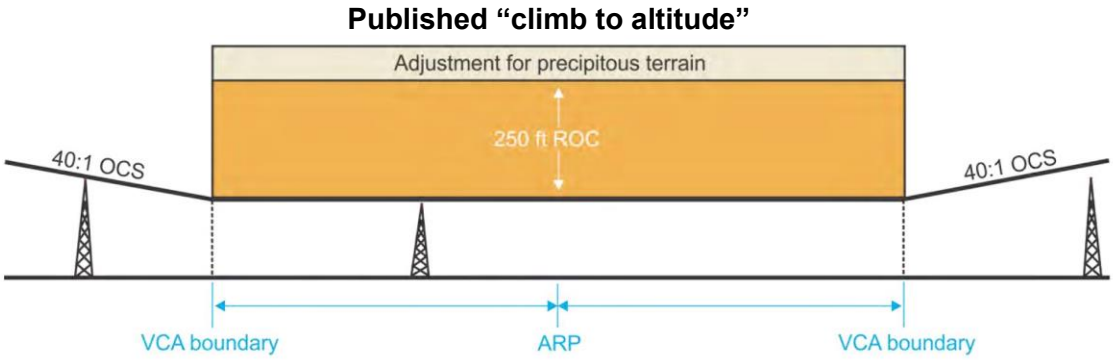
(2) Assess a 40:1 OCS outward from the VCA boundary using the preliminary height of the VCA level surface as the starting OCS height. The 40:1 surface must be evaluated to a minimum distance of 19 NM; expand the assessment to a distance of 40 NM if any part of the assessment area within 19 NM includes designated mountainous terrain.

(3) If the 40:1 OCS is penetrated, increase the VCA level surface by the amount of the greatest penetration.

(4) Add 250 feet of ROC to the final elevation of the VCA level surface. Adjustments for precipitous terrain located within the VCA must be applied as specified in paragraph 3.2.2. Express the resultant altitude in a 100-foot increment; round upward if necessary. This altitude is published as the “climb to altitude” for the VCOA procedure (see figure 12-4-3).

Note: Rounding upward would not be required if the sum of the obstacle’s height, ROC, and required adjustment was in a 100-foot increment (such as 500 feet). Rounding would be required for any other value (for example, 501 feet rounds to 600 feet).

Figure 12-4-3. Diverse VCOA Assessment



Example:

Highest obstacle within VCA:	151 ft
Precipitous terrain adjustment:	70 ft
ROC:	250 ft
Climb to altitude:	471 ft (rounds to 500)

b. Departure routes. Where VCOA diverse departure is not feasible, construct a VCOA departure route based on NDB, VOR, or TACAN guidance.

(1) Construct the VCA by applying paragraph 12-4-2.

(2) Determine the preliminary level surface height by applying paragraph 12-4-3a(1).

(3) This area begins over the ARP or on-airport navaid. Locate, within the VCA, the beginning point of the route. Construct the route using criteria for the navigation system desired as defined in section 3.

(4) The 40:1 surface rise begins along a line perpendicular to the route course and tangent to the VCA boundary (see figure 12-4-4). If the 40:1 OCS is penetrated, increase the VCA level surface by the amount of the greatest penetration.

(5) Determine the climb to altitude by applying paragraph 12-4-3a(4).

c. Departure based on Dead Reckoning (DR):

(1) Construct the VCA by applying paragraph 12-4-2.

(2) Determine the preliminary level surface height by applying paragraph 12-4-3a(1).

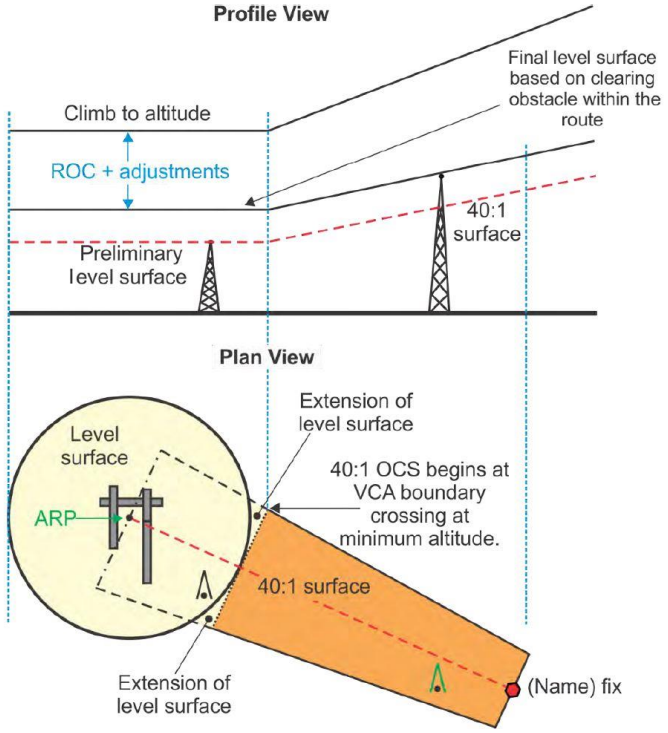
(3) When DR is used, the area has the same width as the VCA abeam the point of beginning. The DR area begins over the ARP. The splay begins where a line constructed perpendicular the DR course and through the ARP intercepts the VCA boundary. It splays 15° each side of and in the direction of the DR course until positive course (track) guidance is acquired (see figure 12-4-5). Limit the DR segment to a maximum distance of 10 NM from the VCA.

(4) The 40:1 surface rise begins along a line perpendicular to the route course and tangent to the VCA boundary (see figure 12-4-5). If the 40:1 OCS is penetrated, increase the VCA level surface by the amount of the greatest penetration.

(5) Determine the climb to altitude by applying paragraph 12-4-3a(4).

(6) Sector VCOA DR departure may be designed due to traffic flow and operational constraints; e.g., routes, airspace boundaries, special use airspace, obstacles, etc. The above criteria (12.4.3, c (1) to (5)) apply to the design to the extreme left and to the extreme right heading of the sector and the 40:1 surface rise begins at the VCA boundary in between the authorized extreme headings of the sector.

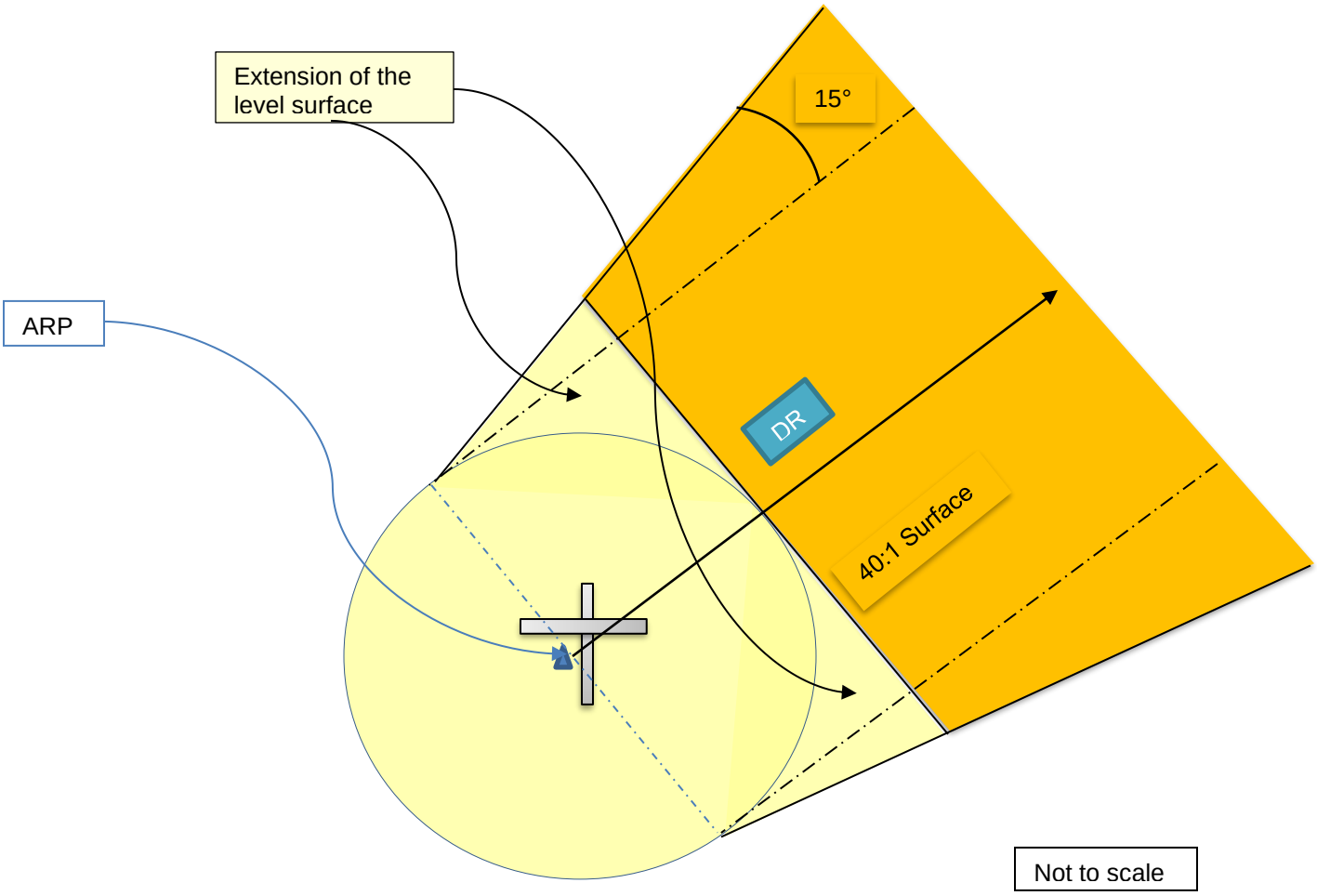
Figure 12-4-4. Route Out of VCA



Not to scale

12.4.4. Reserved.

Figure 12-4-5: VCOA DR Departure



12.4.5. Published Annotations.

The procedure must include instructions to climb in visual conditions to cross a location/fix at or above the climb to altitude determined during the evaluation of the procedure.

a. For the visual climb requirements, the specified take-off minimum visibility "SPEC VIS" must be annotated with the procedure.

b. For a VCOA diverse departure, include the term, “before proceeding on course” following the climb to altitude.

Example: “Climb in visual conditions to cross Castle Airport at or above 2200 BPOC.”

c. For a VCOA route departure, specify the visual climb to altitude, then the initial heading or track followed by the routing.

Examples:

(1) “Climb in visual conditions to cross the airport at or above 4200, then climb on track of 125° to ABC VOR BPOC” ; and

(2) “Climb in visual conditions to cross the airport at or above 5000, then via LEX R-281 to LEX”.

d. For a VCOA DR departure, specify the visual climb to altitude, then the initial heading followed by the routing.

Example: “Climb in visual conditions to cross the airport at or above 5900, continue climb HDG 312° to MEA BPOC”.

e. For a sector VCOA DR departure, specify the visual climb to altitude followed by the sector headings Clockwise (CW) along with the BPOC altitude.

Example: “Climb in visual conditions to cross the airport at or above 5900’, then on a heading between 061 CW to 228 to MEA BPOC.”

SECTION 5. DIVERSE VECTOR AREA (DVA) ASSESSMENT

12.5. Diverse Vector Area (DVA) Assessment

12.5.1. General.

DVA is utilized by ATC radar facilities to allow the radar vectoring of aircraft below the MVA, or for en route facilities, the MIA. A DVA consists of designated airspace associated with a runway where the utilization of applicable departure criteria have been applied to identify and avoid obstacles that penetrate the departure OCS. Avoidance of obstacles is achieved through the application of a sloping OCS within the boundaries of the DVA. Since a sloping OCS is applicable to climb segments, a DVA is valid only when aircraft are permitted to climb uninterrupted from the departure runway to the MVA/MIA (or higher). A DVA is not applicable once an aircraft's climb is arrested. A DVA is not authorised for departure from a heliport.

a. Assess a single DVA at the request of an ATC facility for any candidate runway. Candidate runways are those runways where a diverse departure assessment has identified obstacles that penetrate the 40:1 OCS that require a climb gradient greater than 200 ft/NM to an altitude more than 200 feet above the DER elevation. Do not establish a DVA when obstacles do not penetrate the departure 40:1 OCS, or when the only penetrations are those that require a climb gradient termination altitude of 200 feet or less above the DER elevation (low, close-in obstacles).

b. A DVA is only applicable to the ATC facility (or facilities) that requested it. A maximum of two ATC facilities may use a DVA. When two facilities are authorized use of a DVA, ensure the OEA and all restrictions (such as range of headings, area, climb gradients, etc.) are identical.

c. No obstacles (except low, close-in) may penetrate OCS of the DVA unless isolated in accordance with paragraph 12.5.3.a (see paragraph 12.5.4). **DND Only:** DND radar facilities may require the establishment of a DVA even in the absence of any 40:1 OCS penetrations.

12.5.2. Initial Departure Assessment.

Assess the runway from which ATC desires to vector departing aircraft below the MVA/MIA using paragraph 12.2.1 to determine the location of 40:1 OCS penetrations which are not considered as low, close-in obstacles. The length of the ICA is based on a climb to 400 feet above the DER rounded to the nearest foot. When requested, provide the requesting ATC facility a graphical depiction of the departure penetrations to assist facility managers in visualizing the departure obstacle environment.

12.5.3. Select a DVA Method.

Establish a DVA that either:

(a) isolates penetrating obstacles;
(b) uses a range of authorized headings to define a sector;
(c) climbs to an initial MVA/MIA within a range of headings,
(d) defines an area which avoids penetrating obstacles; or

(e) uses a combination of these methods.

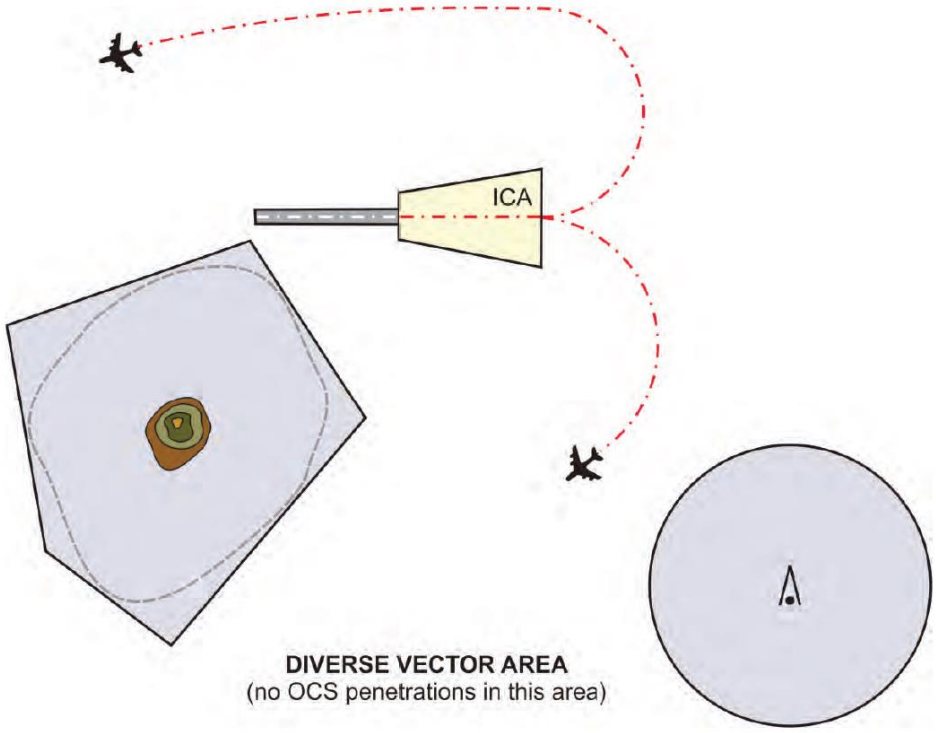
a. Isolate penetrating obstacles. This method is generally suitable for isolating single obstacles, or a group of obstacles in proximity to each other. Boundaries surrounding obstacles that penetrate a departure runway's OCS are established that define an area where vectors below the MVA/MIA are prohibited. Vectors below the MVA which avoid the isolation areas are permitted within the diverse departure evaluation area (25/46 NM from DRP as applicable), minus 5 NM to account for worst case radar separation requirements.

(1) Construct isolation area boundaries around all penetrating obstacles using the MVA sector construction specified in Vol 1, Chapter 10, except a DVA for an ARTCC must use an isolation boundary that provides 5 NM of separation from an obstacle. Consider the ease in constructing and documenting isolation area boundaries when determining the shape of an isolation area which surrounds multiple obstacles or terrain points (zone feature). For example, to simplify construction, documentation, and radar video mapping of an isolation area, it may be preferable to construct the area using only a circle or by using only a minimal series of points and lines. Figure 12-5-1 depicts an example with two isolation areas; one is a circle around a single obstacle and the other is defined by points and lines to define the prohibited area around a terrain contour of irregular shape.

(2) Isolation areas must not overlie any part of the departure runway between the DRP and the DER, nor any part of the ICA associated with the departure runway.

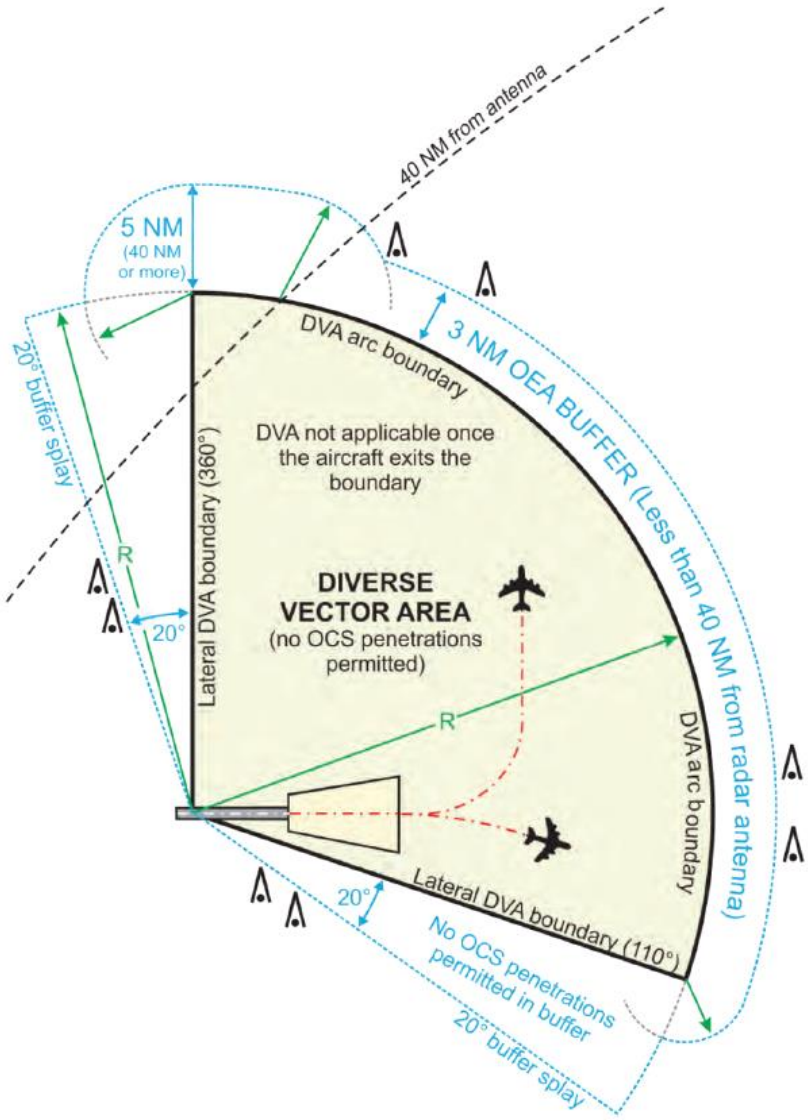
(3) Isolation areas must be located so that sufficient room to vector departing aircraft is provided which would allow ATC to issue vectors as necessary to avoid the areas. This determination must be made in collaboration with the air traffic facility.

Figure 12-5-1. Isolation Areas



b. Define a range of authorized headings. An ATC facility may desire the establishment of a DVA sector which is comprised of a range of authorized headings from the departure runway. For example, the DVA may permit the assignment of headings 360 clockwise through 110 within the DVA evaluation area. The assignment of radar vectors that exceed the authorized range of headings is not permitted until the aircraft reaches the MVA/MIA (see figure 12-5-2).

Figure 12-5-2. Range of Headings Sector



(1) Construct lateral sector boundaries from the DRP which correspond to the desired headings using the Departure Sectors criteria of paragraphs 12.2.2 and 12.2.3, except the sector boundaries must diverge by a minimum of 30 degrees.

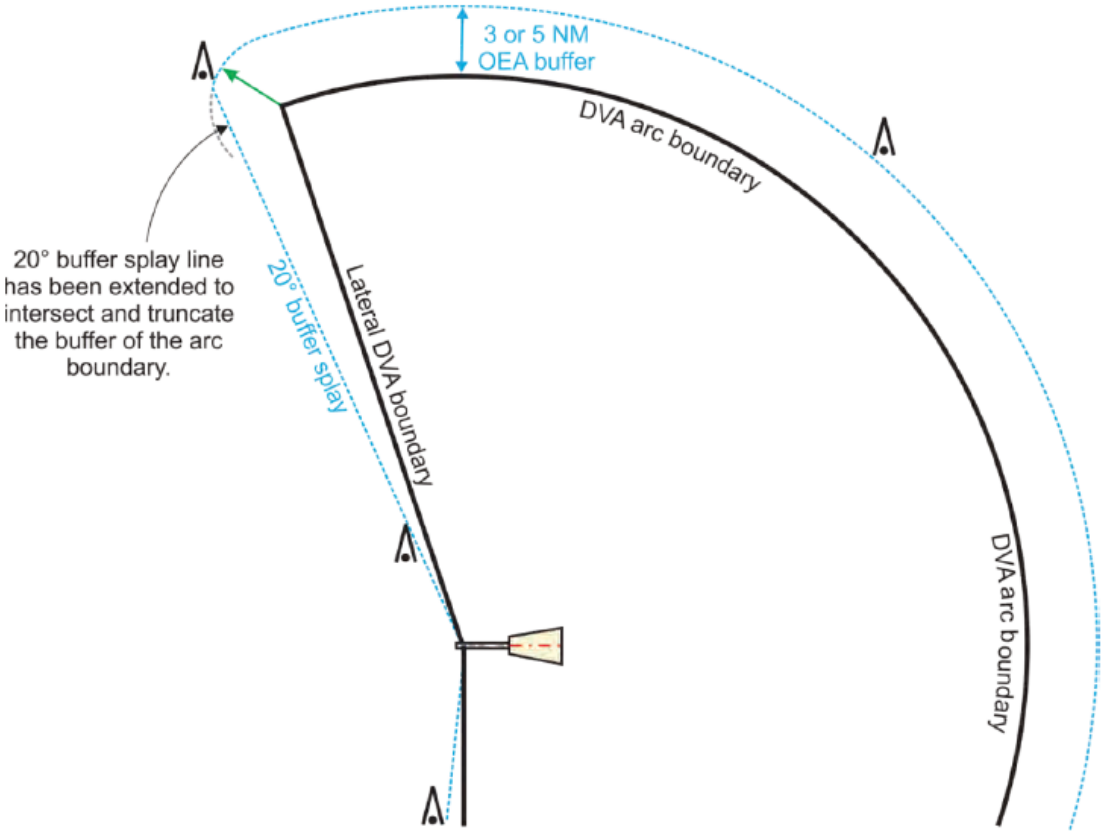
(2) Connect each lateral boundary with an arc centered on the DRP using radius “R” which is equivalent to the desired distance for the DVA.

(3) An OEA buffer expands outward from the DVA boundaries. The buffer of the DVA arc boundary must meet the distance requirements of Vol 1, Chapter 10, Paragraph 10.3.2.a., except a 5 NM buffer always applies to a DVA that will be used by an ARTCC. The lateral buffers begin at DRP and splay outward from the lateral boundaries by 20 degrees.
(4) Connect the 20-degree buffer splay lines with the buffer of the arc boundary as follows:

(a) When the 20-degree splay line is outside the buffer of the arc boundary, join the two buffers with an arc centered on the DRP using radius “R” (see figure 12-5-2).

(b) When the 20-degree splay line is inside the buffer of the arc boundary, extend the splay line until it intersects and truncates the buffer of the arc (see figure 12-5-3).

Figure 12-5-3. Truncation of Lateral Boundary Buffer



(5) The DVA boundaries must provide sufficient maneuvering area to permit ATC to vector an aircraft to remain within the DVA until the aircraft can climb to the MVA/MIA. Determination of sufficient maneuvering area must be made in collaboration with the ATC facility.

c. Climb to an Initial MVA/MIA. ATC may request a DVA based on a range of headings to an initial MVA/MIA. For example, they may request a DVA in the form of, “009 CW 190 to 3500 ft.”

For a DVA of this type, it is necessary to obtain and refer to the currently approved MVA/MIA chart which depicts the sector boundaries and minimum altitudes (see figures 12-5-4 through 12-5-8).

Note: "Initial MVA/MIA" is defined as the altitude at which the DVA terminates and the MVA/MIA is used to provide radar vector service. It will be identified by the requesting ATC facility.

(1) Determine the preliminary 40:1 search boundary's radii (in feet); RA and RB.

(a) R_A =(Initial MVA/MIA -DER Elevation-951-304)× 40

(b) R_B =(Initial MVA/MIA -Airport Elevation-951-400)× 40

Note: 951 represents the least amount of ROC possible (after rounding) within an MVA sector.

Example calculation where MVA is equal to 3500 and DER equal to 618:

R_A =(3500 - 618-951-304)× 40
= 1627 X 40
= 65080

(2) Construct a preliminary search area on the diverse A side of the departure reference line (DRL). Establish point Y and point Z at distance RA from each corner of the ICAE in the direction of the departure along a line which is parallel to the runway centerline. Swing an arc with radius RA centered on each corner of the ICAE from points Y and Z away from the runway centerline until it intersects the DRL. If the distance from the DRP to the intersection of the arc and the DRL is less than RA, then the preliminary search area must be expanded. Expand the area by establishing Points W and X along the DRL at a distance equal to RA and tangentially connect each arc to each respective point (see figure 12-5-5). Complete the search area with a line that connects point Y to point Z (see figures 12-5-4 and 12-5-5).

(3) Construct a preliminary search area on the diverse B side of the DRL using the radius RB. Swing a 180-degree arc centered on the DRP beginning at the DRL to encompass the start end of the runway (see figure 12-5-4).

Figure 12-5-4. Preliminary Search Area Boundary

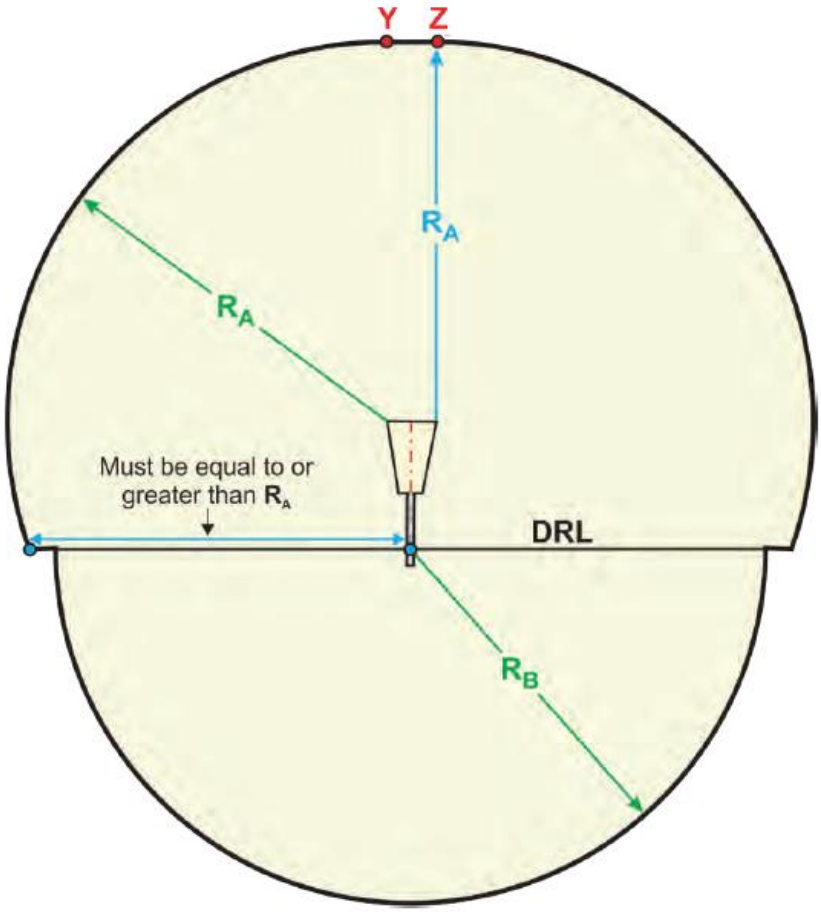
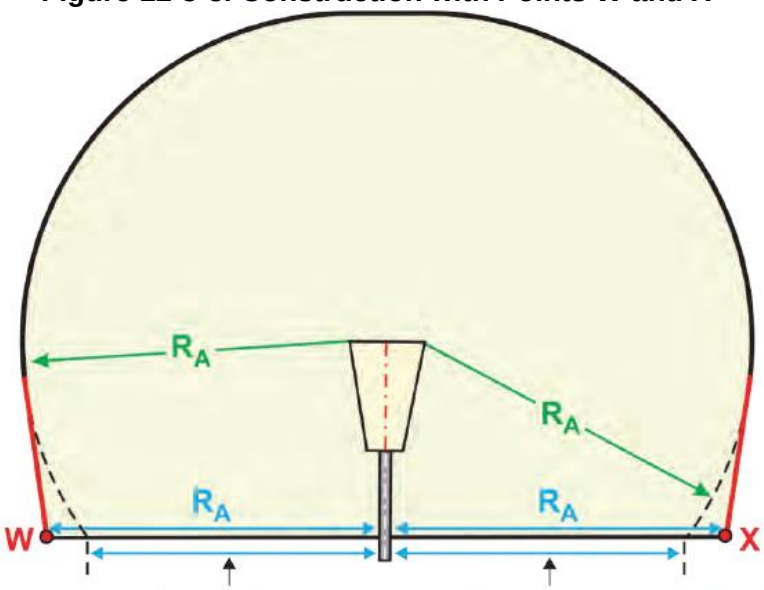


Figure 12-5-5. Construction with Points W and X



When distance from DRP to intersection of DRL and arc is less than R_A, then points W and X must be established along the DRL at a distance equal to R_A. Connect each point tangentially to each respective arc.

(4) Identify all 40:1 OCS penetrations (other than low, close-in) located within the preliminary search area boundaries, or 3/5 NM (appropriate MVA buffer distance per chapter 10, or 5 NM for an MIA) beyond the next higher MVA/MIA sector boundary, whichever is encountered first (see figures 12-5-6 and 12-5-7).

(5) Establish lateral boundaries and associated buffers that avoid the 40:1 penetrations using the departure sectors criteria of paragraph 12.2.2. The maximum range of permitted headings (for example, 310 CW to 050) corresponds to the lateral boundaries. All headings are available when no 40:1 penetrations are located within the search area boundaries. The final OEA includes those areas within the boundaries of the search area located between the 20-degree splay lines (see figure 12-5-8).

Figure 12-5-6. MVA Chart With Applicable Buffer Areas

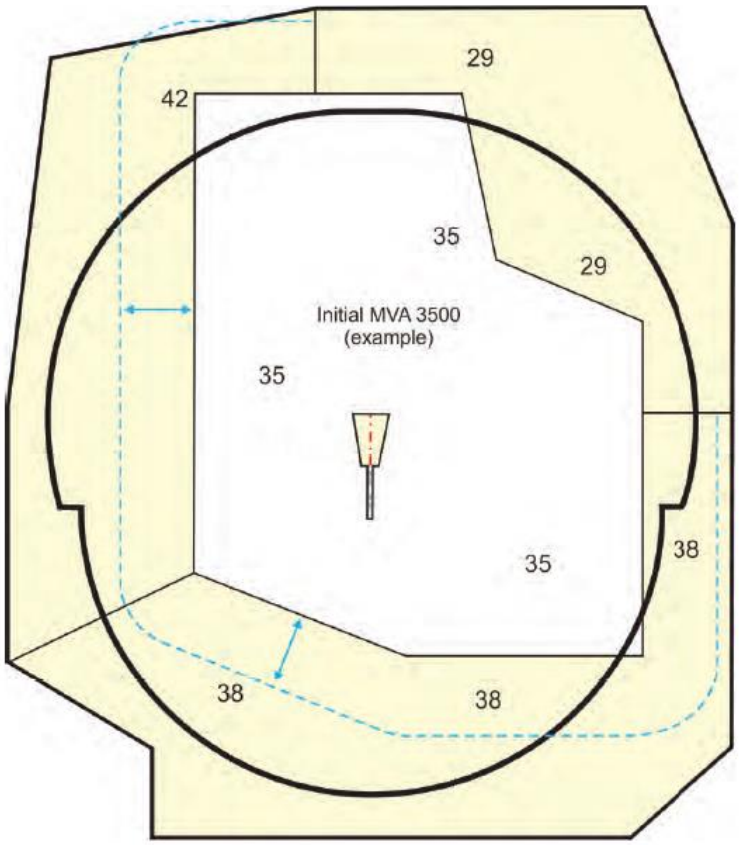


Figure 12-5-7. Obstacle Search Area

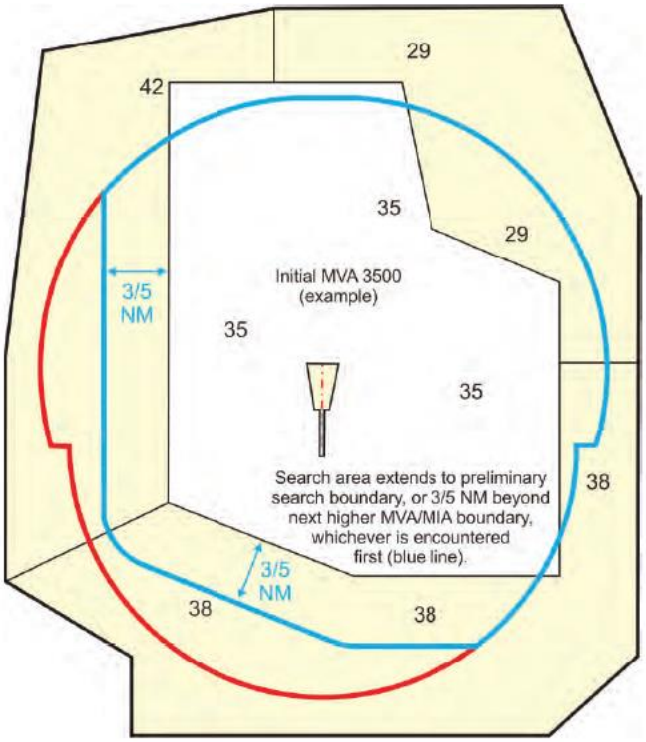
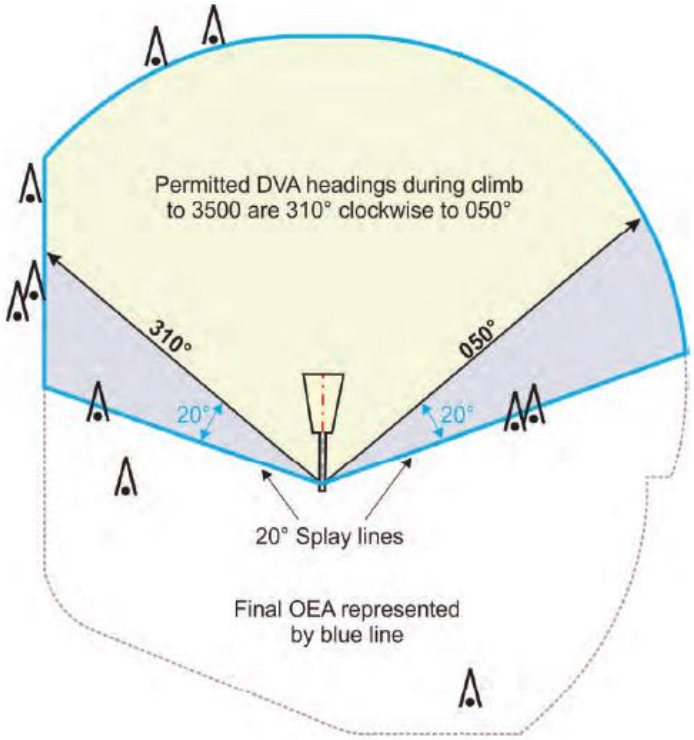


Figure 12-5-8. Permitted DVA Headings Based on Obstacles

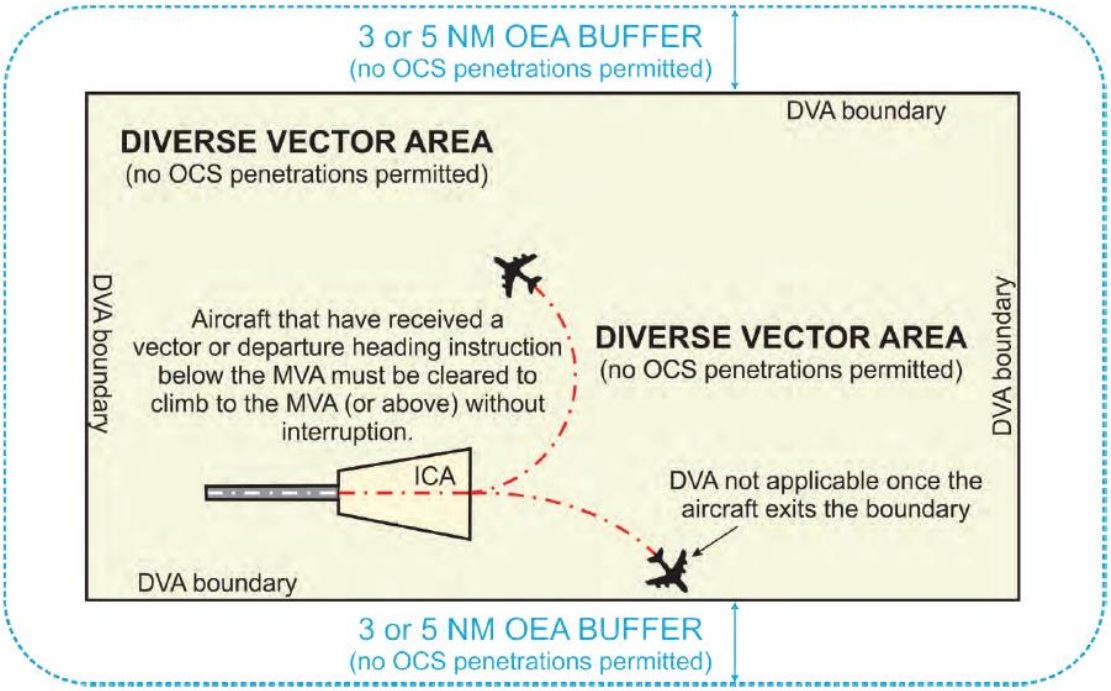


d. Define an area. An area may be defined which excludes all obstacles (low, close-in obstacles are permitted) that penetrate the departure OCS (see figure 12-5-9).

(1) Construct the area boundary and an OEA buffer using the MVA sector construction specified in section 11-3. The defined area may take the form of any shape; however, it must be determined in consultation with the ATC facility to ensure it meets their operational needs and to ensure it provides sufficient maneuvering area for ATC to vector an aircraft to remain within the DVA until the aircraft can climb to the MVA/MIA.

(2) The area boundary must fully encompass the entire width of the departure runway from the DRP towards the DER, as well as the entire ICA associated with the departure runway.

Figure 12-5-9. Defined Area



12.5.4. Climb Gradients.

A DVA that does not require a climb gradient in excess of 200 ft/NM is preferred; however, operational requirements may necessitate a higher climb gradient. When an obstacle penetrates the 40:1 OCS within the DVA OEA, establish a climb gradient and climb gradient termination altitude in accordance with paragraph 12.1.4.

Note: Do not establish climb gradients for low, close-in obstacles or for obstacle that have been isolated in accordance with paragraph 12.5.3.a.

CHAPTER 13. PRECISION APPROACH AND LDA WITH GLIDE SLOPE

SECTION 13-1. GENERAL INFORMATION AND CRITERIA

13.1. General Information

13.1.1. Purpose

This chapter contains criteria applicable to conventional instrument approach procedures with vertical guidance. Apply these criteria to approaches based on instrument landing system (ILS), microwave landing system (MLS), precision approach radar (PAR), and localizer type directional Aids (LDA) with glide slope. See Volume 2 for WAAS and LAAS.

13.1.2. Background

ILS meets the precision approach (PA) standard and may be authorized CAT I, II or III landing minimums. LDA with glide slope only qualifies for APV minimums. PAR and MLS meet the PA performance standard, but may be authorized CAT I landing minimums only.

13.1.3. MSA, Feeder, Initial and Intermediate Segment

For RNAV based feeder, initial and intermediate segments, apply criteria in Volume 2. Otherwise apply criteria in Volume 1, Chapter 2, sections 2 thru 4 except as follows:

a. MSA. Procedures that require GNSS may apply paragraph 2.2.2.b(2) in lieu of 2.2.2.b(1).

b. Initial segment.

(1). Procedure turn. The PT completion altitude must not be lower than the glidepath intercept altitude or more than 500 feet above the PFAF altitude.

(2). High altitude teardrop turn. The teardrop turn completion altitude must not be lower than the PFAF altitude or more than 4000 feet above the PFAF altitude.

c. Intermediate segment. The intermediate segment begins at the IF and extends along the FAC extended to the PFAF. Where a turn from the initial course to the FAC extended is required, the initial course must intercept at or before the IF.

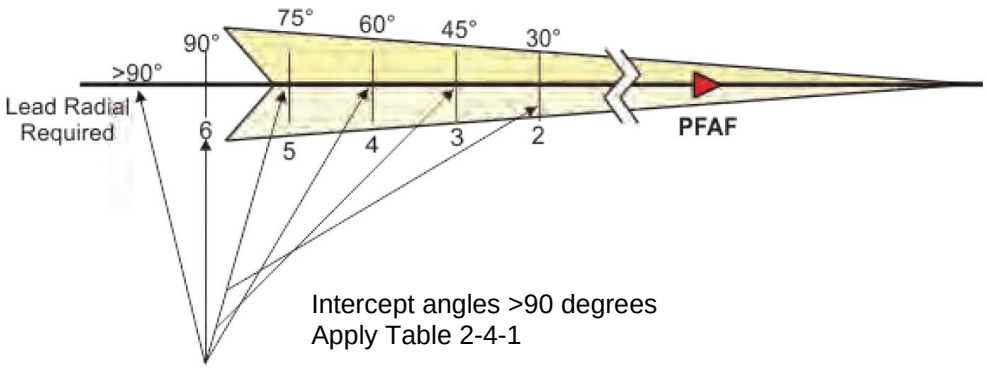
(1). Length. The minimum length of the intermediate segment is 2 NM. Minimum segment length varies where a turn is required at the IF (see figure 13-1-1).

(a) Length is determined by the magnitude of heading change in the turn on to the FAC extended. Use formula 13-1-1 or formula 13-1-2 to determine the minimum length. The maximum angle of intersection is 90 degrees unless a lead radial as specified in paragraph 2.3.3.a, is provided and the length of the intermediate segment is increased as specified in table 2-4-1.

(b) Where the initial segment is based on an arc and the DME source is not collocated with the FAC facility, determine the intercept initial/intermediate segment intercept angle on approach procedures using formula 13-1-3 or formula 13-1-4 (see figure 13-1-2).

1. Use formula 13-1-3 where the DME source is on the arc side of the FAC extended.
2. Use formula 13-1-4 where the DME source is not on the arc side of the FAC extended.

Figure 13-1-1. Minimum Intermediate Segment Length, CAT C, D, E



Formula 13-1-1. Minimum Intermediate Segment Length, CAT A, B

$$\mathbf{CAT\ AB\ MIN_{Lenght}} = \frac{\boldsymbol{\theta}}{\mathbf{18}}$$

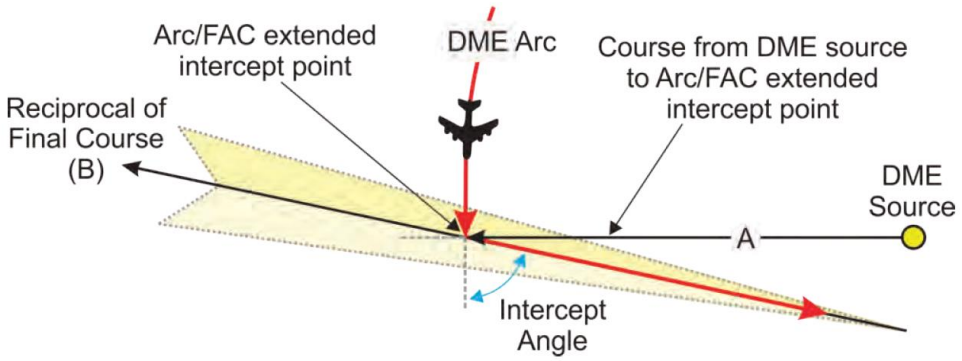
Where:
θ = Intercept angle

Formula 13-1-2. Minimum Intermediate Segment Length, CAT C, D, E

$$\mathbf{CAT\ CDE\ MIN_{Lenght}} = \frac{\boldsymbol{\theta}}{\mathbf{15}}$$

Where:
θ = Intercept angle

Figure 13-1-2. DME Source on Arc Side

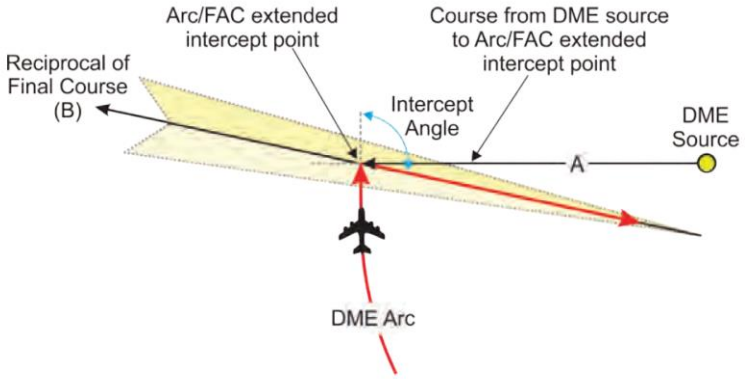


Formula 13-1-3. FAC intercept angle, DME Source on Arc Side

$$\mathbf{90 - [A - B] = Intercept\ Angle}$$

Where:
A = Course from DME source to intercept point
B = Reciprocal of FAC

Figure 13-1-3. DME Source Opposite the Arc Side



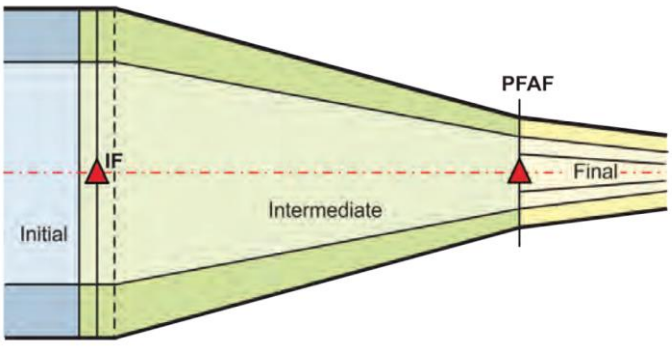
Formula 13-1-4. FAC Intercept Angle, DME Source Opposite the Arc Side

$$\mathbf{90 + [A - B] = Intercept\ Angle}$$

Where:
A = Course from DME source to intercept point
B = Reciprocal of FAC

(2). Width. The intermediate trapezoid begins at the width of the initial segment at the earliest point the IF can be received, and beginning at the latest point the IF can be received it tapers to the width of the final segment at the plotted position of the PFAF (see figure 13-1-4).

Figure 13-1-4. Intermediate Segment Width



(3). Altitude selection. The intermediate altitude must not be lower than the PFAF altitude.

13.1.4. General Requirements

a. GPA (see Volume 1, paragraphs 2.5.2 and 2.5.3).

b. TCH. The published TCH (nearest whole foot) should accommodate the largest aircraft height group normally expected to use the runway and must not be less than the minimum or exceed the maximum TCH.

(1) The maximum published TCH is 60 feet regardless of height group.

(2) CAT I. The TCH is based on achieving an acceptable wheel crossing height (WCH). The WCH is the difference between the published TCH and the approximate glidepath antenna-to-wheel height (see table 13-1-1).

(a) The optimum TCH provides a 30 foot WCH. The minimum WCH is 20 feet and the maximum WCH is 50 feet.

(b) Displaced Threshold. The TCH over a displaced threshold may result in a WCH of not less than 10 feet provided:

1. Pavement equivalent to the strength of the landing runway is present prior to the displaced threshold.
2. The calculated height of the glide slope over the beginning of the pavement prior to the displaced threshold is within the minimum/maximum TCH values.

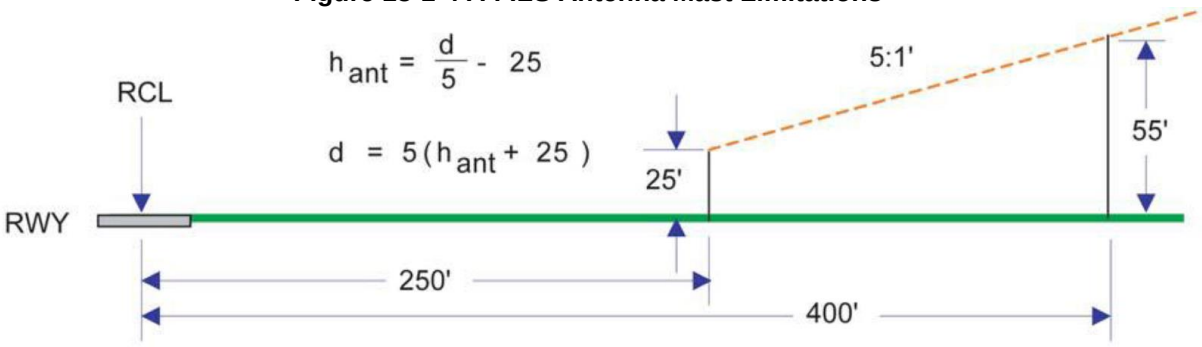
(3) CAT II/III. The optimum TCH is 55 feet. The minimum published TCH is 50 feet regardless of height group.

(4) For the purposes of this chapter, the TCH (unrounded value) is the design TCH designated within the appropriate data source.

c. ILS Antenna Mast Height Limitations for Obstacle Clearance

The standard for locating the ILS antenna mast or monitor is a MINIMUM distance of 400 feet from the runway, measured perpendicular to RCL. The antenna mast should not exceed 55 feet in height above the elevation of the runway centreline nearest it (see Figure 13-1-4 A). At locations where it is not feasible for technical or economic reasons to meet this standard, the height and location of the antenna is restricted according to formula 13-1-4 A.

Figure 13-1-4 A : ILS Antenna Mast Limitations



Formula 13-1-4 A. ILS Antenna Mast Height Limitations	
Math Notation	$h_{ant} = \frac{d}{5} - 25$, AND $d = 5(h_{ant} + 25)$
Standard Text	H_{ANT}=D/5-25 D = 5(H_{ANT}+25)
Given values: H_{ant} = d =	max height of mast above RCL abeam mast (ft) perpendicular dist from RCL (250' MINIMUM)

Table 13-1-1: TCH Requirements.

Representative Aircraft type	Approximate Glidepath to Wheel Height	Recommended TCH +/- 5 Feet	Remarks
Height Group 1 General Aviation, Small Commuters, Corporate Turbojets, T-37, T-38, C-12, C-20, C-21, T-1, Fighter Jets, UC-35,T-3, T-6	10 Feet or less	40 Feet	Many runways less than 6,000 feet long with reduced widths and/or restricted weight bearing which would normally prohibit landings by larger aircraft.
Height Group 2 F-28, CV-340/440/580, B-737, C-9, DC-9, C-130, T-43, B-2, S-3	15 Feet	45 Feet	Regional airport with limited air carrier service.
Height Group 3 B-727/707/720/757, B-52, C-135, C-141, C-17, E-3, P-3, E-8, C-32, A-300/310, A-319/320/321	20 Feet	50 feet	Primary runways not normally used by aircraft with ILS glidepath-to-wheel heights exceeding 20 feet.
Height Group 4 B-747/767/777, L-1011, DC-10, A-330, A-340, A-380 (planned), B-1, KC-10, E-4, C-5, VC-25	25 Feet	55 Feet	Most primary runways at major airports.

Notes:

1. To determine the minimum allowable TCH, add 20 feet to the glidepath-to-wheel height.
2. To determine the maximum allowable TCH, add 50 feet to the glidepath-to-wheel height (not to exceed 60 ft).

d. PFAF. Calculate the along-track distance in feet from the LTP/FTP to the PFAF using formula 13-1-5.

Formula 13-1-5. Distance LTP/FTP to PFAF

$$\mathbf{D_{PFAF}} = \mathbf{r} \times \frac{\mathbf{In}\left(\frac{\mathbf{r} + \mathbf{PFAF_{alt}}}{\mathbf{r} + \mathbf{LTP_{elev}} + \mathbf{TCH}}\right)}{\mathbf{tan(GPA)}}$$

Where:

$\mathbf{LTP_{elev}}$ = LTP/FTP MSL elevation
$\mathbf{PFAF_{alt}}$ = Intermediate segment altitude

e. NDB as GP check altitude

When installed with the ILS, the NDB must meet the accuracy standards of the Marker Beacon (ICAO Annex 10, Vol 1 - difference filed) (i.e. the NDB must be under the centerline of localizer beam). Cross bearings (from NDB, VORs, etc) to the FAF do not meet accuracy standards for the GP check altitudes.

Notes:

1. For the purpose of TP308/GPH209, when used as a substitute for an outer marker in establishing GP check altitude, an NDB shall be considered under the centerline of the localizer beam when it exists within the “W” Obstacle Clearance Surface of an ILS Instrument Approach Procedure. Consider that the goal is to get as close to the extended centreline as practicable while realizing there are physical and logistical limitations at times.

2. For DME as GP check altitude, see Vol 1, Chapter 9, paragraph 9.1.2.

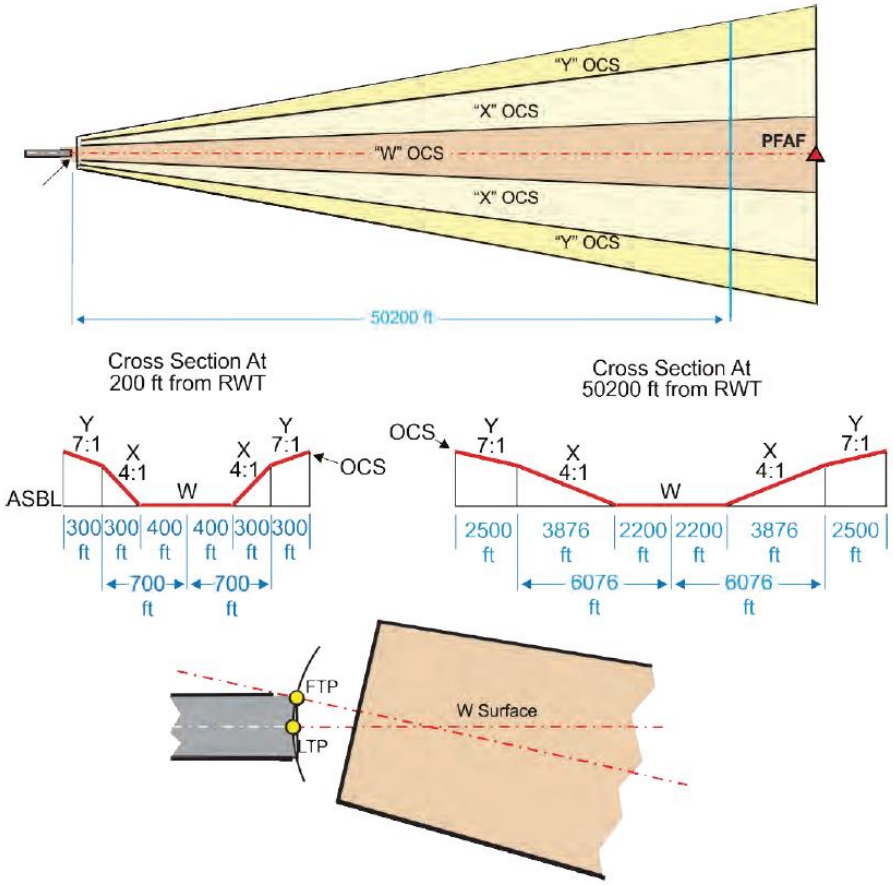
SECTION 13-2. FINAL APPROACH SEGMENT

13.2. Final Approach Segment

13.2.1. Final Segment

a. Area. The area originates 200 feet from LTP or FTP and extends to the PFAF. The primary area consists of the “W” and “X” OCS, and the secondary area consists of the “Y” OCS (see figure 13-2-1).

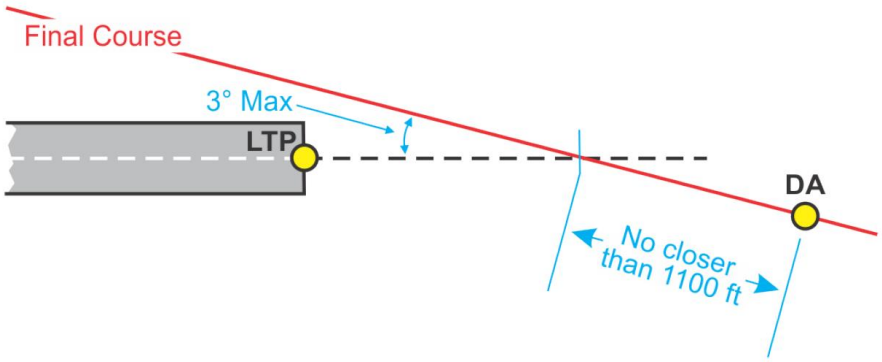
Figure 13-2-1. Final Segment OEA/OCS



b. Alignment.

(1) ILS. The final course is normally aligned with the RCL extended (±0.03 degrees) through the LTP (± 5 feet). Where a unique operational requirement indicates a need to offset the course from RCL, the offset must not exceed three degrees. The offset course must intersect the runway centerline at a point no closer than 1100 feet inside the decision altitude (DA) point (see figure 13-2-2). The DA point for this evaluation is the point on the glideslope where the altitude is equal to the published DA less any RASS and precipitous terrain adjustments. For offset courses the minimum HAT is 250 feet and the minimum RVR is 2600.

Figure 13-2-2. ILS Offset Final



(2) LDA with GS. The final course maximum offset from RCL extended is 15 degrees. The final course must cross the RCL extended at least 3000 feet from LTP, but no more than 5200 feet from LTP.

13.2.2. OCS Slope

a. Determine the OCS slope associated with a specific GPA using formula 13-2-1.

Formula 13-2-1. OCS Slope

$$\mathrm{OCS_{Slope}} = \frac{102}{\mathrm{GPA}}$$

Example:
$\mathrm{OCS_{Slope}}$=102/3.1
$\mathrm{OCS_{Slope}}$ ≈32.90

b. Origin. The OEA (all OCS surfaces) originates from LTP elevation at a point 200 feet from LTP (see figure 13-2-3) measured along course centerline and extends toward the PFAF. The longitudinal (along-track) rising W surface slope begins at a calculated distance "$\mathrm{d_{origin}}$" feet from the LTP (use formula 13-2-2).

Formula 13-2-2. Slope Origin Distance

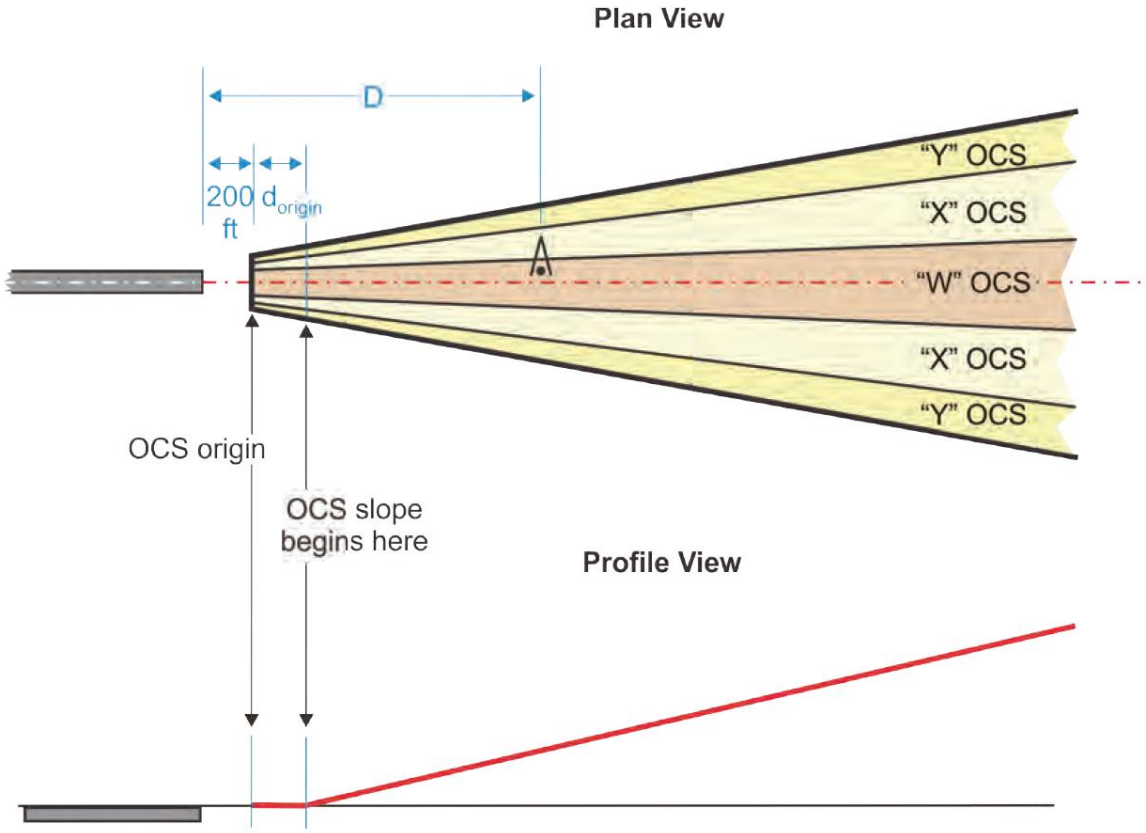
$$\mathrm{d_{origin}} = \text{greater of } 200 \text{ or } 1154 - \frac{\mathrm{TCH}}{\tan(\mathrm{GPA})}$$

Example:

$$\mathrm{d_{origin}} = 1154 - \frac{55}{\tan(3.1)}$$

$\mathrm{d_{origin}}$≈138.45 feet
$\mathrm{d_{origin}}$=200 feet (200 ft or greater)

Figure 13-2-3. OCS Slope Origin When "d_{origin}" Greater than 200



f. Obstacle effective elevation (O_{EE}). Because the earth curves away from the OCS as distance from course centerline increases, the MSL elevation of an obstacle is reduced to account for this. Use formula 13-2-3 to calculate O_{EE}.

Formula 13-2-3. Obstacle Effective Elevation

$$O_{EE} = Obs_{MSL} - \left[(r + LTP_{elev}) \times \left(\cos\left[\frac{OBS_Y \times 180}{r \times \pi}\right]^{-1} - 1\right) + Q\right]$$

Where:
Obs_{MSL} = Obstacle MSL elevation
OBS_Y = Perpendicular distance (feet) from course centerline to obstacle
Q = Obstacle adjustment (feet) for X or Y surface rise. Zero (0) if in the W surface.

Example:

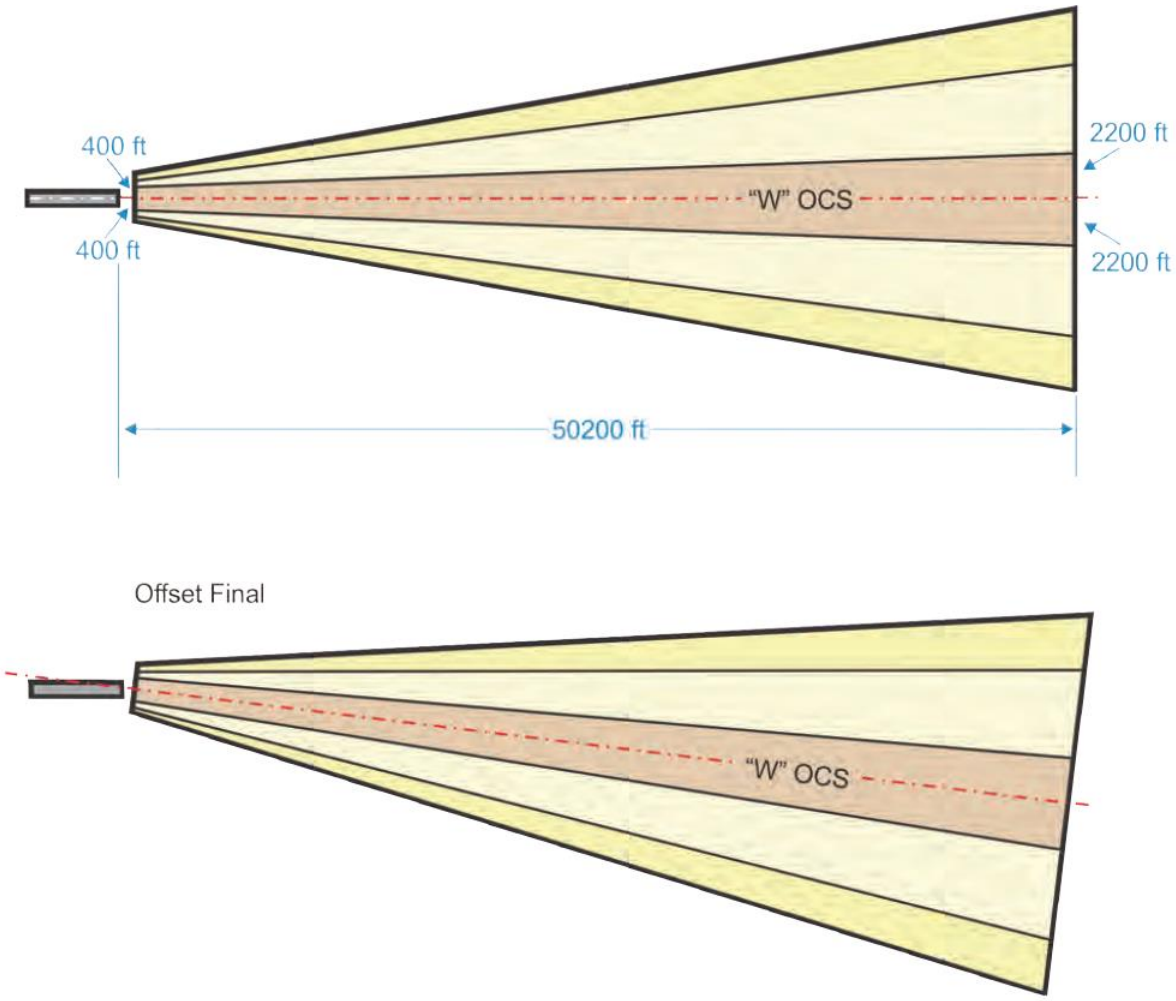
$$O_{EE} = 2768.9 - \left[(r + 1125.4) \times \left(\cos\left[\frac{1432.5 \times 180}{r \times \pi}\right]^{-1} - 1\right) + 192.90\right]$$

$O_{EE} \approx 2575.95$ ft

13.2.3. “W” OCS

a. Width. The width is 400 feet on each side of course at the beginning, and expands uniformly to 2200 feet on each side of course at 50200 feet from LTP/FTP. Use formula 13-2-4 to calculate the “W” OCS half-width at a specified distance.

Figure 13-2-4. “W” OCS



Formula 13-2-4. “W” OCS Half-Width at Specified Distance

$$\mathbf{W_{boundary}} = \mathbf{0.036} \times \mathbf{d_{LTP}} + \mathbf{392.8}$$

$\mathbf{d_{LTP}}$ = distance (feet) from LTP/FTP as measured along FAC
$\mathbf{W_{boundary}}$ = perpendicular distance (feet) from course centerline to “W” surface outer boundary

Example:

$\mathbf{W_{boundary}}$ = 0.036×5462.03+392.8
$\mathbf{W_{boundary}}$ ≈ 589.43 feet

b. Elevation. Use formula 13-2-5 to calculate the "W" OCS angle and formula 13-2-6 to calculate the "W" OCS elevation for any specified distance beyond the OCS origin.

Formula 13-2-5. "W" OCS Angle

$$\mathrm{OCS}_{\mathrm{angle}} = \mathrm{atan}\left(\frac{\mathrm{GPA}}{102}\right)$$

Example:

$\mathrm{OCS}_{\mathrm{angle}} = \mathrm{atan}\left(\frac{3.1}{102}\right)$
$\mathrm{OCS}_{\mathrm{angle}} \approx 1.74^{\circ}$

Formula 13-2-6. "W" OCS Elevation

$$\mathbf{OCS_{elev}} = \frac{(\mathbf{r} + \mathbf{LTP_{elev}}) \times \cos(\mathbf{OCS_{angle}})}{\cos\left[\frac{(\mathbf{d_{LTP}} - \mathbf{d_{origin}}) \times 180}{\mathbf{r} \times \pi} + \mathbf{OCS_{angle}}\right]} - \mathbf{r}$$

Where:

$\mathbf{OCS_{angle}}$= Formula 13-2-5 result
$\mathbf{d_{LTP}}$= Distance (feet) from LTP (FTP if applicable) to point of interest as measured along FAC
$\mathbf{d_{origin}}$ = Distance (feet) from LTP/FTP to OCS slope origin (Formula 13-2-2 result)

Example:

$$\mathbf{OCS_{elev}} = \frac{(\mathbf{r} + \mathbf{1125.4}) \times \cos(\mathbf{1.74})}{\cos\left[\frac{(\mathbf{5280} - \mathbf{200}) \times 180}{\mathbf{r} \times \pi} + \mathbf{1.74}\right]} - \mathbf{r}$$

W $\mathrm{OCS}_{\mathrm{elev}}$ ≈ 1280.35 feet

c. OCS evaluation. Compare the "W" OCS evaluation abeam the obstacle location with the O_{EE}. Lowest minimums are achieved when the "W" surface is clear. If the surface is penetrated by an obstacle take one or more of the following actions:

(1) Remove or adjust the obstruction location and/or height.

(2) Raise the GPA (see paragraph 13.2.7).

(3) Displace the RWT to eliminate the penetration.

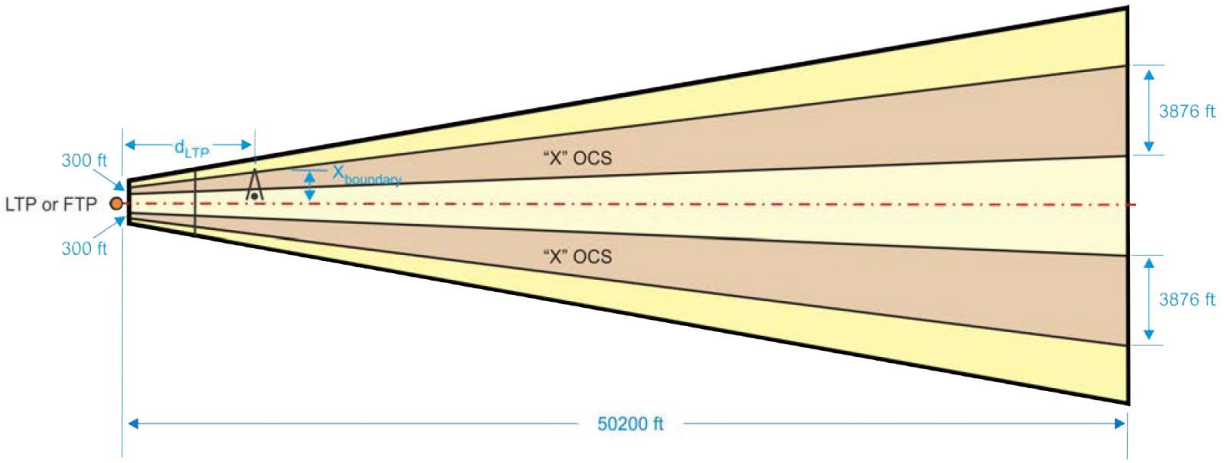
(4) If the penetration cannot be eliminated, adjust the DA (see paragraph 13.2.8).

(5) Raise the TCH. Coordination must be accomplished with appropriate agencies due to the cost of moving ILS equipment.

13.2.4. "X" OCS.

a. Width. Use formula 13-2-7 to calculate the perpendicular distance ($X_{boundary}$) from the course to the outer boundary of the "X" OCS at a specified distance.

Figure 13-2-5. “X” OCS



Formula 13-2-7. Perpendicular Distance to X Boundary

$$X_{boundary} = 0.10752 \times d_{LTP} + 678.496$$

Where:
d_{LTP} = Distance “D” (feet) from LTP (FTP if applicable) to point of interest as measured along FAC
$D_x = X_{boundary}$

Example:
$X_{boundary}$ = 0.10752×5462.03+678.496
$X_{boundary}$ ≈ 1265.77 feet

b. Elevation. The “X” OCS begins at the height of the “W” surface and rises at a slope of 4:1 in a direction perpendicular to the final approach course. The MSL elevation of an obstacle in the “X” surface is reduced by the amount of surface rise. Use formula 13-2-8 to determine the obstacle height adjustment “Q” for use in formula 13-2-3. Evaluate the obstacle in accordance with paragraph 13.2.3.c.

Formula 13-2-8. "X" OCS Obstacle Adjustment

$$Q = \frac{OBS_Y - W_{boundary}}{4}$$

Where:

OBS_Y = Perpendicular distance (feet) from the course centerline to the obstacle
$W_{boundary}$ = Perpendicular distance (feet) between FAC and the "W" surface boundary

Example:

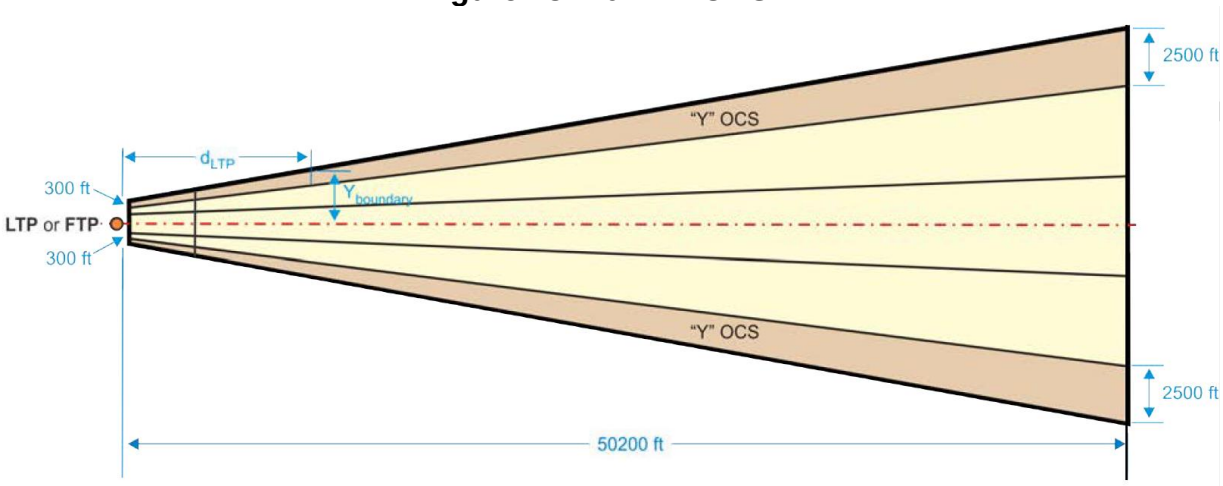
$$Q = \frac{1265.77 - 589.43}{4}$$

Q ≈169.09 feet

13.2.5. "Y" OCS

a. Width. Use formula 13-2-9 to calculate the perpendicular distance ($Y_{boundary}$) from the course to the outer boundary of the "Y" OCS at a specified distance.

Figure 13-2-6. "Y" OCS



Formula 13-2-9. Perpendicular Distance to Y Boundary

$$Y_{boundary} = 0.15152 \times d_{LTP} + 969.696$$

Where:
d_{LTP} = Distance "D" (feet) from LTP (FTP if applicable) to point of interest as measured along FAC
$D_y = Y_{boundary}$

Example:

$Y_{boundary}$ =0.15152 × 5462.03 + 969.696
$Y_{boundary}$ ≈1797.30 feet

b. Obstacle Adjustment. The “Y” OCS begins at the height of the “X” surface and rises at a slope of 7:1 in a direction perpendicular to the final approach course. The MSL elevation of an obstacle in the “Y” surface is reduced by the amount of “X” and “Y” rise. Use formula 13-2-10 to determine the obstacle height adjustment “Q” for use in formula 13-2-3. Evaluate the obstacle in accordance with paragraph 13.2.3.c.

Formula 13-2-10. “Y” OCS at Specified Distance

$$Q = \frac{X_{boundary} - W_{boundary}}{4} + \frac{OBS_Y - X_{boundary}}{7}$$

Where:
$X_{boundary}$= Perpendicular distance (feet) between FAC and the “X” surface boundary
$W_{boundary}$= Perpendicular distance (feet) between FAC and the “W” surface boundary
OBS_Y = Perpendicular distance (feet) from the course centerline to the obstacle

Example:

$$Q = \frac{1265.77 - 589.43}{4} + \frac{1432.5 - 1265.77}{7}$$

Q ≈192.90 feet

13.2.6. DA and Height Above Touchdown (HAT)

The DA value may be derived from the HAT. The minimum HAT for PA CAT I is 200 feet. The minimum HAT for LDA with GS is 250 feet. Calculate DA using formula 13-2-11; calculate HAT using formula 13-2-12.

Formula 13-2-11. DA

$$\boldsymbol{DA = HAT + TDZE}$$

Formula 13-2-12. HAT

$$\boldsymbol{HAT = DA - TDZE}$$

13.2.7. Raising GPA for OCS penetrations

Raising the GPA may eliminate OCS penetrations. Apply formula 13-2-13 to determine the revised minimum GPA.

Formula 13-2-13. GPA Adjustment

$$\theta_{\text{adjusted}} = \tan\left[\text{acos}\left(\frac{\text{SRD}^2 + (\text{r} + \text{LTP}_{\text{elev}})^2 - (\text{r} + \text{O}_{\text{EE}})^2}{2 \times \text{SRD} \times (\text{r} + \text{LTP}_{\text{elev}})}\right) - 90\right] \times 102$$

Where:
SRD = Formula 13-2-14 result
O_{EE} = Formula 13-2-3 result

Example:

$$\theta_{\text{adjusted}} = \tan\left[\text{acos}\left(\frac{3795.85^2 + (\text{r} + 1125.4)^2 - (\text{r} + 1274.5)^2}{2 \times 3795.85 \times (r + 1125.4)}\right) - 90\right] \times 102$$

$\theta_{\text{adjusted}} \approx 4.00^{\circ}$

Formula 13-2-14. Square Root Distance (SRD)

$$SRD = \sqrt{(\text{r} + \text{O}_{\text{EE}})^2 + (\text{r} + \text{LTP}_{\text{elev}})^2 - 2 \times (\text{r} + \text{O}_{\text{EE}}) \times (\text{r} + \text{LTP}_{\text{elev}}) \times COS\left[\frac{(d_{LTP} - d_{origin}) \times 180}{r \times \pi}\right]}$$

Where:
O_{EE} = Formula 13-2-3 result
d_{LTP} =Along track distance (feet) from LTP to penetrating obstacle
d_{origin} = Distance (feet) from LTP to OCS origin

Example:

$$SRD = \sqrt{(\text{r} + 1274.5)^2 + (\text{r} + 1125.4)^2 - 2 \times (\text{r} + 1274.5) \times (\text{r} + 1125.4) \times COS\left[\frac{(3992.7 - 200) \times 180}{r \times \pi}\right]}$$

SRD≈ 3795.85 feet

13.2.8. Adjustment of DA for Final Approach OCS Penetrations.

The DA may be increased to provide sufficient obstacle clearance (see figure 13-2-7).

a. DA distance from LTP/FTP. Use formula 13-2-15 to determine the distance from LTP/FTP to the adjusted DA point (d_{DA}).

Formula 13-2-15. Distance from LTP/FTP To Adjusted DA Point

$$d_{DA} = \frac{r \times \pi}{180} \times \left(90 - OCS_{angle} - \operatorname{asin}\left[\frac{\cos(OCS_{angle}) \times (r + LTP_{elev})}{r + O_{EE}}\right]\right) + d_{origin}$$

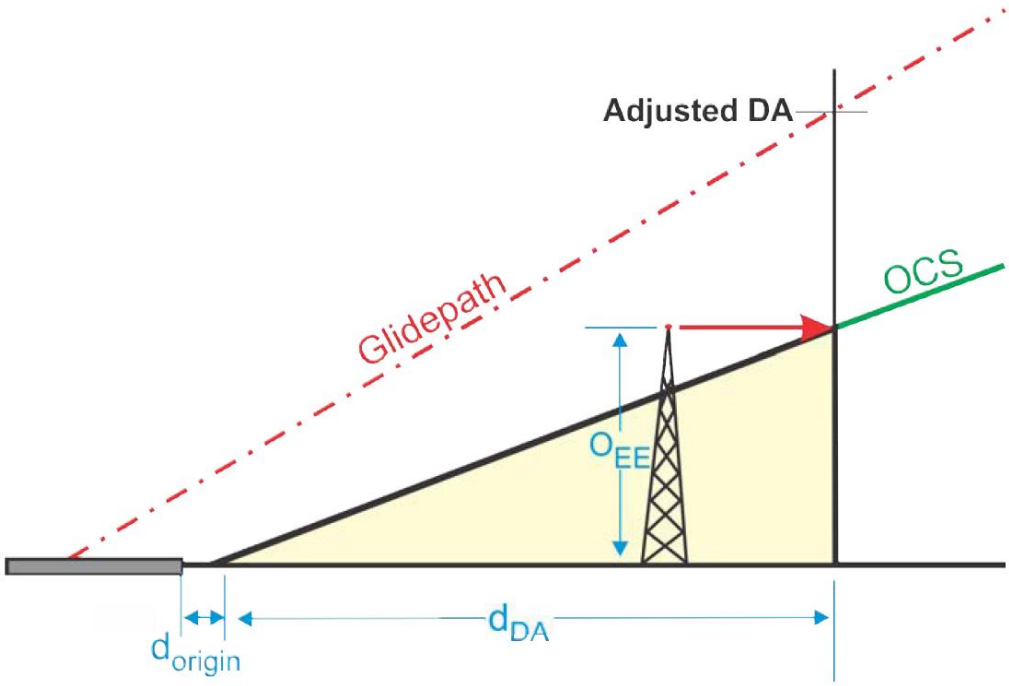
Where:
OCS_{angle}= Formula 13-2-5 result
d_{origin} = Distance (feet) from LTP/FTP to OCS origin
O_{EE}= See Formula 13-2-3 result

Example:

$$d_{DA} = \frac{r \times \pi}{180} \times \left(90 - 1.74 - \operatorname{asin}\left[\frac{\cos(1.74) \times (r + 1125.4)}{r + 1271.5}\right]\right) + 200$$

d_{DA} ≈ 4991.01 feet

Figure 13-2-7. DA Adjustment



b. Use formula 13-2-16 to calculate the adjusted DA.

Formula 13-2-16. Adjusted DA ($\mathbf{DA_{adj}}$)

$$DA_{adj} = \frac{(r + LTP_{elev} + TCH) \times \cos(GPA)}{\cos\left(\frac{d_{DA} \times 180}{r \times \pi} + GPA\right)} - r$$

Where:
d_{DA}= Formula 13-2-15 result

Example:

$$DA_{adj} = \frac{(r + 1125.4 + 55) \times \cos(3.1)}{\cos\left(\frac{4991.01 \times 180}{r \times \pi} + 3.1\right)} - r$$

DA_{adj} ≈ 1451.32 feet (rounded to 1452 feet)

c. Use formula 13-2-17 to calculate the revised minimum HAT and maximum ROC.

Formula 13-2-17. Minimum HAT and Maximum ROC

$$\text{MinHAT and MaxROC}_{Revised} = \frac{GPA}{3} \times 250$$

d. Compare HAT based on adjusted DA and the minimum HAT based on formula 13-2-17. Publish the DA associated with the higher of the two.

SECTION 13-3. CAT I MISSED APPROACH SEGMENT

13.3. CAT I Missed Approach Segment

13.3.1. General Information

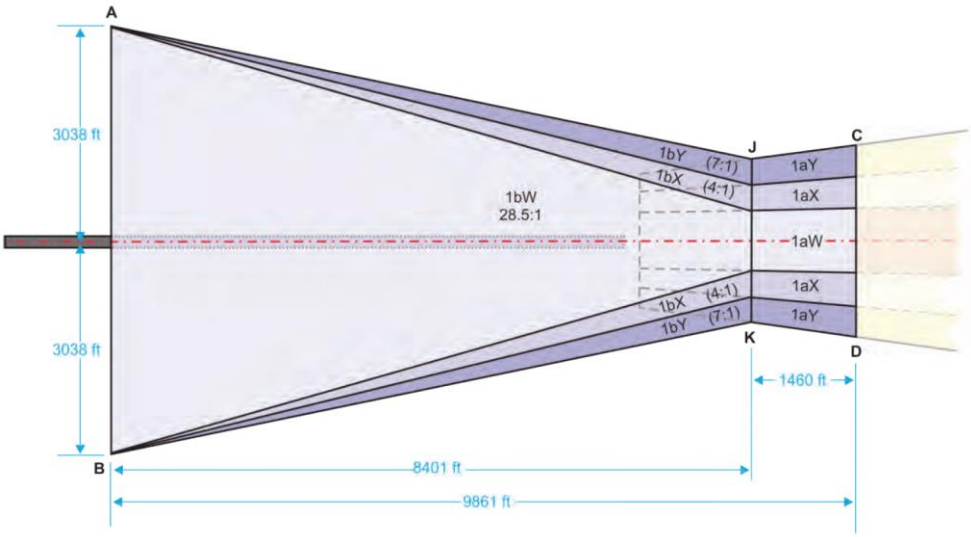
This section applies to missed approach segments based on conventional (non-RNAV) guidance. Apply the LPV missed approach criteria specified in Volume 2 when the missed approach is based on RNAV guidance. The missed approach segment begins at DA and ends at the clearance limit. It is comprised of section 1 (initial climb) and section 2 (from end of section 1 to the clearance limit). The MA procedure is limited to two turns.

13.3.2. Section 1

Apply this paragraph when the final segment criteria specified within Section 13-2 is used to evaluate the final approach segment.

a. Section 1 is aligned with the final approach course. It is comprised of two subsections, 1a and 1b. Section 1 begins at a point where DA is achieved, less any RASS and precipitous terrain adjustments (line C-D). For example, if the published DA is 500 feet and incorporates a 100 foot RASS adjustment, then section 1 would begin at the point where a 400 foot DA point would be located. Section 1 extends 9861 feet from line C-D and terminates at line A-B (see figure 13-3-1).

Figure 13-3-1. Missed Approach Area Section 1



b. Section 1a.

(1) Area. Section 1a begins at line C-D and overlies the final segment OEA. It extends 1460 feet in the direction of the missed approach to line J-K. Section 1a is subdivided into section 1aW, sections 1aX, and sections 1aY. Each of the subsections corresponds to the underlying FAS “W”, “X”, and “Y” surfaces.

(2) OCS. The elevations of the section 1a surfaces are equal to the underlying “W,” “X,” or “Y” surface as appropriate. The section 1a surfaces must not be penetrated.

c. Section 1b.

(1) Area. Section 1b begins at line J-K at the end of section 1a and is aligned with the final approach course extended. It extends 8401 feet to line A-B. This section is subdivided into sections 1bW, sections 1bX, and sections 1bY. Apply formula 13-3-1 to calculate the distance from course centerline to the boundary of these areas.

(a) Section 1bW. This section extends from the end of section 1aW for a distance of 8401 feet. Its lateral boundaries splay from the ending width of section 1aW to a width of 3038 feet each side of the extended FAC.

(b) Sections 1bX. These sections extend from the end of sections 1aX for a distance of 8401 feet. The inner boundaries are shared with the lateral boundaries of section 1bW. The outer boundaries taper to points 3038 feet each side of the extended FAC.

(c) Sections 1bY. These sections extend from the end of sections 1aY for a distance of 8401 feet. The inner boundaries are shared with the outer boundaries of section 1bX. The outer boundaries taper to points 3038 feet each side of the extended FAC.

Formula 13-3-1. Section 1b Boundary Distances

$$1b_{boundary} = \frac{d_{1aEnd} \times (3038 - 1a_{boundary})}{8401} + 1a_{boundary}$$

Where:
$1b_{boundary}$ = The boundary of interest (that is, 1bW, 1bX, or 1bY)
d_{1aEnd} = Distance (feet) as measured along section 1 centerline from line J-K
$1a_{boundary}$ = Distance (feet) as measured along line J-K from centerline of section 1 to respective ending 1a boundary. For example, if calculating 1bX width, then use 1aX distance.

Example:

$$1b_{boundary} = \frac{2591.8 \times (3048 - 481.06)}{8401} + 481.06$$

$1b_{boundary}$ ≈1269.90 feet

(2) OCS elevation.

(a) Section 1bW. The OCS begins at an elevation equal to the ending elevation of section 1aW and rises in the direction of the extension of the FAC at a slope of 28.5:1. Apply formula 13-3-2 to determine the Section 1bW elevation at any distance from line J-K.

(b) Sections 1bX. The OCS begins at the boundary with section 1bW and rises perpendicularly from the extended FAC at a slope of 4:1. Use formula 13-2-8 to calculate the adjustment “Q” for “X” surface obstacles.

(c) Sections 1bY. The OCS begins at the boundary with section 1bX and rises perpendicularly from the extended FAC at a slope of 7:1. Use formula 13-2-10 to calculate the adjustment “Q” for “Y” surface obstacles.

Formula 13-3-2. Section 1bW OCS Elevation

$$\mathrm{OCS}_{\mathrm{Section1bW}} = \ e^{\left(\frac{\mathrm{d_{OCS}}}{\mathrm{r} \times 28.5}\right)} \times (\mathrm{r} + \ \mathrm{OCS}_{\mathrm{start}}) - \mathrm{r}$$

Where:
$\mathrm{d_{OCS}}$ = Distance from end of Section 1a (line J-K) as measured along FAC extension
$\mathrm{OCS}_{\mathrm{start}}$ = Ending elevation of section 1aW
$\mathrm{OCS}_{\mathrm{Section1bW}} = \ \mathrm{OCS}_{\mathrm{elev}}$

Example:

$\mathrm{OCS}_{\mathrm{elev}} = \ e^{\left(\frac{2591.8}{\mathrm{r} \times 28.5}\right)} \times (\mathrm{r} + \ 1191.75) - \mathrm{r}$
$\mathrm{OCS}_{\mathrm{elev}}$ ≈1282.70 feet

(3) OCS evaluation. The section 1bW, 1bX, and 1bY surfaces must not be penetrated. Use formula 13-3-3 to determine the amount of section 1b surface penetration.

Formula 13-3-3. Section 1b Surface Penetration

$$\mathrm{p} = \ \mathrm{O}_{\mathrm{MSL}} - \ \mathrm{Q} - \mathrm{1bW}_{\mathrm{elev}}$$

Where:
$\mathrm{O}_{\mathrm{MSL}}$ = Obstacle elevation (MSL)
Q=Obstacle adjustment (feet) for X or Y surface rise. Zero (0) if in the W surface
$\mathrm{1bW}_{\mathrm{elev}}$ =Elevation (feet) of the 1bW surface abeam the obstacle

Example:

p =1325.8−24.22−1282.70
p ≈18.88 feet

(4) OCS penetration. If any section 1b surface is penetrated, take one or more of the following actions (see figure 13-3-2):

(a) Removing or adjusting the obstruction location and/or height.

(b) Raising GPA within categorical limits.

(c) Adjusting DA. For a surface 1b penetration of p feet, the DA point must move $\Delta \mathrm{d_{DA}}$ feet further from the LTP to raise the surface above the penetration (see formula 13-3-4).

Formula 13-3-4. DA Adjustment

$$\Delta d_{DA} = \frac{p \times 28.5 \times FAS_{Slope}}{28.5 + FAS_{Slope}}$$

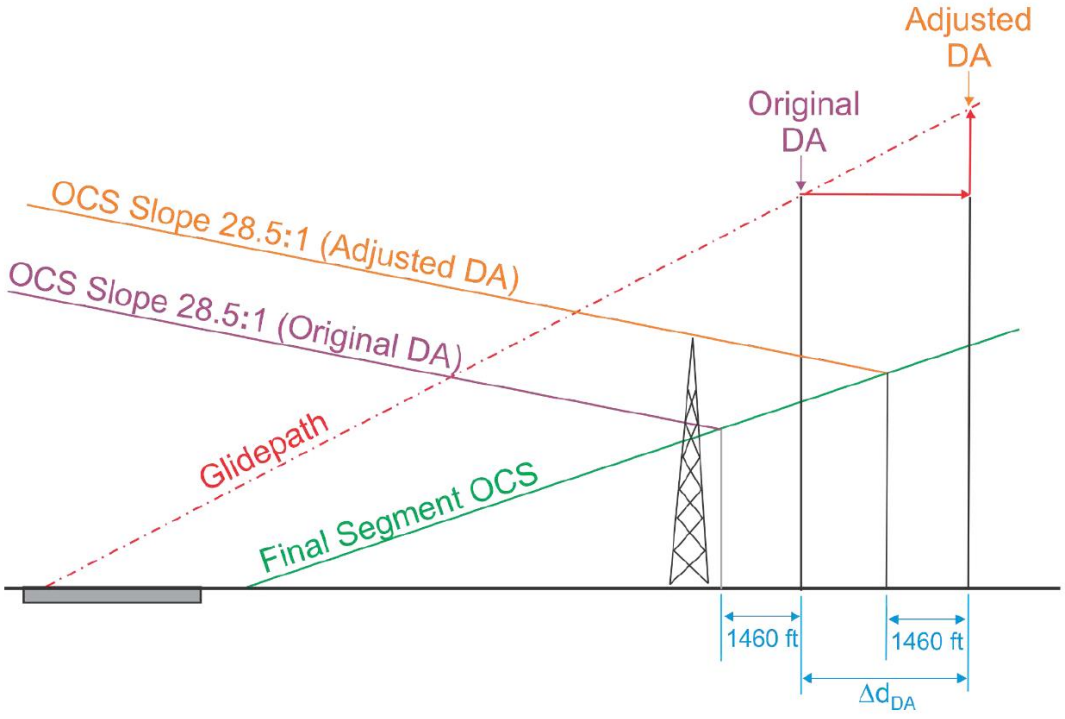
Where:
p=Penetration (feet) of the 1b OCS
FAS_{Slope} =Final approach segment OCS slope ratio

Example:

$$\Delta d_{DA} = \frac{18.88 \times 28.5 \times 34}{28.5 + 34}$$

$\Delta d_{DA} \approx 292.72$ feet

Figure 13-3-2. Penetration of Section 1b OCS



d. Apply formula 13-3-5 to calculate aircraft elevation at the end of section 1.

Formula 13-3-5. Aircraft Elevation at End of Section 1

$$AC_{Section\ 1End} = DA - \tan(\theta) \times 1460 + \frac{8401 \times 0.3048 \times 200}{1852}$$

Where:
DA = DA less any adjustments
θ = GPA
$AC_{Section\ 1End}$ = Section 2 start altitude

Example:

Section 2 start altitude = $1225 - \tan(3.1) \times 1460 + \frac{8401 \times 0.3048 \times 200}{1852}$

Section 2 start altitude ≈1422.45 feet

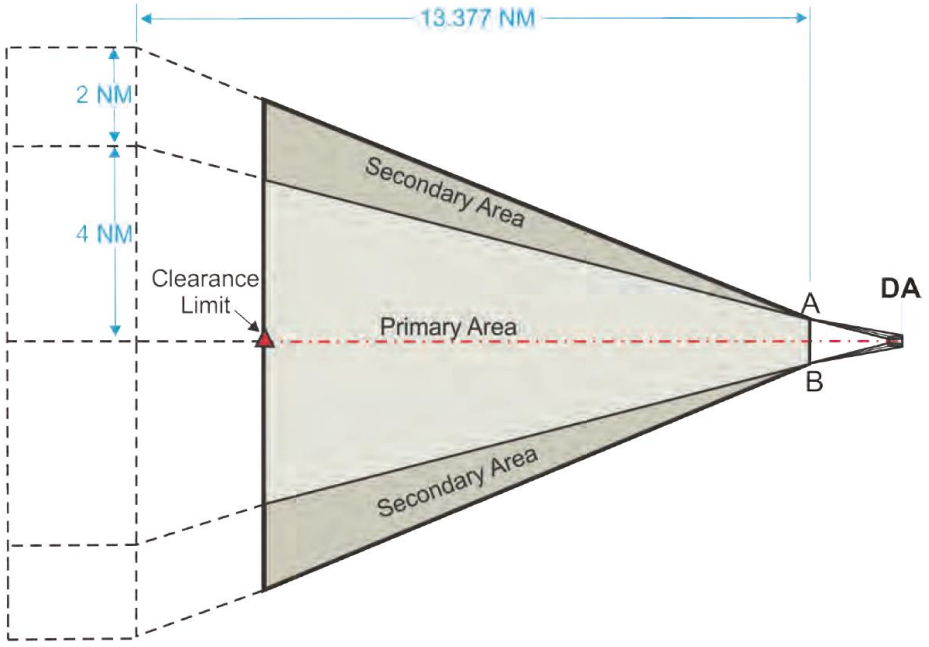
13.3.3. Section 2

Section 2 starts at the end of section 1 centered on the published missed approach course and ends at the clearance limit. Secondary areas may be established where PCG is available. Apply paragraph 2.7.8.d to determine the preliminary charted missed approach altitude, paragraph 2.7.8.e to assess the need for a climb-in-holding evaluation, and paragraph 2.7.8.f to determine the charted missed approach altitude.

a. Straight. Apply to turns of 15 degrees or less from continuation of the FAC.

(1) Straight area. The width increases from ± 3038 feet at line A-B to reach ± 6 NM at a point 13.377 NM from the beginning. Where applicable, secondary areas begin at 0 NM wide and expand to reach 2 NM on both sides of the primary area at 13.377 NM (see figure 13-3-3).

Figure 13-3-3. Section 2, Straight Missed Approach Area with PCG



(2) Obstacle clearance. Within the primary area, obstacles are measured shortest distance to line A-B. The section 2 OCS start height is the section 1 OCS end elevation. The standard OCS in the primary area is a 40:1 slope. For obstacles located in the secondary area, apply the primary OCS slope to a point abeam the obstacle, then apply

a 12:1 secondary OCS (perpendicular to course) from the primary boundary to the obstacle.

b. Combination straight and turning. Apply when a turn fix is established on a course 15 degrees or more from continuation of the FAC or when it is necessary to specify a turn initiation area (TIA) before beginning a turn (see Figure 13-3-4).

(1). Straight portion ending at turn fix. Apply paragraph 13.3.3a for the straight portion, extended to the turn fix. Secondary areas are not permitted in the straight section.

(2). Straight portion ending at a TIA. Specify a minimum turn altitude in a 20-foot increment that is at least 400 feet above TDZE rounded to the nearest foot, and is greater than the aircraft elevation at the end of section 1 (see Formula 13-3-6). Apply paragraph 13.3.3.a until reaching Line A'- B', which is the point the minimum turning altitude is expected to be reached.

(3). Turning portion. The area begins at the end of the straight portion. The flight track and outer boundary radii are specified in paragraph 2.7.6 and Table 2-7-1. The outer and inner boundaries expand to reach ± 6 NM at a point 13.377 NM from the beginning of section 2. Where applicable, secondary areas begin after completion of the turn at 0 NM wide and expand to reach 2 NM on both sides of the primary area at 13.377 NM (see Figure 13-3-4). The secondary area begins where a line perpendicular to the straight flight path, originating at the point of completion of the turn, intersects the outer boundaries of the missed approach segment. For turning obstacle clearance, apply paragraph 2.7.7, except zones 1 and 4 are not applicable. Other exceptions are noted below.

(a) When a fix denotes the turn point and PCG is available following the turn, connect the inside turn boundary to point B', D, or T (when it can be determined, is the point of tangency between the outer boundary radii and the inner boundary expansion line) whichever results in the larger area. Point B' is located on the outside turn edge at the end of the straight portion. Establish point D on the inside boundary of either section 2 or section 1, measured 9000 feet prior to point A' along the boundaries of the straight portion and if necessary, section 1. In zone 2, obstacles are measured shortest distance to the boundary of section 1 or the straight portion of section 2 on the side of the turn. The zone 2 OCS start height is equivalent to the OCS elevation at the turn fix. Zone 3 obstacles are measured shortest distance to point D. The zone 3 OCS start height is the aircraft altitude at the turn fix calculated using Formula 13-3-6 (see Figure 13-3-4).

Formula 13-3-6. Calculated Aircraft Altitude at Turn Fix

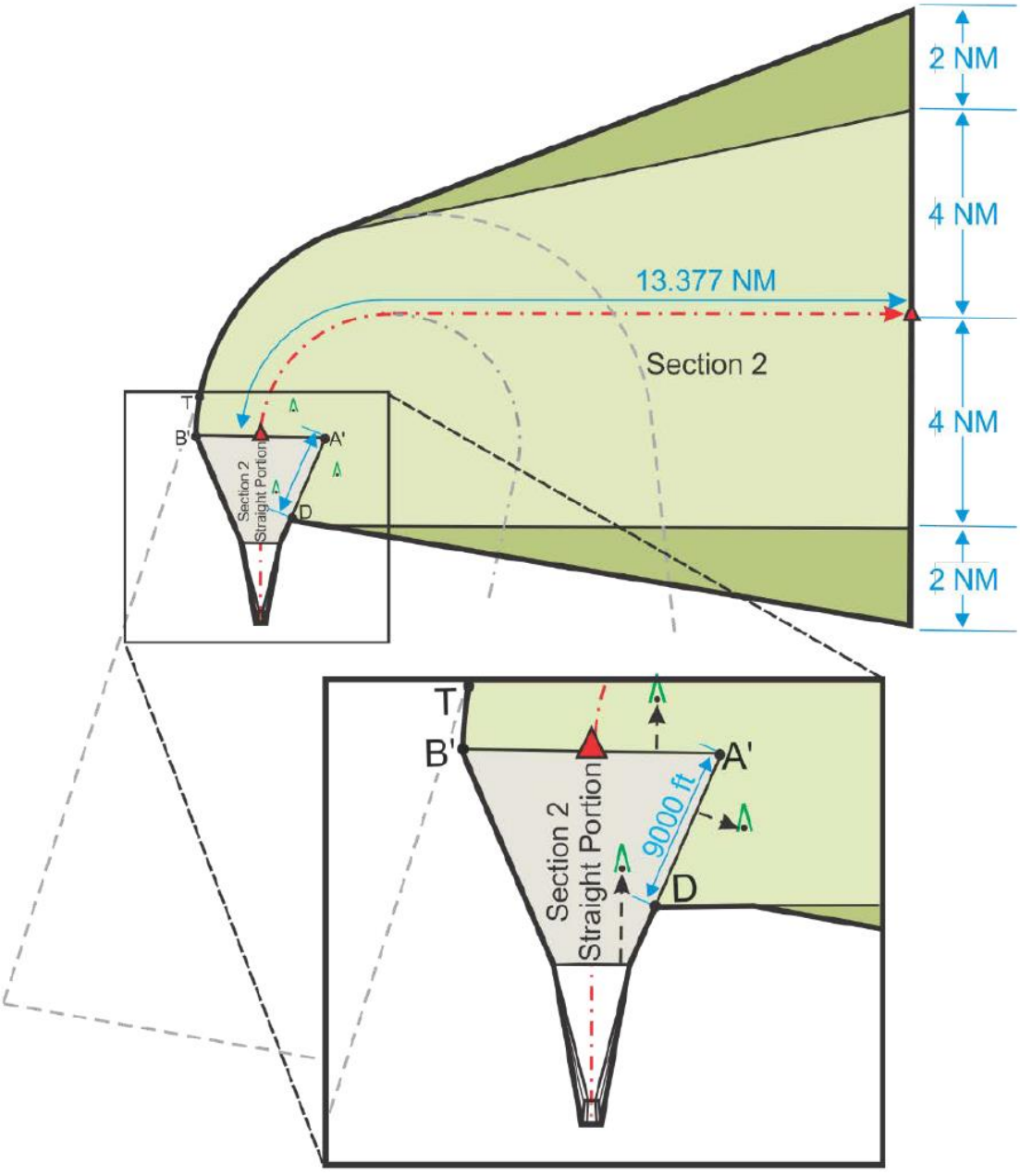
$$\mathrm{turnfix}_{\mathrm{MSL}} = \frac{\mathrm{d}_{\mathrm{straight}} \times 0.3048 \times \mathrm{CG}}{1852} + \mathrm{AC}_{\mathrm{Section\ 1End}}$$

Where:

$\mathrm{turnfix}_{\mathrm{MSL}}$ = Aircraft altitude at turn fix (MSL)
$\mathrm{d}_{\mathrm{straight}}$ = Distance (feet) from end of section 1 to turn point
CG = Climb gradient (200 ft/NM or as specified)
$\mathrm{AC}_{\mathrm{Section\ 1End}}$= Formula 13-3-5 result.

(b) When the turn is based on a TIA, or when PCG is not available following the turn, the inside turn boundary connects to point B', C, or T (when it exists) whichever results in the larger area. Point B' is located on the outside turn edge at the end of the straight portion. In zone 2, obstacles are measured shortest distance to the boundary of section 1 or to the boundary of the straight portion of section 2. The zone 2 OCS start height is equivalent to the end OCS elevation of the straight portion of section 2, less any RASS and precipitous terrain adjustments for the final segment. Zone 3 obstacles are measured shortest distance to point C. The zone 3 OCS start height is the specified turn altitude, less any RASS and precipitous terrain adjustments for the final segment.

Figure 13-3-4. Combination Straight and Turning Missed Approach Area



13.3.4. Missed Approach Climb Gradient

Where the section 2 OCS is penetrated and the lowest HAT is required, a missed approach climb gradient greater than 200 ft/NM may be specified (see Volume 1, paragraph 2.7.10). Calculate the required climb gradient termination altitude and the climb gradient by applying formula 13-3-7 and formula 13-3-8.

Formula 13-3-7. Required Climb Gradient Termination Altitude

$$\mathrm{CG_{term}} = 48 \times \mathrm{D} + \mathrm{O}_{MSL} - \frac{\mathrm{d_{primary}}}{12} + \mathrm{AC_{start}} - \mathrm{OCS_{start}} + \mathrm{RASS}$$

Where:

D = Shortest distance (NM) section 2 origin to obstacle or secondary measurement point
$\mathrm{O_{MSL}}$ = Obstacle elevation (MSL)
$\mathrm{AC_{start}}$ = Starting altitude (feet) of the aircraft
$\mathrm{OCS_{start}}$ = Starting altitude (feet) of the OCS
RASS = greatest RASS adjustment (feet) for final if applicable (either primary remote or secondary)
$\mathrm{d_{primary}}$ = perpendicular distance(feet) from primary area edge

Formula 13-3-8. Required Climb Gradient

$$\mathrm{CG} = \frac{\mathrm{CG_{term}} - \mathrm{AC_{start}} - \mathrm{RASS}}{\mathrm{D}}$$

Where:

$\mathrm{CG_{term}}$= Result from formula 13-3-7
$\mathrm{AC_{start}}$ = Starting altitude (feet) of the aircraft
D = Shortest distance (NM) section 2 origin to obstacle or secondary measurement point
RASS = RASS adjustment used in Formula 13-3-7.

SECTION 13-4. SPECIAL AUTHORIZATION (SA) CAT I MISSED APPROACH

13.4. Special Authorization (SA) CAT I Missed Approach

13.4.1. General Information.

This section describes criteria for the evaluation of SA CAT I ILS procedures and is authorized for use under Transport Canada through the Special Authorization/Specific Approval – SA CAT I.

13.4.2. Final Approach Segment.

The CAT I ILS final approach segment obstacle evaluation applies to the SA CAT I approach authorization. The CAT I procedure must support a 200-foot HAT and lowest possible visibility (no restrictions incurred by lack of infrastructure or obstacle surface penetrations).

13.4.3. Approach Minimums.

a. The lowest SA CAT I HAT is 150 feet. Do not establish an SA CAT I procedure if the required HAT value is greater than 185 feet.

b. SA CAT I procedures require radio altimeter (RA) minimums. If flight inspection determines the procedure RA is unsatisfactory, then an SA CAT I procedure is not authorized.

c. Determine the published RVR using table 13-4-1 (see exception in paragraph 13-4-4.a(2)).

Table 13-4-1. Minimum RVR Values

HAT RANGE	RVR[1]
150-170	1400
171-185	1600

Note: [1] Published RVR must not be less than the minimum aerodrome operating visibility for the runway or surface of intended use (i.e. ½ SM or RVOP visibility or LVOP visibility).

13.4.4. Missed approach evaluation.

a. On runways with established CAT II approaches, evaluate the missed approach segment by applying paragraph 13-5-4 except:

(1) Obstacle penetrations of missed approach surface “A” do not require a HAT adjustment unless the obstacle penetrates the surface by more than 50 feet. When the amount of penetration exceeds 50 feet, adjust the HAT one foot for each foot of surface penetration in excess of 50 feet. For example, if the object penetrates the surface by 58 feet, then increase the HAT from 150 feet to 158 feet.

(2) Do not increase HAT for penetrations of the missed approach surface “B”, “C”, or “D", however if the penetration exceeds the surface height by more than 70 feet, then increase runway visual range (RVR) from 1400 to 1600.

(3) Table 13-4-2 is provided as a quick-reference for assessing each missed approach surface area.

Table 13-4-2. CAT II Missed Approach Surface Penetration Disposition

SURFACE A	SURFACE A1	SURFACE B, C, OR D
1. Adjust HAT upward one foot for each foot of penetration as if the HAT was adjusted, but do not publish a revised HAT until the adjustment exceeds 50 feet; in this case, the amount of HAT adjustment is equal to the amount of penetration that exceeds 50 feet. 2. Increase RVR by applying table 13-4-1 as appropriate. 3. An adjusted HAT greater than 185 feet is not authorized.	Penetration not authorized unless deemed acceptable in accordance with the CAT II missed approach standard.	1. Adjust HAT upward one foot for each foot of penetration in excess of 50 feet as if the HAT was adjusted, but do not publish a revised HAT. 2. Increase RVR by applying table 13-4-1 based on the adjusted HAT. 3. An adjusted HAT greater than 185 feet is not authorized.

b. On runways without a CAT II ILS procedure, apply section 13-3 with the following exceptions.

(1) Aircraft are assumed to be 200 feet above the DA at the end of section 1 (9861 feet from the DA point).

(2) Minimum turn altitude is 400 feet above the TDZE rounded to the nearest foot; therefore, a combination straight and turning missed approach must always be constructed to accommodate a climb to at least 400 feet above TDZE before a turn can commence.

(a) Straight Portion. Do not extend section 1. Construct the straight portion by applying 13.3.3.a (section 2, straight missed approach construction) from the end of section 1 through the necessary distance for the aircraft to reach the specified turn altitude. The straight portion is considered part of section 2. Secondary areas are not permitted in the straight portion.

(b) Turning Portion. The area begins at the end of the straight portion.

(3) Any obstacle located within section 1 of the missed approach that would qualify to be eliminated from consideration under the CAT II missed approach standard may also be eliminated from consideration using the CAT I standard.

c. SA CAT I ILS procedures with obstacle driven missed approach climb gradients of up to 425 ft/NM may be established as public-use procedures when evaluated under paragraph 13.4.4.b. Consider this option prior to adjusting the HAT.

SECTION 13-5. CAT II/III ILS EVALUATION

13.5. CAT II/III ILS Evaluation

13.5.1. General Information

This section describes criteria for the evaluation of CAT II and III ILS procedures.

13.5.2. Final Approach Segment

The CAT I ILS final approach segment obstacle evaluation applies to the CAT II/III approach authorization. The CAT I procedure must support a 200-foot HAT and lowest possible visibility (no restrictions incurred by lack of infrastructure or obstacle surface penetrations). The GPA must be 3.0 degrees.

13.5.3. Approach Minimums

The lowest CAT II HAT is 100 feet. Apply table 13-5-1 to determine the minimum RVR associated with the lowest authorized CAT II HAT (see paragraph 13.5.6 for CAT III RVR requirements).

Table 13-5-1. Minimum Authorized CAT II RVR

HAT (FEET)	RVR[1]
100-140	1200
141-180	1600
181-199	1800

Note: [1] Published RVR must not be less than the minimum aerodrome operating visibility for the runway or surface of intended use (i.e. ½ SM or RVOP visibility or LVOP visibility).

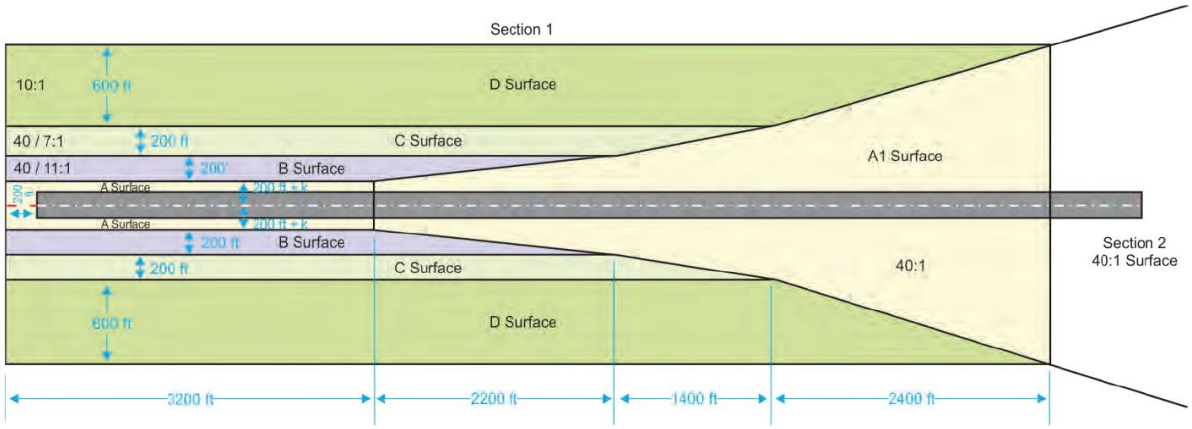
13.5.4. Missed Approach Segment

The CAT II/III missed approach area is comprised of two sections.

a. Section 1 (see figure 13-5-1).

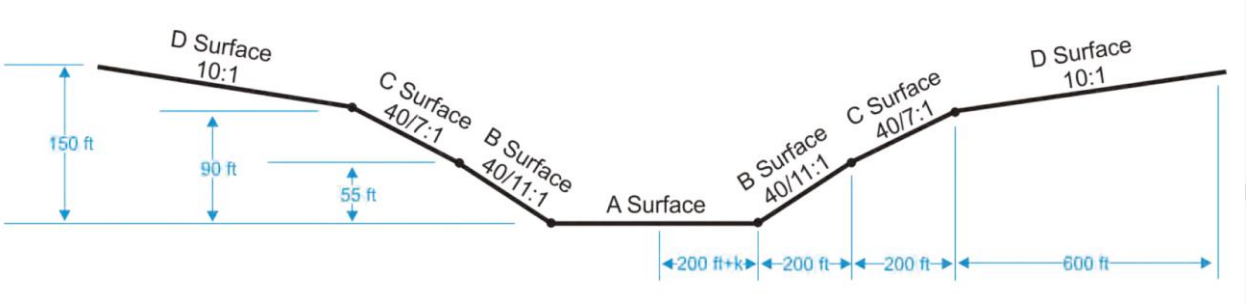
(1) The section 1 area begins at the end of the final approach OCS and is aligned with a continuation of the FAC, continuing in the direction of landing for a distance of 9200 feet excluding extensions. It is comprised of five surfaces: A, B, C, D, and A1.

Figure 13-5-1. Section 1 Plan View



(2) The OCS slopes associated with surface A, B, C, and D are depicted in figure 13-5-2. Surface A1 has a slope of 40:1 rising in the direction of the missed approach.

Figure 13-5-2. Section 1 Profile View and OCS Slopes



(a) Apply formula 13-5-1 to calculate the MSL height of the surface A, B, C, or D OCS at any given distance (X) from the LTP and (Y) from the runway centerline when X is 3000 feet or less.

Formula 13-5-1. Surface A, B, C, D Surface Height Where X ≤ 3000 and Y:

$Y < (200 + k)$: $h = e$ A Surface

$Y \geq (200 + k)$: $h = \frac{11 \times (Y - (200+k))}{40} + e$ B Surface

$Y > (400 + k)$: $h = \frac{7 \times (Y - (400+k))}{40} + 55 + e$ C Surface

$Y > (600 + k)$: $h = \frac{Y - (600+k)}{10} + 90 + e$ D Surface

Where:

h = MSL height of OCS
X = Distance (feet) from runway threshold measured parallel to runway centerline
Y = Perpendicular distance (feet) from runway centerline
e = MSL elevation of the runway centerline at distance X
k = 0 if airport elevation ≤ 1000 MSL, otherwise k = 0.01(airport elevation – 1000)

(b) Apply formula 13-5-2 to calculate the MSL height of the B, C, D, or A1 OCS at any given distance (X) from the LTP and (Y) from the runway centerline when X is greater than 3000 feet but equal to or less than 9000 feet.

Formula 13-5-2. Surface B, C, and D Surface Height Where X > 3000 and Y:

$Y > (200 + k)$: $h = \frac{11 \times (Y - (200+k))}{40} + f$ B Surface

$Y > (400 + k)$: $h = \frac{7 \times (Y - (400+k))}{40} + 55 + f$ C Surface

$Y > (600 + k)$: $h = \frac{Y - (600+k)}{10} + 90 + f$ D Surface

Where:

h = MSL height of OCS
X = Distance (feet) from runway threshold measured parallel to runway centerline
Y = Perpendicular distance (feet) from runway centerline
f = MSL elevation of the runway centerline 3000 feet from threshold
k = 0 if airport elevation ≤ 1000 MSL, otherwise k = 0.01(airport elevation – 1000)

(c) Apply formula 13-5-3 to calculate the MSL height of the surface A1 at any given distance (X) from the LTP and (Y) from the runway centerline when X is greater than 3000 feet but equal to or less than 9000 feet.

Formula 13-5-3. Surface A1 Surface Height

$$h = \frac{X - 3000}{40} + f$$

Where:
h = MSL height of OCS
X = Distance (feet) from runway threshold measured parallel to runway centerline
f = MSL elevation of the runway centerline 3000 feet from LTP

(3) An obstacle must not penetrate the OCS of surface A, B, C, D, or A1 unless the obstacle is either deemed acceptable under table 13-6-1, or the minimums are adjusted as follows:

(a) Surface A or inner approach OFZ. Adjust the HAT upward one foot for each foot of surface penetration. A CAT II procedure is not authorized if the resultant HAT is greater than 199 feet.

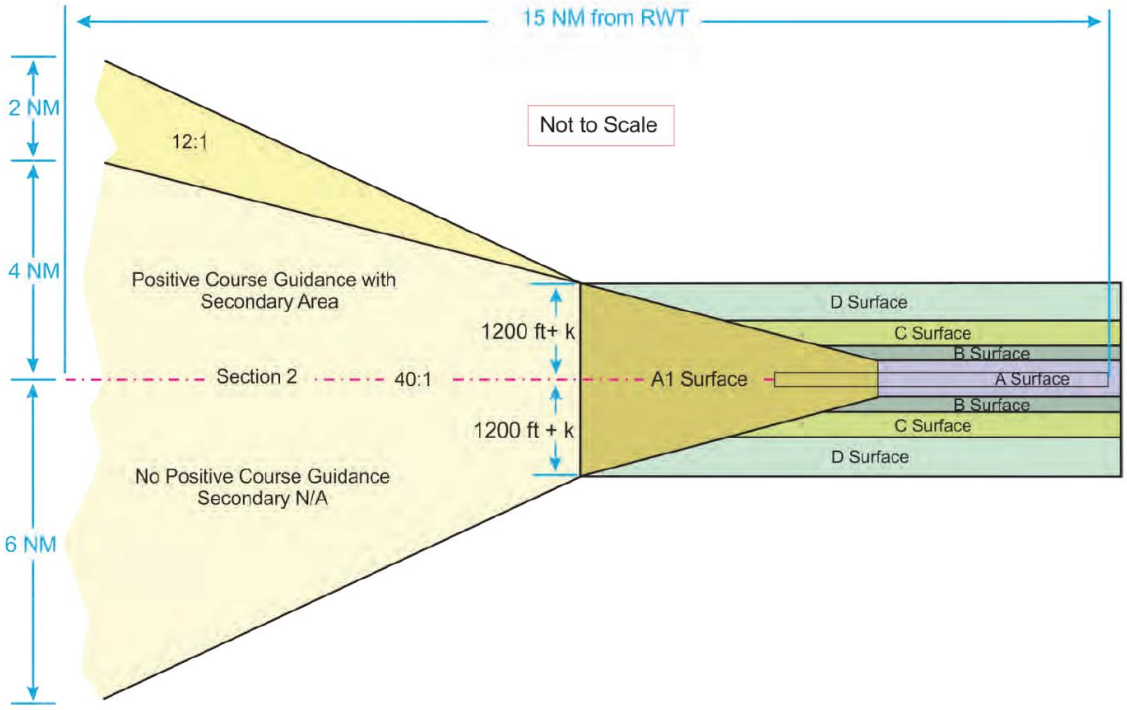
(b) Surface B, C, or D. Increase RVR as specified in table 13-5-1 as if the HAT was adjusted, but do not raise the HAT.

(c) Surface A1. This surface must not be penetrated unless the obstacle is deemed acceptable under table 13-6-1.

b. Section 2 (see figure 13-5-3).

(1) Straight-ahead missed approach area (applies to turns 15 degrees or less). This area starts at the end of the A1 surface and is centered on the specified missed approach course. The width increases uniformly from +/- (1200 + k) feet at the beginning to en route width at a point 15 NM from the LTP. When PCG is provided for the missed approach procedure, secondary areas that are zero miles wide at the point of beginning and which increase uniformly to initial secondary width may be added to section 2.

Figure 13-5-3. Straight Missed Approach Area



(2) Turning Missed Approach Area (applies to turns of more than 15 degrees) (see figure 13-5-4). Design the procedure to accommodate an aircraft turning at least 400 feet above the TDZE. Aircraft are assumed to be 200 feet above the runway elevation at the end of the A1 surface; therefore, an extension to the A1 surface must be constructed (referred to as $A1_{extended}$). Determine the length of $A1_{extended}$ by applying formula 13-5-4.

Formula 13-5-4. $A1_{extended}$ Length

$$d = \left(T_{MSL} - (f + 200)\right) \times \left(\frac{1852}{0.3048 \times CG}\right)$$

Where:

d = Length of $A1_{extended}$ from end of surface A (feet)
T_{MSL} = Aircraft MSL turn height (minimum is TDZE elevation + 400)
f = MSL elevation of the runway centerline 3000 feet from LTP
CG = Climb gradient (normally 200 ft/NM)

(a) The $A1_{extended}$ surface area splays outward at 15 degrees from the missed approach course until reaching the turn altitude/point (see figure 13-5-5).

(b) The flight track and outer boundary radii of the turn are specified in paragraph 2.7.6 and table 2-7-1 both originating on a line marking the end of the $A1_{extended}$ surface. Unless a fix/facility identifies the turn point, the inner boundary line commences at the inside turn edge of the D surface opposite the end of the touchdown area (A surface). When the turn point is marked by a fix/facility, the inside tieback may be constructed relative to the end of the $A1_{extended}$ surface. When the point on the inside turn side of

section 2 area abeam the clearance limit is past an imaginary line extended perpendicular to the edge of section 1 abeam the end of the touchdown zone on inside turn side, the inner boundary line commences on the outside turn edge of the D surface opposite the end of the touchdown area [(A surface) (see figure 13-5-6)]. The outer and inner boundary lines extend to points each side at flight track at the clearance limit at a rate that achieves initial segment width 15 NM from the LTP. Where secondary areas are required, they must commence after completion of the turn at the point where PCG is achieved.

(3) Section 2 OCS is a 40:1 inclined plane originating at the end of section 1.

(a) Beginning height is equivalent to the end of the A1 surface height on centerline.

(b) The beginning height of the section 2 OCS outside of the $A1_{extended}$ surface is equivalent to the ending height of the $A1_{extended}$ surface on centerline. Obstacles outside of the $A1_{extended}$ surface are measured to the nearest edge of section 1 (or to the $A1_{extended}$ surface).

(c) Section 3 is necessary for turns more than 90 degrees as described in paragraph 2.7.7.b, except point “B” is defined as the point of the inside of turn edge of section 1 abeam the end of the A surface regardless of the location of the inside tieback point (see paragraph 13.5.5b(2)(b)).

(d) The 40:1 OCS within section 2 (to include $A1_{extended}$) and section 3 must not be penetrated by an obstacle.

Figure 13-5-4. Turning Missed Approach Area

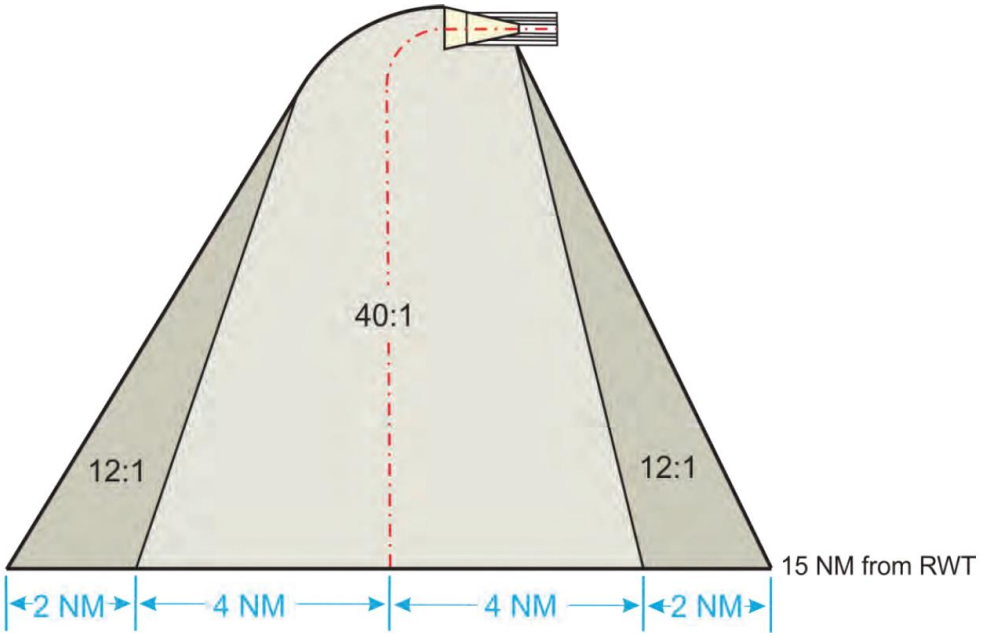


Figure 13-5-5. Turning Missed Approach OCS Detail

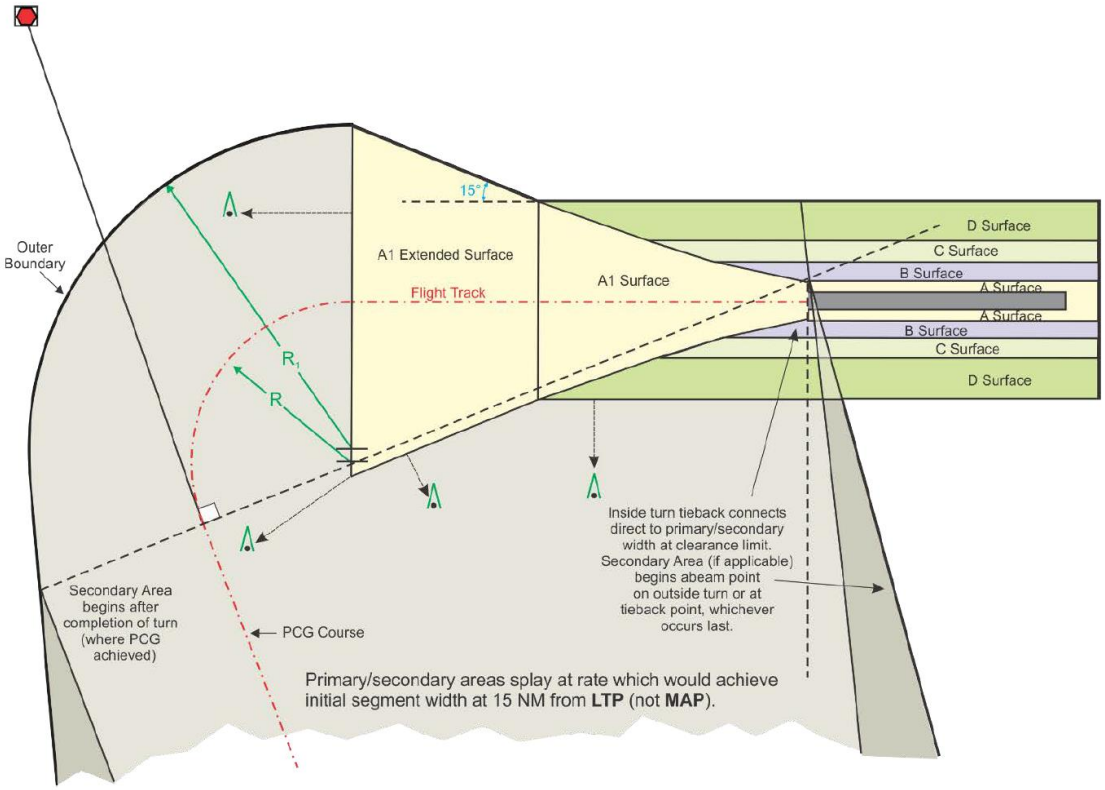
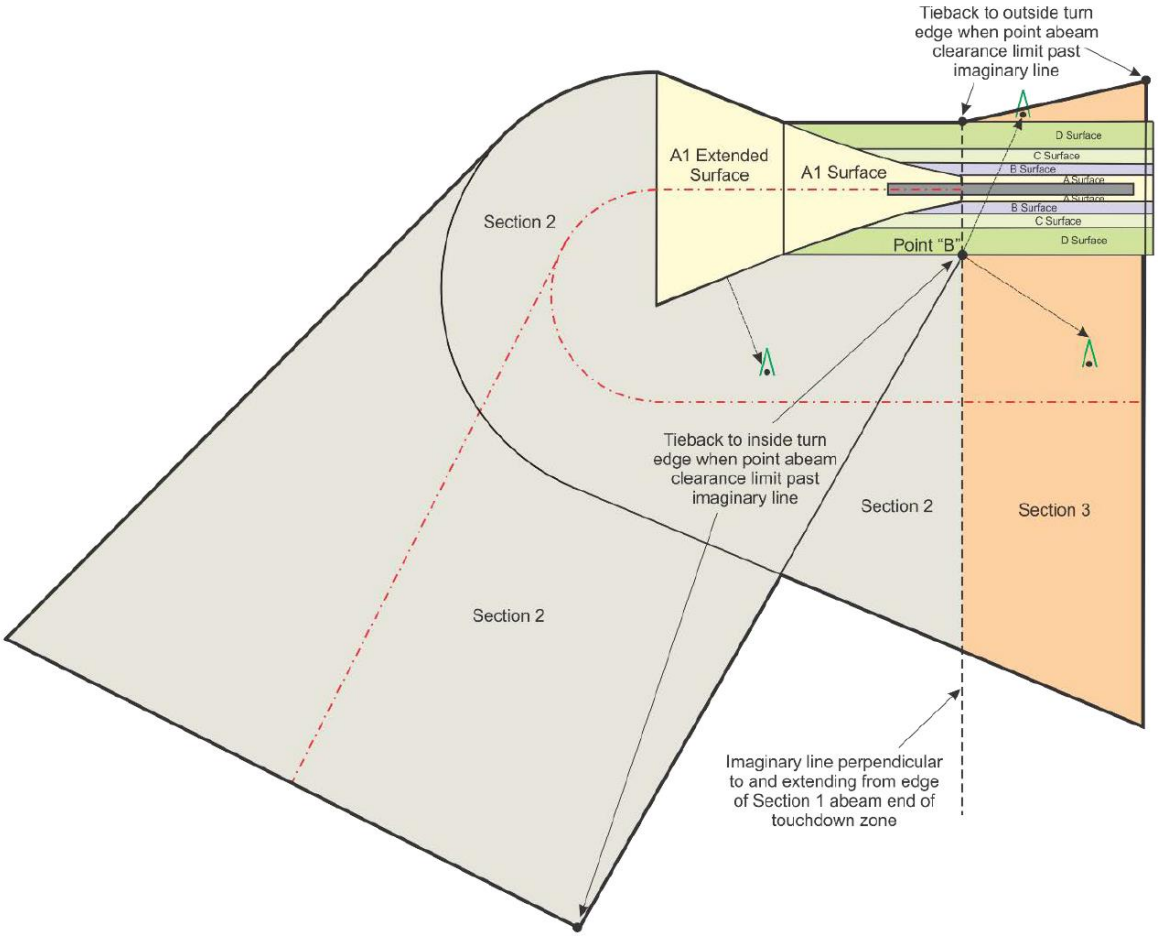


Figure 13-5-6. Turning Missed Approach OCS Detail (Continued)



13.5.5. REQUIREMENTS FOR CAT III ILS

Except as noted within this paragraph, the requirements for CAT II ILS applies.

a. Minimums.

(1) Publish the lowest authorized CAT III RVR when the runway supports unrestricted CAT II operations (100-foot HAT and RVR 1200).

(2) The following CAT III minimum RVR standards are applicable based on equipment performance class:

(a) III/E/3 for RVR ≥ 600

(b) III/E/4 for RVR < 600

(3) The published RVR must not be less than the minimum aerodrome operating visibility for the runway or surface of intended use (i.e. ½ SM or RVOP visibility or LVOP visibility).

SECTION 13-6. PA AND APV OBSTACLE ASSESSMENT

13.6. PA and APV Obstacle Assessment

13.6.1. Acceptable Obstacles.

Certain equipment essential to flight operations may penetrate PA and APV final approach and missed approach surfaces without impacting the procedure. Refer to table 13-6-1 to determine if an obstacle is permitted to be excluded from obstacle clearance consideration based on its type and location. If an obstacle is permitted to be excluded, then no adjustment to the procedure is required.

Table 13-6-1. Acceptable Obstacles

OBSTACLE TYPE	LOCATION
VASIS/PAPI[1]	CAT II/III Section 1 Missed Surface A, B, A1
Approach Lights[1]	Final Segment OCS
RTIL RWY THLD Identification Lights[1] Runway and taxiway lights[2]	CAT II/III Section 1 Missed Surface A, B
Airport Signs[3]	Final Segment OCS CAT II/III Section 1 Missed Surface A, B
PAR components[4] Radar reflectors[4] (frangible mounted)	CAT II/III Section 1 Missed Surface B
Aircraft and Vehicles	Final segment OCS[5] CAT II/III Section 1 Missed Surface B, C, A1[6]

[1]When installed in accordance with TP312 Section 5.3.
[2]When installed in accordance with TP312 Section 5.3.
[3]When installed in accordance with TP312 Section 5.4.
[4] Must be at least 400 feet from RCL and no higher than 15 feet above the closest point on the RCL.
[5] Only when the requirements of paragraph 13.6.2.b are met.
[6] Only when the requirements of paragraph 13.6.2.c are met.

13.6.2. Aircraft and Ground Vehicles as Obstacles

Taxiing, holding, parked aircraft and ground vehicles are considered obstacles for instrument procedure obstacle clearance except as permitted by application of table 13-6-1.

a. Evaluation. When evaluating aircraft as obstacles, consider the location of the taxiway or ramp and consider the highest aircraft surface that falls within the area. For ground vehicles, consider the road/taxiway/ramp with routine vehicle traffic and apply the appropriate height from TP312, Chapter 4 and TP308, Volume 1, Chapter 2, paragraph 2.1.12.

b. Final segment obstacles. Taxiing, holding, and parked aircraft/ground vehicles are considered obstacles in the final segment OCS unless positive controls have been established to keep the surfaces clear when aircraft are on approach to the same runway. Controls must also prevent vehicles that penetrate the OCS from parking in the surface without being in direct contact with ATC.

c. CAT II/III Section 1 Missed Surface B, C, A1 obstacles. Aircraft and vehicles may be excluded from obstacle clearance consideration provided they are operating on a taxiway that is distanced appropriately from the runway. Appropriate runway-to-parallel taxiway distances are specified within TP312, Chapter 5. Entry and exit taxiways are considered compliant if the hold line-to-runway centerline distances meet the airport design standards specified in TP312, Chapter 5.

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CHAPTER 14. SIMULTANEOUS APPROACH OPERATIONS

SECTION 14-1. SIMULTANEOUS INDEPENDENT APPROACHES SPACED AT LEAST 4300 FEET APART

14.1. Simultaneous Independent Approaches Spaced at Least 4300 Feet Apart

14.1.1. Purpose

This section provides criteria for instrument approaches that are requested for Simultaneous Independent Parallel Instrument Approach (SIPIA) operations. SIPIA operations use approaches, authorized by chart notes, to parallel runways spaced at least 4300 feet apart.

14.1.2. Overview

Simultaneous approach operations (dual and triple) provide increased capacity without diminishing safety by authorizing reduced ATC separation when appropriate conditions/mitigations are in place to maintain a low level of risk.

14.1.3. Types of Approaches

The following types of approaches are authorized to support SIPIA operations.

a. ILS. Include LOC minimums on the same chart unless requested otherwise.

b. GLS.

c. RNAV (GNSS) with LPV and/or LNAV/VNAV minimums.

d. RNAV (RNP).

14.1.4. Approach Design

IAP’s used for SIPIA operations must comply with the applicable design standards, except as stated in this chapter.

14.1.5. Final Approach Design

Alignment of the FAC should be straight-in along the RCL extended. An offset FAC alignment, as described in paragraph 14.2.5.d, may be used if requested by ATC or a user. No course change is permitted at the FAF/PFAF except as allowed in section 14-5.

14.1.6. Missed Approach Design

a. Dual widely spaced SIPIA operations. Missed approach courses must have a combined divergence of at least 30 degrees until other means of separation are provided.

b. Triple widely spaced SIPIA operations. The missed approach course for the center runway is a continuation of the FAC. The course for each ‘outboard’ runway must diverge at least 30 degrees from the center runway in opposite directions. At least one

outside parallel must have a turn height specified that is not greater than 500 feet above the airport elevation; this may be rounded up to the next 100-foot MSL increment for the published turn altitude.

c. Alternate missed approach. Where an alternate missed approach has been established for an approach authorized for use during simultaneous operations, it must also comply with the preceding restrictions.

14.1.7. Reserved

14.1.8. Conditions and Coordination

a. This criteria does not allow any of the following situations:

(1) Independent approach operations involving runways that are not parallel.

(2) Missed approaches with radius-to-fix (RF) turns.

(3) Triple independent approach operations where any one set of parallel runways are closely spaced.

(4) Quadruple independent approach operations.

(5) Simultaneous independent operations at airport elevations above 6000 feet MSL.

(6) Two adjacent airports to have simultaneous independent approach operations.

b. Coordination information. When approach procedures authorize simultaneous operations, the following information must be included in the procedure package as applicable.

(1) Include the type of operation (such as dependent, independent, or both, SCP) to be authorized for the approach.

(2) List each simultaneous runway pair/triple and the approaches authorized for simultaneous operations with the approach being submitted.

(3) Indicate the altitude/point where the simultaneous operation will begin (depicted as “Point S” in the figures in the chapter and described in paragraph 14.2.4.b).

(4) Incorrect flight procedure selection information as identified in paragraph 14.5.3.

SECTION 14-2. SIMULTANEOUS CLOSE PARALLEL (SCP) APPROACHES SPACED AT LEAST 3000 FEET APART BUT LESS THAN 4300 FEET APART

14.2. SIMULTANEOUS CLOSE PARALLEL (SCP) APPROACHES SPACED AT LEAST 3000 FEET APART BUT LESS THAN 4300 FEET APART

14.2.1. Purpose

This section provides criteria for instrument approaches that are requested for SCP operations to parallel runways spaced less than 4300 feet but at least 3000 feet apart.

14.2.2. General Guidance

IAP's used for SCP operations must comply with the applicable design standard's, except as stated in this chapter.

14.2.3. Types of Approaches

The following types of approaches are authorized to support SCP operations:

a. ILS.

b. GLS.

c. RNAV (GNSS) with LPV and/or LNAV/VNAV minimums.

Note: Pilot procedures and in-cockpit duties for RNP AR operations and PRM have not been evaluated for compatibility, therefore RNP AR is not authorized for these approaches.

14.2.4. Approach Design

Approaches requested to be authorized for simultaneous approach operation to runways spaced at least 3000 feet must have vertical guidance. For GL and RNAV (GNSS) approaches used for SCP, flight director or autopilot and GNSS are required.

a. Feeder routes and initial approach segment. The initial approach is normally done by vectors, but when requested by ATC may also be made from a NAVAID, fix, or waypoint. SCP approaches are normally published without transition routes (unless requested by ATC). Procedure turn and high altitude teardrop turn procedures must not be included on an SCP approach procedure.

b. Intercept angle/point. If ATC requests a route, instead of or in addition to vectors, apply standard design guidance to the initial segment route except the maximum intercept angle between the FAC extended (LOC/RNAV/GLS course/track) and the initial segment (if used) must be limited to reduce the risk of overshooting the FAC extended. The maximum intercept angle for the route is the same (30 degrees or as stated in Standard 821) as would be used for vectors. Also, the intercept point with the FAC extended must be designed to be at or outside the intercept altitude/point (depicted as "Point S" in the figures in this chapter) beyond which ATC no longer provides a minimum of 1000 feet vertical or 3 NM ATS surveillance separation. Coordinate with ATC if that information is not included in the procedure request.

c. Alignment. No course change between the intermediate segment and final approach segment is permitted at the PFAF except as allowed in section 14-5. This applies to either a straight-in or offset FAC.

14.2.5. Final Approach Design

a. Alignment of the FAC, for dual runway operations spaced at least 3600 feet. The alignment is recommended to be straight-in along the extended RCL; however, an offset FAC alignment may be used if requested by ATC or a user.

b. Alignment of the FAC, for runways spaced less than 3600 feet. When high update radar is not used, the alignment must have one FAC to be straight-in along the extended RCL and one offset FAC alignment for each runway pair to be authorized for simultaneous operations.

c. Alignment of the FAC, for triple runway simultaneous operations. The center runway FAC must be straight-in along the extended RCL. The outside runway FAC, for runway pairs spaced at least 3900 feet is recommended to be straight-in along the extended RCL, but an offset FAC alignment may be used if requested by ATC or a user. The outside runway FAC, for runway pairs spaced less than 3900 feet, must have the FAC alignment to be offset in the direction away from the center runway FAC. The minimum runway spacing for triples is 3000 feet (the same as for dual runways).

d. Offset FAC. The offset FAC must be aligned at least 2-½ degrees divergent from the other FAC, but not more than 3.0 degrees.

   Note: Autopilots with autoland are only used for localizers aligned with the RCL; therefore, Category II and III are not applicable to an offset FAC approach.

e. Obstacle assessment. An obstacle assessment must be performed for all runways using SCP procedures (see VOL 1, Chapter 14, Appendix A).

14.2.6. Missed Approach Design

Missed approach procedures for SCP approaches should specify a turn as soon as practical (but not below 400 feet above TDZE, rounded to the nearest foot).

a. Divergence. Missed approach courses, for each pair of SCP procedures, must have a combined divergence of at least 45 degrees until other means of separation are provided.

b. Start of divergence. The 45 -degree divergence must be established by 0.5 NM past the most distant DER.

Exception: A distance greater than 0.5 NM is allowed if the NTZ and the controller monitoring (which is established by ATC, not the procedure development specialist) is extended to the point where the 45 -degree divergence is achieved (see figures 14-2-1 and 14-2-2). Coordinate with ATC, as necessary.

Figure 14-2-1. Missed Approach Divergence Within 0.5 NM of DER

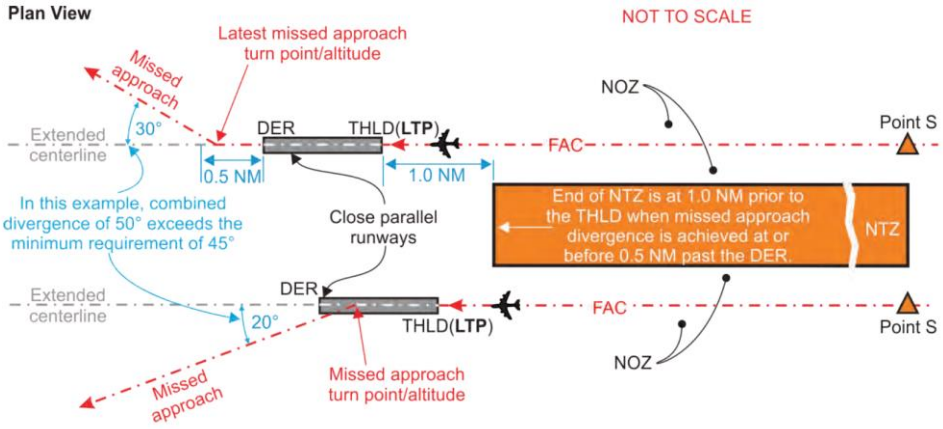
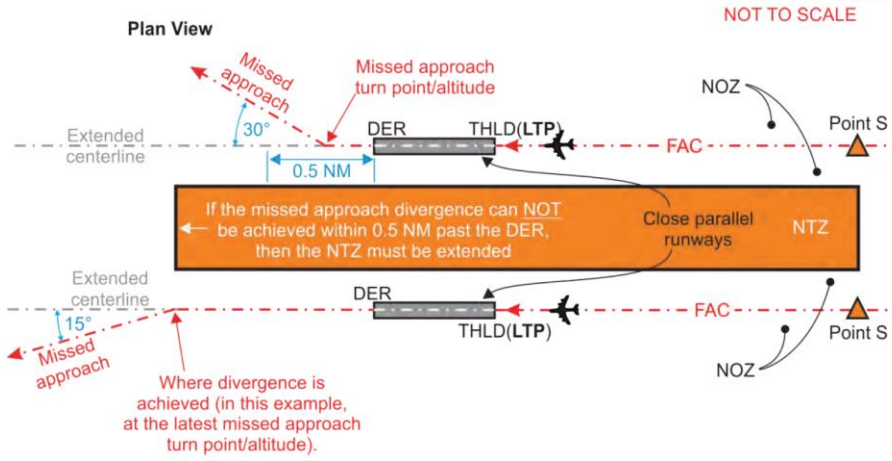


Figure 14-2-2. Missed Approach Divergence Delayed Beyond 0.5 NM



c. Offset FAC design. Where an offset FAC is used, the first missed approach turn point must be established so that the applicable (for the fastest category aircraft expected to utilize the offset FAC) flight track radius must not exceed one tenth of the distance from the landing runway centerline to the adjacent runway centerline (including the extended runway centerlines). The purpose of that requirement is to have the plotted missed approach flight track to not overlap the NTZ or the extension of the edge of the NTZ.

d. Alternate missed approach. Where an alternate missed approach has been established for an approach authorized for use during SCP operations, it must also comply with the preceding restrictions.

14.2.7. Procedure Naming and Charting

A separate instrument approach procedure must be published for each runway in the close parallel pair of runways. Identify SCP procedures by including “PRM” in the title in accordance with paragraph 161.i.

14.2.8. Conditions and Coordination

a. This criteria does not allow any the following situations:

(1) Independent approach operations involving runways that are not parallel.

(2) Missed approaches with radius-to-fix (RF) turns.

(3) Simultaneous operations at airport elevations above 2000 feet MSL.

b. Coordination information. When SCP procedures authorize simultaneous operation, the procedure package must include the information listed in paragraph 14.1.8.b.

c. To develop and publish an attention all users page (AAUP).

d. Obstacle assessment. When an obstacle assessment surface evaluation for breakout situations is available, include that documentation along with the SCP procedure package (see section 14-4 and VOL 1, Chapter 14, Appendix A for guidance for an obstacle assessment surface evaluation).

SECTION 14-3. **RESERVED**

SECTION 14-4. BREAKOUT OBSTACLE ASSESSMENT FOR SIMULTANEOUS INDEPENDENT PARALLEL INSTRUMENT APPROACH OPERATIONS

14.4. Breakout Obstacle Assessment for Simultaneous Independent Parallel Instrument Approach Operations

14.4.1. Scope

A breakout obstacle assessment must be completed as part of the planning/evaluation for simultaneous independent approach operations to close parallel runways. For other simultaneous approach operations, this assessment may be used.

14.4.2. Assessment

The breakout obstacle assessment includes the following:

a. Refer to the most recent diverse departure assessment for the reciprocal runway. For example, if the simultaneous approach is to runway 17L, then refer to the diverse departure assessment for runway 35R.

b. Review the results of the diverse departure assessment to determine whether all surfaces are clear or to develop a list of all penetrating obstacles. The output from the diverse departure assessment is an acceptable means of documenting the results.

c. There is the option of using all of the obstacle penetrations identified by the diverse departure assessment. If all obstacles are to be used, proceed with paragraph 14.4.3 below, otherwise determine if any of the obstacle penetrations identified in paragraph 14.4.2.b also penetrate any of the parallel approach obstruction assessment surfaces described in VOL 1, Chapter 14, Appendix A, paragraph 2. Obstacles that do not penetrate any of the parallel approach obstruction assessment surfaces may be ignored. The remaining (penetrating) obstacles must be considered under paragraph 14.4.3.

14.4.3. Obstacle Penetration Mitigations

Penetrating obstacles must be mitigated by the ATC facility through accomplishment of one or more of the following actions. A safety risk analysis may be helpful in identifying the most appropriate action(s):

a. Remove or lower the obstacles (if practicable).

b. Establish local procedures for avoiding the penetrating obstacles when breakouts occur.

c. Display penetrating obstacles on the controller’s ATS surveillance display to aid in avoidance during breakouts.

14.4.4. Breakout obstacle assessment

The breakout obstacle assessment is subject to the periodic review and continuous maintenance requirements specified within Chapter 1.

SECTION 14-5. SIMULTANEOUS INDEPENDENT PROCEDURES CONSIDERED ESTABLISHED ON A PBN SEGMENT OF A PUBLISHED INSTRUMENT APPROACH

14.5. Simultaneous Independent Procedures Considered Established on a PBN Segment of a Published Instrument Approach

14.5.1. Purpose

This section provides design criteria for Performance Based Navigation (PBN) instrument approaches intended for simultaneous operations that allows ATC to discontinue 1000 feet or 3-NM separation once the aircraft is established on an approved PBN segment of an approach, in accordance with the Established on RNP (EoR) concept.

14.5.2. Approach design

Apply Volume 2, and sections 14-1 and 14-2 of this document along with the following requirements.

a. Additional requirements:

(1) Only RNAV (GNSS) and RNAV (RNP) procedures are authorized.

(2) Use of GNSS is required.

(3) Use of flight director (FD) or auto pilot (AP) is required.

(4) When designing a procedure to an offset FAC or a procedure paired with and offset FAC, the final roll-out point on the offset FAC must be at least 3600 feet for dual operations or 3900 feet for triple operations from the final roll-out point to the FAC extended of the paired approach.

(5) When designing procedures from the same side of the FAC, the paired approach tracks must be no closer than 3 NM from each other until being monitored by a final monitor controller.

(6) Airspeed restrictions.

(a) TF legs. Establish an airspeed restriction not faster than 180 KIAS at or prior to the start fix of the FAC intercept leg.

(b) RF legs. Establish an airspeed restriction for the start waypoint of an RF leg that joins the FAC using along-track distance (see table 14-5-1).

Table 14-5-1. RF Max Airspeed Restriction

RF leg length	Max KIAS
≥ 4NM	210
≤ 4NM ≥ 3NM	200
≤ 3NM ≥ 2NM	190
≤ 2NM	180

14.5.3. Track Separation

The approach design must provide for aircraft to become established on a unique initial or intermediate approach segment associated with the simultaneous approach procedure. A

initial or intermediate approach segment is considered unique when separated by at least 0.5 NM from the track of any other RNAV (GNSS) or RNAV (RNP) approach. In addition, an initial or intermediate approach segment is considered unique even if it does not have a unique track, if latter segments of the approach provide a unique track for at least 50 seconds prior to crossing the first FAC (see formula 14-5-1). The unique track allows ATC adequate time to identify that an aircraft is not flying the expected track due to selection of an incorrect flight procedure. The track separation must be continued until crossing the first FAC. See Figure 14-5-1 for a conceptual example of required track separation with TF legs; see Figure 14-5-2 for an example with RF legs.

Note: ICAO 9643 Appendix A, A4 is an acceptable alternate method for approach design consideration and tracking separation, which can be used in lieu of paragraph 14.5.3.

Formula 14-5-1. Incorrect Flight Procedure Separation Distance

$$D = \frac{(V_{KTAS} + V_{KTW}) \times 50}{3600}$$

Figure 14-5-1. Incorrect Flight Procedure Selection (TF Legs)

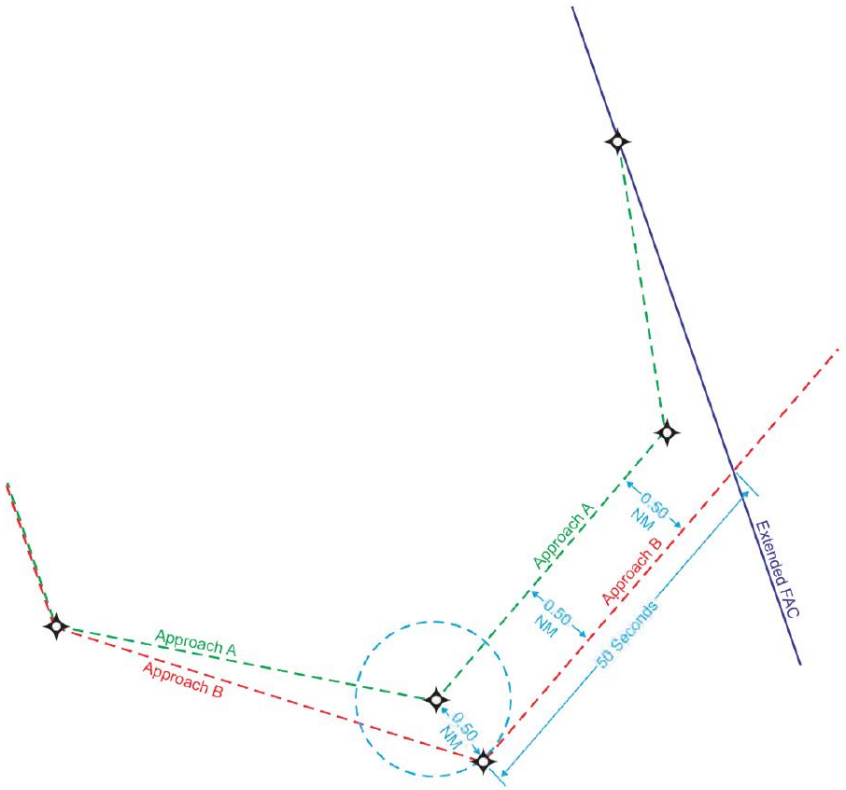
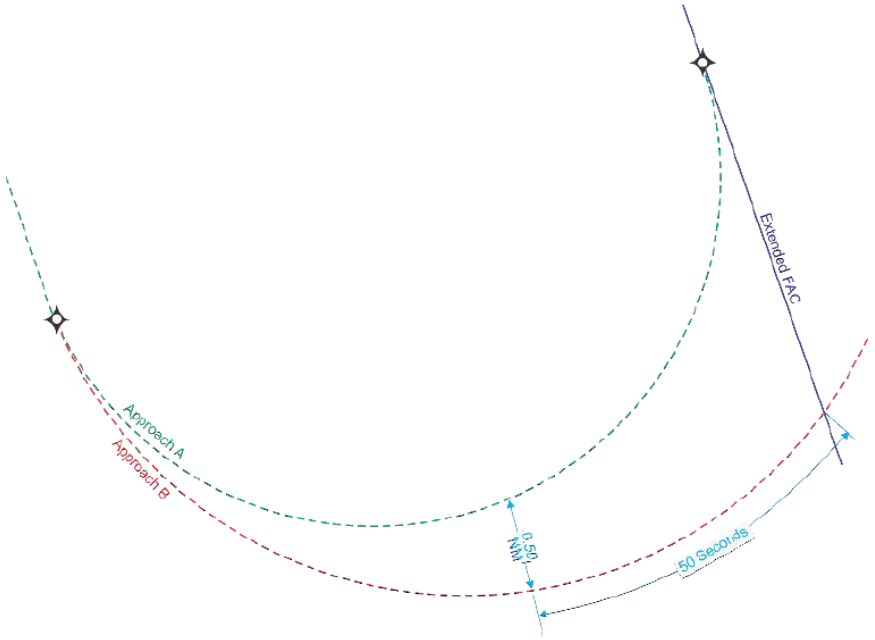


Figure 14-5-2. Incorrect Flight Procedure Selection (RF Legs)



14.5.4. Alignment

a. FAC offsets. Offsets must be divergent from other paired FAC, regardless of spacing.

b. FAC intercept. To decrease the probability of overshoots and to minimize FMA and TCAS alerts, the following restrictions apply;

(1) TF legs.

(a) The intercept angle of the last leg prior to FAC (intercept leg) must be 10 degrees or less.
(b) The start fix of the intercept leg must be at least 0.2 NM from the closest point on the FAC (extended).

(c) The leg preceding the intercept leg must converge with the FAC (extended) at an angle of 60 degrees or less.

(2) RF legs. For designs using multiple consecutive RF legs to join the FAC, the arc radius of the leg joining the FAC must be the same or larger than the arc radius of any preceding RF leg.

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Appendix A. Obstacle Assessment Surface Evaluation for Simultaneous Independent Parallel Instrument Approach (SIPIA) Operations

1. General

a. General. This appendix characterizes criteria used during the interim test phase of evaluating close parallel operations where early turnout obstacle assessments were accomplished by contractual means using terrestrial photometric techniques combined with survey methods of surface evaluation. Although this evaluation is based on the historical use of two ILS approaches, the assessment technique is also used for evaluation of independent simultaneous approach operations using RNAV (GNSS), RNAV (RNP), GLS, LDA with glide slope, or LOC. The depictions in this appendix show straight-in FACs, but an offset course may be evaluated by rotating the areas that are adjacent to the offset course by the amount of the offset and measuring perpendicular to the offset FAC. Only a single evaluation is needed to each runway and should generally be based on primary approach procedure used during simultaneous operations (for example, the ILS approach). Facility information (GPA, TCH, threshold elevations, etc.) may be obtained from NAV CANADA.

b. Parallel runway simultaneous approaches. The procedures for airports with multiple parallel runways must ensure that an aircraft approach on one runway is safely separated from those approaching the adjacent parallel runway. An example of such procedures is depicted in figure A-1. Vertical separation is required when lateral separation becomes less than 3 NM, as aircraft fly to intercept and stabilize on their respective FAC. This 1000-foot vertical separation is maintained until aircraft begin descent on the glidepath, except for approach operations which allow less than standard separation prior to the extended FAC described in Chapter 14, section 14-5.

(1) When lateral radar separation is less than the 3 NM and the 1000-foot altitude buffer is lost, the aircraft on adjacent approach courses must be protected by an NTZ and monitored by radar monitor controllers. The controllers will observe the approaches and if an aircraft blunders from the NOZ toward or into a 2000-foot NTZ, the monitor controller can intervene so that threatened aircraft on the adjacent approach(es) are turned away in time to prevent a possible encounter. This maneuver, on the part of the threatened aircraft, is termed a “breakout” because the aircraft is directed out of the approach stream to avoid the transgressor aircraft. A controller for each runway is necessary so that one can turn the transgressing aircraft back to its course centerline while the other directs the breakout (see figure A-2).

Figure A-1. Examples of SIPIA Design with no Transgression Zones and Normal Operating Zones (Dual Approach, Non-PRM, Spacing at least 4300 feet)

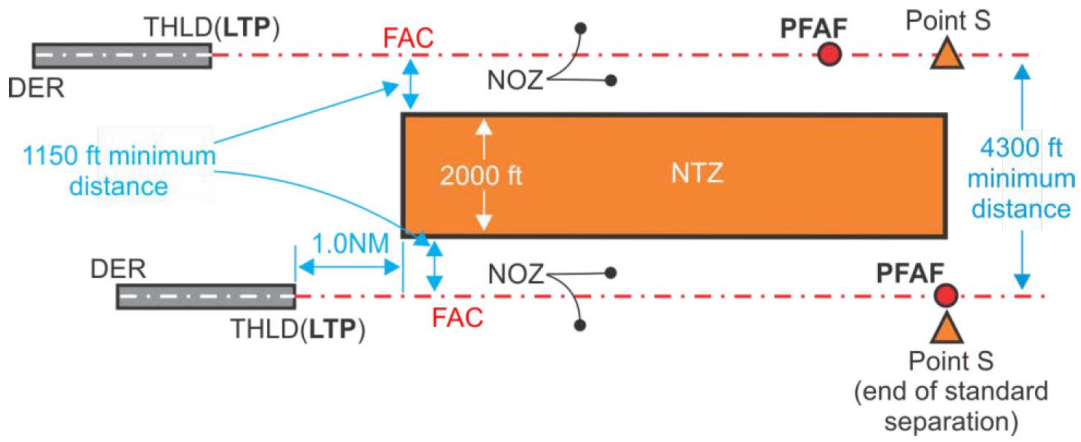
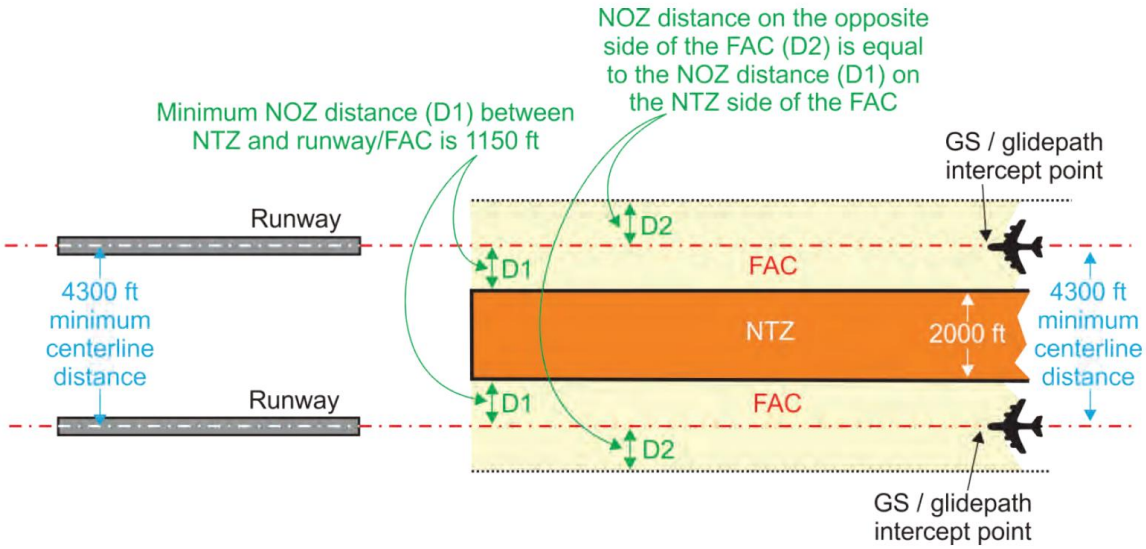
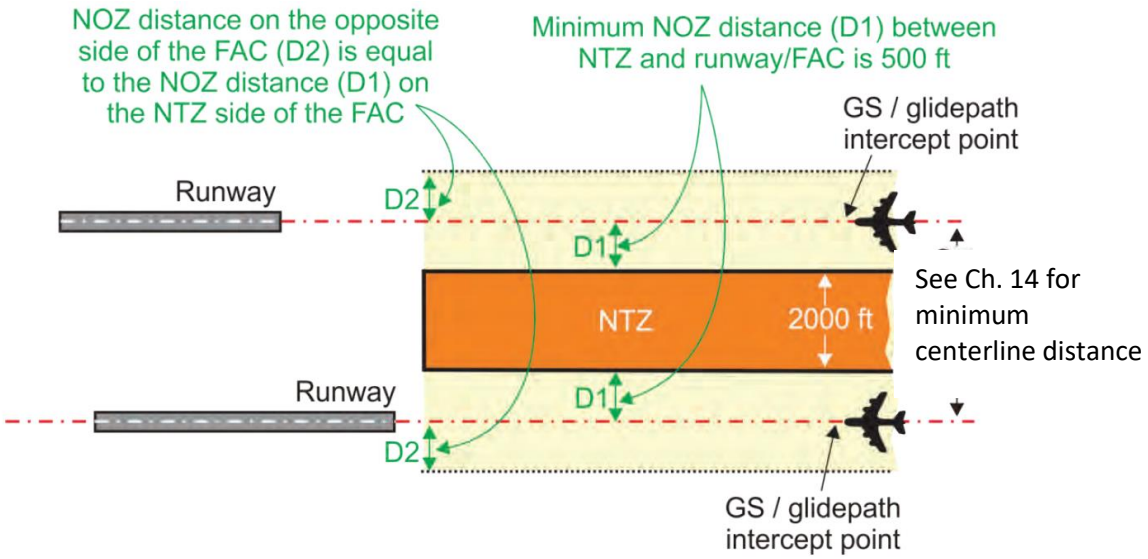


Figure A-2. Simultaneous Parallel Runway Approach Zones



(2) The 2000-foot NTZ, flanked by two equal NOZs, provides airspace limitation guidance to the monitor controller and maneuvering room for the aircraft to recover before entering the NTZ. Aircraft are required to operate on or near the approach course within the limits of the NOZ. For runways spaced less than 4300 feet apart, the controllers transmit on both a separate and discrete frequency and on the tower frequency. Pilots only transmit on the tower frequency but listen to both frequencies. If an aircraft strays into the NTZ or turns to a heading that will take it into the NTZ, it is deemed a threat to an aircraft on the adjacent course and appropriate corrective action or breakout instructions are issued (see figure A-3).

Figure A-3. Simultaneous Approach NTZ and NOZ



2. Parallel Approach Obstruction Assessment.

The parallel approach obstruction assessment is an examination of obstruction identification surfaces, in addition to the TP308/GPH209 surfaces, in the direction away from the NTZ and adjacent runway, into which an aircraft on an early breakout could fly. An obstacle evaluation must be conducted to identify penetrating obstacles as part of a coordinated assessment for all independent SCP approach operations. In these criteria, ILS glidepath/localizer terms are synonymous to and may be used interchangeably with RNAV vertical path and lateral track terms. The surface dimensions for the obstacle assessment evaluation are described in the following paragraphs of this appendix.

Note 1: Parallel approach obstruction assessment surfaces are used for identifying obstacles that may impact simultaneous precision operations.

Note 2: A Parallel approach obstruction assessment surface penetration is when one or more obstructions penetrate the parallel approach obstruction assessment surface.

Note 3: A Parallel approach obstruction assessment controlling obstruction is the obstruction within the boundaries of the parallel approach obstruction assessment surface which constitutes the maximum penetration of that surface.

a. Surface 1. A FAC descent surface which is coincident with the glide slope/glidepath beginning at runway threshold with the width point abeam the threshold 350 feet from runway centerline opposite the NTZ, with lateral boundaries at the outer edge of the LOC course width (CW), and ending at the farthest glide slope/glidepath intercept (see figure A-4).

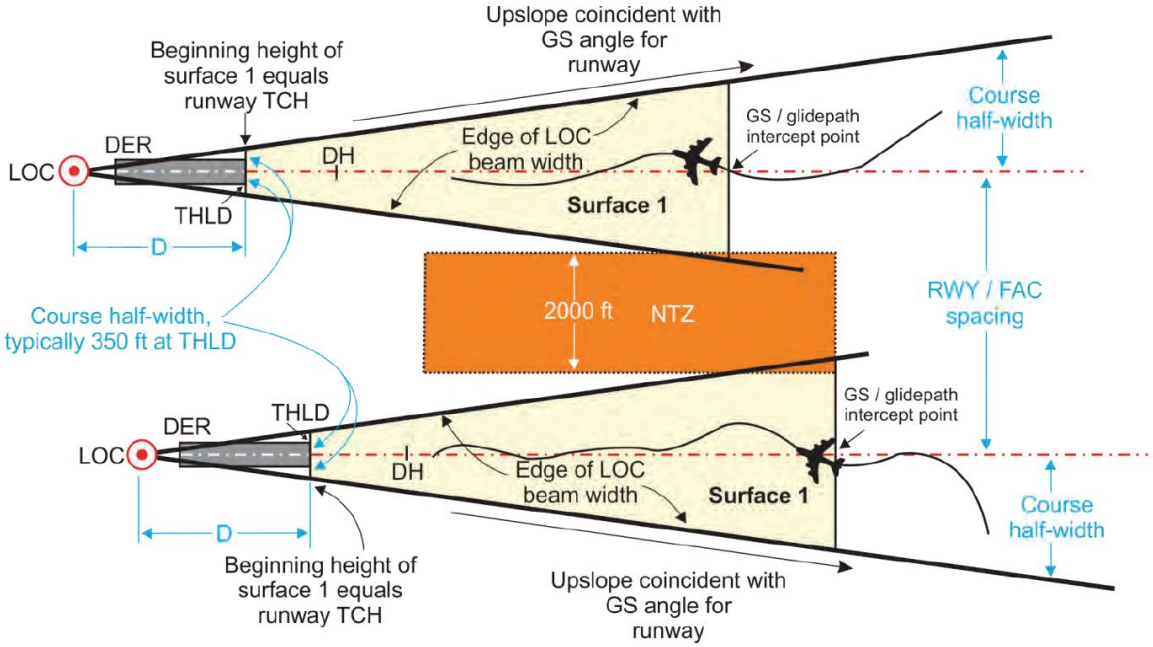
Note: The course width is the angular course deviation required to produce a full scale (+/-) course deviation indication of the airborne navigation instrument. This width is normally tailored to a parameter of not greater than +/- 3 degrees. For precision runways longer than 4000 feet, a linear sector width parameter of +/-350 feet each side of centerline at RWT applies. Few category I localizers operate with a course sector width less than three degrees (+/- 1½ degrees) tailored width may be determined by formula A-1.

Formula A-1. Tailored LOC Angular course width

$$\theta_W = \operatorname{atan}\left(\frac{350}{D}\right)$$

Where:
θ_W = Localizer course sector half-width angle
D = Distance from LOC antenna to RWT (in feet)
Total localizer course sector angle = 2 x θ_W

Figure A-4. Final Approach Descent Surface 1



(1) Length. Surface 1 begins over the runway threshold at a height equal to the TCH for the runway, and continues outward and upward at a slope that is coincident with the glide slope/glidepath, to its ending at the GS/vertical path intercept point.

(2) Width. Surface 1 has a width equal to the lateral dimensions of the LOC course width. The surface 1 half-width (see figure A-4) is calculated using formula A-2 or formula A-3.

Formula A-2. Surface 1 Half-width, Part One

$$\frac{1}{2}\mathrm{W} = \mathrm{A} \times \mathrm{Tan}\left(\frac{\mathrm{B}}{2}\right) + 350$$

Where:
W = Width of surface 1
A = Distance from RWT measured parallel to course
B = Course Width Beam Angle

OR

Formula A-3. Surface 1 Half-width, Part Two

$$\frac{1}{2}\mathrm{W} = \mathrm{L} \times \mathrm{Tan}\left(\frac{\mathrm{B}}{2}\right)$$

Where:
W = Width of surface 1
L = Distance from Azimuth antenna (in feet)
B = Course Width Beam Angle

(3) Height. Surface 1 height at any given centerline distance (d), may be determined in respect to threshold elevation, by adding the TCH to the product of centerline distance in feet from threshold times the tangent of the glide slope/glidepath angle (see formula A-4).

Formula A-4. Surface 1 Height Above LTP Elevation

$$\mathrm{h1} = [\mathrm{d} \times \mathrm{Tan}(\mathrm{GPA})] + \mathrm{TCH}$$

Where:
h1 = Surface 1 height above LTP Elevation

b. Surface 2.

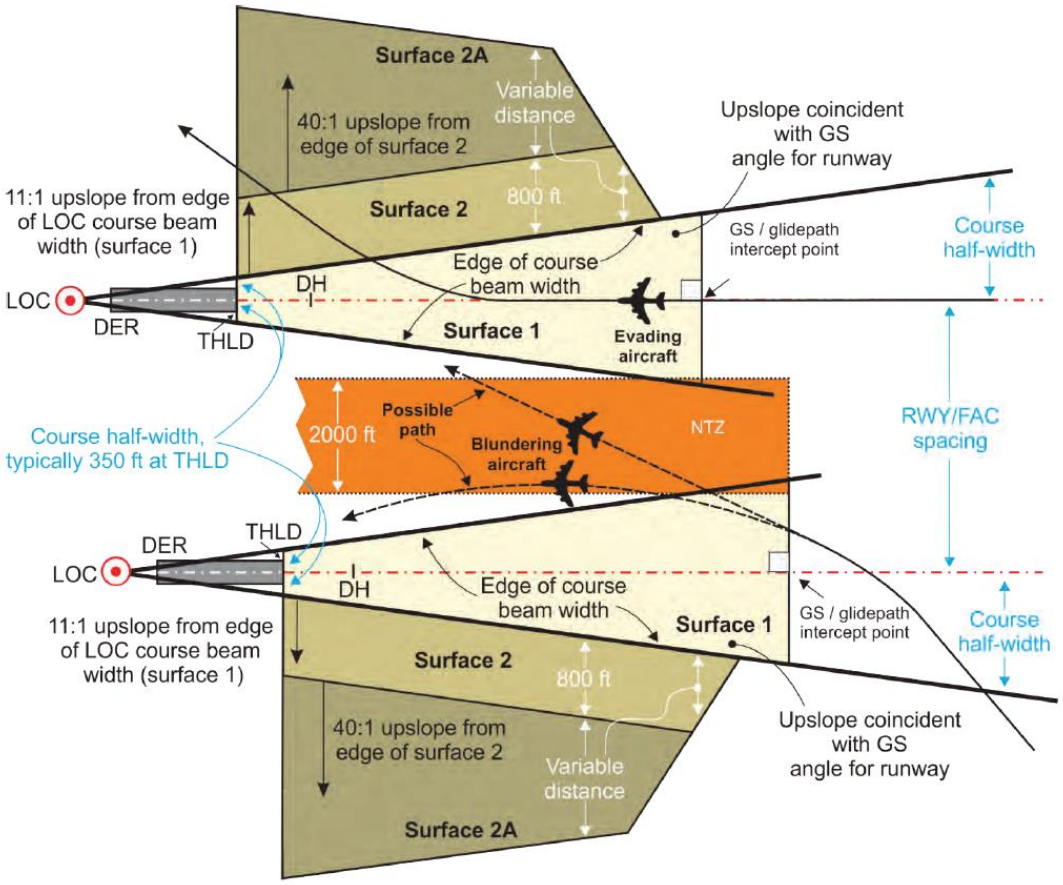
(1) Length [same as paragraph 2a(1)].

(2) Width and height. Surface 2 shares a common boundary with the outer edge of surface 1 on the side opposite the NTZ. Surface 2 begins at the height of surface 1 and slopes upward and outward for 800 feet from the edge of the surface 1 at a slope of 11:1, measured perpendicular to the FAC. After 800 feet, surface 2A uses a slope of 40:1. Further application is not required when the 11:1 or 40:1 surface reaches a height of 1000 feet below the MOCA, MSA, or MVA, whichever is applicable (see figure A-5).

Note 1: If more than one is applicable, use 1000 feet below the lowest applicable MOCA, MSA, or MVA. If an airport is in a designated mountainous area, instead of 1000 feet, use the applicable ROC.

Note 2: The 40:1 surface provides evaluation for breakout in any direction and is recommended. For locations that limit the amount of turn on the breakout, a higher surface may be used instead of the 40:1 surface with a site specific review by NAV CANADA.

Figure A-5. Parallel Approach Obstacle Assessment Surface 2



Notes:

1. The outer edges of surfaces 2 and 2A are at a variable distance, as needed to reach the applicable level surface height.

2. Surface 2 height = surface 1 height + rise of 11:1 slope measured from nearest edge of the localizer course beam width (surface 1) to the obstacle measured perpendicular to the FAC.

3. Surface 2A height = surface 2 height + rise of 40:1 slope measured from nearest edge of surface 2 to the obstacle, measured perpendicular to the FAC.

4. An example of an aircraft breakout is illustrated in figure A-5 by the blundering aircraft approaching/entering the NTZ causing the controller to have to issue a vector to the evading aircraft.

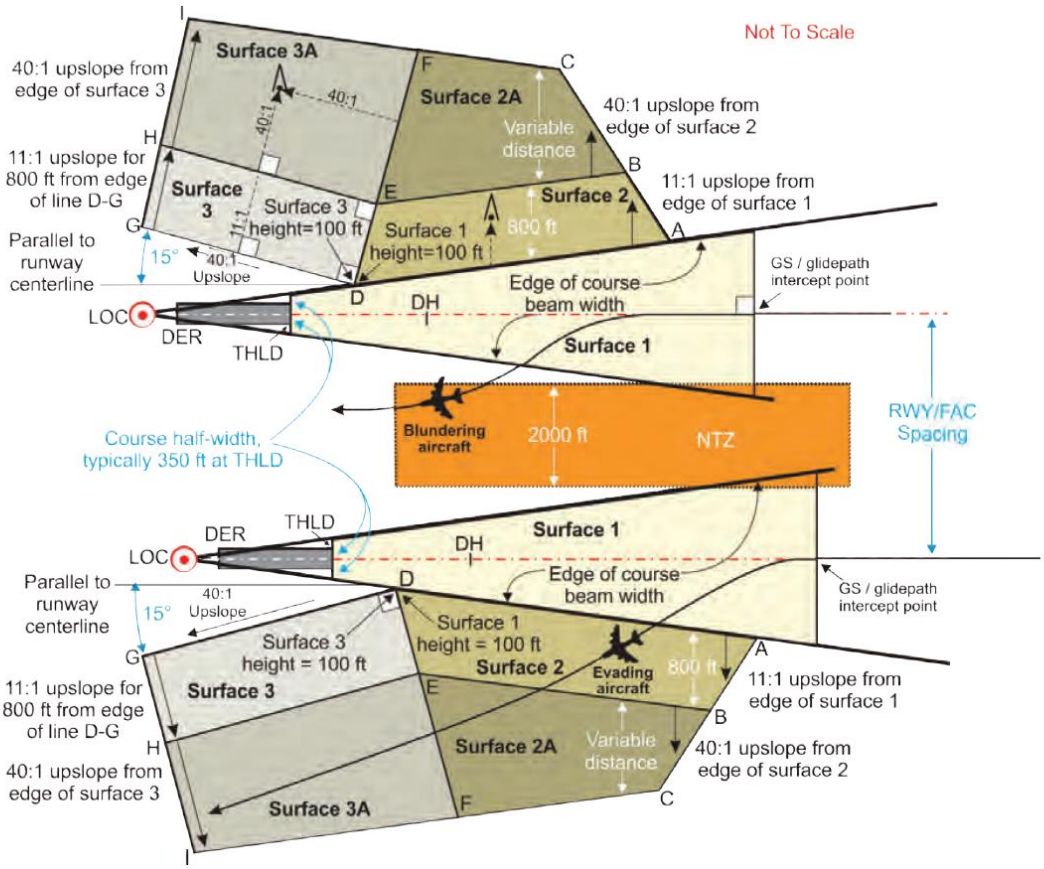
c. Surface 3 (CAT I).

(1) Length. For category I operations, surface 3 begins at the point where surface 1 reaches a height of 100 feet. Use 100 feet above the threshold elevation or use 100 feet above the touchdown elevation (TDZE), whichever was used in the procedure design. Surface 3 slopes upward and outward for 800 feet from the edge of line D-G at a slope of 11:1, measured perpendicular to the line D-G. After 800 feet, surface 3A uses a slope of 40:1. Surface 3 extends to the point where the 11:1 or 40:1 slope reaches a height of 1000 feet below the MOCA, MSA, or MVA, whichever is applicable.

(2) Width. From the beginning point, the edge of surface 3 area splays at a 15-degree angle from a line parallel to the runway centerline.

(3) Height. Surface 3 begins at a height of 100 feet above THLD/TDZE (equal to the height of surface 1 at that point). The surface rises longitudinally at a 40:1 slope along the 15-degree splay line D-G while continuing laterally outward and upward at an 11:1 slope (line D-E is perpendicular to the 15-degree splay line D-G). Surface 3A uses a 40:1 slope. Further application is not required when the 11:1 or 40:1 slope reaches a height at 1000 feet below the MOCA, MSA, or MVA, whichever is applicable (see figure A-6).

Figure A-6. Parallel Approach Obstacle Assessment Surface



Notes:
1. The outer edges of surfaces 2, 2A, 3, and 3A are at a variable distance, as needed to reach the applicable level surface height.
2. Surface 3 height = surface 1 height (100 feet above runway) + rise of 40:1 slope measured along line D-G + rise of 11:1 slope measured from nearest edge of line D-G to the obstacle

(measured perpendicular to line D-G).

3. Surface 3A height = surface 3 height + rise of 40:1 slope measured (from obstacle) perpendicular to line D-G.

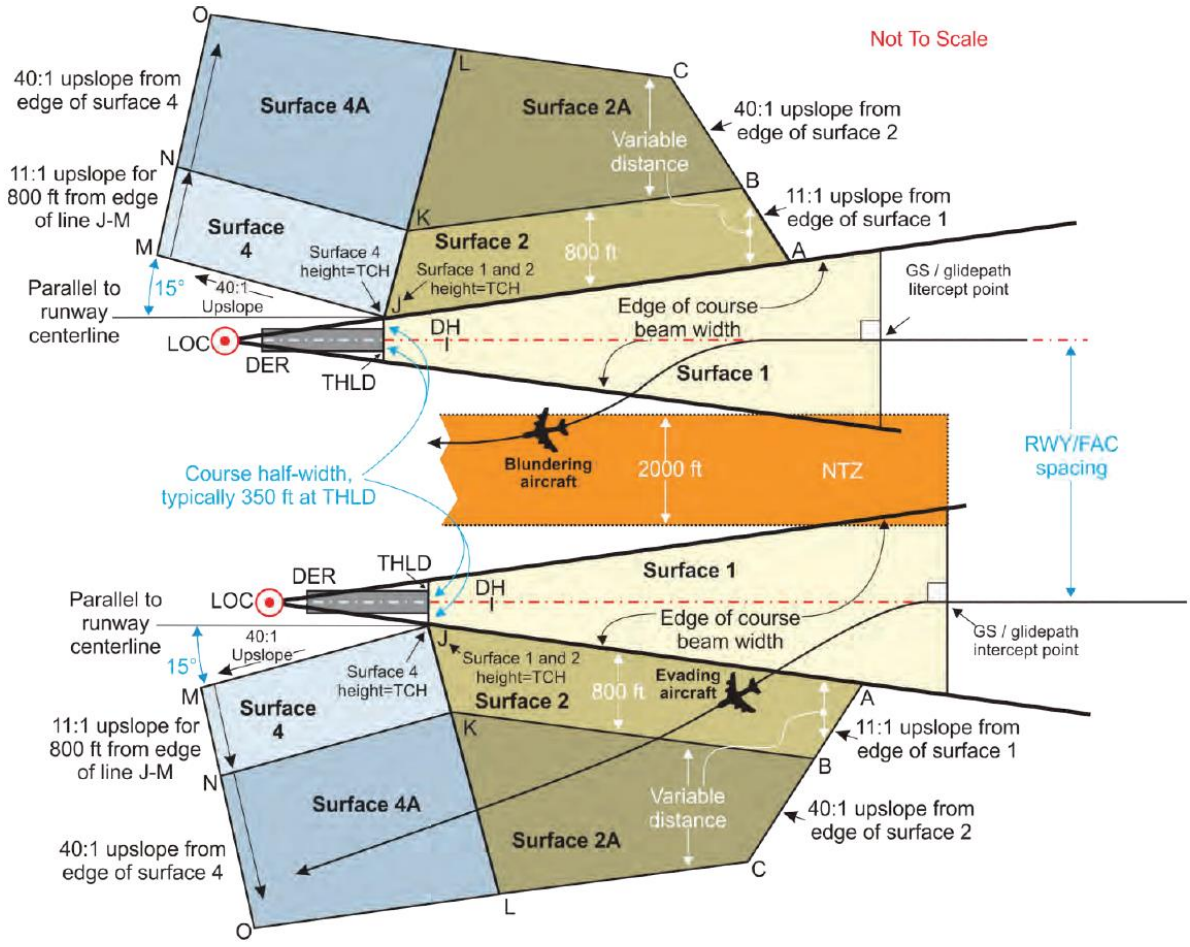
d. Surface 4 (CAT II).

(1) Length. Surface 4 begins at the point where surface 1 reaches the TCH and extends to the point where the 11:1 or 40:1 slope reaches a height of 1000 feet below the MOCA, MSA, or MVA, whichever is applicable. Surface 4 slopes upward and outward for 800 feet from the edge of line J-M at a slope of 11:1, measured perpendicular to the FAC. After 800 feet, surface 4A uses a slope of 40:1.

(2) Width. From the point of beginning, the edge of surface 4 area splays at a 15-degree angle from a line parallel to the runway centerline.

(3) Height. Surface 4 begins at the point where surface 1 reaches the TCH and rises longitudinally at a 40:1 slope along the 15-degree splay line J-M, while continuing laterally outward and upward at an 11:1 slope. Further application is not required when the 11:1 or 40:1 slope reaches a height of 1000 feet below the MOCA, MSA, or MVA, whichever is applicable (see figure A-7).

Figure A-7. Parallel Approach Obstacle Assessment Surface 4



Notes:

1. The outer edges of surfaces 2 and 2A or 4 and 4A are at a variable distance, as needed to reach the applicable level surface height.

2. Surface 4 height (above the TCH) = rise of 40:1 slope measured along line J-M + rise of 11:1 slope measured from nearest edge of line J-M to the obstacle (measured perpendicular to line J-M).

3. Surface 4a height = surface 4 height + rise of 40:1 slope measured (from obstacle) perpendicular to line J-M.

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CHAPTER 17. EN ROUTE CRITERIA

1700—1709. Reserved

SECTION 1. VHF OBSTACLE CLEARANCE AREAS

1710. En Route Obstacle Clearance Areas

Obstacle clearance areas for en route planning are identified as "primary", "secondary", and turning areas.

1711. Primary Areas

a. Basic Area. The primary en route obstacle clearance area extends from each radio facility on an airway or route to the next facility. It has a width of 8 NM; 4 NM on each side of the centreline of the airway or route (see Figure 17-1).

b. System Accuracy. System accuracy lines are drawn at a 4.5° angle on each side of the course or route (see Figure 17-1). The apexes of the 4.5° angles are at the facility. These system accuracy lines will intersect the boundaries of the primary area at a point 50.8 NM from the facility. (Normally 51 NM is used.) If the distance from the facility to the change over point (COP) is more than 51 NM, the outer boundary of the primary area extends beyond the 4 NM width along the 4.5° lines (see Figure 17-2). These examples apply when the COP is at mid point. Para 1716 covers the effect of offset COP or dogleg segments.

c. Termination Point. When the airway or route terminates at a navigational facility or other radio fix, the primary area extends beyond that termination point. The boundary of the area may be defined by an arc which connects the two boundary lines. The centre of the arc is, in the case of a facility termination point, located at the geographic location of the facility. In the case of a termination at a radial or DME fix, the boundary is formed by an arc with its centre located at the most distant point of the fix displacement area on course line. Figure 17-8 and its inset show the construction of the area at the termination point.

1712. Secondary Areas

a. Basic Area. The secondary obstacle clearance area extends along a line drawn 2 NM on each side of the primary area (see Figure 17-3).

b. System Accuracy. Secondary area system accuracy lines are drawn at a 6.7° angle on each side of the course or route (see Figure 17-3). The apexes are at the facility. These system accuracy lines will intersect the outer boundaries of the secondary areas at the same point as primary lines, 51 NM from the facility. If the distance from the facility to the COP is more than 51 NM the secondary area extends along the 6.7° line (see Figure 17-4 and Para 1716.c. and d. for offset COP or dogleg airway).

c. Termination Point. Where the airway or route terminates at a facility or radio fix the boundaries are connected by an arc in the same way as those in the primary area. Figure 17-8 and its inset show termination point secondary areas.

1713. Turning Segments

a. Definition. The en route turning area may be defined as an area, which may extend the primary and secondary obstacle clearance areas when a change of course is necessary. The dimensions of the primary and secondary areas will provide adequate protection where the aircraft is tracking along a specific radial, but when the pilot executes a turn, the aircraft may go beyond the boundaries of the protected airspace. The turning area criteria supplements the airway and route segment criteria to protect the aircraft in the turn.

b. Requirement for Turning Segment Criteria. Because of the limitation on aircraft indicated air speeds below 10,000 feet MSL some conditions do not require the application of turning area airspace criteria.

(1) The graph in Figure 17-5 may be used to determine if the turning segment should be plotted for airways/routes below 10,000 feet MSL. If the point of intersection on the graph of the "amount of turn at intersection" versus "VOR facility to intersection distance" falls outside the hatched area of the graph, the turning segment criteria need not be applied.

(2) If the "amount of turn" versus "facility distance" values fall within the hatched area or outside the periphery of the graph, then the turning segment criteria must be applied as described in Para 1714.

c. Track. The flight track resulting from a combination of turn delay, inertia, turning rate, and wind effect is represented by a parabolic curve. For ease of application, a radius arc has been developed which can be applied to any scale chart.

d. Curve Radii. A 250-knot IAS, which is maximum allowed below 10,000 feet MSL, results in radii of 2 NM for the primary area and 4 NM for the secondary area up to that altitude. For altitudes at or above 10,000 feet MSL up to but not including 18,000 feet MSL the primary area radius is 6 NM and the secondary area radius is 8 NM. At and above 18,000 feet MSL the radii are 11 NM for primary and 13 NM for secondary.

e. System Accuracy. In drawing turning segments it will be necessary to consider system accuracy factors by applying them to the most adverse displacement of the radio fix or airway/route boundaries at which the turn is made. The 4.5 and 6.7° factors apply to the VOR radial being flown but since no pilot or aircraft factors exist in the measurement of an intersecting radial, a navigation facility factor of plus-or-minus 3.6° is used (see Figure 17-6).

Note: If a radio fix is formed by intersecting signals from two LF, or one LF and VOR facility, the obstacle clearance areas are based upon accuracy factors of 5.0° (primary) and 7.5° (secondary) each side of the course or route centreline of the LF facilities. If the VOR radial is the intersecting signal, the 3.6° value stated in Para 1713.e applies.

1714. Application Of Turning Segment Criteria

a. Techniques. Figures 17-8, 17-9, and 17-10 illustrate the application of the criteria. They also show areas which may be deleted from considerations when obstacle clearance is the deciding factors for establishing minimum en route altitudes (MEAs) on airways or route segments.

b. Computations. Computations due to obstacles actually located in the turning segments will probably be indicated only in a minority of cases. These methods do, however, add to the flexibility of procedures designers in resolving specific obstacle clearance problems without resorting to the use of deviations to procedures.

c. Minimum Turning Altitude (MTA). Where the application of the turn criteria obviates the use of an MEA with a cardinal altitude, the use of an MTA for a special direction of flight may be authorized.

1715. Turn Area Template

A turn area template has been designed for use on charts scaled at 1:500,000 (see Figure 17-7). It is identified as a “TA-1.”

a. Use of Template Intersection Fix.

(1) **Primary Area**. At an intersection fix the primary obstacle clearance area arc indexes are placed at the most adverse points of the fix displacement area as determined by the outer intersections of the en route radial 4.5° lines (VOR) and the cross-radial 3.6° lines (VOR) (see Figures 17-8 and 17-9). If LF signals are used the 5.0° system accuracy lines apply. The parallel dashed lines on the turn area template are aligned with the appropriate system accuracy lines and the curves are drawn.

(2) **Secondary Area "Outside" Curve**. The outside curve of the secondary area is the curve farthest from the navigation facility that provides the intersecting radial. This curve is indexed to the distance from the fix to the en route facility as follows:

(a) Where the fix is less than 51 NM from the en route facility, the secondary arc is started at a point 2 NM outside the primary index with the parallel dashed lines of the template aligned on the 4.5° lines (see Figure 17-8).

(b) Where the fix is farther than 51 NM from the en route station, the arc is started at the point of intersection of the 3.6 and 6.7° lines with the parallel dashed lines of the template aligned on the 6.7° lines (see Figure 17-9).

(3) **Secondary Area "Inside" Curve**. The inside curve is the turning segment arc which is nearest the navigation facility which provides the intersecting radial. This arc is begun 2 NM beyond the primary index and on the 3.6° line. The parallel dashed lines on the turning segment template are aligned with the 4.5° lines from the en route station.

(a) Where the fix is less than 51 NM from the en route facility and the magnitude of the turn is less than 30°, the "inside" curves do not affect the size of the secondary area.

(b) Where the distance from the en route facility to the fix is more than 51 NM but the magnitude of the turn is less than 45°, the "inside" curves do not increase the size of the secondary area.

(c) Where the magnitude of the turn is greater than those stipulated in (a) and (b) the "inside" curves will affect the size of the secondary area.

(d) Whether the secondary area curves affect the size of the secondary obstacle clearance area or not, they must be drawn to provide reference points for the tangential lines described in (4) below.

(4) **Connecting Lines**. Tangential straight lines are now drawn connecting the two primary arcs and the two secondary arcs. The outer limits of both curves are symmetrically connected to the respective primary and secondary area boundaries in the direction of flight by lines drawn at a 30° angle to the airway or route centreline (see Figures 17-9 and 17-10).

b. Use of Template When Fix Overheads A Facility (see Figure 17-10). The geographical position of the fix is considered to be displaced laterally and longitudinally by 2 NM at all altitudes.

(1) **Primary Arcs**. The primary arcs are indexed at points 2 NM beyond the station and 2 NM on each side of the station. The parallel dotted lines on the template are aligned with the airway or route boundaries and the curves drawn.

(2) **Secondary Arcs**. The secondary arcs are indexed 2 NM outside the primary points, and on a line with them. The parallels dotted lines on the template are aligned with the airway or route boundaries and the curves drawn.

(3) **Connection Lines**. Tangential straight lines are now drawn connecting the two primary and the two secondary arcs. The outer limits of both curves are connected to the primary and secondary area boundaries by intercept lines, which are drawn 30° to the airway or route centreline. The 30° lines on the template may be used to draw these intercept lines.

c. Deletion Areas. Irregular areas remain on the outer corners of the turn areas (see Figures 17-8, 17-9, and 17-10). These are the areas identified in Para 1714 which may be deleted from consideration when obstacle clearance is the deciding factor for determination of MEA on an airway or route segment.

(1) Where the "outside" secondary area curve is started within the airway or route secondary area boundary (see Figure 17-8), the area is blended by drawing a line from the point where the 3.6° (5.0° with LF facility) line meets the line which forms the en route secondary boundary tangent to the "outside" secondary arc. Another line is drawn from the point where the same 3.6° (or 5.0°) line meets the line, which forms the primary boundary, tangent to the matching primary arc. These two lines now enclose the secondary area at the turn. The corner, which was formerly part of the secondary area, may be disregarded; the part, which was formerly part of the primary area, may now be considered secondary area. These areas are shaded in Figure 17-8.

(2) Where the secondary curve is indexed on the secondary area boundary formed by the 6.7° lines, the arc itself cuts the corner and prescribes the deleted area (see Figure 17-9). This condition occurs when the radio fix is over 51 NM from the en route navigation facility.

(3) When overheading the facility, the secondary area corner deletion area is established by drawing a line from a point opposite the station index at the secondary area boundary, tangent to the secondary "outside" curve (see Figure 17-10). A similar line is drawn from a point opposite the station index at the primary area boundary, tangent to the primary turning arc. The corner formerly part of the primary area now becomes secondary area. Shading in Figure 17-10 shows the deletion areas.

1716. Change Over Points (COP)

Points have been defined between navigation facilities along airway/route segments, which are called "change over points (COP)". These points indicate that the pilot using the airway/route should "change over" the navigation equipment to receive course guidance from the facility ahead of the aircraft instead of the one behind. These COP divide a segment and assure continuous reception of navigation signals at the prescribed minimum enroute IFR altitude (MEA). They also assure that aircraft operating within the same portion of an airway or route segment will not be using azimuth signals from two different navigation facilities. Where signal coverage from two facilities overlaps at the MEA, the COP will normally be designated at the mid point, and is not shown on the chart. Where radio frequency interference or other navigation signal problems exist, the COP will be at the optimum location, taking into consideration the signal strength, alignment error, or any other known condition, which affects reception. The effect, of COP on the primary and secondary obstacle clearance areas is as follows:

a. Short Segments. If the airway or route segment is less than 102 NM long and the COP is placed at the mid point, the obstacle clearance areas are not affected (see Figure 17-11).

b. Long Segments. If the distance between two facilities is over 102 NM and the COP is placed at the mid point, the system accuracy lines extend beyond the minimum widths of 8 and 12 NM, and a flare results at the COP (see Figure 17-12).

c. Offset Cop. If the change over point is offset due to facility performance problems, the system accuracy lines must be carried from the farthest facility to a position abeam the change over point, and these lines on each side of the airway or route segment at the COP are joined by lines drawn from the nearer facility. In this case the angles of the lines drawn from the nearer facility have no specific angle (see Figure 17-13).

d. Dogleg Segment. A dogleg airway or route segment may be treated in a manner similar to that given offset COPs. The system accuracy lines will be drawn to meet at a line drawn as the bisector of the dogleg "bend" angle and the boundaries of the primary and secondary areas extended as required (see Figure 17-14).

1717. Course Change Effect

The complexity of defining the obstacle clearance areas is increased when the airway or route becomes more complex. Figure 17-15 shows the method of defining the primary area when a radio fix and a COP are involved. Note that the system accuracy lines are drawn from the farthest facility first, and govern the width of the airway or route at the COP. The application of secondary area criteria results in a segment similar to that depicted in Figure 17-16.

1718. Reserved

1719. Protected En Route Areas/Segments

As previously established, the en route areas, which must be considered for obstacle clearance protection, are identified as primary and secondary turn areas. The overall consideration of these areas is necessary when determining obstacle clearances.

SECTION 2. VHF OBSTACLE CLEARANCE

1720. Obstacle Clearance, Primary Area

a. Non-Mountainous Regions. The minimum obstacle clearance over areas not designated as, mountainous will be 1,000 feet over the highest obstacle.

b. Mountainous Areas. Owing to the action of Bernoulli Effect and of atmospheric eddies, vortices, waves, and other phenomena, which occur in conjunction with the disturbed airflow attending the passage of strong winds over mountains, pressure deficiencies manifested as very steep horizontal pressure gradients develop over such regions. Since down drafts and turbulence are prevalent under these conditions, the hazards to air navigation are multiplied. Except as set forth in (1) below, the minimum obstacle clearance over terrain and manmade obstacles, within designated mountainous regions will be 2,000 feet.

(1) Obstacle clearance may be reduced to not less than 1,500 feet above terrain and manmade obstacles within the designated mountainous regions located in eastern Canada which includes part of Quebec, New Brunswick and Newfoundland as described in TP 1820 DAH/GPH 204.

Note: Altitudes of 1,000 feet of obstacle clearance within designated mountainous regions may be provided on airways/routes located within terminal areas. That segment is to be identified by a fix or facility.

1721. Obstacle Clearance, Secondary Areas

In all areas, mountainous and non-mountainous, obstacles which are located in the secondary areas will be considered as obstacles to air navigation when they extend above the secondary obstacle clearance plane. This plane begins at a point 500 feet above the obstacles upon which the primary obstacle clearance area MOCA is based, and slants upward at an angle which will cause it to intersect the outer edge of the secondary area at a point 500 feet higher (see Figure 17-17). Where an obstacle extends above this plane, the normal MOCA shall be increased by adding to the MSL height of the highest penetrating obstacle in the secondary area the required clearance (C), computed with the following formula:

$$\frac{D_1}{D_2} = \frac{500}{C} \text{ or } C = \frac{500 \times D_2}{D_1}$$

D_1 is the total width of the secondary area.

D_2 is the distance from the obstacle to the OUTER edge of the secondary area.

Note: Add an extra 1,000 feet in mountainous regions where 2,000 feet of obstacle clearance is provided and 500 feet in the region where 1,500 feet of obstacle clearance is provided.

D_1 has a total width of 2 NM, or 12,152 feet out to a distance of 51 NM from the en route facility, and then increases at a rate of 236 feet for each additional NM.

Example: An obstacle which reaches 1,875 feet MSL is found in the secondary area 6,170 feet inside the outer secondary area boundary and 46 NM from the facility (see Figures 17-17 and 17-18).

D_1 is 12,152 feet
D_2 is 6,170 feet

$$\frac{500 \times 6{,}170}{12{,}152} = 253.8 \text{ (254 feet)}$$

Obstacle height (1,875) + 254 = 2,129.
MOCA is 2,200 feet.

1722. Obstacle Clearance Graph

Figure 17-19 is a secondary area obstacle clearance graph, designed to allow the determination of clearance requirements without using the formula. The left axis shows the required obstacle clearance; the lower axis shows the distance from the outer edge of the secondary area to the obstacle. The slant lines are facility distance references.

Facility distances, which fall between the charted values, may be found by interpolation along the vertical distance lines.

a. Application. To use the secondary area obstacle clearance chart, enter with the value representing the distance from the outer edge of the secondary area to the obstacle. In the problems above this distance was 6,170 feet. Proceed up to the "51 NM or less" line and read the clearance requirement from the left axis. The chart reads 254 feet, the same as was found using the formula. To solve the second problem, re-enter the chart at 6,170 feet and move vertically to find 68 NM between the 60 and 70 NM facility distance slant lines. The clearance requirement shown to the left is 191 feet, the same as found using the formula.

b. Finding the MOCA. The required clearance, found by using the graph, is now added to the MSL height of the obstacle to get the MOCA.

(1) 46 NM from facility:

254 + 1,875 = 2,129 (2,200 MSL).

(2) 68 NM from facility:

191 + 1,875 = 2,066 (2,100 MSL).

1723—1729. Reserved

SECTION 3. ALTITUDES

1730. Minimum Reception Altitudes (MRA)

It is necessary to establish MRAs in all cases where designated intersections along airways or routes are formed by intersecting radials that require higher altitudes for the reception of that radial than the established MEA along the airway or route segment.

1731. En Route Minimum Holding Altitudes

Criteria for holding pattern airspace and obstacle clearance are specified in Chapter 18.

1732. Minimum En Route Altitudes (MEA)

An MEA will be established for each segment of an airway/route from radio fix to radio fix. The MEA will be established based upon obstacle clearance over the terrain or over manmade objects, adequacy of navigation facility performance, and communications requirements. The MEA shall also be at or above the base of controlled airspace. Segments are designated West to East and South to North. Altitudes will be established to the nearest 100-foot increment; i.e. 4,049 feet becomes 4,000 feet; and 4,050 feet becomes 4,100, as long as the minimum required obstacle clearance is not violated.

Note: Care must be taken to insure that all MEAs based upon flight inspection information have been corrected to and reported as true altitudes above mean sea level (MSL).

1733—1739. Reserved

SECTION 4. NAVIGATION GAP

1740. Navigational Gap Criteria

Where a gap in course guidance exists, an airway or route segment may be approved in accordance with the criteria set forth in Para 1740.c, provided:

a. Restrictions.

(1) The gap may not exceed a distance which varies directly with altitude from zero NM at sea level to 65 NM at 45,000 feet MSL;

(2) Not more than one gap may exist in the airspace structure for the airway/route segment;

(3) A gap may not occur at any airway or route turning point, except when the provisions of Para 1740.b.(2) are applied; and

(4) Where the MEA has been established with a gap in navigational signal coverage, the gap area will be identified by distance from the navigation facilities on the chart, depicting the airway/route segments.

b. Authorization. MEAs with gaps shall be authorized only where a specific operational requirement exists. Where gaps exceed the distance in Para 1740.a.(1), or are in conflict with the limitations in Para 1740.a.(2) or (3), the MEA must be increased as follows:

(1) For straight segments:

(a) To an altitude which will meet the distance requirement of Para 1740.a.(1), or;

(b) When in conflict with Para 1740.a.(1) or (2) to an altitude where there is continuous course guidance available.

(2) For turning segments. Turns to intercept radials with higher MEAs may be allowed provided;

(a) The increase in MEA does not exceed 1500 feet; and

(b) The turn does not exceed 90°.

(3) When in conflict with Para 1740.b.(1) or (2) to an altitude where there is continuous course guidance available.

c. Use Of Steps. Where large gaps exist which require the establishment of altitudes that obviate the effective use of airspace, consideration may be given to the establishment of MEA "steps". These steps may be established at increments of not less than 2,000 feet below 18,000 feet MSL, or not less than 4000 at 18,000 and above, provided that a total gap does not exist for the segment within the airspace structure. MEA steps shall be limited to one step between any two facilities to eliminate continuous or repeated changes to altitude in problem areas. MEA changes shall be identified by designated radio fixes.

d. Gaps. Allowable navigational gaps may be determined by reference to the graph in Figure 17-23.

EXAMPLE: The problem drawn on the chart shows the method used to determine the allowable gap on a route segment with a proposed MEA of 27,000 feet. Enter the graph at the left edge with the MEA of 27,000 feet. Move to the right to the interception of the diagonal line. Move to the bottom of the graph to read the allowable gap. In the problem drawn, a 39 NM gap is allowable.

1741—1749. Reserved

SECTION 5. LOW FREQUENCY AIRWAYS OR ROUTES

1750. LF Airways Or Routes

a. Usage. LF navigation facilities may be used to establish en route airway/route segments.

b. Obstacle Clearance Areas (see Figures 17-24 and 17-25).

(1) The primary obstacle clearance area boundaries of LF segments are lines drawn 4.34 NM (5 statute miles) on each side of and parallel to the segment centreline. These boundaries will be affected by obstacle clearance area factors shown in Para 1750.c.

(2) The LF secondary obstacle clearance areas extend laterally for an additional 4.34 NM on each side the primary area. The boundaries of the secondary areas are also affected by the obstacle clearance areas factors shown in c. below.

c. Obstacle Clearance Area Factors (see Figures 17-24 and 17-25).

(1) The primary of LF segments is expanded in the same way as for VHF airways/routes. Lines are drawn at 5° off the course centreline from each facility. These lines meet at the mid point of the segment. Penetration of the 4.34 NM boundary occurs 49.61(50) NM from the facility.

(2) The secondary areas are expanded in the same manner as the secondary areas for VHF airways/routes. Lines are drawn 7.5° on each side of the segment centreline. These 7.5° lines will intersect the original 8.68 NM secondary area boundaries at 65.93 (66) NM from the facility.

d. Obstacle Clearance

(1) Obstacle clearance in the primary area of LF airways or routes is the same as that required for VOR airways/routes. The areas over which the clearances apply are different, as shown in Para 1750.c.

(2) Secondary area obstacle clearance requirements for LF segments are based upon distance from the facility and location of the obstacle relative to the inside boundary of the secondary area.

(a) Within 25 NM of the facility the obstacle clearance is based upon a 50:1 plane drawn from the primary area boundary 500 feet above the obstacle, which dictates its MOCA and extending to the edge of the secondary area. When obstacles penetrate this 50:1 plane, the MOCA for the segment will be increased above that dictated for the primary area obstacle as detailed in Table 17-1.

(b) Beyond the 25 NM distance from the facility, the secondary obstacle clearance plane is flat. This plane is drawn from the primary area boundary 500 feet above the obstacle, which dictates its MOCA and extending to the edge of the secondary area. If an obstacle penetrates this surface the MOCA for the segment will be increased so as to provide 500 feet of clearance over the obstacle (see Figure 17-27 and Para 1750.d.(2)(c)).

(c) Obstacle clearance values shown in (a) and (b) above are correct for non-mountainous, areas only. For areas designated as mountainous add 1,000 feet, or 500 feet, as applicable.

1751. LF/MF Facility to VHF/UHF Facility Airway or Air Route

Airways and air routes may be constructed between LF/MF and VHF/UHF facilities. The criteria for area construction and obstacle clearances are contained in the appropriate section within this chapter. However, due to the different system accuracies (primary area 4.5° for VHF/UHF and 5.0° for LF/MF and secondary area 6.7° for VHF/UHF and 7.5° for LF/MF), to ensure proper obstacle assessment for the entire airway or air route, primary and secondary LF/MF system accuracy criteria shall be applied for the entire length of the airway or air route between the LF/MF and VHF/UHF facility.

This means that when constructing the airway or air route, the LF/MF primary obstacle clearance area of 4.34 NM each side of centerline and the secondary obstacle clearance area of 4.34 NM each side of the primary area shall be applied for the entire airway or air route. In addition, the LF/MF primary area shall be expanded 5.0° off the course centerline from each facility and the secondary area shall be expanded 7.5° off the course centerline from each facility for the entire airway or air route.

1752. Application Of Variation To Calculate LF/MF Tracks

When calculating airway or air route tracks, the appropriate variation shall be applied to the LF/MF segment true bearing to ensure that the aircraft will be positioned on the desired inbound radial at the COP. Proper application of variation is necessary to minimize track error and to ensure the aircraft is positioned on course at the change over point. This calculation is made from facility to facility and NOT redone for each airway segment between fixes.

If midpoint variation were to be used (see Figure 17-29A) this does not happen. The aircraft heading would initially overcorrect, based on the difference between local variation at the site and the midpoint variation. This over correction will decrease as the aircraft proceeds toward the midpoint, at which time the aircraft would be flying on the proper heading but has not corrected back to the desired track .On a long leg, the resulting track error can be greater than 20nm.

Therefore, to minimize this error and to position the aircraft on the desired track at the midpoint of the airway/air route, ¼ point variation shall be used (see Figure 17-29B). Due to the difference between the local variation at the aircrafts position and the ¼ point variation, the aircraft heading will initially overcompensate, resulting in a track error. As the aircraft proceeds, this error will decrease until at the ¼ point the aircraft will be flying the proper heading but now be just parallel to the desired track. As the aircraft proceeds toward the midpoint it will begin to correct back and ideally be on the desired track at the midpoint (see Figure 17-29B).

Using the same basic rational, in the instance of a dogleg or published COP, the variation to the LF/MF leg shall be the variation at the mid point of that particular segment (see Figure 17-29C).

In summary, the variation(s) to apply to the LF/MF track calculations shall be as follows:

a. LF/MF to LF/MF

¼ point variation (see Figure 17-29B).

b. LF/MF to VHF/UHF

¼ point variation for the LF/MF segment (see Figure 17-29C).

The VHF/UHF Radial shall be calculated based on the calibrated variation used for that facility. These values are published in the Canada Flight Supplement, Part D.

c. COP/Dogleg Segment

Mid-point variation for the LF/MF-COP segment shall be used to calculate the track (see Figure 17-29C).

The VHF/UHF-COP segment track will be calculated in accordance with Para 1752.b.2.

1753—1759. Reserved

SECTION 6. MINIMUM DIVERGENCE ANGLES

1760. General

a. Governing Facility. The governing facility for determining the minimum divergence angle depends upon how the fix is determined.

(1) Where the fix is predicated on an off-course radial or bearing, the distance from the fix to the facility providing the off-course radial or bearing is used.

(2) Where the fix is predicated on the radials or bearings of two intersecting airways or routes, the distance between the farthest facility and the fix will be used to determine the angle.

b. Holding. See Chapter 18 for minimum divergence angle when holding will be authorized at an intersection.

1761. VHF Fixes

a. The minimum divergence angle for those fixes formed by intersecting VHF radials are determined as follows:

(1) When both radio facilities are located within 30 NM of the fix, the minimum divergence is 30°.

(2) When the governing facility is over 30 NM from the fix, the minimum allowable angle will be increased at the rate of 1° per NM up to 45 NM (45°).

(3) Beyond 45 NM, the minimum divergence angle increases at the rate of ½° per NM.

EXAMPLE: Distance from fix to governing facility is 51 NM.

51 - 45 = 6 NM. x ½ = 3 additional degrees.

Add this 3° to the 45° required at 45 NM and get 48° minimum divergence angle at 51 NM.

b. Figure 17-28 may be used to define minimum divergence angles. Using the foregoing example, enter the chart at the bottom with the facility distance (51 NM). Move up to the "VHF Fix" conversion line. Then move to the left to read the angle – 48°.

1762. LF or VHF/LF Fixes

a. Minimum divergence angles for LF or integrated (VHF/LF) fixes are determined as follows:

(1) When the governing facility is within 30 NM of the fix, the minimum divergence angle is 45°.

(2) Beyond 30 NM the minimum angle must be increased at the rate of 1° for each NM, except for fixes on long over water routes where the fix will be used for reporting purposes and not for traffic separation.

EXAMPLE: The distance from the governing facility is 51 NM.

51 - 30 = 21

Add 21° to 45° required at 30 NM to get the required divergence angle, 66°.

b. Figure 17-28 may be used to define minimum angles for LF or VHF/LF fixes. Using the foregoing example, enter at the bottom of the chart with the 51 NM distance between the facility and fix. Move up to the "LF or INTEGRATED FIX" conversion line, then left to read the required divergence angle, 66°.

1763—1799. Reserved

Distance from Primary Boundary	Height added to Obstacle in the Secondary Area
0 – 1 SM (0.00 – 0.87 NM)	500 feet
> 1 – 2 SM (0.87 – 1.74 NM)	400 feet
> 2 – 3 SM (1.74 – 2.61 NM)	300 feet
> 3 – 4 SM (2.61 – 3.48 NM)	200 feet
> 4 – 5 SM (3.48 – 4.34 NM)	100 feet
Note: See Figure 17-23 for cross section view. Also Para 1750.d.(2)(c)	

Table 17-1: Increase To MOCA When 50:1 Obstacle Clearance Plane Penetrated. Para 1750.d.(2)(a)

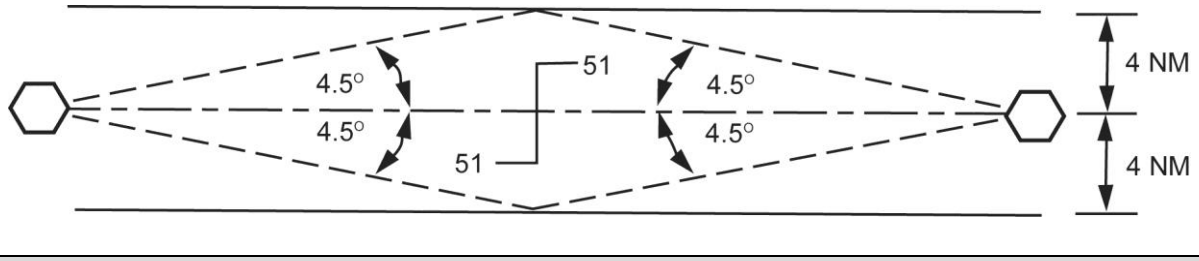


Figure 17-1: Primary Obstacle Clearance Area. Para 1711.a.

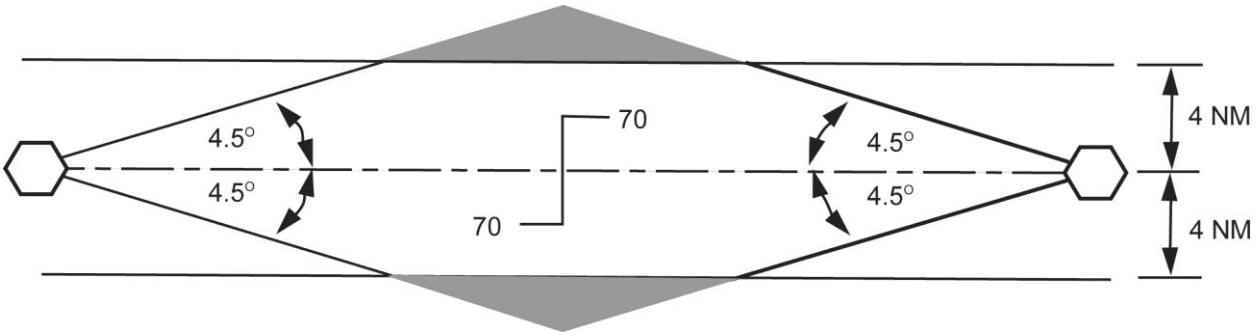


Figure 17-2: Primary Obstacle Clearance Area. Para 1711.b.

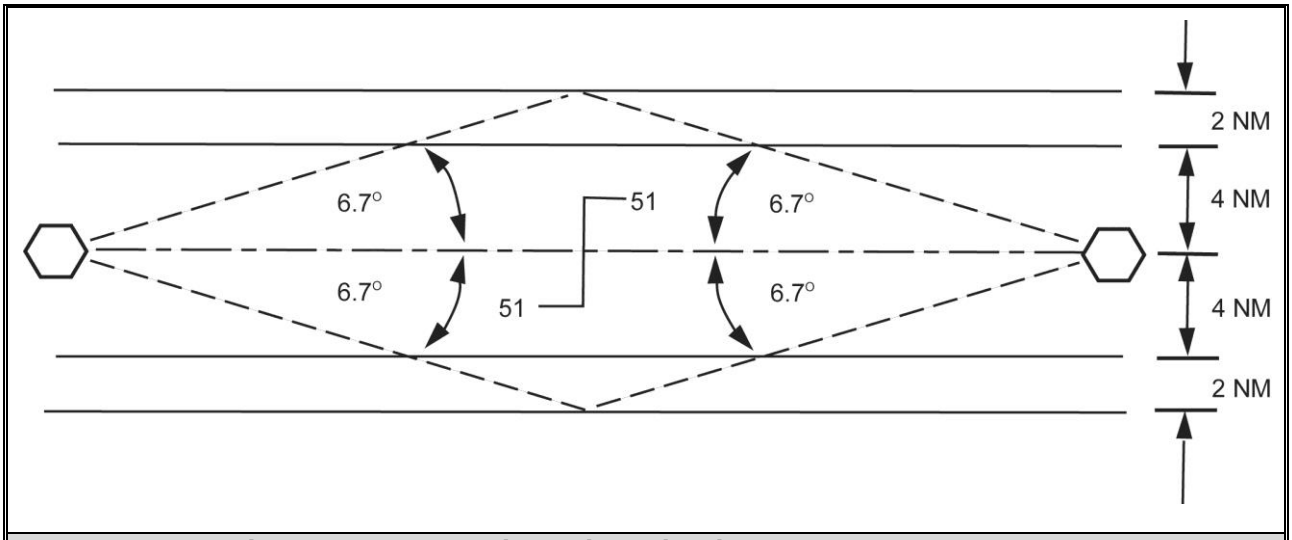


Figure 17-3: Secondary Obstacle Clearance Areas. Para 1712.a.

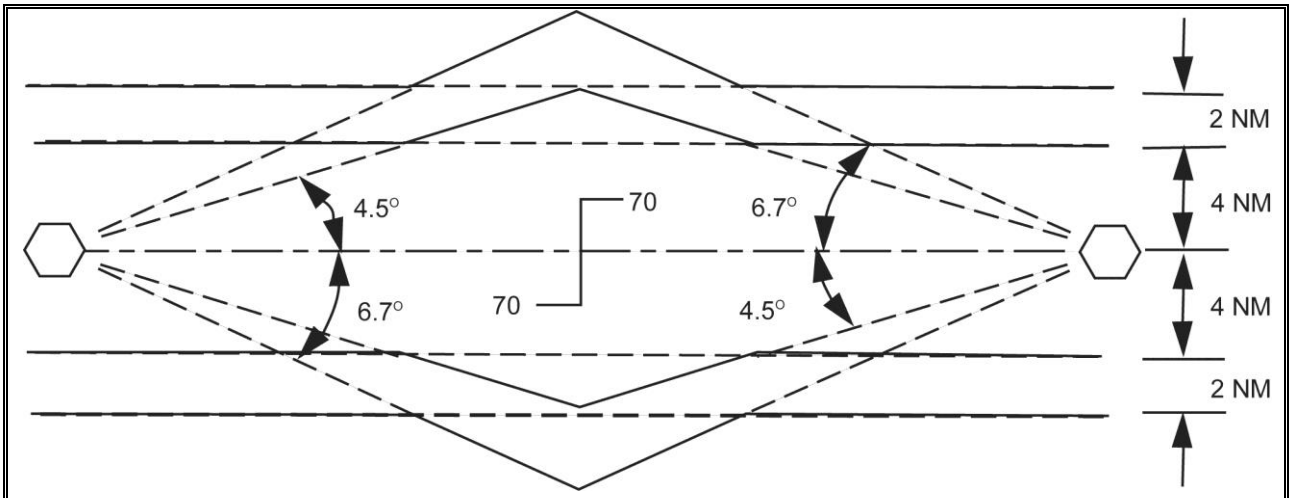


Figure 17-4: secondary obstacle clearance areas. Application of system accuracy lines. Para 1712.b.

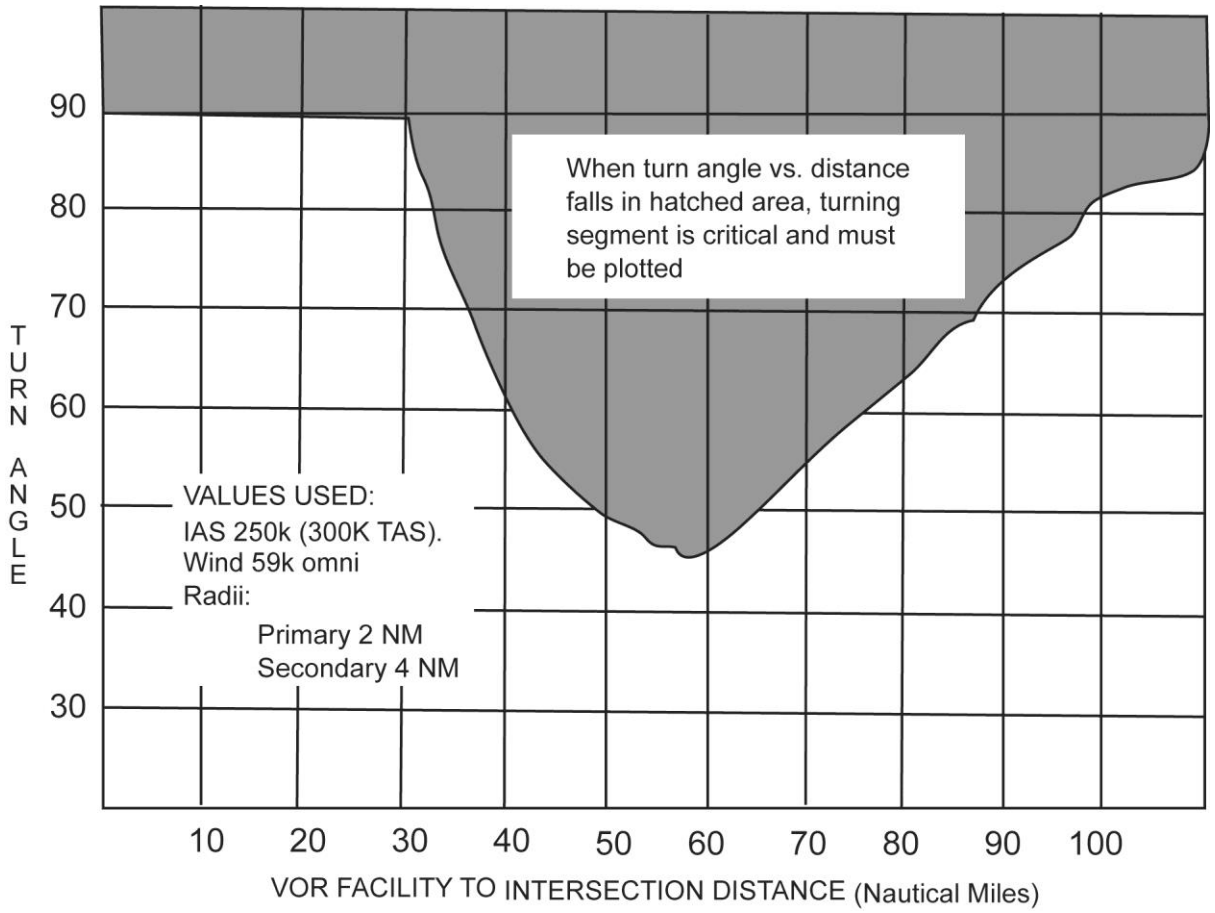


Figure 17-5: Turn Angle vs Distance. Para 1713.b (1) and (2).

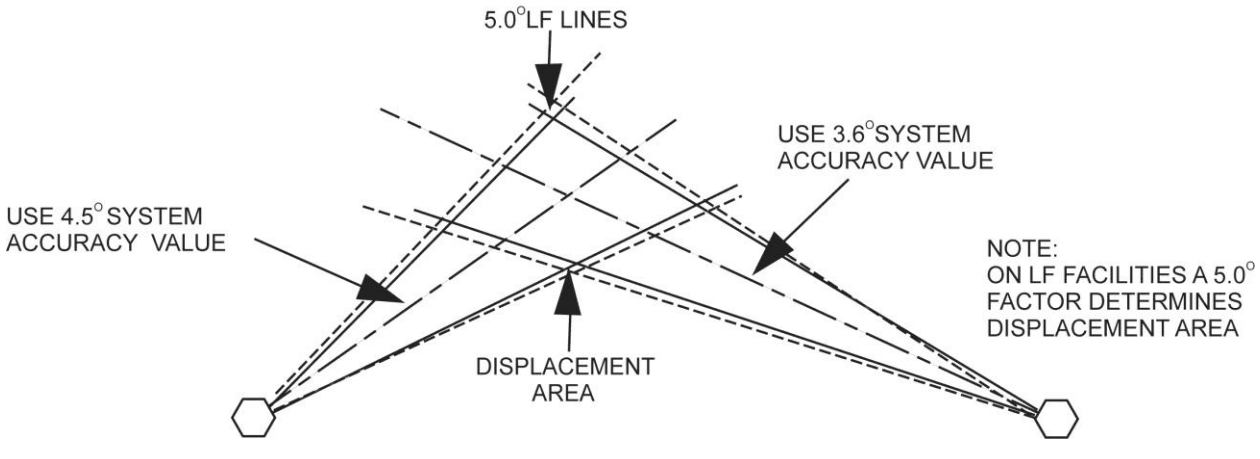


Figure 17-6: Fix Displacement. Para 1713.e.

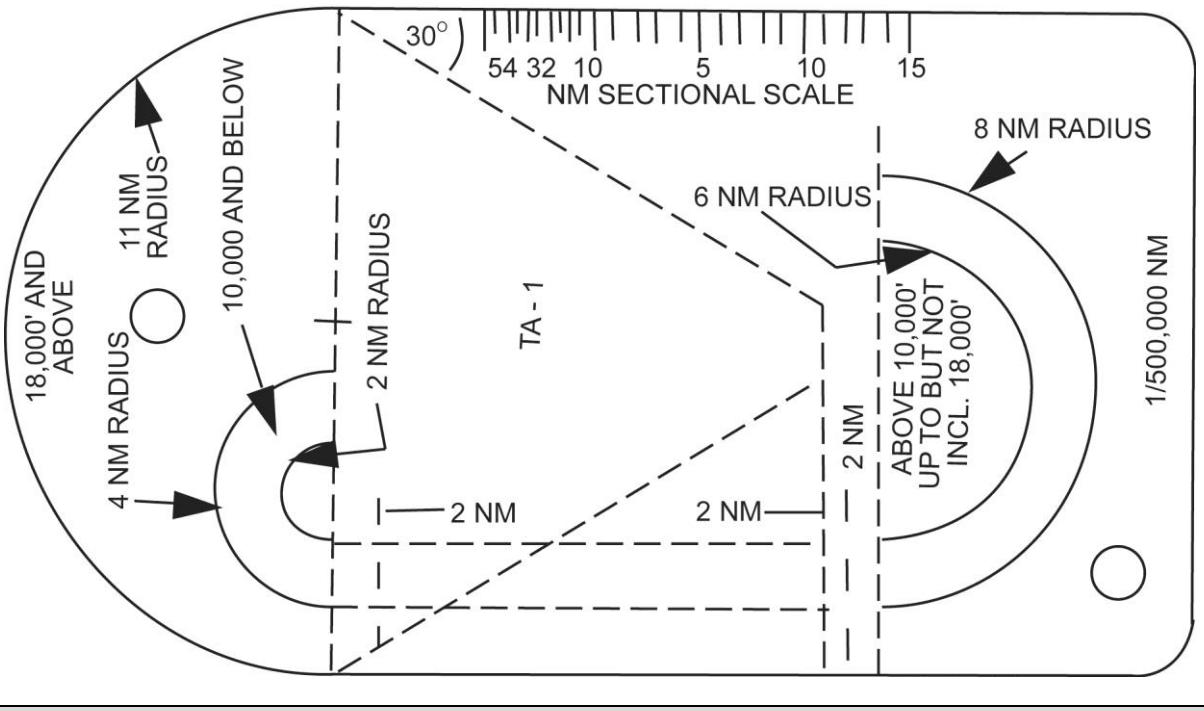


Figure 17-7: Turning Segment Template. Para 1715.

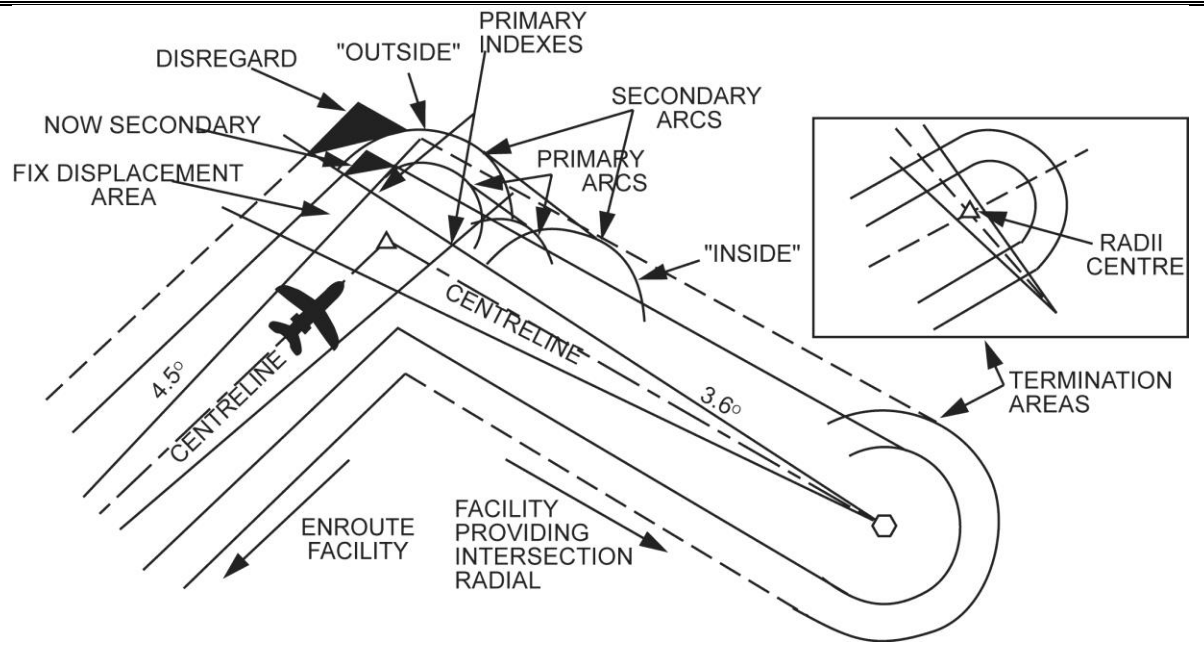


Figure 17-8: turning segment, intersection fix. Facility distance less than 51 nm. Para 1715.a and b.

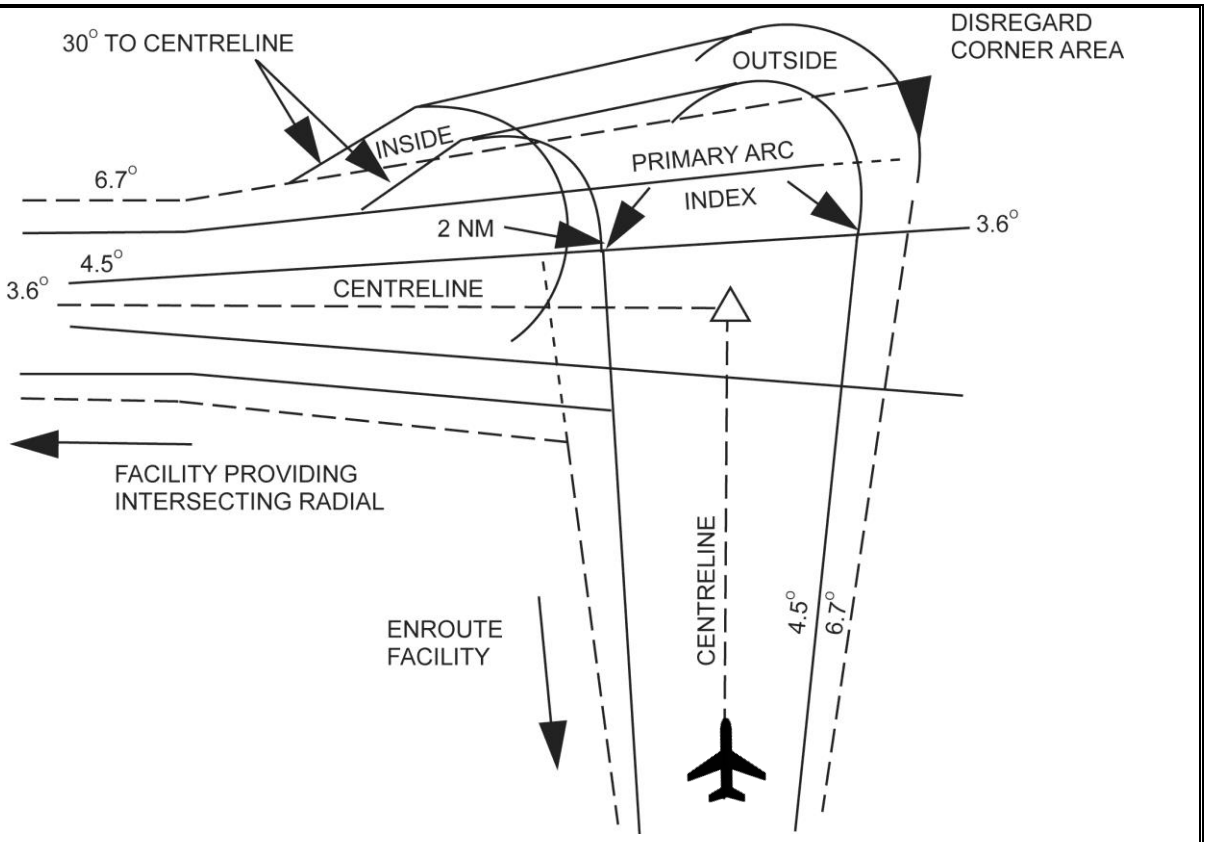


Figure 17-9: turning segment, intersection fix. Facility distance beyond 51 nm. Para 1715.a and b.

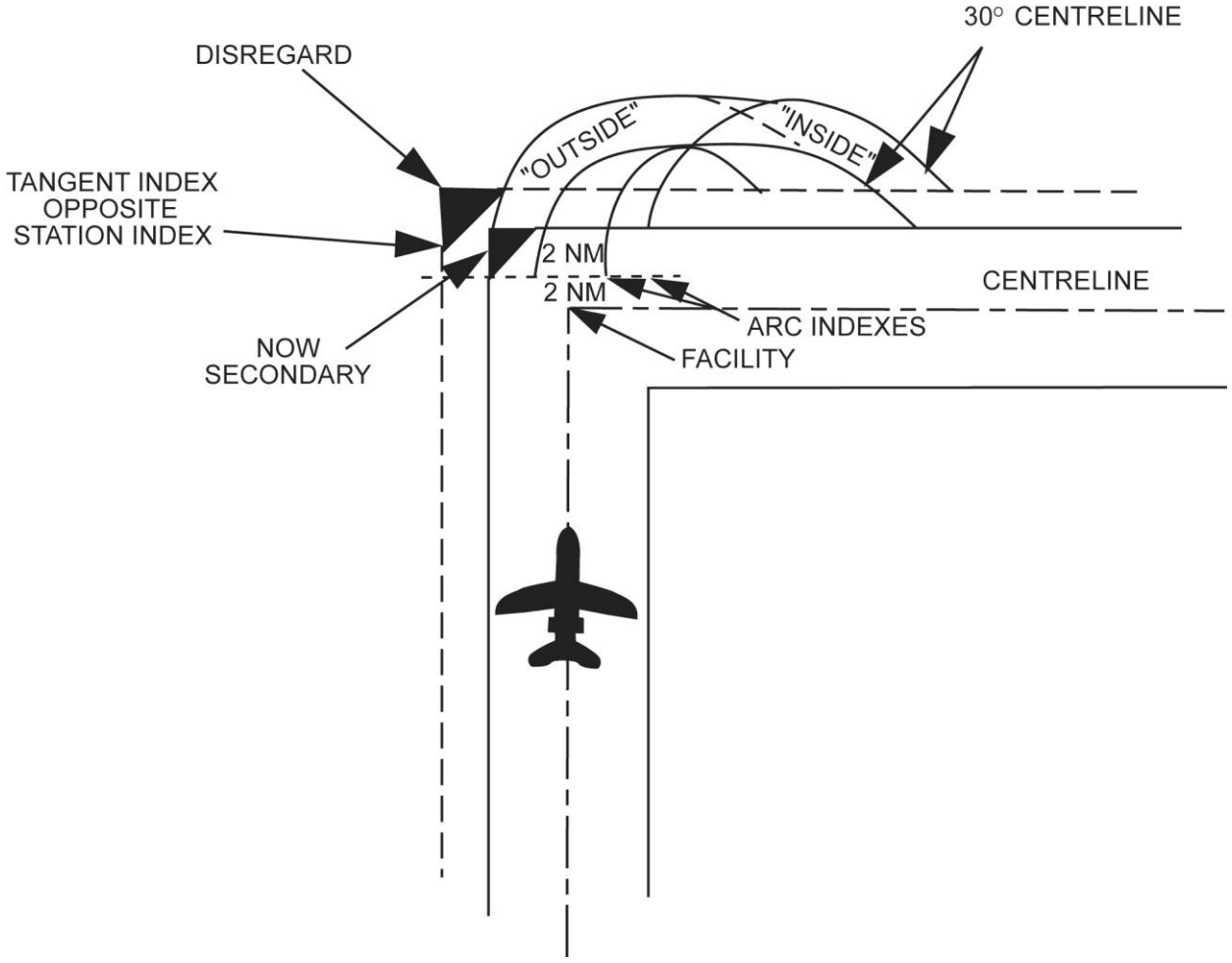


Figure 17-10: Turning Segment Overhead The Facility. Para 1715.b.

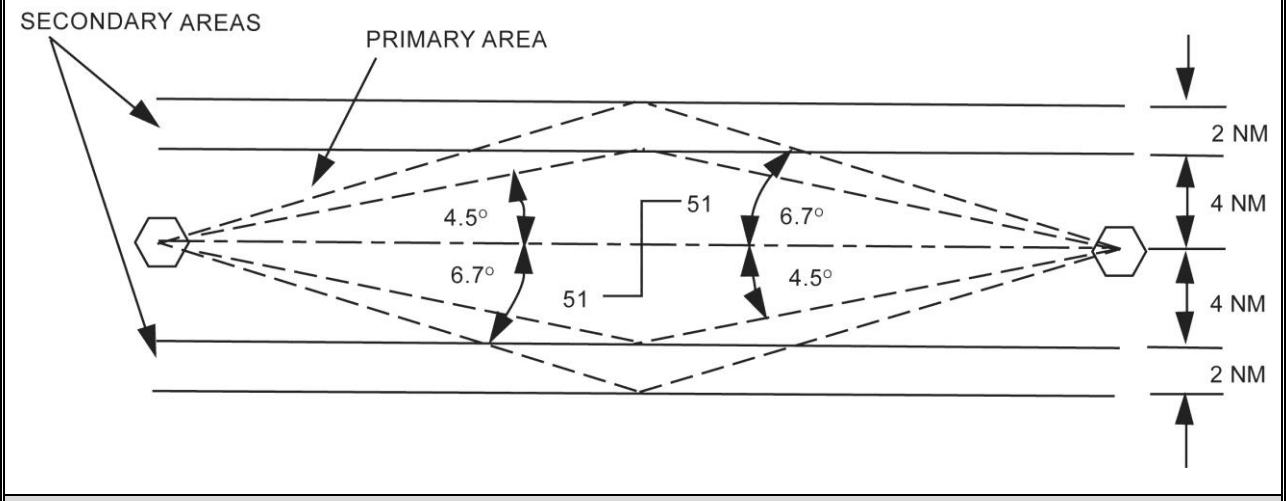


Figure 17-11: COP effect. Short airway or route segment. Para 1716.a.

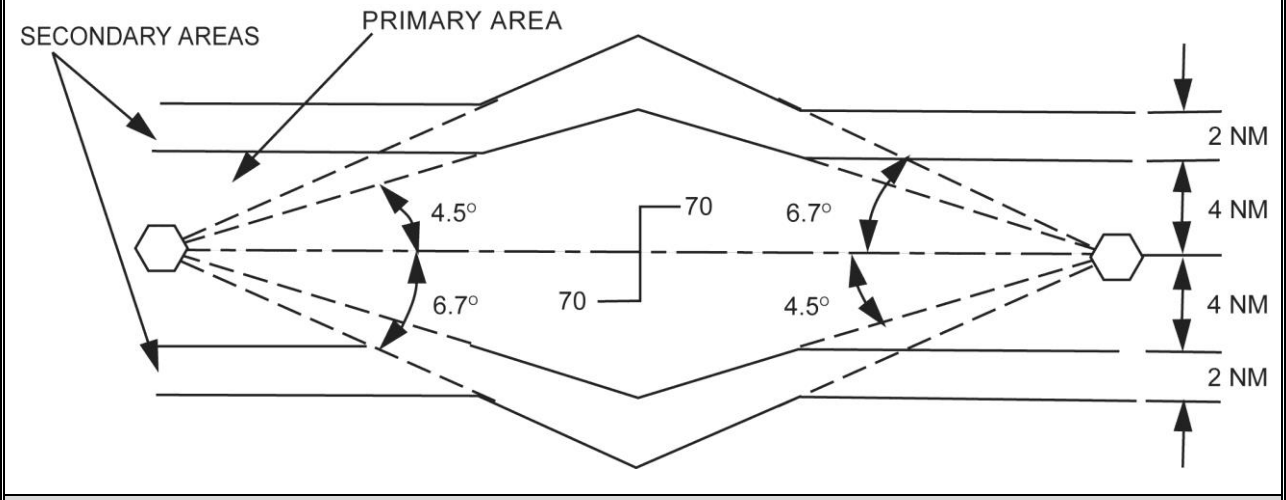


Figure 17-12: COP Effect. Long Airway Or Route Segment. Para 1716.b.

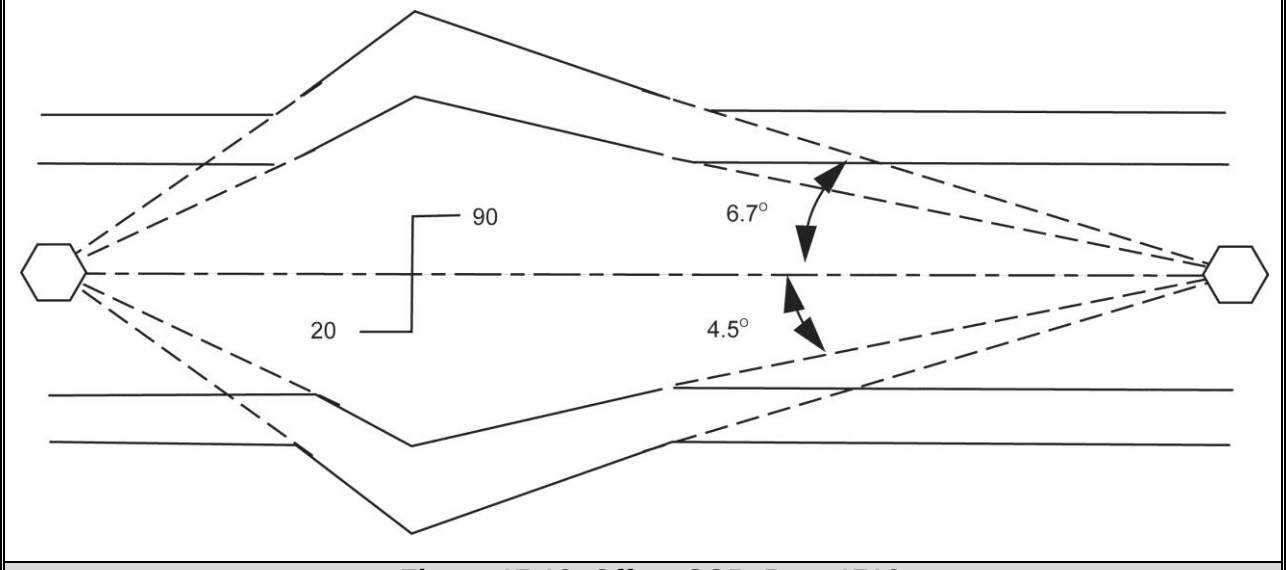


Figure 17-13: Offset COP. Para 1716.c.

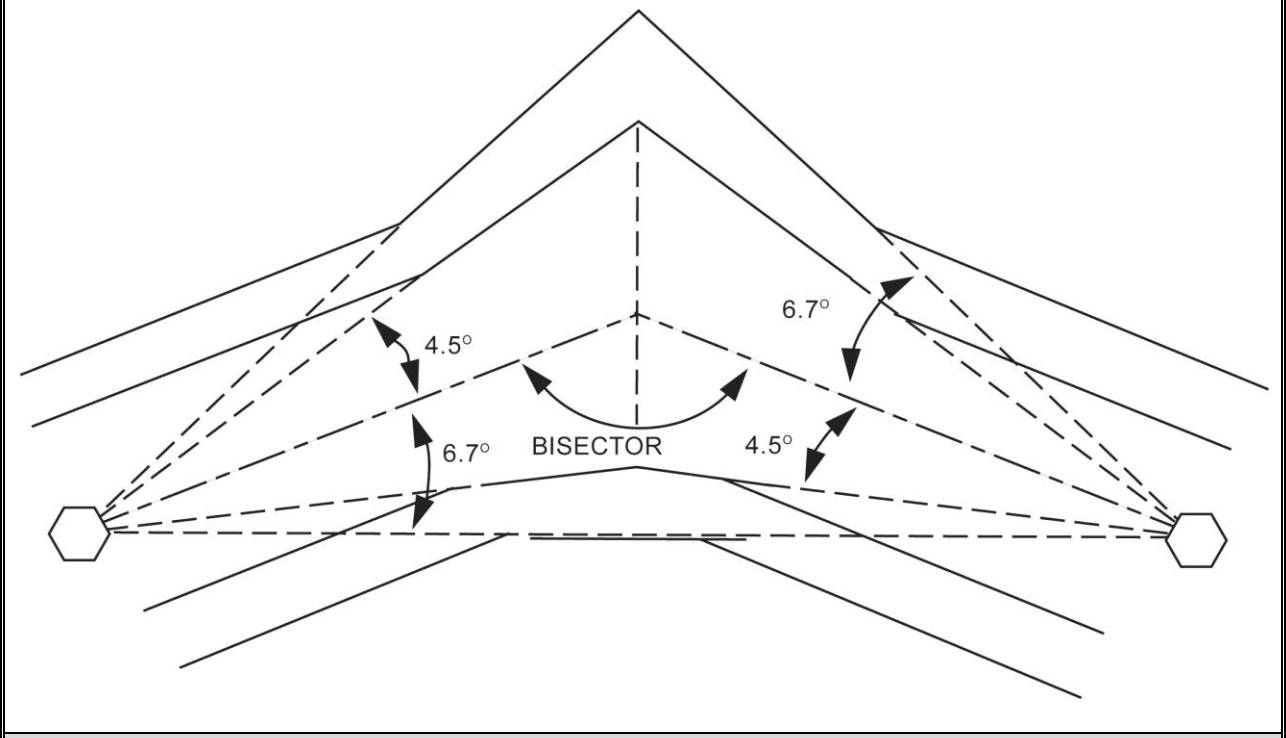


Figure 17-14: Dogleg Segment. Para 1716.d.

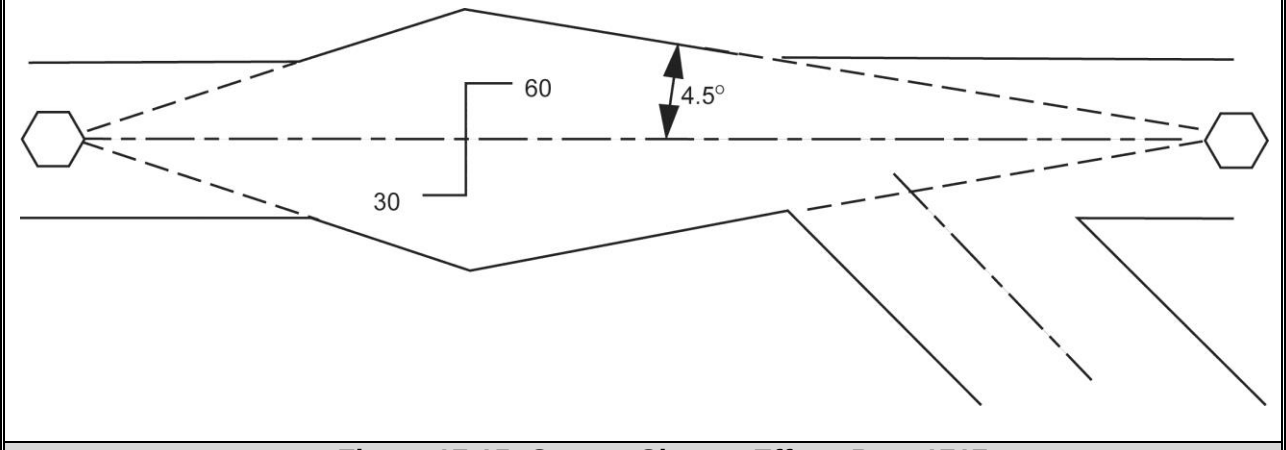


Figure 17-15: Course Change Effect. Para 1717.

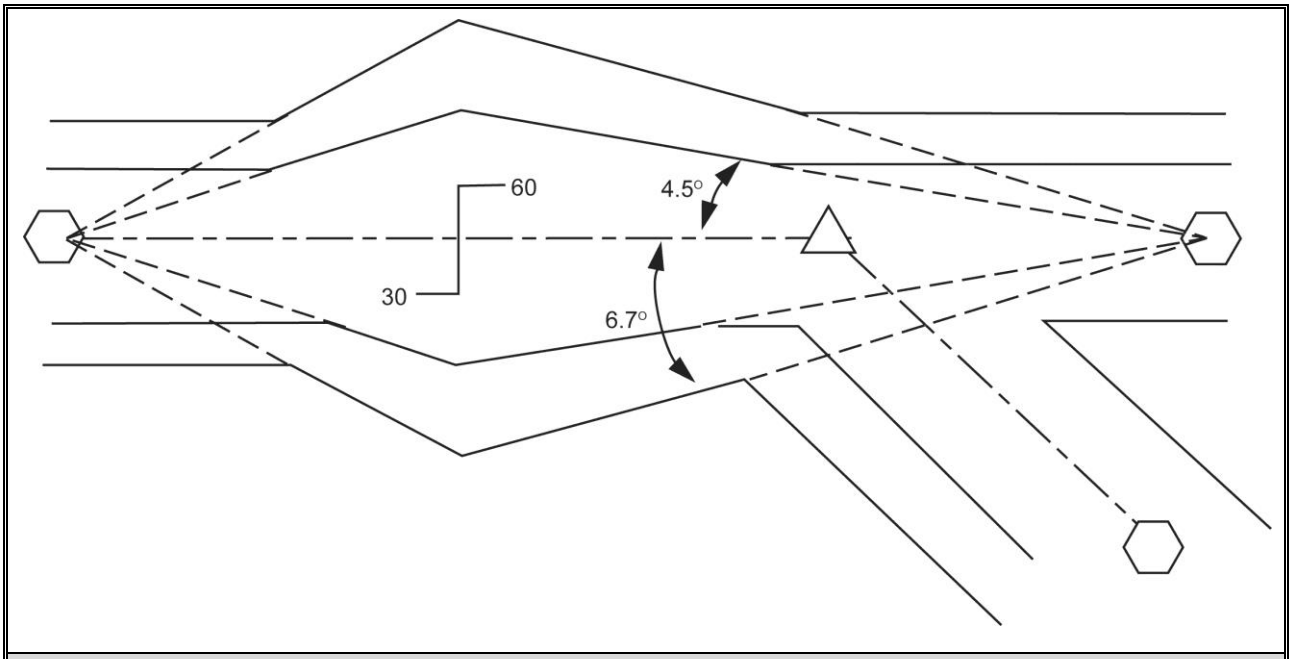


Figure 17-16: Application Of Secondary Areas. Para 1717.

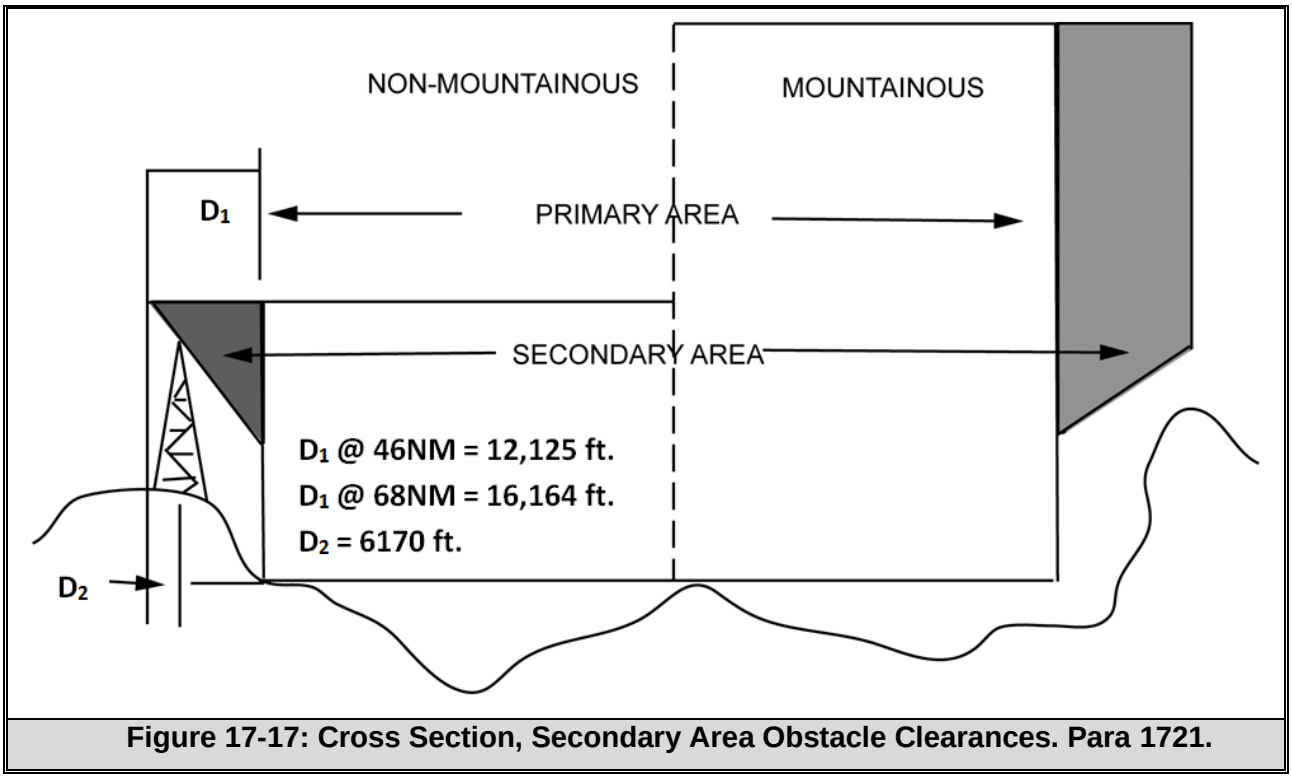


Figure 17-17: Cross Section, Secondary Area Obstacle Clearances. Para 1721.

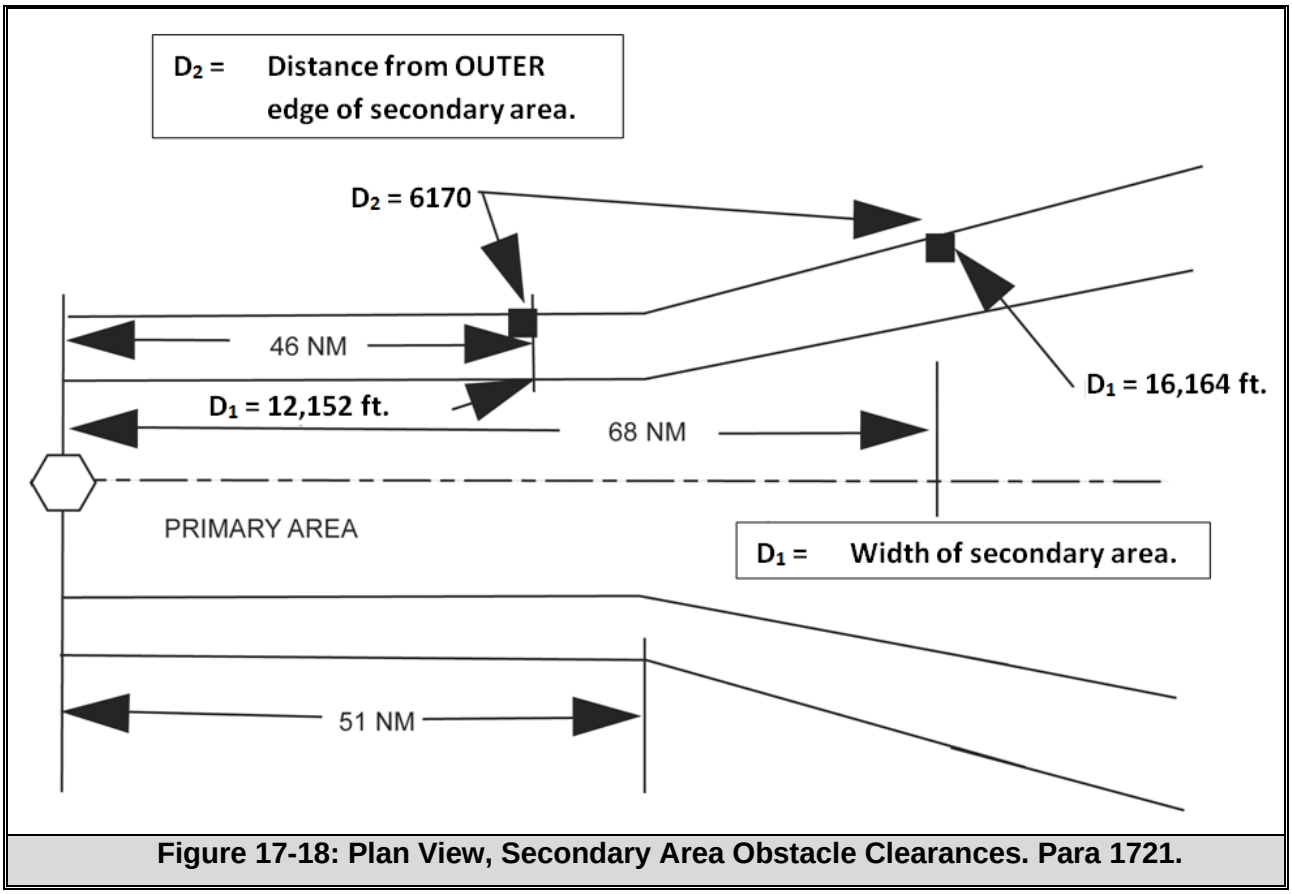


Figure 17-18: Plan View, Secondary Area Obstacle Clearances. Para 1721.

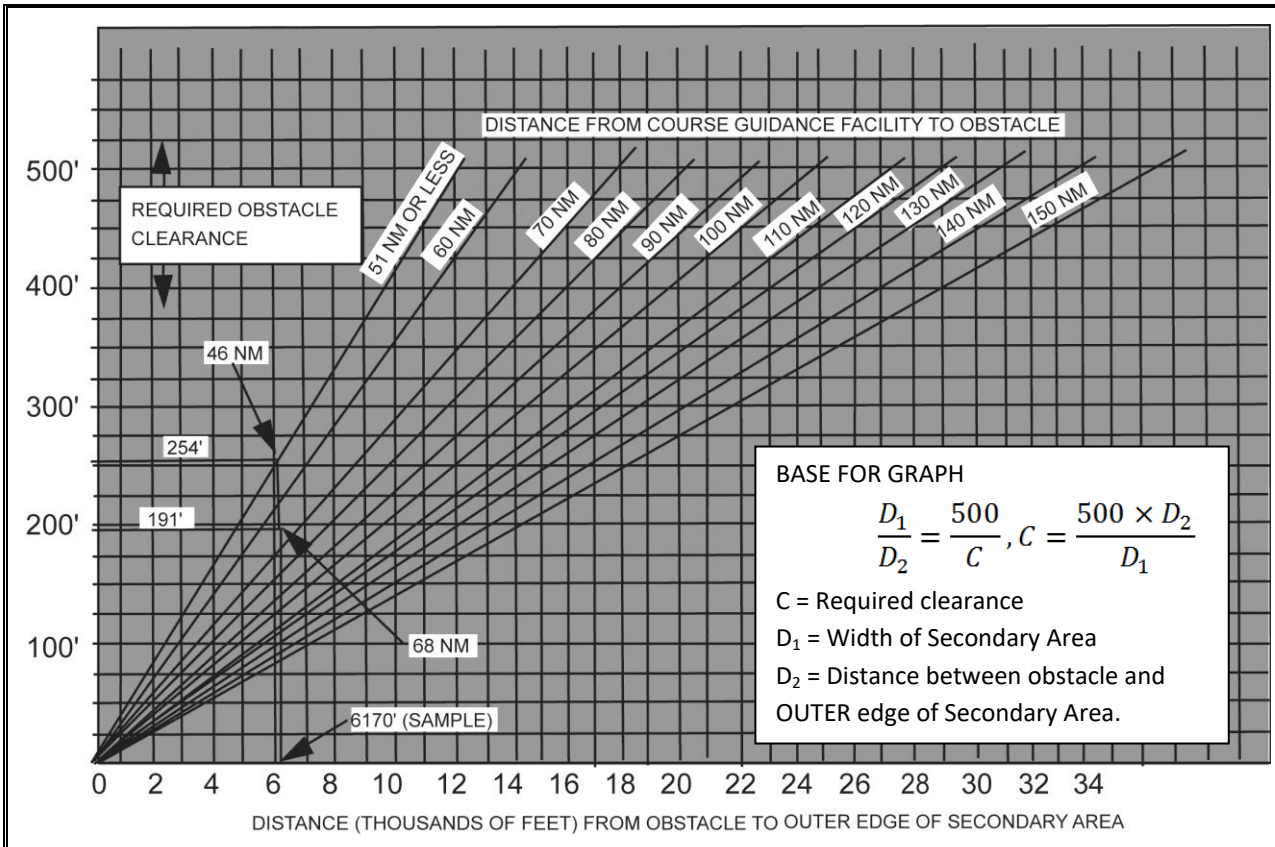
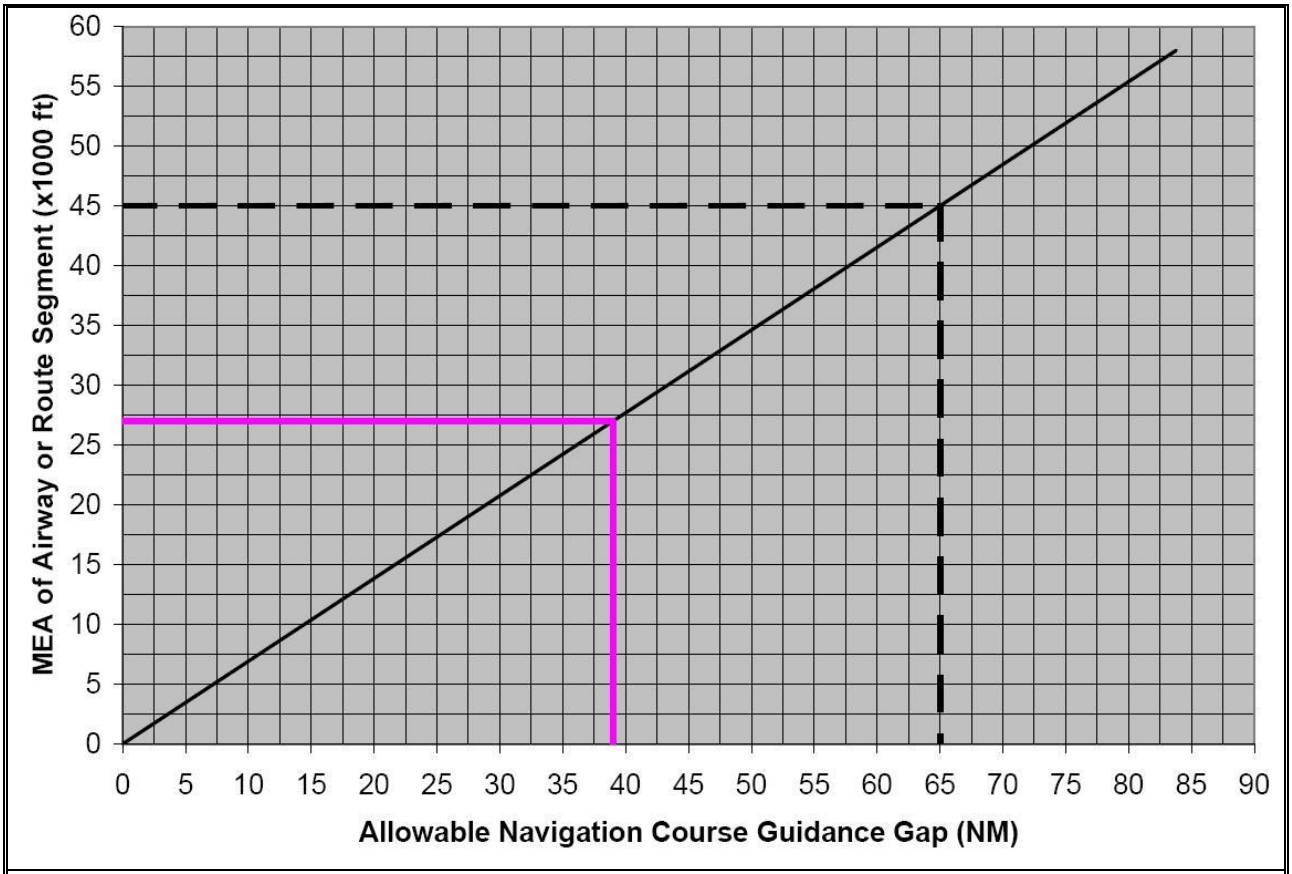


Figure 17-19: Secondary Obstacle Clearance. Para 1722.

Figures 17-20 to 17-22: Reserved



Example: Enter with MEA of 27,000', Read Allowable Gap 39 NM

Figure 17-23: Allowable Navigation Course Guidance Gaps. Para 1740.

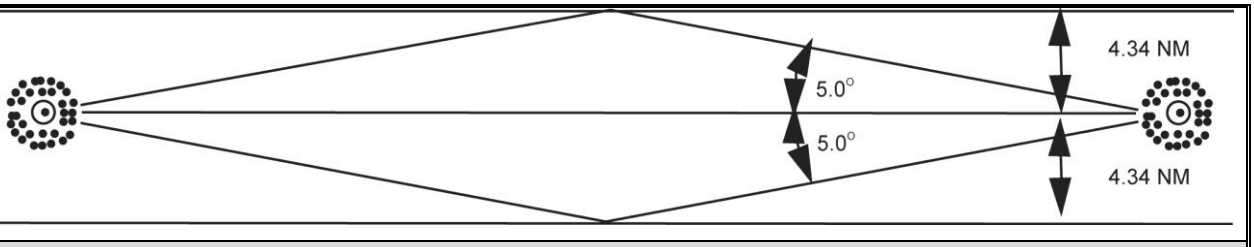


Figure 17-24: LF Segment Primary Obstacle Clearance Area. Para 1750.b.

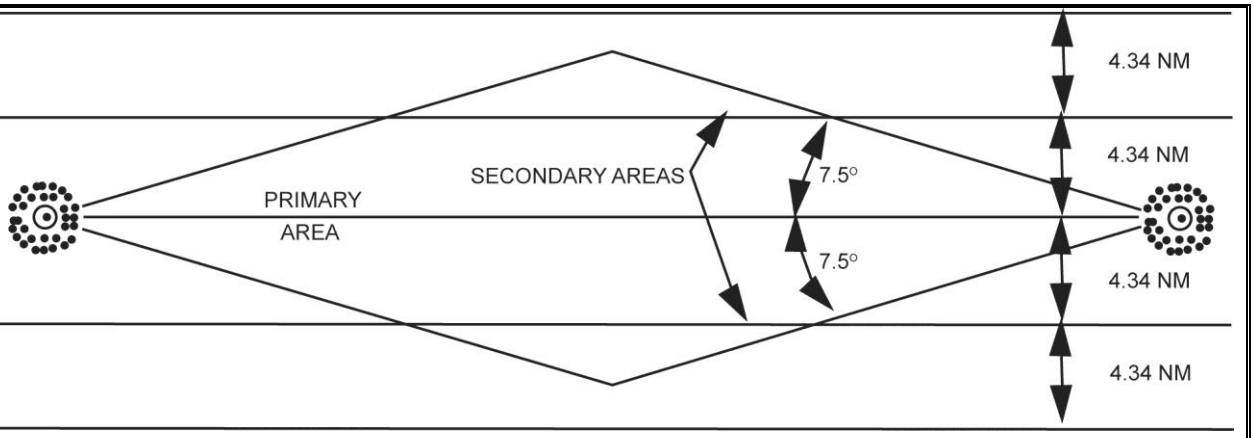


Figure 17-25: LF Segment Secondary Obstacle Clearance Area. Para 1717.B.

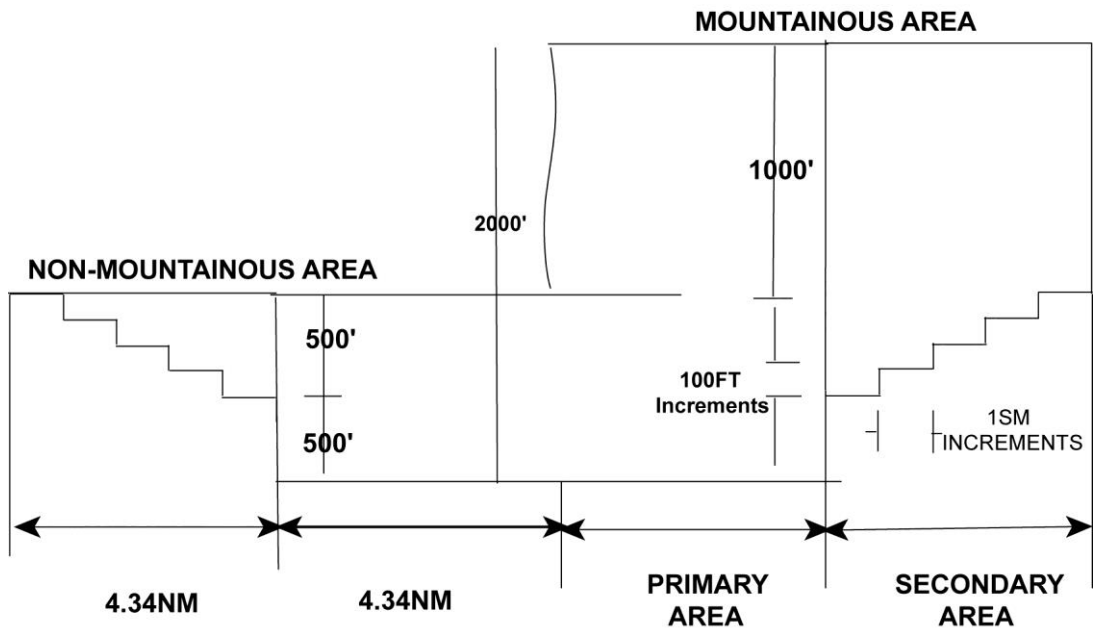


Figure 17-26: LF Segment Obstacle Clearance Within 25 NM Of Enroute Facility. Para 1750.d.

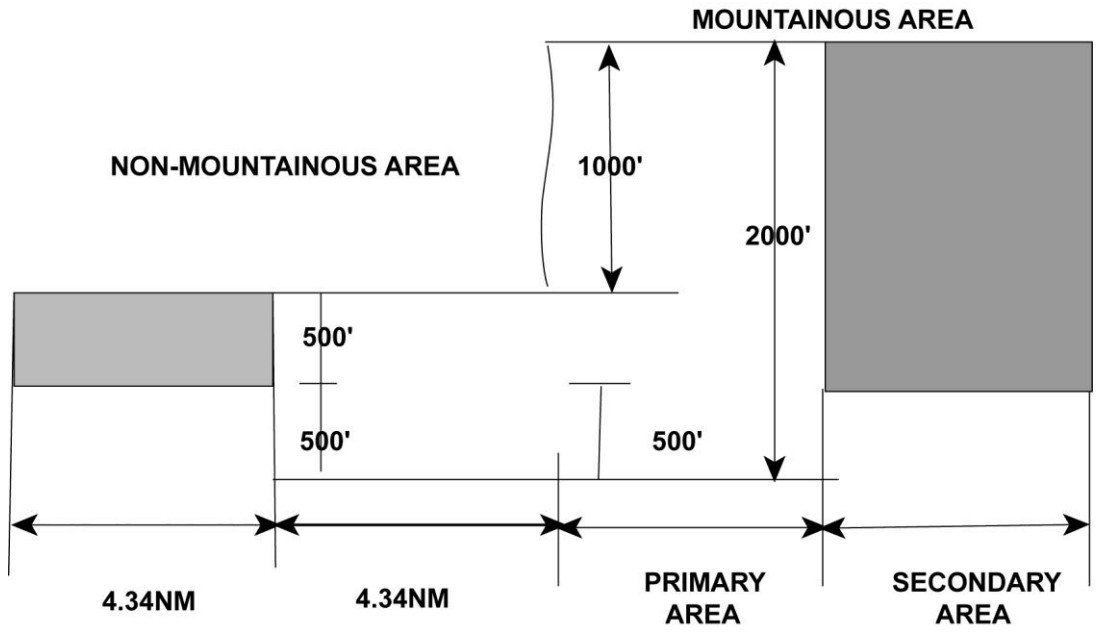


Figure 17-27: LF Segment Obstacle Clearance Area beyond 25 NM From Enroute Facility. Para 1750.d.

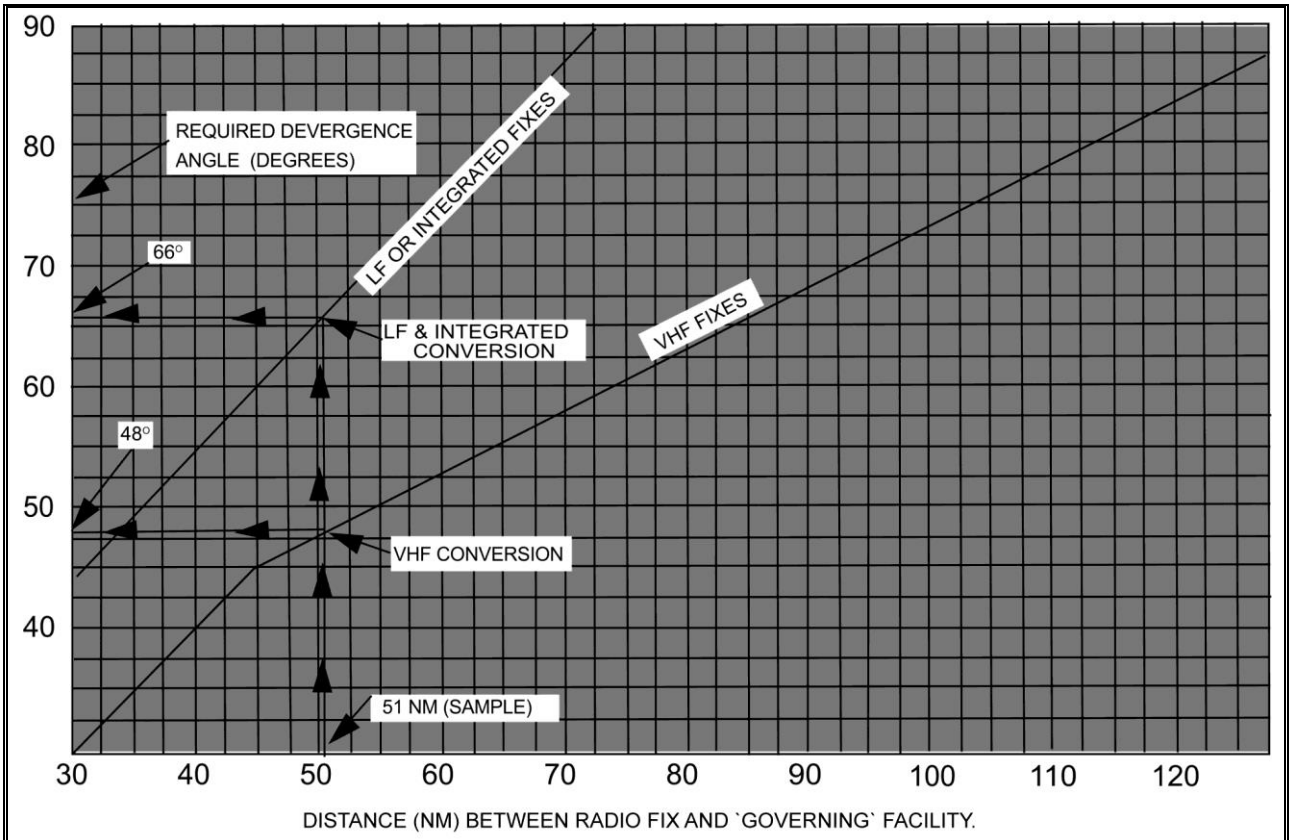


Figure 17-28: Minimum Divergence Angle For Radio Fix. Para 1761.b and 1762.b.

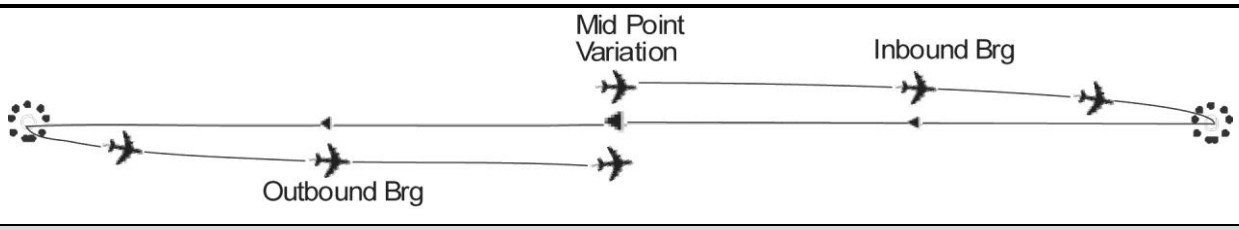


Figure 17-29a: Track Using Midpoint Variation. Para 1752.

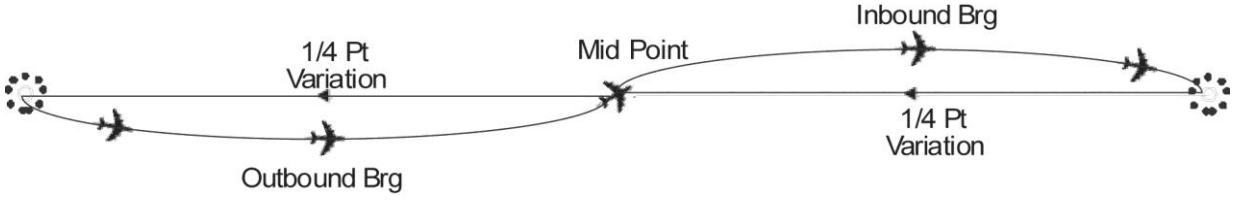


Figure 17-29b: Track Using Quarterpoint Variation. Para 1752.

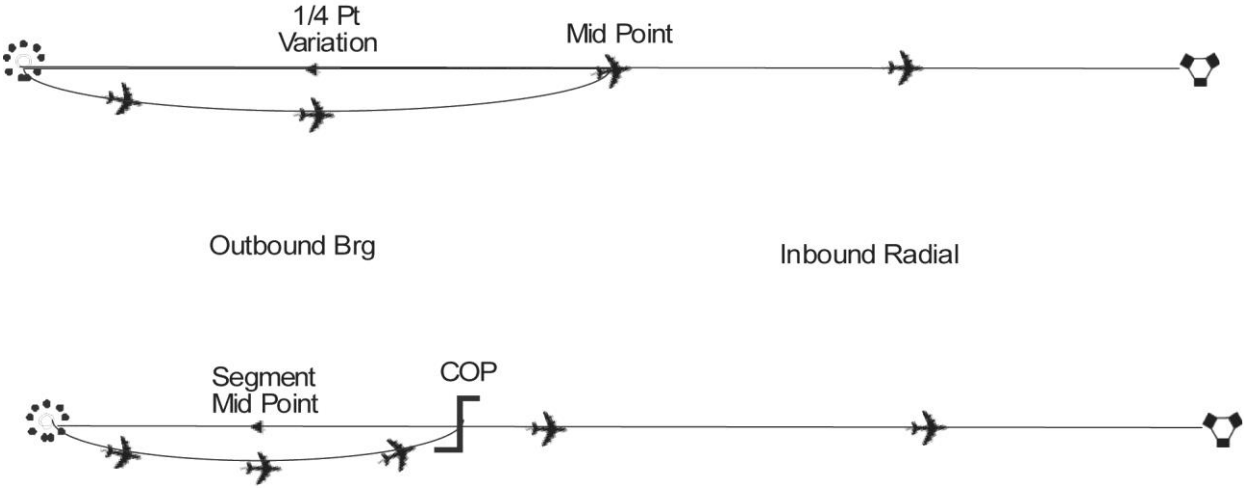


Figure 17-29c: Application Of Quarter point Variation For LF/MF to VHF/UHF Facilities. Para 1752.

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CHAPTER 18. HOLDING CRITERIA

SECTION 1. PATTERN DESIGN ASSUMPTION

18.1. Pattern Design Assumption.

18.1.1. Development Concept.

Efficient and economical use of airspace requires standardization of aircraft entry and holding maneuvers. These criteria incorporate factors which affect aircraft during these maneuvers.

18.1.2. Turn Effect.

This holding criteria is based on 25 degrees of bank to compensate or a standard rate turn, whichever requires the least bank.

18.1.3. NAVAID Ground and Airborne System Tolerance.

The basic holding criteria apply to conventional NAVAIDs such as VOR, a VOR with DME, and/or NDB, TACAN, and LOC/DME. The term VOR/DME is used generically throughout this document for all single DME type systems to avoid confusion with DME/DME. These criteria contain allowances for:

a. Cone of ambiguity: related to altitude, and

(1) System error: ± 5 degrees,

(2) Aircraft Course Indicator: ± 10 degrees for full instrument deflection, and

(3) Total tolerance of (1) and (2): 15 degrees.

b. Intersection disparity: related to system error,

(1) Distance of the holding point from the furthest NAVAID,

(2) Overhead “to-from” error: 4 degrees, and

(3) Delay in recognizing and reacting to fix passage: six seconds for entry turn, applied in the direction most significant to protected airspace.

18.1.4. Effect of Wind.

Analysis of winds recorded at various levels over a five-year period led to the adoption of a scale of velocities beginning with 50 knots at 4000 feet MSL and increasing at a rate of three knots for each additional 2000 feet of altitude to a maximum of 120 knots.

18.1.5. Development.

Develop holding to accommodate the performance capabilities of pertinent civil and military aircraft. Evaluate the full size of the holding pattern primary and secondary areas for obstacle clearance, with no fix-end or outbound-end reduction applied. Do not permit the use of smaller pattern number/pattern sizes for “on-entry” procedures.

18.1.6. Application in the Canadian Domestic Airspace (CDA).

Holding airspace area dimensions permit use of all types of holding when the operational assumptions for flying the aircraft are complied with.

18.1.7. Uncharted holding.

Holding over a fix in the CDA that does not have a charted holding pattern is not addressed in this document.

18.1.8. Reserved.

SECTION 2. PATTERN COMPONENTS

18.2. Pattern Components.

18.2.1. Area.

a. Primary Area. Dimensions for manual construction, and templates discussed in this document define only the primary area of the holding pattern (see section 18.3).

b. Secondary Area. A secondary area 2 NM wide surrounds the perimeter of the primary area in all cases.

c. When paragraph 18.7.3 is used, the primary holding area must encompass the departure or missed approach segment width at the holding fix (see figure 18-7-1).

18.2.2. Outbound Leg Length.

Base the outbound leg length on either time or distance. Standard time values are one minute for altitudes from the Minimum Holding Altitude (MHA) at or below 14000 feet and 1½ minutes above 14000 feet. Establish the distance value of the outbound leg consistent with section 18.13 for VOR/DME, or with section 18.10 for RNAV.

18.2.3. Maximum Holding Airspeed.

a. Develop holding patterns based upon maximum airspeeds of table 18-2-1, with the exception of Increased Airspeed Holding Operations defined in section 18.12. Holding patterns developed at other than the standard airspeeds must be annotated in order for pilots and controllers to know that either slower airspeeds are required, or higher airspeeds are allowed.

Table 18-2-1: Maximum Holding Airspeeds.

Altitude	Maximum Holding Airspeed
At or below 6000 feet	200 KIAS
Above 6000 feet up to and including 14000 feet	230 KIAS
Above 14000 feet	265 KIAS

Note: At Canadian Military airfields, the maximum holding airspeed is 310 KIAS unless otherwise noted.

b. Where operationally necessary, restrict holding patterns to the following speeds when the procedure has the restriction annotated:

(1) 175 KIAS at altitudes from MHA to 18000 feet MSL, as part of an instrument approach procedure that is restricted for use by CAT A and B aircraft only. Development of 175 KIAS holding patterns must only be accomplished to avoid obstacles and terrain.

(2) 210 KIAS at altitudes above 6000 feet through 14000 feet MSL or 230 KIAS at altitudes above 14000 feet.

18.2.4. Obstacle Clearance for Level Holding.

The minimum ROC in the primary area is 1000 feet. In mountainous regions apply additional obstacle clearance for en route holding. The minimum ROC in the secondary area is 500 feet at the primary boundary, tapering uniformly to zero feet at the outer edge (see Vol 1, Chapter 2, figure 2-3-2). Apply Vol 1, Chapter 2, Formula 2-3-2 to determine the minimum ROC at any given point in the secondary area. Adjustments for precipitous terrain must be applied as specified in paragraph 3.2.2. Standalone holding associated only with the en route structure, (that is, published only on an en route chart), must provide at a minimum the same ROC as the associated route. Additional precipitous terrain adjustment may apply based on portions of the holding encompassing an area of precipitous terrain which does not affect the en route segment. Establish minimum holding altitude in 100-foot increments. The selected altitude must provide the minimum ROC (plus adjustments as specified paragraph 3.2.2.); for example, when obstacle elevation plus ROC and adjustments equals 1501, round up to 1600 feet. See section 18.7 for climb-in-hold obstacle clearance.

18.2.5. Communications.

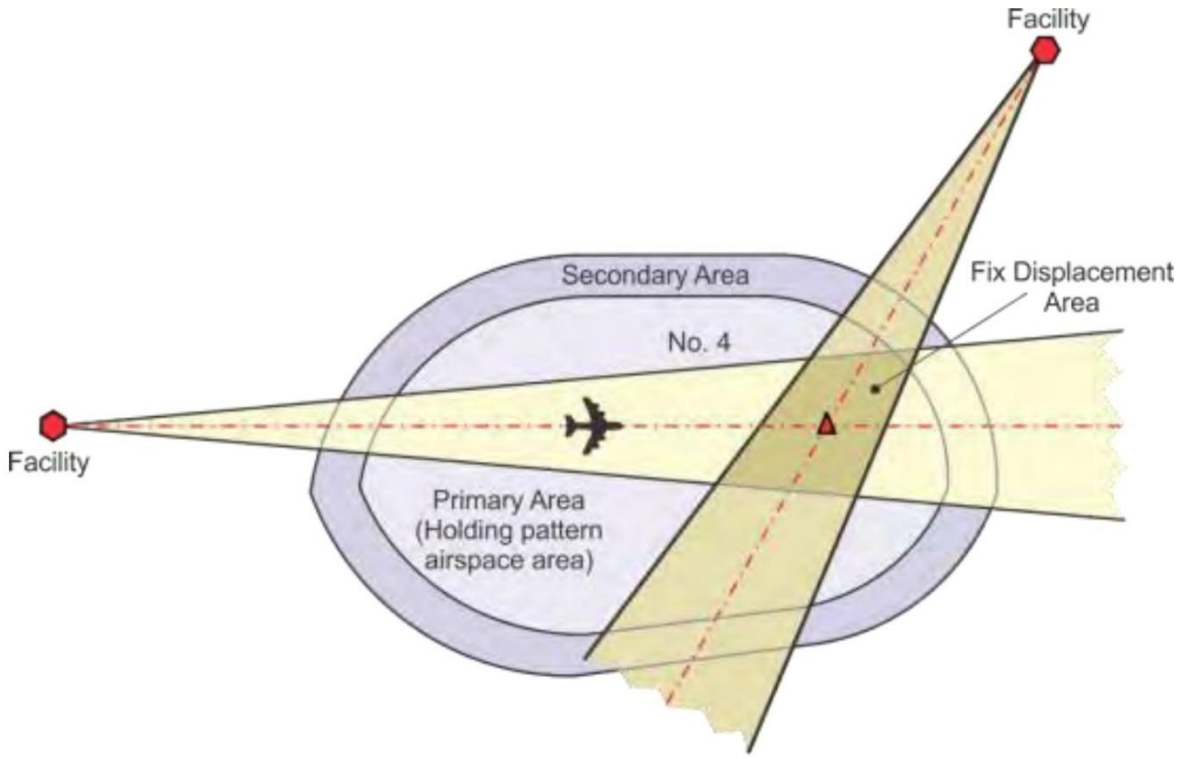
Require communications on appropriate ATS (Air Traffic Services) frequencies throughout the entire holding primary pattern area from the MHA up to and including the maximum holding altitude. Increase the MHA if communications are not satisfactory at the MHA.

Supplementary note: Not applicable for hold in uncontrolled airspace.

18.2.6. Intersection Fix.

When holding at an intersection fix the selected pattern must be large enough for the primary area to contain at least three corners of the fix displacement area (see figure 18-2-1, paragraphs 2.8.5. and 2.8.6.).

Figure 18-2-1: Holding Pattern Number Application



SECTION 3. PRIMARY AREA SIZE DETERMINATION

18.3. Primary Area Size Determination.

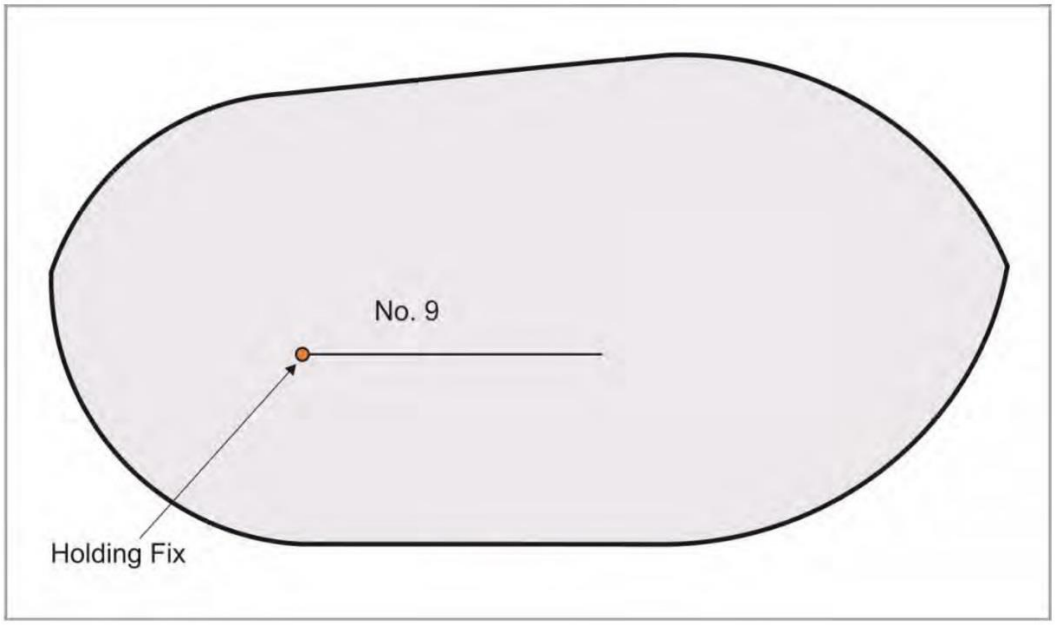
18.3.1. Size and Numbering.

Each pattern size is related to one or more even-numbered altitudes/flight levels and is identified by a pattern number for easy reference. There were originally 31 holding pattern sizes defined, which were commonly referred to as templates, since plastic templates were generally used to speed construction. With the change to automated construction in most cases today, the term template has been dropped except in cases specifically referring to the use of the plastic templates. Pattern sizes one to three are no longer in use. The size is fixed for a given pattern number; however, the placement of the protected area varies depending on whether slant-range is a factor in the navigation system or not.

18.3.2. Pattern Numbers.

The dimensions provided for each pattern number are used to determine holding airspace obstacle protection. Figure 18-3-1 shows the shape of the protected airspace primary area, the size varies by the pattern number.

Figure 18-3-1: Holding Pattern Primary Area



18.3.3. Altitude Levels.

Table 18-3-1, Holding Pattern Selection Chart, provides holding levels from MHA to FL 500 at intervals of 2000 feet. Holding at 2000 feet and below requires use of the appropriate pattern for 2000 feet. Holding at higher even altitudes requires use of appropriate altitude/flight level patterns as listed in table 18-3-1. Holding at odd altitudes above 2000 feet is determined by use of the next higher even altitude/flight level pattern.

Table 18-3-1: Holding Pattern Selection Chart.

	The distance is Fix to NAVAID					
	0-14.9 NM	15-29.9 NM and RNAV	≥ 30 NM	0-14.9 NM	15-29.9 NM and RNAV	≥ 30 NM
	Pattern No.					
Altitude	**175 KIAS**			**200 KIAS**		
2000	4	4	4	4	4	5
4000	4	4	4	4	5	6
6000	4	4	4	5	6	7
Altitude	**175 KIAS**			**210 KIAS**		
8000	4	4	5	6	7	8
10000	4	5	6	7	8	9
12000	5	6	7	7	8	9
14000	6	7	8	8	9	10
16000	7	8	9			
FL180	8	9	10			
FL200	8	9	10			
FL220	9	10	11			
FL240	10	11	12			
FL260	11	12	13			
FL280	12	13	14			
FL300	13	14	15			
Altitude	**230 KIAS**			**265 KIAS**		
2000	5	6	7	7	8	9
4000	6	7	8	8	9	10
6000	7	8	9	9	10	11
8000	8	9	10	10	11	12
10000	9	10	11	11	12	13
12000	9	10	11	12	13	14
14000	10	11	12	13	14	15
16000	12	13	14	15	16	17
FL180	13	14	15	16	17	18
FL200	14	15	16	17	18	19
FL220	15	16	17	18	19	20
FL240	16	17	18	19	20	21
FL260	17	18	19	20	21	22
FL280	18	19	20	21	22	23
FL300	19	20	21	22	23	24
FL320	20	21	22	23	24	25
FL340	21	22	23	24	25	26
FL360	22	23	24	25	26	27
FL380	23	24	25	26	27	28
FL400	24	25	26	27	28	29
FL420	25	26	27	28	29	30
FL440	26	27	28	28	29	30
FL460	27	28	29	29	30	31
FL480	28	29	30	31		
FL500	28	29	30			

Notes: 1. Columns are used based on the distance column header for conventional holding.
2. Use the 15-29.9 NM column to determine the pattern number used for RNAV patterns.

18.3.4. Fix-to-NAVAID Distances.

Fix-to-NAVAID distance is the measured ground distance in nautical miles from the holding fix to the NAVAID. Apply separately slant-range, or DME distance. Pattern number sizes are shown for three ranges of fix-to-NAVAID distances: 0-14.9 NM, 15-29.9 NM, and 30 NM and over. When a fix is based on two NAVAIDs, use the greatest fix-to-NAVAID distance for pattern/ number determination. This applies to any type or combination of NAVAIDs used to establish a holding fix.

18.3.5. Pattern Applicability.

Table 18-3-1, contains fix-to-NAVAID distance columns, airspeed sections, which lead you to the correct altitude level, and pattern/number pairing. Additional information concerning special purpose holding patterns for turbulent air/maneuvering speed, climb-in-hold, descend-in-hold, helicopter and RNAV are contained in the appropriate section.

18.3.6. Pattern Selection.

Analyze holding patterns incrementally for all altitudes requested by ATC and for all applicable speeds. Apply appropriate obstacle clearance to all obstacles within each pattern number area. Save some time by initially evaluating the patterns for the highest speed. If the same controlling obstruction or minimum holding altitude results, document the obstruction and the associated smaller pattern number; the evaluation is complete. If the minimum holding altitudes differ, a more detailed incremental analysis is necessary.

Example Problems:

1. For crossing radial based holding, assume that civil aviation aircraft are to hold at a fix located 32 NM from the farthest NAVAID used to form the fix. Altitudes involved are 8000 feet through 14000 feet. From table 18-2-1, select airspeed of 230 KIAS. By reference to table 18-3-1, select pattern number 10 to determine the area to be protected for 8000 feet; number 11 for 9000/10000 feet; number 11 for 11000/12000 feet; number 12 for 13000/14000 feet. Apply each pattern number to the fix individually to determine obstacle clearance.

2. For restricted airspeed, assume that a 175 KIAS restricted holding pattern is to be developed at a fix located 12 NM from the farthest NAVAID used to form the fix. Altitudes involved are 2000 feet through 12000 feet. Reference to table 18-3-1, indicates use of pattern number five (12000 feet). When it is applied to the fix, no conflict with obstacles is indicated between 12000 feet and 5000 feet. However, a conflict at 4000 feet and below exists. Reference to table 18-3-1, indicates use of pattern number four for 4000 feet and below. If pattern number four does not conflict with the obstacle, it can be published as requested, otherwise the minimum holding altitude would be restricted to 5000 feet. Chart the holding pattern with the holding speed cartographic icon (i.e. “175 kt”) restriction.

SECTION 4. DME APPLICATIONS WITH SLANT-RANGE

18.4. DME Applications with Slant-Range.

18.4.1. Slant-Range Effect.

VOR/DME, TACAN, and other systems using a single DME such as NDB/DME and LOC/DME, measure the distance from the aircraft receiver to the NAVAID; therefore, the horizontal distance from the aircraft to the NAVAID decreases with altitude even though the indicated distance remains the same. An airborne VOR/DME reading of 5 NM at FL 300 would indicate that an aircraft is directly over the NAVAID. The location of an aircraft with the same 5 NM indicated VOR/DME distance at altitudes between overhead the fix and the surface would form an arc beginning over the NAVAID to a point on the surface 5 NM from the NAVAID. Therefore, near the surface, a holding fix could be 5 NM horizontally from the NAVAID, but at 13000 feet, it would be 4.52 NM horizontally from the NAVAID. In this instance, 5 NM is the fix-to-NAVAID distance, which is the distance from the plotted position of the holding fix to the NAVAID, and 4.52 NM is the slant-range/geographical distance, which is the horizontal (geographic) distance from where the aircraft would be located at the maximum holding altitude to the NAVAID. When establishing a VOR/DME holding fix, determine the difference between fix-to-NAVAID and slant-range/geographical distance to ensure the holding fix is not too close to the NAVAID (inside the no-course signal zone). Govern differences by requirements in paragraph 18.4.4.

18.4.2. Determining VOR/DME Distances.

Use the slant-range formulas in section 18.14 to accurately determine the height above the NAVAID, slant-range, slant-range/ geographical and fix-to-NAVAID distances, as well as the differences between those values used to determine pattern placement. Figure 18-14-1 illustrates the relationship between the distances. First, use formula 18-14-1 to determine the height of the maximum holding altitude above the NAVAID, since that value is required by most of the other formulas. Multiple formulas are required to determine the final value in many cases.

18.4.3. No-Course-Signal Zone.

Calculate no-course-signal zone information using formulas 18-14-4 or 18-14-5 to determine the minimum fix-to-NAVAID distance at the maximum holding altitude. Do not establish VOR/DME fixes within the no-course-signal zone.

18.4.4. Fix Distance Variances.

For the purpose of accurate plotting of holding pattern airspace, differences between fix-to-NAVAID and slant-range/geographical distance can be significant. When establishing or changing the use of a VOR/DME holding fix, use the following guidance to determine how the distance differences are applied:

a. Use whole NM for slant-range distance where possible on non-RNAV procedures. In all cases, do not publish distances less than tenths.

Example: It is desired to hold aircraft at the minimum VOR/DME distance at 10000 feet. Formula 18-14-5 shows the intersection of the 10000 feet altitude line and the edge of the no-course-signal zone occurs at a fix-to-NAVAID distance of 2.35 NM. Using formula 18-14-2 the slant-range is 2.86 NM. Slant-range distance should normally be rounded up for ease of use by aircrews in VOR/DME holding, and to avoid placing the fix in the no signal area. Therefore, holding should be based on a 3 NM VOR/DME fix.

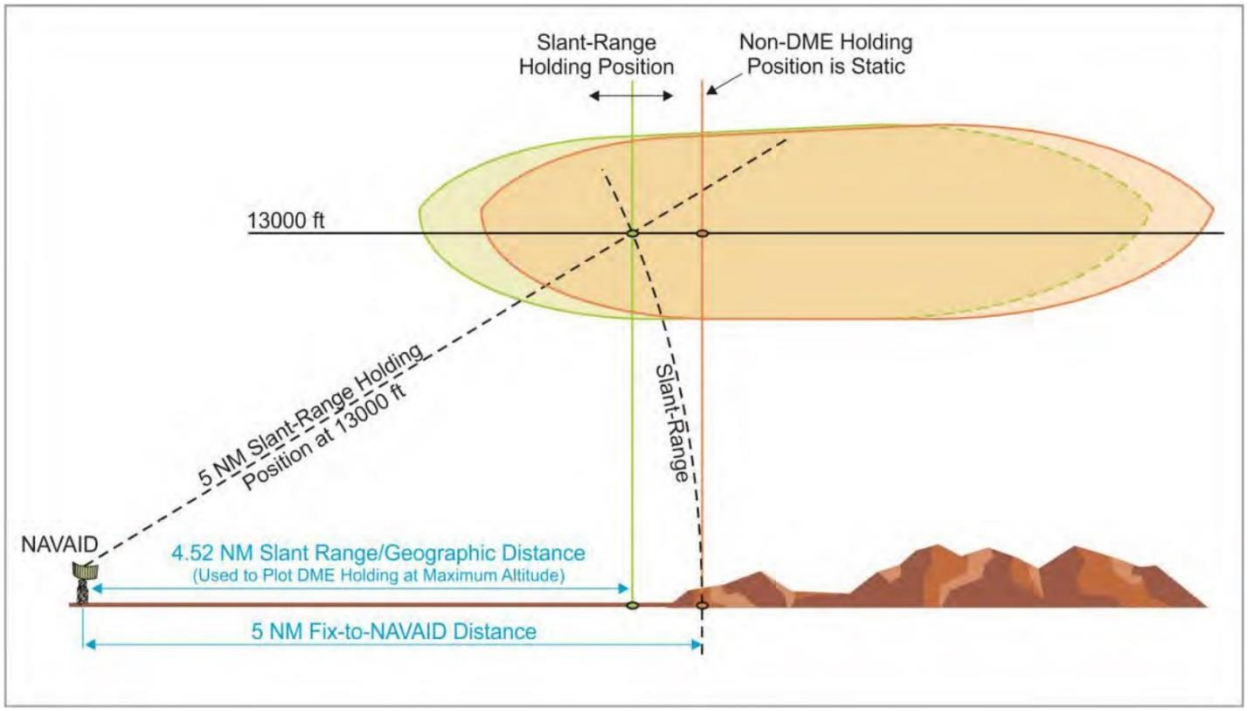
b. When slant-range/geographical distance differs 0.25 NM or less from fix-to-NAVAID distance, the difference may be disregarded 14000 feet and below. A difference of 0.5 NM or less may be disregarded above 14000 feet [see formula 18-14-8 to compute the difference].

c. When a VOR/DME slant-range holding fix will be collocated with another established fix, which is not based on slant-range, including GPS and RNAV, [see section 18.10] and the distance from the fix to the NAVAID forming the holding course is also used as the VOR/DME slant-range distance, significant variances per paragraphs 18.4.4a and 18.4.4b may exist. Plotting of protected holding pattern airspace may be affected. Significant variances must be governed by the following:

(1) Since holding patterns often are used in multiple procedures, and RNAV substitution is allowed in conventional holding, both slant-range and without slant-range operations must be accommodated in holding patterns designed for VOR/DME. Either VOR/DME and VOR intersection holding, or other non-DME protected holding airspace, must be plotted at the VOR intersection/non-DME location and re-plotted at the slant-range/geographical distance. See formula 18-14-7 and 18-14-8 to convert the fix-to-NAVAID distance for the non-DME fix to slant-range/geographic distance at the maximum holding altitude, and apply in the proper direction for holding toward or away from the NAVAID. The perimeter of the two plots outlines the primary airspace to be protected (see figure 18-4-1). The published holding distance is the fix-to-NAVAID distance; however, the slant-range/geographic distance must be outside the no-course signal zone. Use formulas 18-14-4 or 18-14-5 to check that the newly determined slant-range/geographic distance is not inside the no-course signal zone.

Example: Establish a VOR/DME fix for holding at FL 200 and below, at 30 NM fix-to-NAVAID distance. Reference formulas 18-14-7 and 18-14-8 and compute the slant-range/ geographical distance associated with 30 NM, which is 29.82 NM. The difference of 0.18 NM may be disregarded in protected airspace plotting. However, if the desired fix-to-NAVAID distance was changed to 10 NM, the slant-range/geographical distance becomes 9.44 NM, which creates 0.56 NM difference. This difference is significant; therefore, protected airspace would be based on 9.44 NM fix-to-NAVAID distance and a 10 NM fix-to-NAVAID distance as described in paragraph 18.4.4c.

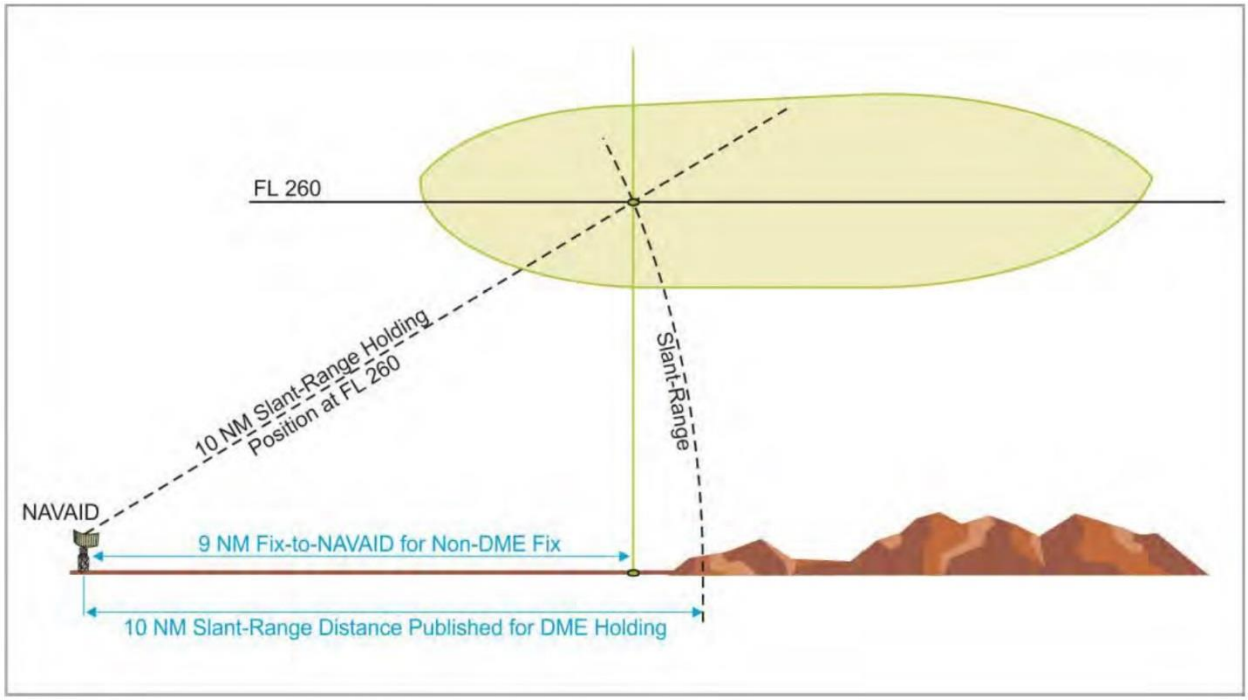
Figure 18-4-1. Collocated VOR/DME and Non-DME Holding Airspace, inbound Toward NAVAID



Note: Figure 18-4-1 shows holding toward the NAVAID with extended airspace at the fix end when holding away from the NAVAID, the extended airspace would be on the outbound end.

(2) When it is desirable to contain VOR/DME and non-VOR/DME holding within a single pattern size, use a slant-range distance different from the fix-to-NAVAID distance. Use formulas 18-14-1 and 18-14-2 to select a slant-range distance, which is coincident with the fix-to-NAVAID distance determined, by the non-DME position, at the highest altitude to be used for VOR/DME holding (see figure 18-4-2). If it is desired to publish the holding fix based on a specified slant-range distance, use formula 18-14-3 to convert the slant-range distance to a fix-to-NAVAID distance. The published DME value is the fix-to NAVAID distance and must only be used when the difference is less than 0.25 NM at or below 14000 feet or 0.5 NM above 14000 feet, using formula 18-14-6.

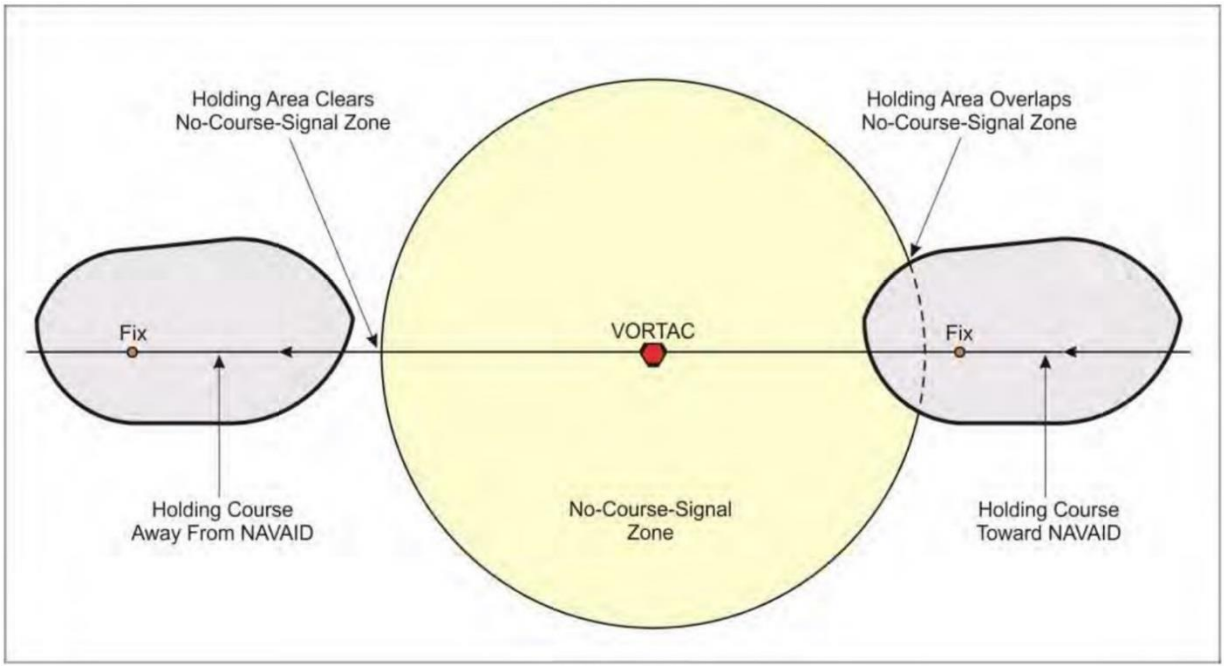
Figure 18-4-2. Collocated Holding Fix Using Single Pattern Number



18.4.5. Holding Toward/Away from the NAVAID.

Holding may be accomplished inbound to a VOR/DME fix either toward or away from a NAVAID (see figure 18-4-3).

Figure 18-4-3. VOR/DME Holding



a. **Toward the NAVAID.** When the VOR/DME holding course is toward the NAVAID, the fix end of the holding area, but not the fix itself, may lie within the no-course-signal zone (see formulas 18-14-4 or 18-14-5 to determine the edge of the no-course-signal zone at a given altitude).

b. **Away from the NAVAID.** When the VOR/DME holding course is away from the NAVAID, no part of the pattern area may lie within the no-course-signal zone.

18.4.6. Distance Based Holding Leg Lengths.

Table 18-3-1 provides pattern number information applicable to both time and distance based patterns. The outbound leg of a timed pattern is standard according to altitude (see paragraph 18.2.3); however, outbound leg distances for DME patterns vary depending on the fix-to-NAVAID distance and the pattern number being used. Appropriate leg length information can be found in section 18.13, however to accommodate RNAV substitution, the leg length must not be more than the applicable distance specified in table 18-10-1.

18.4.7. Reduction in area size.

No reduction in area size is authorized for obstacle clearance purposes.

18.4.8. VOR/DME Example Problems.

Two problems are set forth below with step-by-step solutions. Solution to the first problem is simple and requires one pattern size. The second problem is complex containing two parts. Several pattern sizes and changes to leg length are needed for its solution based on altitude and associated airspeeds. A third problem outlines some additional steps required.

a. **Problem 1.** The holding course is toward the NAVAID, maximum aircraft holding speed is restricted to 175 knots, on a CAT A and B only procedure, altitudes are MHA through 8000 feet, and fix-to-NAVAID distance is 6 NM.

Solution: Refer to table 18-3-1, speed group 175 knots, distance group 0-14.9 NM, altitude eight, pattern/number four. Refer to section 18.13, fix-to-NAVAID distance 6 NM, pattern number four and 5 NM is listed as maximum leg length. Pattern number four with a 5 NM leg length is supported by the obstacle protection.

b. **Problem 2.** The holding course is toward the NAVAID, maximum aircraft holding speed is 230 knots, altitudes are MHA (13000 feet) through FL 390, and fix-to-NAVAID distance is 30 NM.

(1) Part 1: Find the correct pattern size and related leg length for FL 390.

Solution: At FL 390 and 30 NM fix-to-NAVAID distance, determine slant-range distance using Formula 18-14-2, 30.67 NM. The 0.67 NM difference must receive consideration consistent with paragraph 18.4.4. Refer to table 18-3-1, and determine the pattern number/altitude relationship for the 230-knot speed at fix-to-NAVAID distance 30 NM,

pattern number 26 is indicated. Refer to section 18.13. For 30 NM and pattern number 26, maximum leg length is 20.

(2) Part 2: Find the correct pattern/pattern number size for the MHA of 13000 feet.

Solution: Refer to table 18-3-1, and determine the appropriate pattern, number 12. Refer to section 18.13 and find the maximum leg length of nine.

(3) Part 3, Final Solution to Problem 2: The range of leg lengths listed in part one (FL 390) 20 NM or less. Compare the findings of part one with part two. Part two (13000 feet) findings indicate a maximum leg length of 9 NM. Therefore, a 9-NM leg length is selected to serve MHA through FL 390.

c. Problem 3. The holding course is away from the NAVAID. Application of criteria to these situations is handled in the same manner as outlined in paragraphs 18-4-8a and 18-4-8b, with two exceptions:

(1) Section 18.13 must be used to determine leg length and numbered area information.

(2) Pattern numbers must be used to determine:

(a) That appropriate numbered areas do not infringe on the no-course-signal zone and/or,

(b) The location of a holding point will keep the holding area from infringing on the no-course-signal zone.

SECTION 5. TEMPLATE TRACING

18.5. Template Tracing.

18.5.1. Template Usage.

Today, most holding pattern construction is accomplished using automation. The existing plastic templates are still valid when used with charts of the appropriate scale. References to templates only apply to users physically using this method of construction. Pattern Numbers directly correspond to template numbers.

18.5.2. Basic Perimeter.

The perimeter of the template contains four radii and two straight lines. Position the holding fix grommet hole (see figure 18-3-1) over the fix, align the solid black line with the holding course, and trace the pattern perimeter.

a. Right turn patterns. Trace with imprinted numbers face-up and readable.

b. Left turn patterns. Trace with imprinted numbers facedown.

SECTION 6. MANUAL CONSTRUCTION OF PATTERNS

18.6. Manual Construction of Patterns.

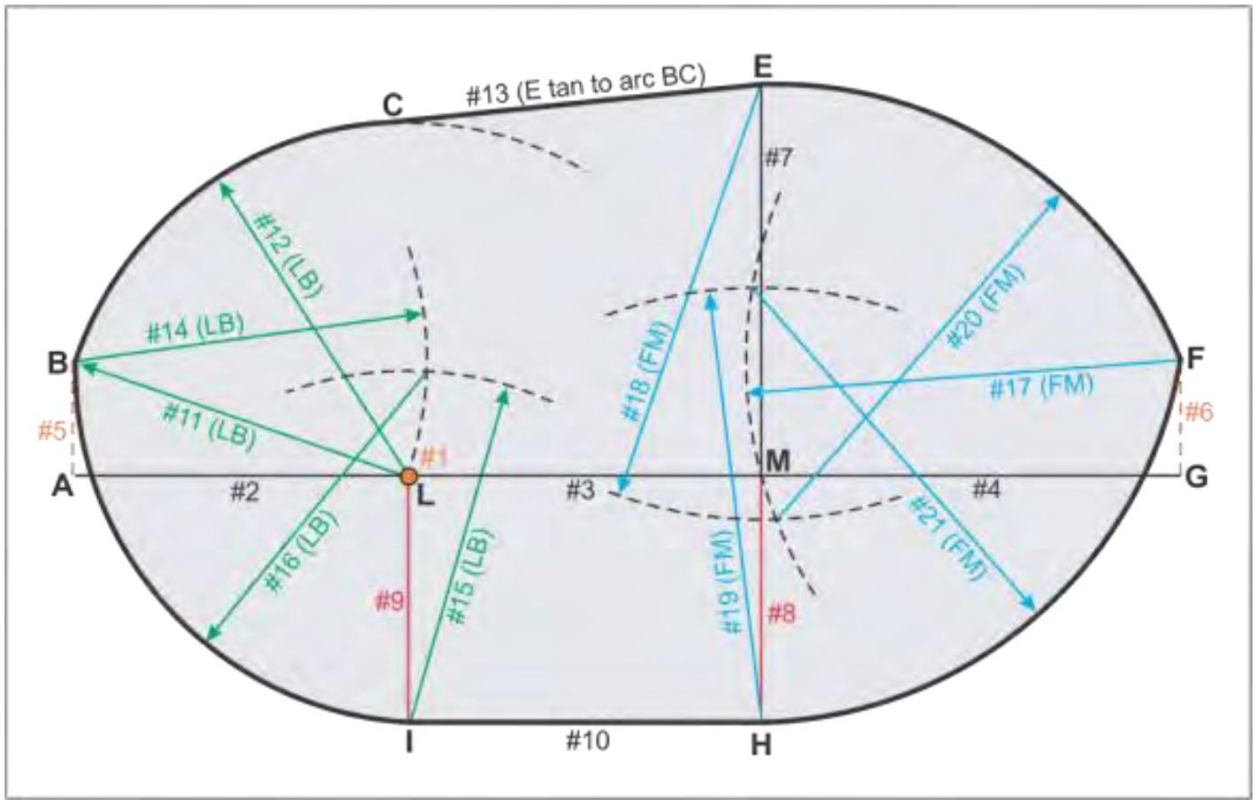
18.6.1. Requirement.

When a different scale is desirable/necessary, or automation is not available, holding patterns may be manually constructed as outlined in this section. Dimensions in this section provide the basis for automation of holding construction, and how to derive the distances not provided by the table, which are only established during construction.

18.6.2. Basic Primary Area Construction (right-hand pattern).

Each size may be constructed by using figure 18-6-1, dimensions of table 18-6-1, and the following directions (for left-hand pattern reverse the instructions):

Figure 18-6-1. Construction Sequence for Basic Area



Note: All lines that are the same length are the same color. Numbering of the lines represents the order in which the instructions draw the lines and arcs.

a. Line 1. Identify and mark holding fix as letter L.
b. Lines 2 through 4. Draw course line; A to L, L to M, and M to G.
c. Lines 5 through 9. At a 90-degree angle from the course line ALMG locate above A, (B) above G, (F) above M, (E) below M, (H) and below L, (I).

d. Line 10. Connect I and H with a straight line.
e. Line 11 and 12. Place compass center at L, set for distance L-B, and draw an arc from B to beyond C.
f. Line 13. Draw a straight line from E to a point of tangency with the B-C arc.
g. Lines 14 through 16. With the compass still set for distance L-B; place compass center at B and draw a short arc above L; relocate compass center at I and draw a short arc across the first arc; relocate compass center at the intersection of the arcs and connect I-B.
h. Lines 17 through 21. Place compass center at F and set for distance between F-M; draw an arc from above H to below E. Place compass center at E and draw a short arc below M. Place the compass center at H and draw a short arc above M. The arcs formed from E and H intersects the arc formed from F. Place compass center at the appropriate intersection of these arcs and connects E-F; place compass center at the other intersection and connect F-H.

Table 18-6-1. Holding Pattern Dimensions (NM).

Pattern Number	A-L	L-M	M-G	L-I M-H	M-E	A-B G-F (J-K)	(J-L)	Total Length	Total Width
4	4.5	4.3	5.6	3.5	5.3	1.5	3.3	14.4	8.8
5	4.9	4.5	6.1	3.8	5.7	1.7	3.6	15.5	9.5
6	5.6	4.8	6.5	4.2	6.4	2.0	4.1	16.9	10.6
7	6.0	6.6	8.2	4.6	7.2	2.2	4.4	20.8	11.8
8	6.5	6.8	9.3	4.9	7.7	2.3	4.7	22.6	12.6
9	7.0	7.0	9.7	5.3	8.3	2.5	5.1	23.7	13.6
10	7.6	7.3	10.4	5.7	8.9	2.7	5.5	25.3	14.6
11	8.0	7.5	11.1	6.2	9.6	2.9	5.9	26.6	15.8
12	8.7	7.8	11.7	6.5	10.2	3.1	6.3	28.2	16.7
13	9.2	8.6	12.1	7.0	10.9	3.3	6.7	29.9	17.9
14	9.9	8.9	12.8	7.5	11.6	3.6	7.1	31.6	19.1
15	10.4	9.6	13.1	7.7	12.1	3.8	7.5	33.1	19.8
16	11.1	9.9	13.7	8.2	12.8	4.0	7.8	34.7	21.1
17	11.9	10.1	14.8	8.6	13.6	4.3	8.3	36.8	22.2
18	12.7	10.5	15.7	9.2	14.6	4.5	8.9	38.9	23.8
19	13.8	11.1	16.8	9.9	15.7	4.8	9.5	41.7	25.6
20	14.5	11.5	18.0	10.5	16.5	5.2	10.1	44.0	27.0
21	15.5	11.8	18.8	11.2	17.6	5.5	10.7	46.1	28.8
22	16.5	12.1	21.2	11.9	18.8	5.9	11.4	49.8	30.7
23	17.6	12.4	21.6	12.7	20.1	6.3	12.2	51.6	32.8
24	19.2	12.9	23.4	13.7	21.7	6.9	13.1	55.5	35.4
25	21.2	13.3	25.5	14.7	23.4	7.4	14.2	60.0	38.1
26	22.9	13.8	27.6	16.1	25.7	8.1	15.4	64.3	41.8
27	24.6	14.4	29.5	17.3	27.3	8.8	16.5	68.5	44.6
28	26.9	15.2	32.6	18.9	30.2	9.6	18.2	74.7	49.1
29	28.0	15.8	34.6	20.1	32.0	10.0	19.3	78.4	52.1
30	29.2	16.4	35.3	21.3	33.2	10.4	20.2	80.9	54.5
31	30.9	17.0	37.0	22.5	34.5	11.0	21.9	84.9	57.0

SECTION 7. CLIMB-IN-HOLD

18.7. Climb-in-Hold.

18.7.1. Climb-in-Hold Evaluations.

Applied when it is necessary for aircraft to utilize a holding pattern to reach the en route altitude prior to departing a designated holding fix as part of the departure procedure or missed approach procedure. Use of the higher airspeeds which may be required to accomplish the maneuver are only authorized when the holding pattern is charted as climb-in-hold. Aircrews must climb continuously until the specified altitude is reached. Speed restrictions (other than 310 KIAS) must be charted for climb-in-hold procedure.

18.7.2. Climb in Hold Airspeed Determination.

Required climb speeds, often exceed the maximum level holding speeds in table 18-2-1. Therefore, the following criteria must be used to provide for such operations.

a. Except as provided in paragraph 18.7.2b, the 310 KIAS pattern must be used for climb-in-hold evaluations.

   Example: Departing aircraft must climb to FL 180 in a holding pattern. The fix-to-NAVAID distance is 22 NM.

   Solution: Refer to table 18-7-1, pattern/pattern number 21 is indicated.

b. As part of a missed approach or departure procedure, for obstacle and terrain avoidance, you may reduce speed pattern to evaluate the climb-in-hold. Evaluate the climb-in-hold patterns in the following order: 310/265/230/200 KIAS (200 KIAS is only available up to 6000 ft ASL).

   Notes:
   1) It is highly encouraged to use reasonable means to establish a 310 KIAS climb-in-hold pattern before attempting to reduce the pattern size.
   2) For lateral airspace requirements, only the primary portion of the template area is required

Table 18-7-1. Increased Holding Airspeed Holding Pattern Sizes (Altitude-Pattern Number) - Climb-in-Hold.

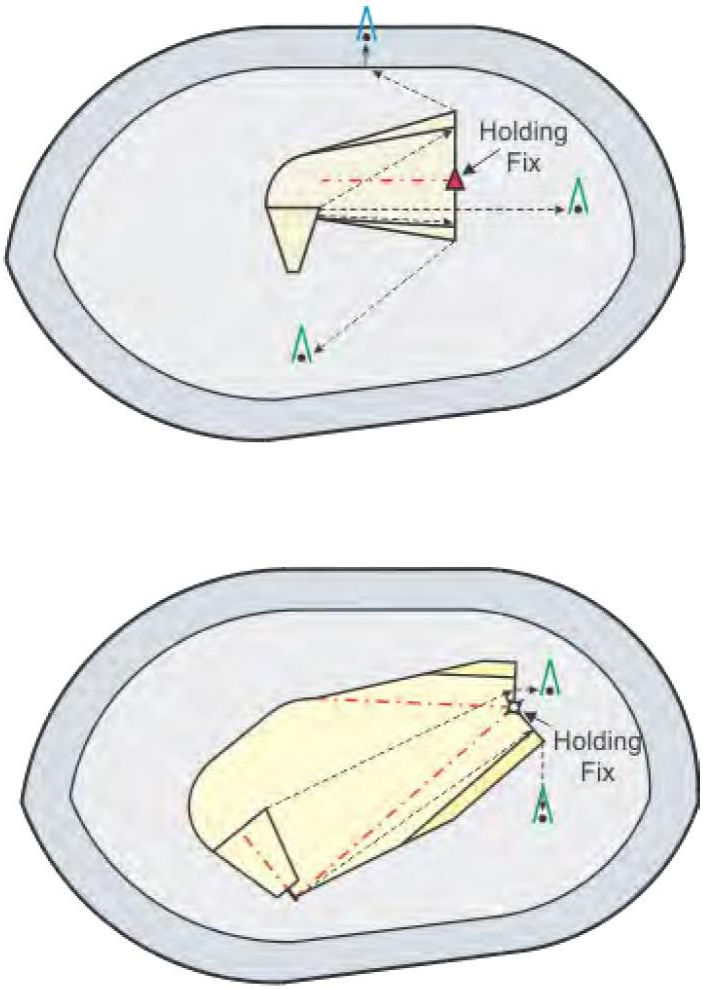
	The distance is Fix to NAVAID		
	0-14.9 NM	15-29.9 NM and RNAV	≥ 30 NM
	310 KIAS Climb-in-Hold		
Altitude	Holding Patter No.		
2000	11	12	13
4000	12	13	14
6000	13	14	15
8000	14	15	16
10000	15	16	17
12000	17	18	19
14000	18	19	20
16000	19	20	21
FL180	20	21	22
FL200	21	22	23
FL220	22	23	24
FL240	22	23	24
FL260	24	25	26
FL280	24	25	26
FL300	25	26	27
FL320	26	27	28
FL340	27	28	29
FL360	28	29	30
FL380	29	30	31
FL400	30	31	

18.7.3. Climb-in-hold Obstacle Evaluation.

When a climb-in-hold is used, either due to the required ROC not being achieved at the holding fix, or when more climb is required prior to departing the holding fix, on a departure or missed approach, no obstacle may penetrate the holding surface. This surface begins at the end of the segment leading to the plotted position of the holding fix. It rises at a 40:1 rate to the edge of the primary area, then at a 12:1 rate to the outer edge of the secondary area. The beginning height of the 40:1 surface varies with the ending height of the missed approach/departure OCS at a point on the end of the segment line nearest the obstacle being evaluated. Measurements to obstacles located in the climb-in-hold area (beyond the clearance limit) should be completed in two separate steps: (1) through the previous segment to the closest point to the obstacle on the end of the segment line, and (2) directly to the obstacle (see figure 18-7-1). Precipitous terrain is not applied to the sloping surface of the climb in hold; however, the level holding surface must be evaluated for precipitous terrain.

Note: The pattern size that is used at the top of the climb-in-hold evaluation is used throughout the climb-in-hold evaluation and is also used for MHA.

Figure 18-7-1. Climb-in-Hold Obstacle Evaluation



SECTION 8. DESCEND-IN-HOLD PATTERNS

18.8. Descend-in-Hold Patterns.

18.8.1. Descend-in-Hold.

Applied when it is necessary for aircraft to utilize a holding pattern, to descend to an altitude prior to departing a designated holding fix, typically for an arrival. The procedure must be annotated “Descend-in-Hold” and the holding pattern must be charted in the plan view.

18.8.2. Descend-in-Hold Airspeed Determination.

Standard holding pattern airspeeds for the altitude are used; no increase in airspeed is required.

18.8.3. Descend-in-Hold Criteria.

Standard holding criteria is applied where descend in hold is established.

SECTION 9. OPERATIONAL APPLICATIONS

18.9. Operational Applications.

18.9.1. Establishing Fixes. Establish holding pattern fixes as follows.

a. Overhead the NAVAID fixes are authorized only for LF and VOR facilities and, when DME is not used, for VOR holding at VOR Collocated Tactical Air (VORTAC) facilities.

b. VOR/DME fixes must not be established overhead the NAVAID from which inbound holding course information would be derived (see formulas 18-14-4 or 18-14-5 to determine the minimum holding distance from the NAVAID when using VOR/DME).

c. Intersection fixes must be formed by radials/courses/bearings, which are at an angle of not less than 45 degrees to each other.

18.9.2. Pattern Alignment.

Whenever possible, the holding pattern must be aligned to accommodate entry to the holding area along the inbound holding course, its reciprocal, or at a relatively small angle. However, when the flight path to be flown is along an arc, the holding pattern should be aligned on a radial. When a holding pattern is established at a PFAF and a PT is not used, the inbound course of the holding pattern must be aligned to coincide with the FAC unless the PFAF is a facility. When the PFAF is a facility (non-RNAV holding), the inbound holding course, and the FAC must not differ by more than 30 degrees. Exit from the holding pattern should be as an extension of the inbound holding course where possible. Turns, when exiting holding, may create issues with the length of the inbound leg or the following leg, or with descent or climb gradients.

18.9.3. VOR/DME Leg Length Selection.

Use the longest leg length accommodated by all the pattern numbers being applied to the holding pattern.

18.9.4. VOR/DME Holding Direction.

An inbound holding course toward the NAVAID has the following advantages over an inbound holding course away from the NAVAID:

a. It provides a greater choice of leg lengths.

b. When associated with an instrument approach, the aircraft on the inbound holding course will normally be on-course toward the approach NAVAID.

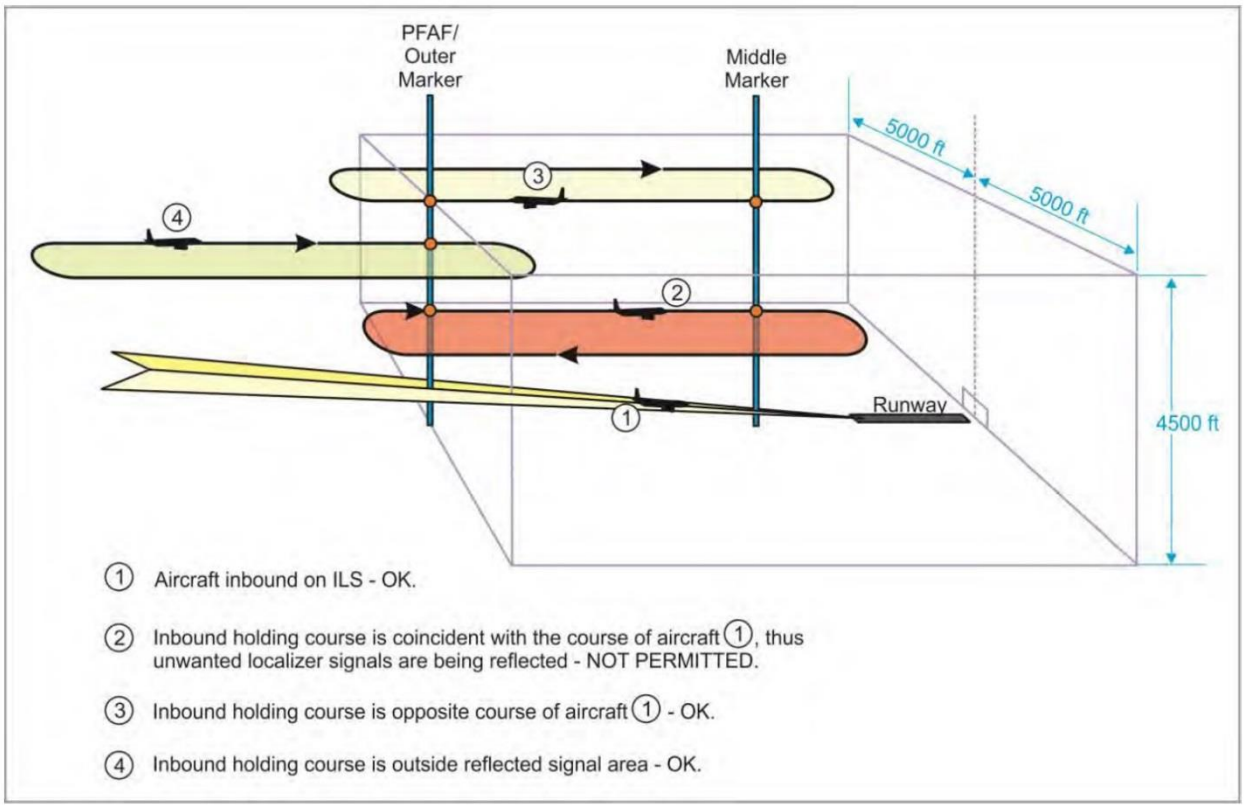
18.9.5. Establishing MHAs.

MHAs are determined by service providers during procedure design in accordance with paragraphs 18.2.3 and 18.2.4.

18.9.6. Holding Patterns on or Adjacent to ILS Courses.

Do not establish a holding pattern inbound on or adjacent to an ILS localizer between the PFAF and the localizer antenna below 5000 feet above the antenna elevation, regardless of the guidance used for the holding pattern. This is to avoid creating unwanted reflected signals (see figure 18-9-1). Holding patterns opposite to the inbound course are acceptable.

Figure 18-9-1. ILS Reflected Signal Area



SECTION 10. RNAV HOLDING PATTERNS

18.10. RNAV Holding Patterns.

18.10.1. General Information.

This section contains criteria for holding patterns associated with GNSS equipment, and other RNAV systems without slant-range using basic holding techniques. For VOR/DME RNAV apply section 18.1.

18.10.2. Criteria Development.

Basic holding pattern assumptions in section 18.2 are used for these holding patterns.

18.10.3. Restrictions.

Do not establish a holding pattern or a hold-in-lieu-of-PT (course reversal) at the FAF of an RNAV procedure.

18.10.4. RNAV Holding Patterns.

Use pattern sizes listed in table 18-3-1 (under the fix-to-NAVAID Distance column) for 15-29.9 NM for RNAV holding.

18.10.5. RNAV Leg Length Determination.

When Leg length used, the distance must be specified on all RNAV holding patterns. Table 18-10-1 contains the maximum leg length, which may be specified for a RNAV holding pattern. Enter table 18-10-1 with the holding pattern number from table 18-3-1 and read the maximum leg length.

Table 18-10-1. RNAV Holding Maximum Outbound Leg Length.

Pattern Number	Maximum Outbound Leg Length (NM)	Pattern Number	Maximum Outbound Leg Length (NM)
4	4	18	11
5	4	19	11
6	5	20	12
7	6	21	12
8	6	22	12
9	7	23	12
10	7	24	13
11	8	25	13
12	8	26	14
13	9	27	14
14	9	28	15
15	10	29	16
16	10	30	16
17	10	31	16

SECTION 11. HELICOPTER HOLDING PATTERNS

18.11. Helicopter Holding Patterns.

18.11.1. Helicopter (Copter) Holding.

Patterns assume at least 90 KIAS while holding.

18.11.2. Copter Holding Procedures.

Copter holding published on copter charts is based on pattern number four. If the holding is published on other than a copter chart, or other types of aircraft will hold at the same fix, establish multiple holding patterns and ensure the copter holding is annotated, or base the pattern used for the copter procedure on standard holding requirements.

SECTION 12. INCREASED AIRSPEED HOLDING PATTERN OPERATIONS

18.12. Increased Airspeed Holding Pattern Operations.

18.12.1. Turbulent Air Operation.

When ATC advises during the design process that turbulent air conditions are known to exist in an area, use table 18-12-1 to determine the required pattern size for evaluation. This is especially critical in a non-RADAR environment.

18.12.2. Maximum Holding Speed in Turbulent Air Conditions.

Holding airspace is developed based on 280 KIAS maximum holding speed together with other factors and components listed in sections 18.1 and 18.2. This special speed category provides airspace sizes for holding operations conducted in turbulent air conditions by aircraft whose normal maximum holding speed does not exceed 265 KIAS. Holding patterns are listed in table 18-12-1.

Table 18-12-1. Increased Holding Airspeed Holding Pattern Sizes (Altitude-Pattern number Number) – Turbulent Air.

	The distance is Fix to NAVAID		
	0-14.9 NM	15-29.9 NM and RNAV	≥ 30 NM
	280 KIAS Turbulent Air Holding		
Altitude	Holding Pattern No.		
2000	9	10	11
4000	10	11	12
6000	11	12	13
8000	12	13	14
10000	13	14	15
12000	14	15	16
14000	15	16	17
16000	16	17	18
FL180	17	18	19
FL200	18	19	20
FL220	19	20	21
FL240	20	21	22
FL260	21	22	23
FL280	22	23	24
FL300	23	24	25
FL320	24	25	26
FL340	25	26	27
FL360	25	26	27
FL380	26	27	28
FL400	27	28	29
FL420	28	29	30
FL440	29	30	31

18.12.3. Operational Use.

a. Limit the maximum altitude in an existing holding pattern. One method for handling turbulent air holding is to correlate the holding pattern size currently used at individual holding fixes with the information in table 18-12-1. For example, pattern number 20 is being used at a fix 20 NM from the NAVAID (265 KIAS speed group, from MHA through FL 240); correlating pattern number 20 to table 18-12-1 discloses that it is usable from MHA through FL 220 at 280 KIAS. The holding airspace at such a fix would accommodate normal holding at FL 240 and below, or turbulent air holding at FL 220 and below.

b. Develop separate turbulent air holding pattern. Another method of handling turbulent air holding is to establish separate patterns for this purpose at locations where these larger pattern sizes can be accommodated. It may be desirable to do this for each altitude strata in situations where a different holding fix is needed for each stratum.

Note: Crews have no way of knowing if additional obstacle protection has been provided unless turbulent air holding pattern is charted and annotated.

SECTION 13. VOR/DME LEG LENGTH DETERMINATION

18.13. VOR/DME Leg Length Determination.

18.13.1. General.

This chapter provides information used to determine the maximum allowable DME leg length, given the fix-to-NAVAID distance, the pattern number, and holding course direction to or from the NAVAID.

a. Numbers extending horizontally across the top of each table represent usable fix-to-NAVAID distances (geographical distances).

b. Vertical numbers on the left side of each page represent pattern numbers.

c. Find appropriate leg lengths by first locating the appropriate table for the desired holding direction, toward or away from the NAVAID, then the page of the table containing the desired fix-to-NAVAID distance in the row across the top, and pattern number size in the left column. Determine the usable leg lengths by locating the fix-to-NAVAID distance across the top of the table, then reading vertically down until opposite (horizontally) the selected pattern number(s). Usable leg lengths are listed at the intersection of the column and row, or the first value to the left of this point in the row when a line is used to indicate use at multiple fix-to-NAVAID distances.

Example: Locate fix-to-NAVAID distance 8.5 NM. Read vertically down until opposite pattern number four, then follow the horizontal line to the left until reaching listing “5”. A 5-NM leg length should be selected to maximize level flight between turns.

Table 18-13-1. (1/3) Holding Course Toward the NAVAID. Usable DME Leg Lengths.

Fix-to-NAVAID (geographical - not DME) Distance in Nautical Miles

Pattern Number	2	3	5	6	7	9	11	12	15	20
4.	6	5							4	
5.	6		5				4			
6.		6						5		
7.		8						7		

Pattern Number	3	4	5	6	7	8	9	10	12	14	15	17	18	19	20
8.	9		8										7		
9.		9		8						7					
10.		10	9								8				
11.		10						9							
12.			10			9									
13.				11						10					

Pattern Number	4	5	6	7	8	9	11	12	14	15	16	19	20
14.				12			11						
15.	13				12								11
16.		14			13					12			
17.			14					13				12	
18.		15				14						13	

Pattern Number	6	7	8	10	11	13	14	15	19	20
19.	16				15				14	
20.	17			16				15		
21.		18		17			16			
22.			18					17		

Table 18-13-1. (2/3). Holding Course Toward the NAVAID. Usable DME Leg Lengths.

Fix-to-NAVAID (geographical - not DME) Distance in Nautical Miles

Pattern Number	8	9	10	12	13	14	15	17	18	19	20
23.	20			19			18				
24.		21		20				19			
25.		22			21					20	
26.			24			23		22			21

Pattern Number	11	12	13	14	15	16	17	19	20
27.	25			24					23
28.		27			26		25		
29.		28		27					26
30.			29					28	

Pattern Number	14	16	19	20
31.	29		28	

Pattern Number	21	26	30	70
4.	4			
5.	5	4		
6.	5			
7.	7			
8.	7			

Pattern Number	21	24	26	34	50	70
9.	7					
10.	8				7	
11.	9	8				
12.	9			8		
13.	10			9		

Table 18-13-1. (3/3). Holding Course Toward the NAVAID. Usable DME Leg Lengths.

Fix-to-NAVAID (geographical - not DME) Distance in Nautical Miles

Pattern Number	21	22	28	30	38	40	50	55	70
14.	11	10					9		
15.	11					10			
16.	12		11						
17.	12				11				
18.	13			12				11	

Pattern Number	21	23	25	28	30	32	36	40	45	50	55	60	70
19.	14				13					12			
20.	15		14					13					
21.	16	15				14					13		
22.	16			15					14				

Pattern Number	21	23	24	25	28	29	30	32	36	40	45	60	70
23.	17					16				15		14	
24.	18						17				16	15	
25.	20			19				18		17		16	
26.	21				20				19		18	17	

Pattern Number	21	23	24	25	27	28	32	34	36	40	50	60	70
27.	23		22			21	20			19	18	17	
28.	24			23					22	21	19	18	
29.	26	25			24			23		22	21	20	
30.	26		25					23		22	21	20	

Pattern Number	21	22	26	30	38	45	55	60	70
31.	28	27	26	25	24	23	22	21	20

Table 18-13-2. (1/3). Holding Course Away From the NAVAID. Usable DME Leg Lengths.

Fix-to-NAVAID (geographical - not DME) Distance in Nautical Miles

Pattern Number	11	12	13	15	16	18	19	23	29
4.		2	→	→	→	→	3	→	→
5.		2	→	→	→	→	→	→	→
6.		2	→	→	→	3	→	→	→
7.		2	→	3	→	→	→	→	→
8.			3	→	→	→	→	4	→

Pattern Number	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
9.	2	→	3	→	→	→	→	→	→	4	→	→	→	→	→	→	→
10.		2	→	3	→	→	→	→	→	→	4	→	→	→	→	→	→
11.			2	→	3	→	→	→	→	4	→	→	→	→	3	→	→
12.				2	→	3	→	→	→	4	→	→	→	→	→	→	→
13.				2	→	3	→	→	→	→	4	→	→	→	→	→	→
14.					2	→	3	→	→	→	→	4	→	→	→	→	→
15.					2	→	3	→	→	→	4	→	→	→	→	→	5
16.						2	→	3	→	→	4	→	→	→	→	→	→
17.							2	→	3	→	→	→	4	→	→	→	→

Pattern Number	11	20	21	22	23	24	25	26	27	28	29
18.		2	→	3	→	→	4	→	→	→	→
19.			2	→	→	3	→	→	4	→	→
20.				2	→	→	3	→	→	→	4
21.					2	→	→	3	→	→	→
22.						2	→	→	3	→	→
23.									2	→	→
24.											2

Table 18-13-2. (2/3). Holding Course Away From the NAVAID. Usable DME Leg Lengths.

Fix-to-NAVAID (geographical - not DME) Distance in Nautical Miles

Pattern Number	30	34	38	40	44	55	80
4.	2	3					
5.	2	3					
6.	3						
7.	4					5	
8.	4				5		
9.	4			5			

Pattern Number	30	31	32	36	37	38	42	44	46	50	55	60	65	70	80
10.	4					5									
11.	4		5											6	
12.	4	5											6		
13.	5										6				
14.	4		5								6				
15.	5							6							
16.	5						6								7

Pattern Number	30	31	32	34	35	36	37	38	40	42	44	48	50	55	60	70	80
17.	4	5								6						7	
18.	5							6							7		
19.	4		5						6					7			
20.	4			5						6				7			
21.	4				5					6				7			
22.			4				5				6		7				8
23.				4					5			6			7		8

Table 18-13-2. (3/3). Holding Course Away From the NAVAID. Usable DME Leg Lengths.

Fix-to-NAVAID (geographical - not DME) Distance in Nautical Miles

Pattern Number	30	32	34	35	36	37	38	40	42	44	46	48	50	55	60	65	70	80
24.	2	3			4				5				6		7			8
25.		2		3				4			5			6		7		
26.			2				3		4			5		6		7		
27.						2			3		4			5	6		7	
28.									2		3		4		5	6		7
29.										2			3	4	5		6	7
30.										2		3		4	5			7

Pattern Number	30	48	55	60	65	70	80
31.		2	3	4			

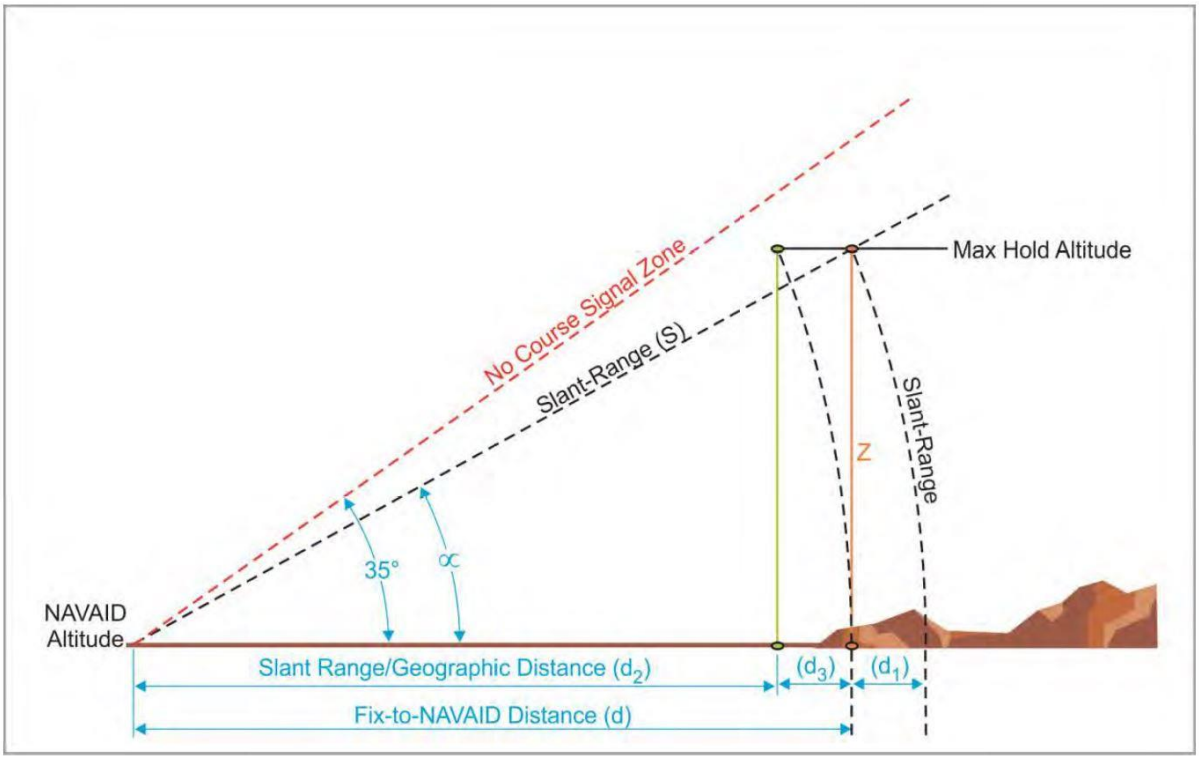
SECTION 14. FORMULAS FOR HOLDING PATTERN PLACEMENT

18.14. Formulas for Holding Pattern Placement.

18.14.1. General.

The formulas in this chapter are used to calculate the values required for evaluating the placement of the holding pattern number and the distances published when charting the holding pattern. More than one formula is required in some calculations. Figure 18-14-1 shows the relationship of the calculations and provides the key to the letters used in the formulas. Formulas 18-14-1 thru 18-14-8 are used as described below and in the previous sections.

Figure 18-14-1. Holding Calculations Relationships



a. Formula 18-14-1 is used to determine the height above the NAVAID at the maximum holding altitude, and converted to NM for use in other calculations.

Formula 18-14-1. Holding Altitude Above the NAVAID (z)

$$z = \frac{(\text{flight}_{\text{elev}} - \text{NAVAID}_{\text{elev}}) \times 0.3048}{1852}$$

Where:

$\text{NAVAID}_{\text{elev}}$ = the elevation of the NAVAID in feet.
$\text{flight}_{\text{elev}}$ = the maximum holding altitude in feet.

b. Formula 18-14-2 is used to determine the slant-range(s) when the fix-to-NAVAID distance (d) is known.

Formula 18-14-2. Slant-range (s) when fix-to-NAVAID distance (d) is Known

$$s = \sqrt{d^2 + z^2}$$

Where:

z = Height above the NAVAID in NM using formula 18-14-1.
d = The fix-to-NAVAID distance in NM.

c. Formula 18-14-3 is used to determine the Fix-to-NAVAID distance (d) when slant-range (s) is known.

Formula 18-14-3. Fix-to-NAVAID Distance (d) When Slant-range is Known

$$d = \sqrt{s^2 - z^2}$$

Where:

z = Height above the NAVAID in NM using formula 18-14-1.
s = The slant-range distance in NM.

d. Formula 18-14-4 and 18-14-5 are used to determine the minimum fix-to-NAVAID distance, at the maximum authorized holding altitude, is calculated based on a 35-degree angle and either the desired slant-range or fix-to-NAVAID distance. Initially calculate this value based on the desired holding location and desired maximum holding altitude (see paragraph 18.4.4a). When dual plotting of the holding pattern number is required, this calculation must be performed using the closest pattern number location to the NAVAID (see slant-range/geographic distance, paragraph 18.1.1e), regardless of the published distance to ensure conventional holding is supported. The maximum holding altitude must always be below the 35-degree no-course signal zone.

Formula 18-14-4. No-Course Signal Zone, Desired Slant-range Distance (s)

$$s = \frac{z}{\sin(35°)}$$

Where:

z = Height above the NAVAID in NM using formula 18-14-1.

Formula 18-14-5. No-Course Signal Zone, Desired Fix-to-NAVAID Distance (d)

$$d = \frac{z}{\tan(35°)}$$

Where:

z = Height above the NAVAID in NM using formula 18-14-1.

e. Formula 18-14-6 identifies the difference between the slant-range distance and fix-to-NAVAID distance, used to determine if a single pattern can be used for both slant range and non-slant range holding. The fix-to-NAVAID distance (d), the slant-range distance (s),

are first calculated using formulas 18-14-2 and 18-14-3, then the difference (d_1) is calculated using formula 18-14-6 (see paragraph 18.4.4b). When the value d_1 exceeds the maximum for using a single pattern, recalculation of the no-course signal zone will be required to determine if the second plotted location (determined by formulas 18-14-7 and 18-14-8 for slant-range/geographic distance) places the aircraft inside the no-course signal zone.

Formula 18-14-6. Difference Between Slant-range (s) and Fix-to-NAVAID Distance (d) is (d_1)

$$\mathbf{d_1 = s - d}$$

Where:

s = The slant-range distance in NM.

d = The fix-to-NAVAID distance in NM.

f. Formula 18-14-7 is used to determine the slant-range/geographical distance based on the fix-to-NAVAID distance and maximum holding Altitude (see paragraph 18.4.4c). The calculated slant-range/geographical distance must be equal or greater than the minimum fix-to-NAVAID distance (d) in formula 18-14-5. Otherwise the second plotted location, used by conventional aircraft, is above the 35 degree line and therefore, inside the no-course signal zone. The difference between the two plotted locations is computed using formula 18-14-8 to determine d_3.

Formula 18-14-7. Slant-range/Geographic Distance (d_2)

$$\mathbf{d_2 = \sqrt{d^2 - z^2}}$$

Where:

d = The fix-to-NAVAID distance in NM.

z = Height above the NAVAID in NM using formula 18-14-1.

Formula 18-14-8. Difference Between Plotted Locations (d_3)

$$\mathbf{d_3 = d - d_2}$$

Where:

d = The fix-to-NAVAID distance in NM.

d_2 = Slant-range/Geographical Distance in NM from formula 18-14-7.

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CRITERIA FOR THE DEVELOPMENT OF INSTRUMENT PROCEDURES

TP 308 / GPH 209 – CHANGE 9.0

VOLUME 2

PERFORMANCE BASED NAVIGATION (PBN)

TRANSPORT CANADA
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VOLUME 2: PERFORMANCE BASED NAVIGATION (PBN)

CHAPTER 1. BASIC CRITERIA INFORMATION

SECTION 1-1: PURPOSE

1.1 Purpose

1.1.1 Purpose of this document: This volume contains criteria for the formulation, review, approval and publication Performance Based Navigation (PBN) instrument procedures. The criteria were developed by United States Federal Aviation Administration's (FAA). This document provides guidance for the design and evaluation of Performance Based Navigation (PBN) Instrument Flight Procedures (IFPs). For the purposes of this publication, PBN IFPs are those based on Area Navigation (RNAV) or Required Navigation Performance (RNP) to include transitions to an Instrument Landing System (ILS) or Ground Based Augmentation (GBAS) Landing System (GLS) final segment and may have Equipment requirements specifications.

1.1.2 Audience. All personnel who are responsible for IFP development and/or evaluation.

SECTION 1-2: BASIC CRITERIA

1.2 Basic Criteria.

1.2.1 **General.** These criteria assumes the use of Global Navigation Satellite System (GNSS) receivers approved for approach operations in accordance with the applicable Technical Standard Order (TSO) or equivalent criteria and based on NavSpec.

1.2.2 Documentation Accuracy:

a. All latitudes and longitudes to the nearest one hundredth (0.01) arc second; [nearest five ten thousandth (0.0005) arc second for Final Approach Segment (FAS) data block entries];

b. Flight Path Alignment Point (FPAP) mean sea level (MSL) elevation to the nearest foot;

c. FPAP height above ellipsoid (HAE) to the nearest tenth (0.1) meter;

d. Landing Threshold Point (LTP) mean sea level (MSL) elevation to the nearest foot;

e. LTP height above ellipsoid (HAE) to the nearest tenth (0.1) meter;

f. Glidepath angle to the next higher one hundredth (0.01) degree;

g. Courses to the nearest one hundredth (0.01) degree;

h. Course width at threshold to the nearest quarter (0.25) meter; and

i. Distances to the nearest hundredth (0.01) unit [except for “length of offset” entry in Final Approach Segment (FAS) data block which is to the nearest 8 meter value].

1.2.3 **Geospatial standards.** The following standards apply to the evaluation of obstacle and terrain position and elevation data relative to RNAV Obstacle Evaluation Area(s) (OEAs) and Obstacle Clearance Surface(s) (OCSs). Terrain and obstacle data are reported in NAD-83 latitude, longitude, and elevation relative to MSL in Canadian Geodetic Vertical Datum of 1928 (CGVD-28) or Canadian Geodetic Vertical Datum of 2013 (CGVD 2013) vertical datum. Evaluate obstacles using their NAD-83 lateral/horizontal position and CGVD-28 and/or CGVD 2013 elevation value compared to the WGS-84 referenced course centerline (along-track and cross-track), OEA boundaries, and OCS elevations as appropriate. PBN IFPs must be evaluated geodetically [see appendix E].

Note: All reference to WGS-84 or other datum in TP308 must be interpreted as inclusive to approved equivalent datum by Natural Resources Canada.

1.2.4 PBN Concept. The PBN concept is made up of three interrelated elements: the navigation specification, the NAVAID infrastructure, and the navigation application. These three elements define the minimum required aircraft/system performance used as the basis for the obstacle evaluation areas described in this document.

a. Navigation specification (NavSpec). The NavSpec is a set of aircraft/aircrew certification and operational approval requirements that support a navigation application within a defined airspace concept. NavSpecs which require on-board performance monitoring and alerting are termed RNP specifications. Those that do not require on-board performance monitoring and alerting are termed RNAV specifications. The NavSpec defines the performance required by an RNAV or RNP system as well as any functional requirements (e.g., ability to conduct curved path legs). NavSpecs include:

   (1) Performance. The performance required in terms of accuracy, integrity, and continuity.

   (2) Functions. The functions available to achieve the required performance.

   (3) Navigation sensors. The navigation sensors that may be used to achieve the required performance.

   (4) Procedures. Flight crew and other procedures to achieve the required performance.

b. NAVAID infrastructure. NAVAID infrastructure relates to space or ground-based NAVAIDS addressed in the NavSpec.

c. Navigation application. Also referred to as flight phase. A navigation application is the operation in which a specific NavSpec and associated performance requirements applies (e.g., ATS route, IFP segment, etc.).

Table 1-2-1. Navigation Accuracy by NavSpec/Flight Phase

Navigation Specification	Flight Phase						
	Enroute	STAR/ Feeder/TAA	Initial	Intermediate	Final	Missed[1]	Departure
RNAV 2	2	2					2
RNAV 1[2]		1	1	1		1	1
RNP 2	2						
RNP 1[2]		1	1	1		1	1
A-RNP[2,6,9]	2 or 1[8]	1 or 0.3	0.3	0.3	RNP APCH	0.3	1 or 0.3
RNP APCH[2,3]			1	1	0.3[4]/40m[5]	1	
RNP AR APCH			1 - 0.1	1 - 0.1	0.3 - 0.1	0.1 - 1	
RNP AR DP							0.3 -1
RNP 0.3[7]	0.3	0.3	0.3	0.3		0.3	0.3

1. Missed approach section 2 only. RNP AR APCH sections 1a and 1b.
2. STAR/Feeder/TAA, departure, initial, intermediate, and missed section 2. Beyond 30 NM from ARP the effective XTT/ATT for the purpose of IFP design is 2.
3. RNP APCH part A is enabled by GNSS and BARO-VNAV and part B is enabled by SBAS.
4. Part A only.
5. Part B along-track performance is 40 meters; angular performance requirements apply to lateral.
6. A-RNP permits a range RNP lateral navigation accuracies in some flight phases. Apply the largest lateral navigation accuracy for the flight phase unless a smaller value is operationally required to achieve the desired ground track.
7. Primary intended for helicopter operations only. RNP APCH applies to the final flight phase.
8. Remote Continental use 2 (Remote continental airspace is defined as airspace above terrain where line-of-sight communications, independent surveillance and reliable ground-based NAVAIDs are not available. Controllers provide ATS utilizing procedural control and procedural separation).
9. Use of A-RNP missed approach or departure XTT less than 1 should be avoided because it will limit the IFP availability to some users.

Note: Value in NM if not specified.

1.2.5 Obstacle Evaluation Area (OEA) and Flight Path Construction.

a. Courses fixes, boundaries (lateral and longitudinal dimension).

(1) Construct straight-line courses as a WGS-84 ellipsoid geodesic path. If the course outbound from a fix differs from the course inbound to the fix (courses measured at the fix), then a turn is indicated. Construct parallel and trapezoidal boundary lines as a locus of points measured perpendicular to the geodesic path. (The resulting primary and/or secondary boundary lines do not display a “middle bulge” due to curvature of the ellipsoids surface since they are not geodesic paths.) NAD-83 latitude/longitude positions are acceptable for obstacle, terrain, and airport data evaluation. Determine obstacle lateral positions relative to course centerline/OEA boundaries using ellipsoidal calculations (see Appendix E).

(2) Surface Elevations (vertical dimension). Evaluate obstacles, terrain, and airport data using their elevation relative to their orthometric height above the geoid (for our purposes, MSL) referenced to the CGVD-28 and/or CGVD 2013 vertical datum. The elevations of OCSs are determined spherically relative to their origin MSL elevation (CGVD-28 and/or CGVD 2013).

(3) Alignment. The alignment tolerance is ± 0.03 degrees of all course differentials. The general alignment restriction between TF/CF legs at or above FL 195 is limited to a maximum course change of 70 degrees, while below FL 195 is 90 degrees; however, specific requirements stated in a segment's chapter/section take precedence. When preceded by a DF leg, the alignment restriction applies to both the early and late tracks. The general alignment restriction between TF and RF legs is no course change exceeding alignment.

Note: When using pre-established fixes, acceptably small differences in fix coordinates can cause legs to exceed alignment tolerance. The alignment tolerance can be exceeded when the calculated ideal fix coordinates round to match the pre-existing fix coordinates. When an RNAV waypoint is collocated with another type of fix, use the same name for both.

b. Area Dimensions. For IFP design purposes, the term XTT is the larger of basic XTT and the effective XTT associated with a leg.

(1) Length.

(a) Minimum length (fix-to-fix). Generally, minimum leg length is the lesser of 2 × XTT or 1 NM, but where applicable may also be no less than;

1. The sum of the distance of turn anticipation (DTA) for each fly-by (FB) turn [see formula 1-2-1].

Note: Not applicable for FB turns of 10 degrees or less.

Formula 1-2-1. Distance Turn Anticipation

$$\mathrm{DTA} = \mathrm{R} \times \tan\left(\frac{\beta}{2}\right)$$

Where:

β = magnitude of heading change in degrees
R = turn radius

Example:

$\mathrm{DTA} = 3.52 \times \tan(75/2)$
$\mathrm{DTA} \approx 2.7$

Note: This formula produces a value with the same unit as R.

2. For TF legs following a fly-over (FO) turn a length sufficient to allow the aircraft to return to course centerline. Determine using formula 1-2-2.

Formula 1-2-2. TF Minimum Leg Length Following FO Turn

If $\beta < \text{acos}(\sqrt{3}-1)$ use:

$$\mathrm{L} = \mathrm{R} \times \left[\sin(\beta) + 2 \times \sin\left(\text{acos}\left[\frac{1+\cos(\beta)}{2}\right]\right)\right] + \mathrm{DTA}$$

If $\beta \geq \text{acos}(\sqrt{3}-1)$ use:

$$\mathrm{L} = \mathrm{R} \times \left[\sin(\beta) + 4 - \sqrt{3} - \sqrt{3} \times \cos(\beta)\right] + \mathrm{DTA}$$

Note: L must not be less than 1 NM

Where:

R = turn radius at the first fix
β = magnitude of heading change at the first fix
DTA = value from formula 1-2-1 for the second fix

Note: When multiple courses precede the FO fix (e.g., VA-DF legs) use the track resulting in the greatest magnitude of heading change at the first fix.

Example:

$$\mathrm{L} = 5.6 \times \left[\sin(33) + 2 \times \sin\left(\text{acos}\left[\frac{1+\cos(33)}{2}\right]\right)\right] + 2.7$$

L≈10.16

Note: This formula produces a value with the same unit as R.

(b) RF leg length may be calculated using formula 1-2-3. Use in conjunction with formula 1-2-4 when necessary to calculate an RF leg of a specific length.

Formula 1-2-3. RF Leg Length

$$\mathrm{L} = \frac{\alpha \times \pi \times \mathrm{R}}{180}$$

Where:

α = degrees of arc
R = arc radius

Example:

$$\mathrm{L} = \frac{98.9 \times \pi \times 4.2}{180}$$

L ≈ 7.25

Note: This formula produces a value with the same unit as R.

Formula 1-2-4. Degrees of an Arc

$$\alpha = \frac{180 \times L}{\pi \times R}$$

Where:

L = arc length
R = arc radius

Note: This formula works with any unit so long as L & R share the same unit.

Example:

$\alpha = \frac{180 \times 7.25}{\pi \times 4.2}$

$\alpha \approx 98.90^{\circ}$

(c) Maximum length (fix-to-fix). Maximum Standard Instrument Approach Procedure (SIAP) segment length is as specified in Volume 1, chapter 2. In no case should the length of any PBN leg exceed 500 NM.

(d) Along-track tolerance (ATT). OEAs are constructed and evaluated from ATT prior to a leg's initial fix (early) to ATT past its termination fix (late). ATT is equal to the navigation accuracy associated with the flight phase [see table 1-2-1]. ATT (same or adjacent legs) can overlap when legs meet minimum length requirements.

1. Except where specified otherwise (e.g., intermediate segment) use the ATT specific for the leg being constructed for both early and late ATT.

2. The baseline used for determining early/late ATT area depends on the leg/turn type.

a TF (no turn) and FO turn. ATT is relative to a line perpendicular to the inbound leg at the fix [see figure 1-2-1].
b FB turn. ATT is relative to the bisector used for OEA construction [see figure 1-2-2].
c RF. ATT is relative to a line drawn radially from the turn center point. Distance is measured from the fix along the RF arc [see figure 1-2-3].

Figure 1-2-1. ATT Straight

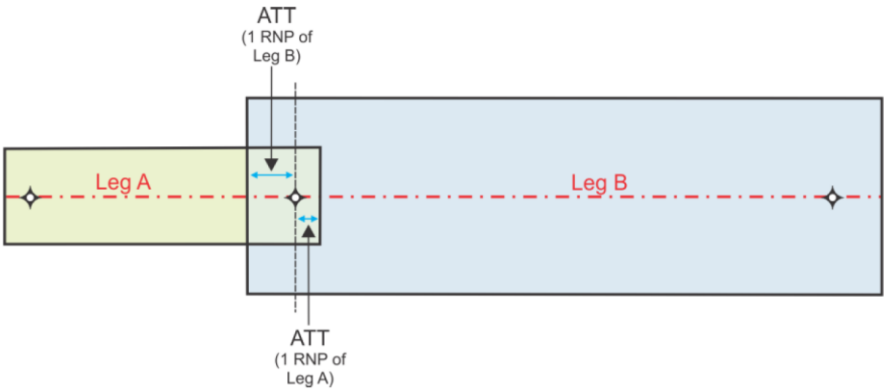


Figure 1-2-2. ATT Turning

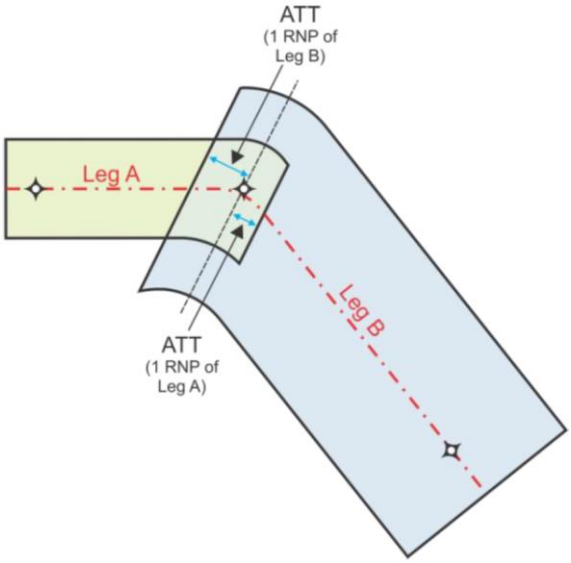
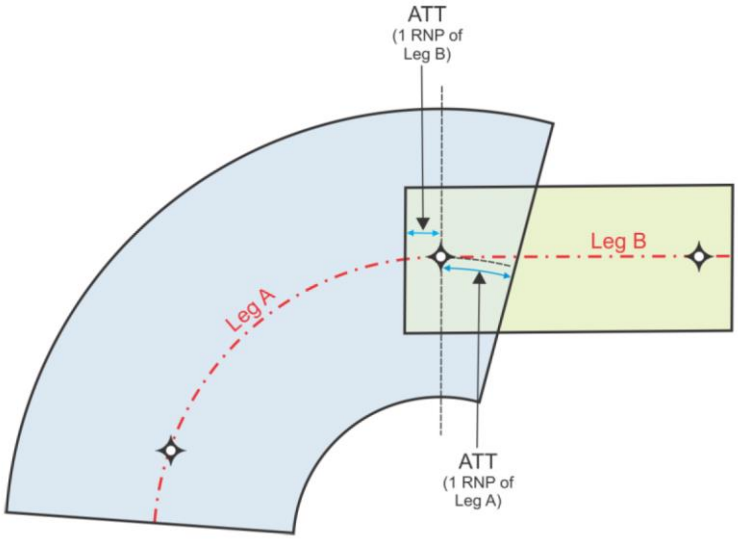


Figure 1-2-3. ATT RF



(2) Width.

(a) Cross-track tolerance (XTT). The XTT is used to determine the OEA lateral dimensions. The XTT is derived from table 1-2-1 navigation accuracy for the defined NavSpec and flight phase. Primary area width is 2 × XTT either side of course and secondary area width is 1 × XTT either side of the primary area, if applicable. The XTT for A-RNP and RNP AR is the specified RNP value for the leg being evaluated. Reference to route width is often specified as NM values measured from secondary area edge across the primary area to the secondary edge at the other side. For example, feeder widths may be referred to as “2-4-4-2.”

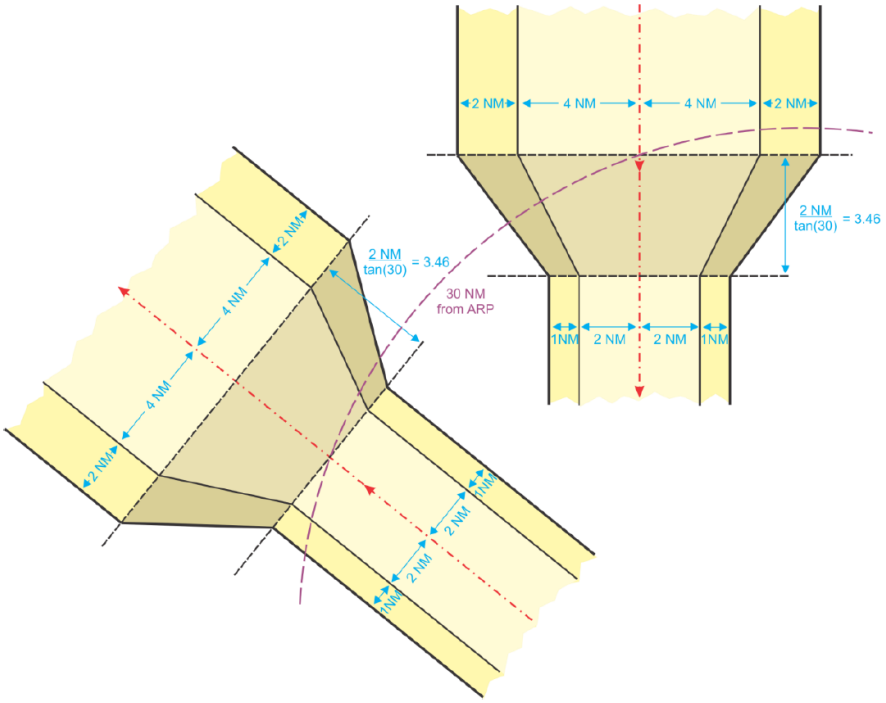
(b) Width changes. RNP AR APCH, A-RNP and RNP AR DP width changes occur abruptly at the start fix of a leg with a new RNP. A-RNP width values may only be decreased prior to final and increased on departure and missed approach. For all other IFPs, OEA construction accommodates width changes at the transition to the final approach mode and at the transition to or from the en route mode. See the applicable chapter for width changes at the final approach transition. For the en route transition, legs that cross a point 30 NM from ARP, the OEA primary area width expands or tapers at a rate of 30 degrees relative to course to the appropriate width [see figure 1-2-4 and figure 1-2-5]. Calculate the total along-track distance required to complete the transition using formula 1-2-5. STAR/feeder and approach legs designed to cross within 30 NM of the ARP more than once do not change to RNAV 1/RNP 1/A-RNP (terminal mode) until the 30 NM limit is crossed for the last time. A departure or missed approach segment designed to cross a point 30 NM from the ARP more than once changes to RNAV 2/RNP 2/A-RNP (en route mode) and remains expanded when it crosses the boundary the first time. A-RNP width changes for mode transitions at 30 NM from ARP use the 30-degree splay method to/from effective XTT.

1. Non-RF width changes.

   a Inbound. The secondary area tapers from en route mode width when the 30 NM point is crossed to terminal mode width abeam the point the primary area is fully tapered. Leg width tapers regardless of fix location within the tapering section unless a turn is associated with the fix. Delay OEA taper until the turn is complete and normal OEA turn construction is possible.

   b Outbound. The secondary area expands from terminal mode width when the 30 NM point is crossed to en route mode width abeam the point the primary area is fully expanded. Leg width expands regardless of fix location within the expansion section unless a turn is associated with the fix. Start the OEA expansion so as to achieve full expansion to en route mode width prior to the turn.

Figure 1-2-4. Non-RF Width Change at 30 NM from ARP



2. RF width changes. Calculate the perpendicular distance from the RF leg track centerline to primary and secondary boundaries at any along-track distance (specified as degrees of RF arc) from the point the track crosses the 30 NM point using formula 1-2-6 [see figure 1-2-5]. The width transition must be fully contained within a single RF leg.

Formula 1-2-5. RF Width Change Distance at 30 NM from ARP

$$D = \frac{2 \times XTT_{Large} - 2 \times XTT_{Small}}{\tan(30)}$$

Where:

XTT_{Large} = the largest XTT value
XTT_{Small} = the smallest XTT value

Note: This formula works with any unit so long as all XTT values share the same unit.

Example:

$$D = \frac{2 \times 2 - 2 \times 1}{\tan(30)}$$

$D \approx 3.46$ NM

Formula 1-2-6. RF Leg XTT Change

$$\text{Boundary} = \frac{1}{2}\,\text{Width}_{Large} - \frac{\frac{1}{2}\text{Width}_{Small} \times x_{angle} \times R \times \pi}{D \times 180}$$

Where:

½ Width_{Large} = 2 × largest XTT for primary area or 3 × largest XTT for secondary area
½ Width_{Small} = 2 × smallest XTT for secondary or 3 × smallest XTT for secondary area
x_{angle} = angle relative to center point from beginning of taper to point of interest
R = arc radius
D = along track distance required to complete the XTT change

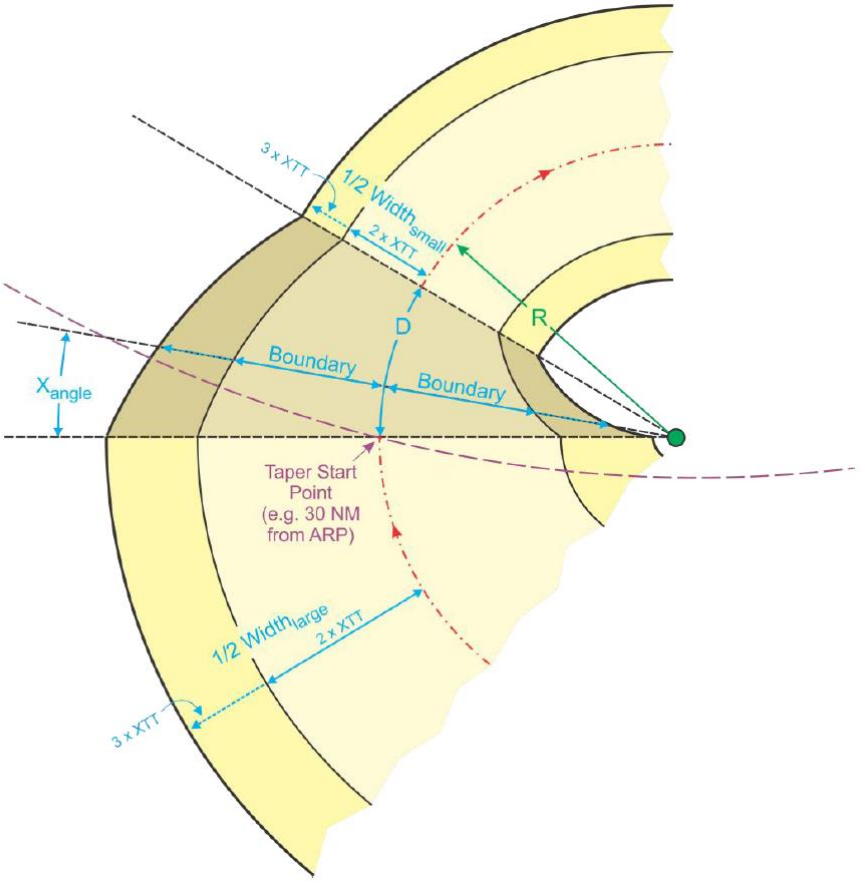
Note: This formula works with any unit so long as all XTT values share the same unit.

Example:

$$\text{Boundary} = 6 - \frac{3 \times 10 \times 6.44 \times \pi}{3.46 \times 180}$$

Boundary ≈ 5.03

Figure 1-2-5. RF Width Change at 30 NM from ARP



c. Turn parameters. For OEA construction, a turn is indicated when the course change exceeds the alignment tolerance of 0.03 degrees [see paragraph 1.2.5.a(3)].

(1) Altitude. Calculate the assumed altitude at a turn fix/point as specified below. For other cases [e.g., Q or T routes, or standard terminal arrival (STAR) or standard instrument departure (SID) legs that precede/follow manual termination legs that make it impractical to determine a starting altitude/point] use the highest anticipated altitude at the turn fix based on specified altitudes, airspace, and anticipated use.

Note: Use of the highest anticipated altitude is required even when obstacle clearance is assured for flyability, path repeatability, and airspace/route separation.

(a) Calculate projected altitude. Except for turns inside the Precision Final Approach Fix (PFAF), projected altitudes are calculated using formula 1-3-8 based on the rise of an assumed vertical path from a specified start point.

1. Final approach segment.

a Turns inside the PFAF. Use the final segment vertical path, i.e., glidepath angle (GPA). Determine the projected altitude by calculating the vertical rise from the Landing Threshold Point (LTP)/Fictitious Threshold Point (FTP) using formula 1-3-4.

b Turns at the PFAF. There is no projected altitude. Use the specified PFAF altitude.

2. Intermediate and initial approach segments. The vertical path is 250 ft/NM (CAT A-E) or 400 ft/NM (COPTER). Determine the projected altitude by calculating the vertical path rise fix-to-fix from the start point/altitude to the turn fix. For the first leg, the start point is the PFAF at the specified PFAF altitude. For subsequent legs, start at the end fix of the preceding leg at the assumed fix altitude.

3. Feeder segments and STAR runway transitions that terminate on an instrument approach procedure (IAP). The vertical path is 250 ft/NM (CAT A-E). Determine the projected altitude by calculating the vertical path rise fix-to-fix from the start point/altitude to the turn fix.

a Feeder. For the first leg, start at the initial approach fix (IAF) at the assumed IAF altitude. The start point/altitude for subsequent legs is the end fix at the assumed fix altitude of the preceding leg.

b STARs. For the first leg, start at the IAP fix at the assumed fix altitude. For subsequent legs, start at the end fix preceding leg at the assumed fix altitude. If a STAR transition serves more than one IAP, base the STAR on the IAP with the highest assumed altitude.

4. Missed approach (MA) and departure (prior to transition route). For MA legs, the vertical path is the higher of 250 ft/NM (CAT A-B), 500 ft/NM (CAT C-E), 400 ft/NM (COPTER), or the specified climb gradient (CG) in effect at the point of interest. For departure legs (all CATs), the vertical path is the higher of 500 ft/NM below 10000 MSL and/or 350 ft/NM 10000 MSL and above (CAT A-E), 400 ft/NM (COPTER) or the specified CG in effect at the point of interest. For MA, the start point for the first leg is the SOC applicable to the approach type [see applicable chapter]. For departures, the start point for the first leg is the departure end of runway (DER) at DER elevation.

a Turn-at-altitude. To calculate the highest altitude in the turn used for OEA construction, see paragraph 1.3.1.g.(3); otherwise use the specified turn altitude. The start point for subsequent legs is the point along the course centerline where the specified turn altitude is reached. Calculate the vertical rise from the start point measured direct to subsequent fix.

b All other turns. Calculate the projected fix altitude by applying the vertical path rise from the start point/altitude along the course

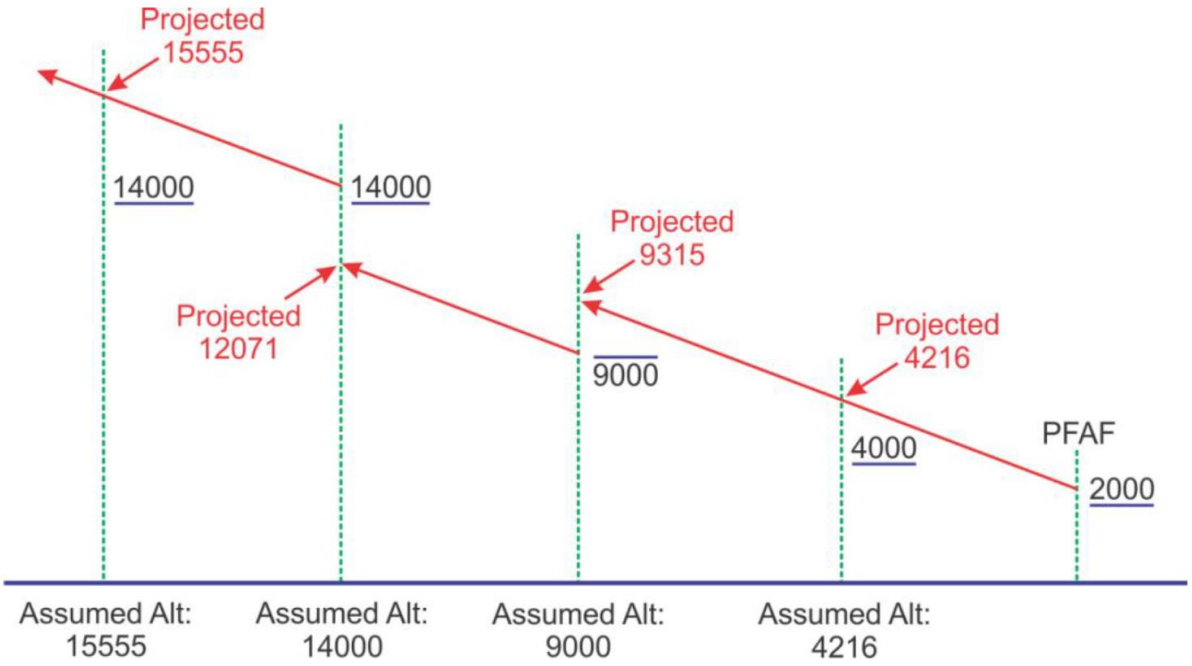
centerline to the subsequent fix/point. For fixes following a DF leg, the course centerline is a direct line from the turn point/fix to the subsequent fix. The start point for subsequent legs is the end fix/point of the preceding leg at the assumed fix/point altitude.

(b) Compare to published altitudes. Compare projected altitude(s) to published altitude(s) to include minimum en route altitudes (MEAs).

(c) Determine assumed altitude [see figure 1-2-6]. The assumed altitude used for turn construction is:

1. The higher of the projected altitude and any published minimum or mandatory altitude.
2. The lower of the projected altitude and any maximum altitude, to include the overall maximum altitude applicable to the flight phase (e.g., missed approach clearance limit altitude). The maximum altitude at a fix or for the flight phase can also be specified by ATC.

Figure 1-2-6. Assumed Altitudes for OEA Turn Construction



(2) Airspeed. Locate and use the appropriate KIAS from table 1-2-2. Determine the KTAS for the turn using formula 1-2-7 based on the assumed altitude at the turn fix/point [see paragraph 1.2.5.c(1)].

Table 1-2-2. Indicated Airspeeds (KIAS)

Flight Phase		Indicated Airspeed By CAT (KIAS)					
		Copter	A	B	C	D	E
At or above 10000 feet							
Enroute, STAR/Feeder/TAA, Initial, Intermediate, Missed, Departure		150	180	250	300	300	350
Below 10000 feet							
Enroute, STAR/Feeder/TAA, Initial, Intermediate		150	150	180	250	250[1]	310
Final		90	90	120	140	165	250
Missed Approach (MA), Departure		150	110	150	240	265	310
Minimum Airspeed Restriction							
Minimum Airspeed Restriction[2]	STAR/Feeder/TAA, Initial, Departure	70[5]	110	140	200[3]	210[3,4]	310
	Intermediate	70[5]	110	140	180	180	310
	Missed Approach	70[5]	100	130	165	185	310
	Final	70[5]	Not Authorized				

1 Consider using 265 KIAS where heavy aircraft routinely exceed 250 KIAS under CAR 602.32(1).
2 Airspeed restrictions may be established at a charted fix to reduce turn radius, avoid obstacles, accommodate ATC request, etc. Use the fewest number of restrictions in the same IFP possible. Especially avoid consecutive restrictions requiring speed changes of less than 20 KIAS in the same or adjoining segments. Missed approach airspeed restrictions should not be used for other than obstacle/terrain avoidance requirements.
3 250 above 10000 feet except for initial and/or STAR termination fix.
4 200 below 3000 feet AGL within 10 NM of a controlled airport under CAR 602.32(1).
5 Helicopter only (COPTER) approach chart may have airspeed restriction to 70 kt, which need to be annotated on the chart.

Formula 1-2-7. True Airspeed

$$V_{KTAS} = \frac{V_{KIAS} \times 171233 \times \sqrt{303 - 0.00198 \times alt}}{(288 - 0.00198 \times alt)^{2.628}}$$

Where:

V_{KIAS} = indicated airspeed for applicable category and segment combination

Example:

$$V_{KTAS} = \frac{165 \times 171233 \times \sqrt{303 - 0.00198 \times 650}}{(288 - 0.00198 \times 650)^{2.628}}$$

$V_{KIAS} \approx 170.88$

(3) Maximum bank angles.

(a) Bank limited turns (assumed altitude at turn point/fix < 500 feet above airport elevation (rounded to the nearest foot)): 3 degrees.

(b) Low altitude transition turns (assumed altitude at turn point/fix from 500 feet above airport elevation (rounded to the nearest foot) up to and including FL 195):

1. XTT of the leg being constructed ≥ 1.0: 25.49 degrees.

2. XTT of the leg being constructed < 1.0: 20 degrees, RF turn 25.49 degrees.

(c) High altitude transition turns (> FL 195): 5 degrees

(d) FB turns only: The lesser of one-half the track change (five degrees minimum) or the applicable low/high altitude transition bank angle. Where operationally beneficial (e.g., to reduce leg length) an exception to the one-half track change rule is authorized at a fix when the XTT for the outbound leg is not less than 1.0, a succeeding turn fix uses the applicable low/high altitude transition bank angle, and/or the succeeding leg meets minimum length requirements.

(4) Tailwind (V_{KTW}). Calculate the appropriate tailwind for the assumed altitude at the turn fix [see paragraph 1.2.5.c(1)] using formula 1-2-8.

Formula 1-2-8. Assumed Tailwind

$$V_{KTW} = 0.00198 \times alt + 47$$

Note: If $alt - apt_{elev} \leq 2000$, $V_{KTW} = 30$

Example:

$V_{KTW} = 0.00198 \times 3400 + 47$

$V_{KTW} \approx 53.73$

(5) Turn radius (R). The design turn radius value is based on the turn parameters assumed tailwind [see formula 1-2-8], groundspeed [see formula 1-2-9], assumed altitude at the turn fix/point [see paragraph 1.2.5.c(1)], and bank angle [see paragraph 1.2.5.c(3)]. Calculate R using formula 1-2-10. For RF turn radius, see paragraph 1.2.5.d(3).

Formula 1-2-9. Groundspeed

If alt >FL 195 use:

$$V_{ground} = \text{lesser of } 570 \text{ or } \frac{0.9941 \times \text{alt}}{100} + 287$$

If alt ≤FL 195 use:

$$V_{ground} = \text{lesser of } 500 \text{ or } V_{KTAS} + V_{KTW}$$

Where:

V_{KTAS} = calculated KTAS using alt and applicable KIAS
V_{KTW} = calculated or historical tailwind (knots) using alt

Example:

$V_{ground} = (0.9941 \times 26500)/100 + 287$
$V_{ground} \approx 550.44$ knots

Formula 1-2-10. Turn Radius

$$R = \frac{V_{Ground}{}^2}{\tan(\phi) \times 68625.4}$$

For FB turns, if resulting DTA > 20 NM, then:

$$R = \frac{20}{\tan(\beta \times 0.5)}$$

Where:

β = magnitude of heading change in degrees
V_{ground} = ground speed (knots)
ϕ = designed bank angle or 5 degrees where > FL 195

Example:

$R = 550.44^2/(\tan(5) \times 68625.4)$
$R \approx 50.46$NM

Formula 1-2-11. RF Bank Angle

$$\phi = \text{atan}\left(\frac{V_{Ground}{}^2}{R \times 68625.4}\right)$$

Where:

V_{Ground} = calculated ground speed (knots) at the highest assumed altitude in the leg
R = turn radius (NM)

Example:

$$\phi = \text{atan}\left(\frac{550.44^2}{50.46 \times 68625.4}\right)$$

$\phi \approx 5.00°$

d. Turn construction. When an RNP change is necessary, the construction of the OEA is accomplished using the RNP value of the leg being evaluated extended into the subsequent leg [see figure 1-2-1, figure 1-2-2, and figure 1-2-3].

(1) Turns at FB fixes [see figure 1-2-7]. The following steps detail the construction of the minimum OEA adjacent to a single FB turn fix. The centerlines and/or the lateral boundaries may need to be temporarily extended to achieve tangency with the turn arcs. To complete the OEA for a leg, apply the appropriate construction criteria for the remaining fix in the leg and then truncate and/or connect the components such that the most adverse boundary is created. The following steps detail construction of the minimum OEA for a FB turn fix. An OEA larger than the minimum is acceptable where connecting boundary lines becomes problematic due to turns and leg lengths. Leg lengths must comply with paragraph 1.2.5.b(1).

(a) Step 1. Establish a line through the turn fix that bisects the turn angle. With the origin on the bisector line, scribe an arc that is tangent to the inbound and outbound centerlines using a radius equal to R.

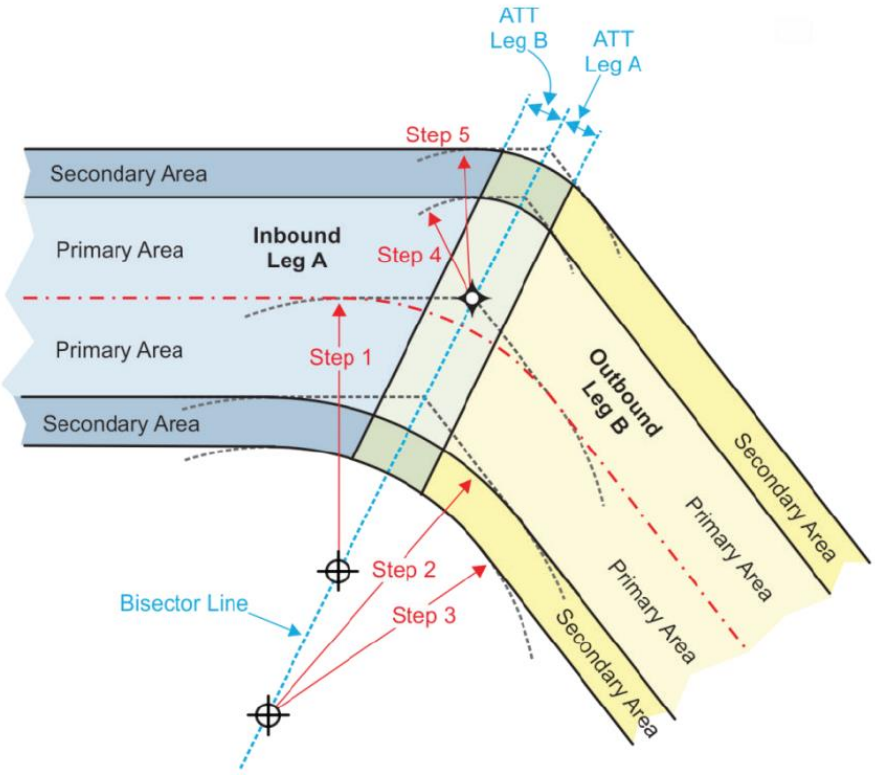
(b) Step 2. Primary area inner boundary. With the origin on the bisector line, scribe an arc that is tangent to the inner primary boundaries of the two legs using a radius equal to R + XTT.

(c) Step 3. Secondary area inner boundary (if applicable). Using the origin from Step 2, scribe an arc that is tangent to the inner secondary boundaries of the two legs using a radius equal to R.

(d) Step 4. Primary area outer boundary. Centered on the turn fix, scribe the primary area outer boundary arc using a radius equal to 2 × XTT.

(e) Step 5. Secondary area outer boundary (if applicable). Centered on the turn fix, scribe the secondary area outer boundary arc using a radius equal to 3 × XTT.

Figure 1-2-7. FB Turn Construction



(2) Turns at FO fixes [see figure 1-2-8 and figure 1-2-9].

(a) Step 1. FO turn construction incorporates a delay in start of turn to account for pilot reaction time and roll-in time. Calculate the extension distance using formula 1-2-12. FO turn construction is not authorized for A-RNP.

Formula 1-2-12. Reaction & Roll Distance

$$D_{rr} = \frac{V_{KTAS} \times 6}{3600}$$

Where:
V_{KTAS} = calculated KTAS using applicable altitude and KIAS combination

Example:

$$D_{rr} = \frac{253.62 \times 6}{3600}$$

$D_{rr} \approx 0.42$ NM

(b) Step 2. Establish the baseline for construction of the turn expansion area as the line perpendicular to the inbound track at a distance past the turn fix equal to ATT + Drr.

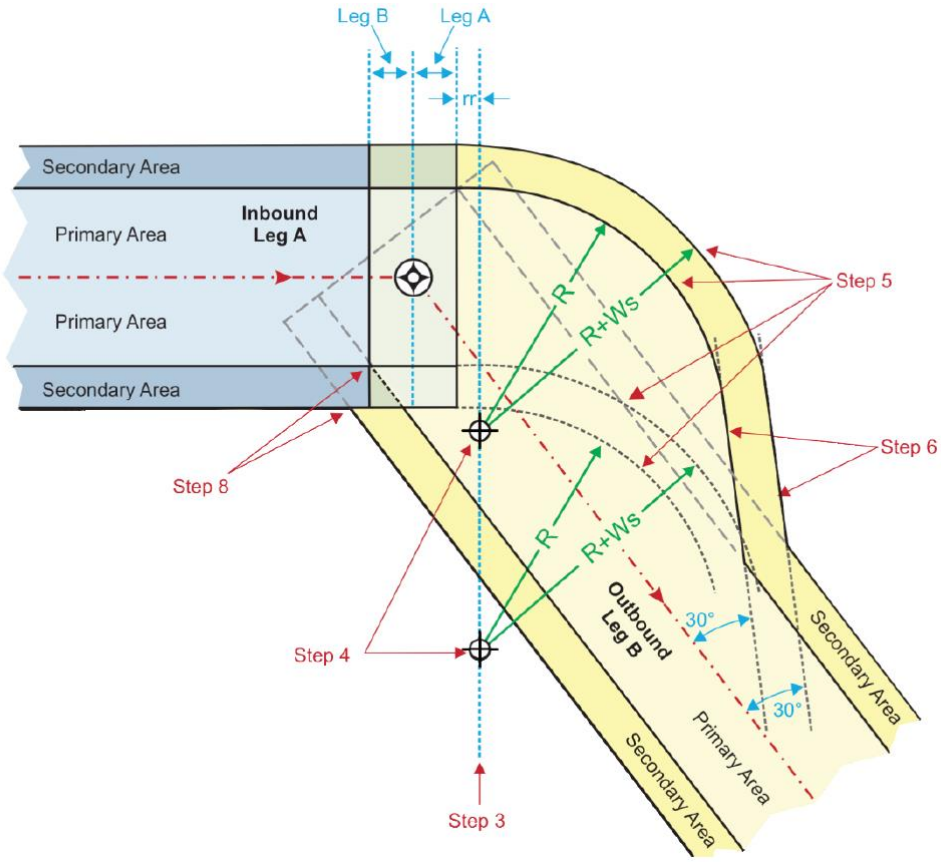
(c) Step 3. Determine R based on bank angle intended for design [see paragraph 1.2.5.c(3)].

(d) Step 4. On the baseline, locate the center points for the primary and secondary turn boundaries. The first is located at a distance R from the non-turning side primary boundary. The second is located at a distance R from the turning side secondary boundary.

(e) Step 5. From these center points construct arcs for the primary boundary of radius R. Complete the secondary boundary by constructing additional arcs of radius R + secondary area width from the same center points.

(f) Step 6. The arcs constructed in Step 5 are tangent to the outer boundary lines of the inbound leg. Construct lines tangent to the arcs based on the first turn point tapering inward at an angle of 30 degrees relative to the outbound track that joins the arc primary and secondary boundaries with the outbound leg primary and secondary boundaries. If the arcs from the second turn point are inside the tapering lines as shown in figure 1-2-8, then they are disregarded and the expanded area construction is completed. If not, proceed to Step 7.

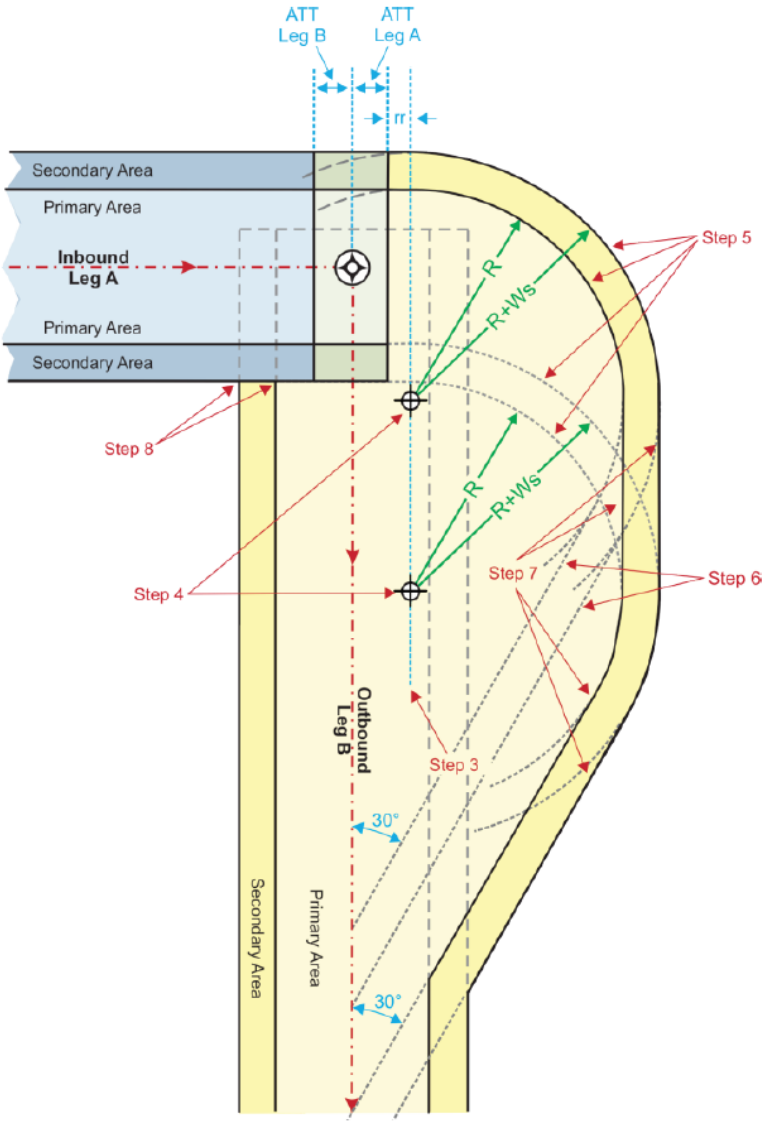
Figure 1-2-8. FO with No Second Arc Expansion



(g) Step 7. If both the inner and outer arcs lie outside the tapering lines constructed in Step 6, connect the respective inner and outer arcs with tangent lines and then construct the tapering lines from the arcs centered on the second center point.

(h) Step 8. The inside turn boundaries are the intersection of the preceding and succeeding leg primary and secondary boundaries.

Figure 1-2-9. FO with Second Arc Expansion



(3) Radius-to-fix (RF) Turn [see figure 1-2-10 and 1-2-11]. RF legs are used to control the ground track of a turn where obstructions prevent the design of a FB or FO turn, or to accommodate other operational requirements. Incorporation of an RF leg limits IFP availability to some users; therefore, an RNP APCH that requires RF leg capability to fly the procedure should be avoided. OEA construction limits turn radius to a minimum value equal to or greater than the OEA (primary and secondary if applicable) half-width. The RF leg OEA boundaries are parallel arcs. For OEA construction, the RF start point is the radius extended to early ATT and the RF end point is the radius extended to late ATT.

(a) Step 1. Determine the leg R that is required to fit the geometry of the terrain/airspace. Enter this R value into formula 1-2-11 t o verify the calculated bank angle (rounded to the nearest whole degree) is ≤ 25 degrees.

(b) Step 2. Locate the turn center at a perpendicular distance R from the inbound and outbound legs.

(c) *Step 3*. Construct an arc of radius R from the point on centerline tangent to the inbound leg at the turn fix to point on centerline tangent to the outbound leg at the turn fix. [See paragraph 1.2.5.a(3) for alignment tolerance.]

(d) *Step 4*. Primary area outer boundary. Construct an arc of radius R + primary area half width from a line originating at the turn center extending radially through the RF start point to a line originating at the turn center extending radially through the RF end point.

(e) *Step 5*. Secondary area outer boundary (if applicable). Construct an arc of radius R + primary area half width + secondary area width from a line originating at the turn center extending radially through the RF start point to a line originating at the turn center extending radially through the RF end point.

1. Case 1. RF Radius greater than or equal to OEA ½ width (primary and secondary if applicable).

a *Step 6*. Primary area inner boundary. Construct an arc of radius R - primary area half width from a line originating at the turn center extending radially through the RF start point to a line originating at the turn center extending radially through RF end point.

b *Step 7*. Secondary area inner boundary (if applicable). Construct an arc of radius R - (primary area half width + secondary area width) from a line originating at the turn center extending radially through the RF start point to a line originating at the turn center extending radially through the RF end point.

2. Case 2. RF Radius less than OEA ½ width (primary and secondary if applicable). This construction is authorized for RNP AR APCH, A-RNP, RNP APCH initial and intermediate segments inside30 NM form ARP, RNP AR DP and RNP-1 DP prior to 30 NM from the ARP.

a *Step 6.* Construct an angle bisection of the RF leg.

b *Step 7.* Construct a line tangent to the RF leg at the angle bisector.

c *Step 8.* Construct an arc with a radius of 3 x XTT that is tangent to the start of the RF and the tangent line at the midpoint of the RF. The centerpoint of this arc is centerpoint1.

d *Step 9.* Construct an arc with a radius XTT from centerpoint1.

e *Step 10.* Construct a line from centerpoint 1 to XTT after the RF end point then radially out from the RF leg centerpoint to the edge of the outer area boundary(s).

f *Step 11.* Construct an arc with a radius of 3 x XTT that is tangent to the tangent line at the midpointof the RF and tangent to the end of the RF. The centerpoint of this arc is centerpoint 2.

g *Step 12.* Construct an arc with a radius XTT from centerpoint 2

h *Step 13.* Construct a line from centerpoint 2 to XTT prior to the RF start point then radially out from the RF leg centerpoint to the edge of the outer area boundary(s).

i *Step 14.* Construct a line from centerpoint 1 to centerpoint 2. The area contained within the overlap of the XTT arcs, the line connecting centerpoint1 and 2 and the RF start and end waypoint ATTs is secondary area. If the XTT arcs don’t overlap, the entirety of the inside turn OEA is primary area.

Figure 1-2-10. RF Turn Construction, Case 1

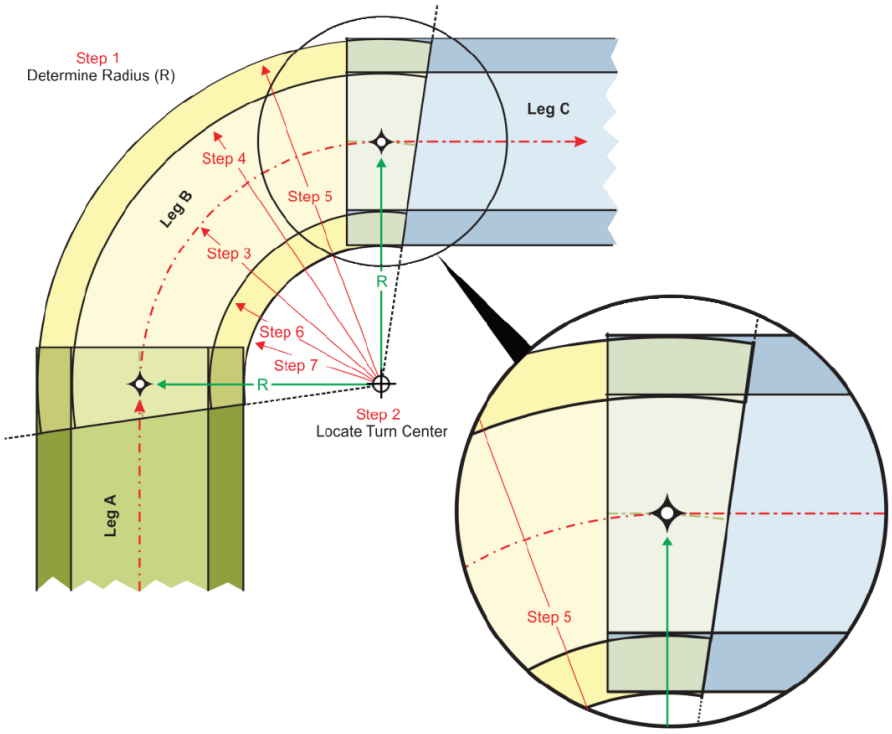
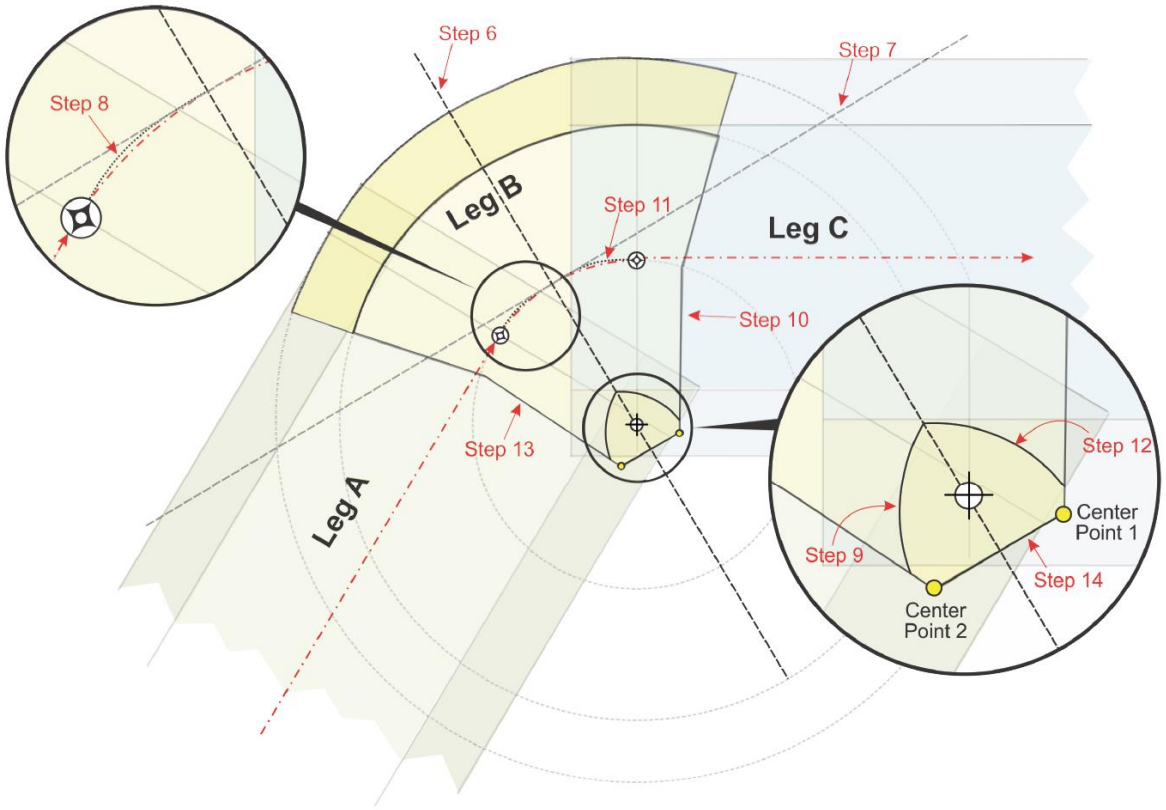


Figure 1-2-11. RF Turn Construction, Case 2



SECTION 1-3. COMMON CRITERIA

1.3 Common criteria.

1.3.1 The following common requirements are applicable to PBN IFPs.

a. Descent gradient (DG) calculation. The applicable Vol 1, chapter 2 applies, except use formula 1-3-1 to calculate descent gradient.

Formula 1-3-1. Descent Gradient

$$\mathrm{DG} = \mathrm{In}\left(\frac{\mathrm{r} + \mathrm{alt_b}}{\mathrm{r} + \mathrm{alt_e}}\right) \times \frac{\mathrm{r}}{\mathrm{D}}$$

Where:
alt_b = beginning altitude (feet)
alt_e = ending altitude (feet)
D = distance (NM) between the points of interest

Example:

$$\mathrm{DG} = \mathrm{In}\left(\frac{\mathrm{r} + 6500}{\mathrm{r} + 3200}\right) \times \frac{\mathrm{r}}{10.36}$$

$\mathrm{DG} \approx 318.46\ \mathrm{ft/NM}$

b. Secondary area (when applicable). Obstacles located in secondary areas are subject to less obstacle clearance than those contained in the primary area. Unless otherwise specified, calculate the secondary ROC using formula 1-3-2. Where an obstacle requires multiple measurements (e.g., an obstacle is equidistant from multiple primary boundary points, it lies along perpendiculars from multiple primary boundary points, etc.), apply the most adverse result from each of the combined primary/secondary measurements. When the secondary area is less than 1 x XTT per paragraph 1.2.5.d(3)(e)2, W_s for Formula 1–3–2 is equal to 1 x XTT in feet.

Formula 1-3-2. Secondary ROC

$$\mathrm{ROC_{secondary}} = (\mathrm{ROC_{min}} + \mathrm{adj}) \times \left(1 - \frac{\mathrm{d_{primary}}}{\mathrm{W_s}}\right) + \mathrm{RASS}$$

Where:

$\mathrm{ROC_{min}}$ = min. secondary ROC (feet) at primary boundary [see Vol 1, chapter 2]
adj = ROC adjustments (feet) such as excessive length of final and precipitous terrain
RASS = remote altimeter setting source adjustment (feet) if applicable
$\mathrm{d_{primary}}$ = dist. (feet) from primary area boundary to obstacle. Zero (0) if not in secondary
$\mathrm{W_s}$ = secondary area width (feet)

Example:

$$\mathrm{ROC}_{\mathrm{secondary}} = (250 + 74.32) \times \left(1 - \frac{405.86}{1822.83}\right) + 91.69$$

$$\mathrm{ROC}_{\mathrm{secondary}} \approx 343.80\ feet$$

c. ATC turns to join initial and intermediate segments. The first leg of an initial and the first leg of an intermediate segment must be a TF that accommodates a 90-degree intercept angle. Use standard turn parameters at the start fix, except a 25-degree bank angle applies. Where a shorter leg is needed, reduce airspeed in increments of not less than five KIAS until the desired length is achieved [see table 1-2-2].

d. Initial approach segment. Initial approach segments consist of one or more TF or RF legs or a hold-in-lieu-of-procedure turn (HILPT). Standard length and alignment applies [see paragraph 1.2.5]. In some cases, initial segments are optional [see Vol 1, Chapter 2, paragraph 2-3-1].

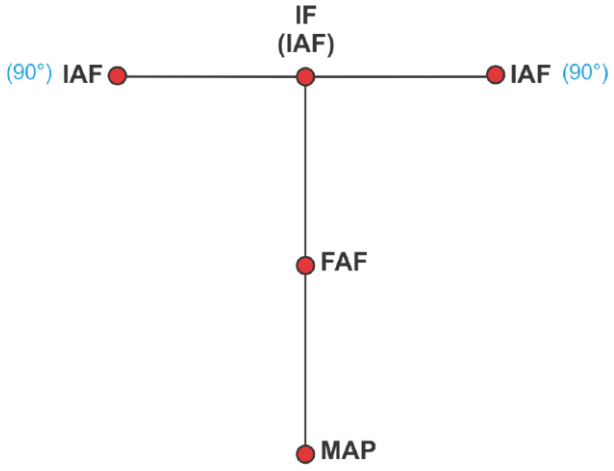
(1) Configuration. The default design incorporates a basic T configuration.

(a) Basic T. Two TF leg initial segments intercept the intermediate segment at 90-degree angles.

(b) Course reversal. Basic T configurations may include a HILPT course reversal initial established at a fix designated as an intermediate fix (IF)/initial approach fix (IAF).

(c) Modified T. Where not practical (e.g., maximum DG exceeded) one or both of the T segments and/or the course reversal may be eliminated.

Figure 1-3-1. Basic T Configuration



(2) Holding pattern. A holding pattern may be incorporated into the initial segment procedure design where an operational benefit can be derived; e.g., arrival holding at an IAF, course reversal pattern at the IF, etc. See Vol 1, chapter 18 for RNAV holding pattern construction guidance.

(a) Arrival holding. Ideally, the holding pattern inbound course should be aligned with the subsequent TF leg (tangent to course at the initial fix of the subsequent RF leg). If the pattern is offset from the subsequent TF leg course, the subsequent leg length must accommodate the resulting DTA requirement. The published holding altitude must be at or above the IAF altitude.

(b) Hold-in-lieu-of-procedure turn (HILPT). Ideally, establish the minimum holding altitude at the minimum IF fix altitude. In any case, the published holding altitude must result in a suitable descent gradient in the intermediate segment. If the pattern is offset from the subsequent TF leg course, the subsequent leg length must accommodate the resulting DTA requirement.

e. Intermediate approach segment. Intermediate approach segments consist of one or more TF or RF legs. Standard length and alignment rules apply [see paragraph 1.2.5] except as follows for the leg ending at the PFAF (the last leg):

(1) Alignment. Use the smallest amount of course change necessary. No course change is default.

(2) Length. For PBN SIAPs, intermediate segment length is independent of the amount of turn at the IF. The default length for CAT A/B is 3 NM. The default length for CAT C/D is 5 N M. The minimum length is as specified in paragraph 1.2.5.b(1). The intermediate segment length may not be greater than 15 NM unless the nominal track of the entire segment is within 15 NM of the ARP. If the intermediate segment exceeds 15 NM and requires a stepdown fix, increase the segment ROC for the segment preceding (as flown) the stepdown fix by five foot per tenth of a track mile between the stepdown fix and the final approach fix. The intermediate segment ROC based on this additive need not exceed 1000 ft. The maximum distance from the stepdown fix to the final approach fix is 15 NM.

f. Final approach segment. SIAPs designed to support Simultaneous Offset Instrument Approaches (SOIA) operations are exempted from standard final segment when compliant with Vol 1, Chapter 14, paragraph 14.3.5.

(1) Fixes.

(a) Final segment fixes. Establish stepdown fixes as ATD fixes relative to the MAP.

(b) Obstacles close to a final approach or stepdown fix. Where turns are designed at the FAF, Vol 1, chapter 2 “General Criteria” applies except for FB turns at the FAF the 7:1 (3.5:1 for helicopters) OIS starts ATT prior to the angle bisector, and extends 1 NM parallel to the final approach centerline.

(2) Final segment vertical path. By default, PBN IFPs should be designed so that all vertical guidance to the runway is based on common TCH and angles. All

vertically-guided PBN approaches charted on the same IFP plate must share common TCH and GPA.

(a) GPA/VDA [see Vol 1 Chapter 2 Section 5].

(b) Threshold crossing height (TCH). The TCH (nearest whole foot) should accommodate the largest aircraft height group normally expected to use the runway and must not be less than the minimum or exceed the maximum TCH. The TCH is based on achieving an acceptable wheel crossing height (WCH). The WCH is the difference between the published TCH and the approximate glidepath-to-wheel height [see table 1-3-1].

1. The default TCH provides a 30-foot WCH. The minimum WCH is 20 feet and the maximum WCH is 50 feet.

2. Displaced threshold. The TCH over a displaced threshold may result in a WCH of not less than 10 feet provided:

a Pavement equivalent to the strength of the landing runway is present prior to the displaced threshold.

b The calculated height of the glidepath over the beginning of the pavement prior to the displaced threshold is within the minimum/maximum TCH values.

(c) Vertical path calculations.

1. DA. Calculate the DA distance from the LTP/FTP using formula 1-3-3. For LPV/GLS, see paragraph 3.4.5.

2. PFAF location. To determine the PFAF location, calculate the distance from the LTP/FTP (straight-in aligned procedures) or MAP (circling aligned procedures) to the point the GPA/VDA or design angle intercepts the intermediate segment altitude [see formula 1-3-3]. For straight-in procedures the beginning altitude is LTP/FTP + TCH. For circling aligned procedures, the beginning altitude is the airport elevation + 50.

Table 1-3-1. TCH Requirements

Representative Aircraft Type	Glidepath-to-Wheel Height (approximate)	Recommended TCH	Remarks
HEIGHT GROUP 1 General Aviation, Small Commuters, Corporate Turbojets, T-38, C-12, C-20, C-21, T-1, Fighter Jets, UC-35, T-3, T-6	10 feet or less	40 feet	Normally runways < 6000 feet long with reduced widths and/ or limited weight bearing, limiting larger aircraft use.
HEIGHT GROUP 2 F-28, B-737, C-9, DC-9, C-130, T-43, B-2	15 feet	45 feet	Regional airport with limited air carrier service.
HEIGHT GROUP 3 B-727/707/720/757, B-52, C-135, C-141, C-17, E-3, P-3, E-8, C32	20 feet	50 feet	Runways not normally used by aircraft with glidepath-to-wheel heights > 20 feet.
HEIGHT GROUP 4 B-747/767/777, DC-10, A-300, B-1, KC-10, E-4, C-5, VC-25	25 feet	55 feet	Most primary runways at major airports.

Notes:
1: To determine the minimum allowable TCH, add 20 ft to the glidepath-to-wheel height.
2: To determine the maximum allowable TCH, add 50 ft to the glidepath-to-wheel height.

Formula 1-3-3. Distance on Baro Glidepath

$$d_{Baro} = \ln\left(\frac{r + alt_e}{r + alt_b}\right) \times \frac{r}{\tan(\theta)}$$

Where:
alt_e = ending altitude (feet)
alt_b = beginning altitude (feet)

Example:

$$d_{Baro} = \ln\left(\frac{r + 4500}{r + 1441.6 + 47}\right) \times \frac{r}{\tan(3)}$$

$d_{Baro} \approx 57452.70$ feet

3. Glidepath altitude. Calculate the altitude of the glidepath at any distance from the LTP/FTP using formula 1-3-4.

Formula 1-3-4. Altitude on Baro Glidepath

$$Z_{Baro} = e^{\left(\frac{d \times \tan(\theta)}{r}\right)} \times (r + alt_b) - r$$

Where:
alt_b = beginning altitude (feet)
d= distance (feet) between the points of interest

Example:
$Z_{Baro} = e^{\left(\frac{4708.89 \times \tan(3)}{r}\right)} \times (r + 404.6 + 45) - r$
$Z_{Baro} \approx 696.39$ feet

g. Missed approach and departure.

(1) Sloping OCS. The OCS slope is dependent on the starting OCS elevation and a specific obstacle of interest. When calculating the height of the sloping surface, a default slope of 40:1 may be used to determine potential controlling obstructions. The actual OCS slope associated with any given obstacle is calculated using formula 1-3-5 and the OCS elevation at a point of interest can be found using formula 1-3-6.

Formula 1-3-5. OCS Slope

$$OCS_{slope} = \frac{d_O}{In\left(\frac{r + O_{elev}}{r + OCS_{start}}\right) \times r}$$

Where:
O_{elev} = actual or $O_{adjusted}$ obstacle elevation (feet)
OCS_{start} = starting altitude (feet)of the OCS
d_O = dist. (feet) from AC_{start} to obstacle (primary) or point abeam obstacle (secondary)

Example:
$$OCS_{slope} = \frac{6076.12}{In\left(\frac{r + 1152.6}{r + 1000.6}\right) \times r}$$

$OCS_{slope} \approx 39.98$ feet

Formula 1-3-6. OCS Elevation

$$\mathrm{OCS_{elev}} = e^{\left(\frac{d_{OCS}}{r \times OCS_{slope}}\right)} \times (r + \mathrm{OCS_{start}}) - r$$

Where:
d_{OCS} = distance (feet) from $\mathrm{OCS_{elev}}$ point to the point of interest
$\mathrm{OCS_{elev}}$ = starting altitude (feet) of the OCS

Example:

$$\mathrm{OCS_{elev}} = e^{\left(\frac{2591.8}{r \times 28.5}\right)} \times (r + 1191.75) - r$$

$\mathrm{OCS_{elev}} \approx 1282.70$ feet

(2) Climb gradient (CG). Obstacle clearance in a climbing segment is dependent on the aircraft maintaining a minimum CG to a specified altitude. The minimum CG (also referred to as standard CG) is 200 ft/NM (400 ft/NM for helicopter). When one or more obstacle penetrates the default OCS, a single increased CG that provides clearance over all penetrations may be established. A CG greater than 425 ft/NM (600 ft/NM for helicopter) is not authorized for missed approach. Calculate the minimum climb gradient required to achieve the termination altitude at a given distance using formula 1-3-7.The aircraft altitude at a point of interest can be found using formula 1-3-8 and the distance required to achieve an altitude at any CG can be found using formula 1-3-9.

Formula 1-3-7. Required Climb Gradient

$$\mathrm{CG} = \ln\left(\frac{r + \mathrm{CG_{term}}}{r + \mathrm{AC_{start}}}\right) \times \frac{r}{D_O}$$

Where:
$\mathrm{CG_{term}}$ = climb gradient termination altitude (feet)
$\mathrm{AC_{start}}$ = starting altitude (feet) of the aircraft (e.g., D ER elevation or SOC)
D_o = dist. (NM) from $\mathrm{AC_{start}}$ to obstacle (primary) or point abeam obstacle (secondary)

Example:

$$\mathrm{CG} = \ln\left(\frac{r + 2626.52}{r + 1402}\right) \times \frac{r}{3.95}$$

$\mathrm{CG} \approx 309.98$ ft/NM

Formula 1-3-8. Achieved Aircraft Altitude

$$\mathrm{alt_e} = \mathrm{e}^{\left(\frac{\mathrm{D} \times \mathrm{Vert_{path}}}{\mathrm{r}}\right)} \times (\mathrm{r} + \mathrm{alt_b}) - \mathrm{r}$$

Where:
D = distance (NM) between the points of interest
$\mathrm{Vert_{path}}$= aircraft vertical path (ft/NM)
$\mathrm{alt_b}$ = beginning altitude (feet)

Example:

$\mathrm{alt_e} = \mathrm{e}^{\left(\frac{0.76 \times 309.98}{\mathrm{r}}\right)} \times (\mathrm{r} + 320) - \mathrm{r}$
$\mathrm{alt_e} = 555.59$ feet

Formula 1-3-9. Climb Distance Between Altitudes

$$\mathrm{D_{climb}} = \mathrm{In}\left(\frac{\mathrm{r} + \mathrm{alt_e}}{\mathrm{r} + \mathrm{alt_b}}\right) \times \frac{\mathrm{r}}{\mathrm{CG}}$$

Where:
$\mathrm{alt_e}$ = ending altitude (feet)
$\mathrm{alt_b}$ = beginning altitude (feet)

Example:

$\mathrm{D_{climb}} = \mathrm{In}\left(\frac{\mathrm{r} + 3300}{\mathrm{r} + 2105}\right) \times \frac{\mathrm{r}}{315}$
$\mathrm{D_{climb}} \approx 3.79$ NM

(3) Wind spiral (WS) parameters. Use the following steps to determine the parameters used in WS construction.

(a) Step 1. Calculate KTAS with using the specified/assumed turn altitude/assumed fix altitude and applicable KIAS. Input this value as the ground speed in formula 1-2-10 to find the no-wind turn radius.

(b) Step 2. Calculate the Turn Rate (TR) using formula 1-3-10. Maximum TR is three degrees per second.

Formula 1-3-10. Turn Rate (TR)

$$\text{TR} = \text{lesser of 3 or } \frac{180 \times V_{KTAS}}{\pi \times R \times 3600}$$

Where:
V_{KTAS} = KTAS using specified/assumed turn altitude/assumed fix alt. and applicable KIAS
R= calculated no-wind turn radius (NM)

Example:

$$\text{TR} = \frac{180 \times 281.30}{\pi \times 4.30 \times 3600}$$

$$\text{TR} \approx 1.04 \text{ degrees/second}$$

(c) Step 3. Determine total magnitude of turn.

1. Turn-at-altitude or turn as soon as practicable. Calculate the total turn magnitude by measuring the arc distance (in degrees) along the no-wind turn radius from the course centerline/late-turn baseline intersection to the direct-to-fix line tangent point.

2. Turn at FO fix. Where the next leg is a DF, use turn-at-altitude or turn as soon as practicable methodology. For TF legs, calculate the total turn magnitude by comparing the inbound and outbound tracks.

(d) Step 4. Determine the highest altitude in the turn using the applicable vertical path [see paragraph 1.2.5.c(1)(a)4 starting at the specified/assumed turn altitude/assumed fix altitude plus 1 NM of flight track distance per 12 degrees total turn magnitude.

(e) Step 5. Calculate the wind spiral increase (ΔR) relative to the no-wind turn radius for a given incremental turn magnitude using formula 1-3-11. The incremental turn magnitude is an angular measurement from the wind spiral baseline about the no-wind turn radius center point which ranges from zero to the total turn magnitude.

Formula 1-3-11. Wind Spiral ΔR

$$\Delta R = \frac{V_{KTW} \times \beta_{increment}}{3600 \times TR}$$

Where:

$\beta_{increment}$ = incremental turn magnitude at point of interest

V_{KTW} = calculated or historical tailwind (knots) using the highest altitude in the turn

TR = calculated turn rate (degrees/second)

Example:

$$\Delta R = \frac{51.55 \times 35}{3600 \times 1.04}$$

$\Delta R \approx 0.48$ NM

(4) Construction baselines. Missed approach/departure construction baselines are commonly identified by the points that they are comprised of, which can be used to mark the beginning, ending, and/or tie-back point for the OEA. When these lines are used to identify tie-back points for turn construction, the placement of the point will be in alphabetical order from turn-side to non-turn side. For example, a right turning missed approach with lines C-D and L-L' will have points C and L on the right, while a left turning missed approach will have them on the left.

h. A-RNP NavSpec leg usage. Use of A-RNP legs requires chart note, “Use of FD or AP required.” Except for obstacles excluded by Annex E paragraph 2.11.4, apply horizontal and vertical accuracy adjustments to obstacles in any segment/leg based on A-RNP. RF turns are the only turn method authorized for turns greater than 45 degrees when using an RNP value less than 1.0 NM.

i. Apply controlling obstacle(s) and the vertical and horizontal accuracy standards in TP308/GPH209 Volume 1 Chapter 2 paragraph 2.1.11 and Annex E paragraph 2.11.5.

1.3.2 TP 308/ GPH 209 Standard for Geodetic Constructions.

See Appendix E.

VOLUME 2: PERFORMANCE BASED NAVIGATION (PBN)

CHAPTER 2: EN ROUTE, STANDARD TERMINAL ARRIVALS, FEEDER ROUTES AND TERMINAL ARRIVAL AREA (TAA)

SECTION 2-1: EN ROUTE

2.1. En route

2.1.1. Air Traffic Service (ATS) Q/T/L Routes. Q, T and L routes may be developed to support en route PBN operations. The NavSpec is RNAV 2 or RNP 2 (En route flight phase with associated XTT of 2). Optional NavSpec may be A-RNP (En route flight phase with associated XTT of 2 or 1 as appropriate). Secondary areas apply.

a. General.

(1) Q routes are high level fixed RNAV routes (FL180 and above).

(2) T routes are low level RNAV routes (below FL180) in controlled airspace.

(3) L routes are low level RNAV routes (below FL180) in uncontrolled airspace.

(4) Leg/Fix type. Use TF legs only. Fixes may only be FB waypoints or NAVAIDs.

b. OEA construction.

(1) Area. Except for route termination fixes, apply paragraph 1.2.5. Where applicable, construction is bi-directional.

(2) Construction at route termination fixes. Vol 1, paragraph 1711 applies except primary and secondary boundary arcs are centered ATT past the termination fix.

c. Obstacle clearance. Vol 1, Chapter 17, section 2 applies. Secondary ROC may be calculated as specified in Vol 1, Chapter 17, section 2 or formula 1-3-2 (of Vol 2 Chapter 1).

d. Altitudes. Vol 1, Chapter 17, section 3 applies, except Minimum Crossing Altitude (MCA) distance are measured from the ATT past the fix.

2.1.2. ATS RNP 0.3 Routes (Helicopter only). RNP 0.3 routes may be developed to support en route PBN copter operations. The NavSpec is RNP 0.3 (En route flight phase with associated XTT of 0.3). Secondary areas apply.

a. General.

(1) RNP 0.3 routes are for use from as low as 1200 feet AGL up to but not including 18000 feet MSL.

(2) Leg/Fix type. Use TF legs only. Fixes may only be FB waypoints or NAVAIDs used as FB waypoints.

b. OEA construction.

(1) Area. Except for route termination fixes, apply paragraph 1.2.5. Where applicable, construction is bi-directional.

(2) Construction at route termination fixes. Vol 1, paragraph 1711 applies except primary and secondary boundary arcs are centered ATT past the termination fix.

c. Obstacle clearance. Vol 1, Chapter 17, section 2 applies. Secondary ROC may be calculated as specified in Vol 1, Chapter 17, Section 2 or Vol 2, Formula 1–3–2.

d. Altitudes. Vol 1, Chapter 17, section 3 applies except MCA distances are measured from ATT past the fix.

SECTION 2-2. STANDARD TERMINAL ARRIVAL (STAR)

2.2. Standard Terminal Arrival (STAR)

2.2.1. PBN STAR. A PBN STAR may be established to transition from the en route environment to the terminal environment. The NavSpec is RNAV 1 (STAR flight phase with associated XTT of 1). Optional NavSpec may be RNP 1 or A-RNP (STAR flight phase with associated XTT of 1 or 0.3 as appropriate). For STARs that serve multiple airports, use the most conservative distance to determine where the effective XTT is 2 [see table 1-2-1 footnote 2]. Secondary areas apply, except for A-RNP.

a. General.

(1) Leg type. Use TF or RF legs, except a heading to a manual termination (VM) or from a fix to a manual termination (FM) leg may be established at the STAR termination.

(2) Fixes.

(a) All fixes prior to the termination fix must be FB.

(b) The termination fix may be either FB or FO depending on whether the STAR connects to a SIAP, the attributes of the common fix, and leg type. For this purpose, the first coded fix of the SIAP (i.e., the start of the SIAP “IF” leg) is considered a FB fix.

1. When the termination fix is a common fix followed by an FM or VM leg, the termination fix attribute should be FO and the SIAP fix should be FB.

2. For other cases, common fix attributes must be identical.

3. When the termination is not at a common fix, the STAR should terminate with a VM or FM leg, at a FO or FB fix.

4. An alternate method may be to add an extra waypoint beyond the last interface waypoint, then the FM or VM.

Note: When more than one transition/common route terminates at the same fix, more than one of the above can apply simultaneously. In those cases, the waypoint attribute must be the same on each of the common routes/runway transitions.

b. Area. Apply paragraph 1.2.5 for area construction and alignment. Construction and alignment in paragraph 1.2.5 also applies to the intersection between initial routing of the STAR and the ATS route where it begins.

Note: When the STAR terminates at a fix on a SIAP, paragraph 1.2.5 applies between the last leg of a STAR and the first leg of SIAP. When a STAR terminates in a VM or FM leg ensure the fix altitude is at or above the MVA/MIA.

c. Obstacle clearance. Apply Vol 1 chapter 17. Alternatively, formula 1-3-2 (of Vol 2 Chapter 1) may be used to calculate secondary ROC.

SECTION 2-3. FEEDER ROUTES

2.3. Feeder routes.

2.3.1. General. A feeder route may be developed as an optional transition from the en route environment to the terminal structure. Use TF and/or RF legs. The NavSpec is RNAV 1 (Feeder flight phase with associated XTT of 1). Optional NavSpec may be RNP 1 or A-RNP (Feeder flight phase with associated XTT of 1 or 0.3 as appropriate) or RNP 0.3 for helicopter. Use an effective XTT of 2 where applicable per table 1-2-1 footnote 2. Secondary areas apply, except for A-RNP.

a. General. Apply paragraph 1.2.5 for course alignment.

b. Area. Apply paragraph 1.2.5 for area construction.

c. Obstacle clearance. Apply Vol 1, Chapter 2, paragraph 2.2.1. Alternatively, formula 1-3-2 (of this order) may be used to calculate secondary ROC.

SECTION 2-4. TERMINAL ARRIVAL AREA (TAA)

2.4. Terminal Arival Area (TAA)

Do not publish an MSA for an approach with a TAA.

2.4.1. General. A TAA may be established as an optional feeder/arrival transition from the en route structure. It consists of TAA arrival areas developed in conjunction with an approach procedure utilizing RNAV initial segments. In the TAA arrival areas, the NavSpec is RNAV 1 or RNP 1 for TAA flight phase. Secondary areas are not applied; however, buffers are defined from each area boundary.

2.4.2. Approach procedure. Design in accordance with the applicable criteria in conjunction with the following guidance.

a. Initial approach segments.

(1) Use TF legs (FB fixes only) in a basic or modified T configuration only [see paragraph 1.3.1.d].

(2) Maximum segment length is 15 NM.

(3) A hold-in-lieu-of-procedure turn (HILPT) initial segment must be established at the IF/IAF at an altitude compatible with the TAA arrival area altitudes [see paragraph 2.4.3.e]. The inbound holding course must be aligned with the intermediate segment.

b. Intermediate approach segment. Establish a single dual purpose IF/IAF using TF (FB fixes only) aligned with the FAS.

c. Missed approach segment. Where possible, design missed approach segments to allow a “direct entry” into a missed approach holding pattern [see figure 2-4-1]. If the missed approach routing terminates at a base area IAF, align the missed approach holding pattern with the initial inbound course [see figure 2-4-2].

Figure 2-4-1. Default Missed Approach Holding Alignment

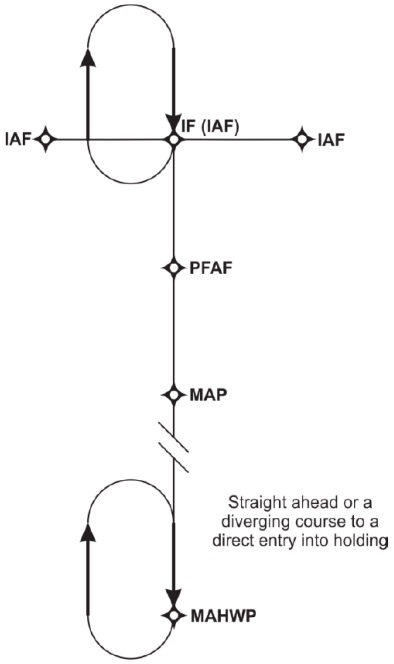
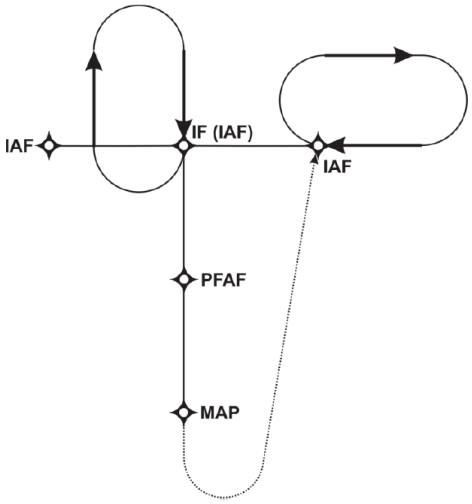
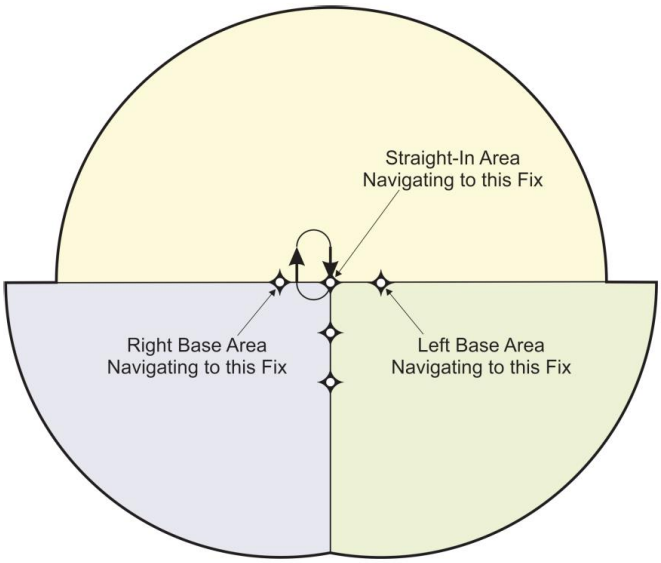


Figure 2-4-2. Missed Approach Holding Alignment at T IAF



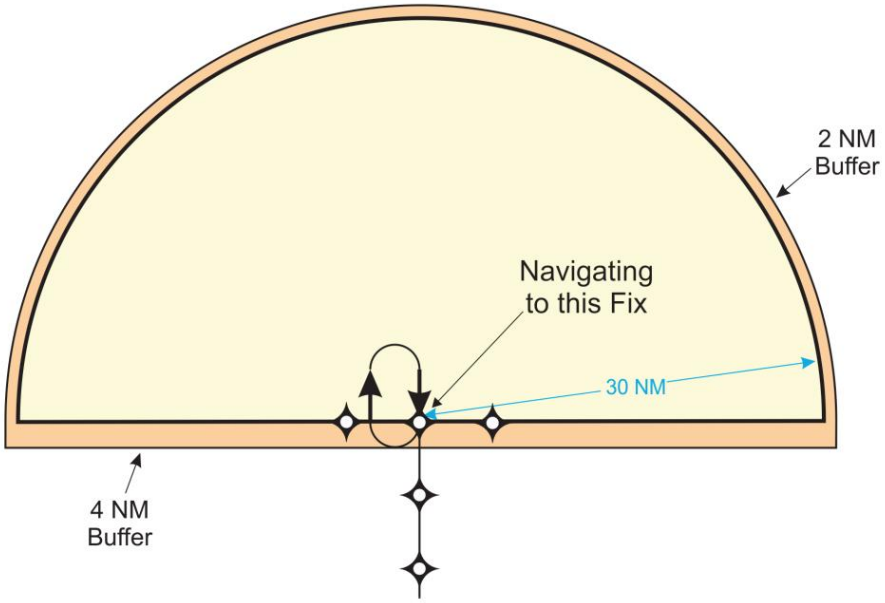
2.4.3. Arrival areas. A default TAA contains a straight-in area, a right base area, and a left base area. Each area is defined relative to a specific IAF [see figure 2-4-3]. The boundary between the straight-in area and the base areas is defined by extensions of the T initial segment track centerlines. The boundary between the right and left base areas is an extension of the intermediate segment track centerline.

Figure 2-4-3. Default TAA Arrival Areas



a. Straight-in area. Construct the base area side boundary by extending a 30-NM line from the IF/IAF through each T initial segment IAF. Construct the outside boundary by connecting the base area side boundary lines with a 30-NM arc centered on the IF/IAF [see figure 2-4-4]. Apply a 4-NM obstacle evaluation buffer on the base area side boundary and a 2-NM buffer on the outside boundary.

Figure 2-4-4. Straight-in Area



b. Right and left base area. The straight-in side boundaries are the initial segment track centerlines from IAF/IF to each IAF extended outward 30 NM. The boundary between the right and left base areas (inside boundary) is an extension of the intermediate segment track centerline. Construct the outside boundaries as 30-NM arcs centered on each IAF from the straight-in side boundary in the appropriate direction (clockwise or counter-clockwise) to the intersection of the intermediate segment track centerline extended [see figure 2-4-5]. Apply a 4-NM obstacle evaluation buffer on the straight-in and inside boundaries and a 2-NM buffer on the outside boundary.

Figure 2-4-5. Right Base Area

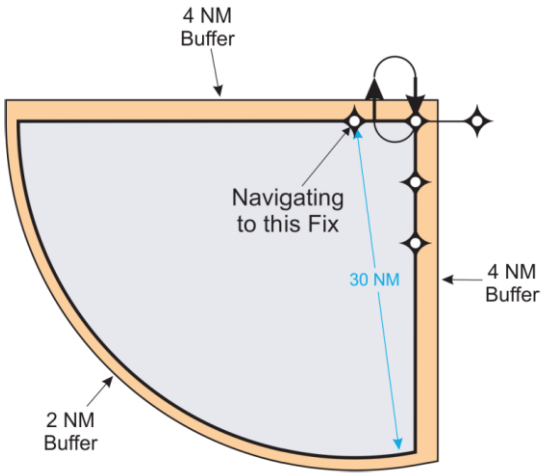
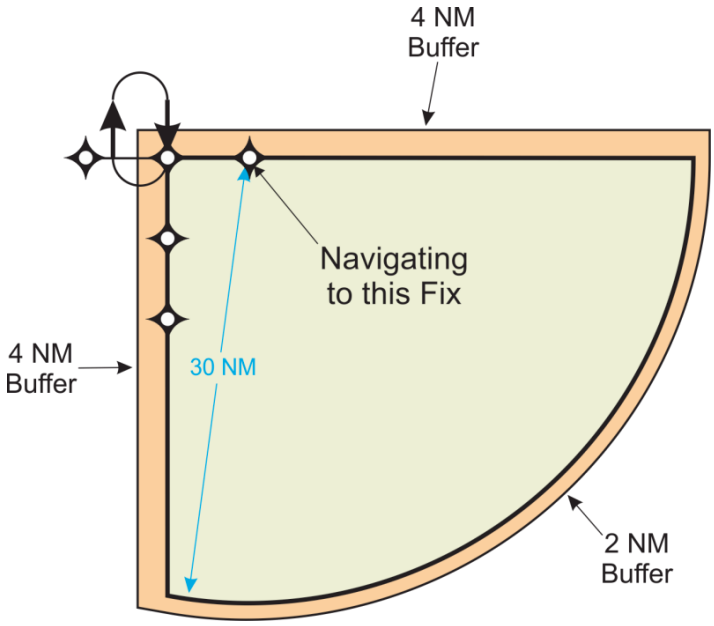


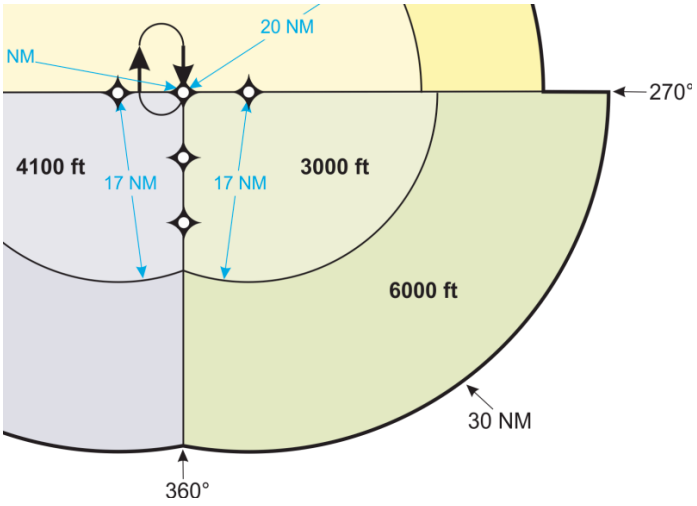
Figure 2-4-6. Left Base Area



c. Area modification. Modifications to the default TAA design may be necessary to achieve an acceptable descent gradient or to meet operational requirements.

(1) Stepdown arcs. Areas may be sub-divided using a stepdown arc [see figure 2-4-7]. Stepdown arcs are centered on the fix associated with the area and may not be less than 4 NM from the center fix or within 4 NM of the outer boundary. Only one stepdown arc may be established per area/sector. A 2-NM obstacle evaluation buffer applies from the stepdown arc. The altitude at the stepdown arc must not result in an excessive descent gradient in the associated NoPT initial calculated as length plus stepdown arc radius.

Figure 2-4-7. Area Modification; Stepdown Arcs



(2) Radial sectorization. The straight in or extended straight-in area [see paragraph 2.4.3.c] may be divided into up to three sectors defined radially by inbound courses to the IF/IAF [see figure 2-4-8]. Radial sectors can be used alone or in conjunction with stepdown arcs [see figure 2-4-9]. The angular size of a sector may not be less than 30 degrees, except a sector with a side defined by a base area boundary that also includes a stepdown arc may not be less than 45 degrees. A 4-NM obstacle evaluation buffer applies to radial sector boundaries.

Figure 2-4-8. Area Modification; Straight-in Area Radial Sectorization

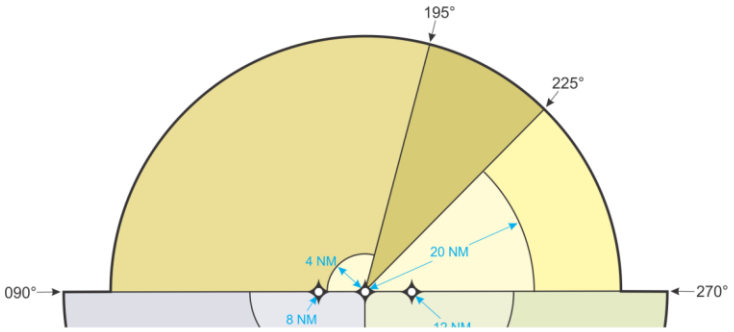
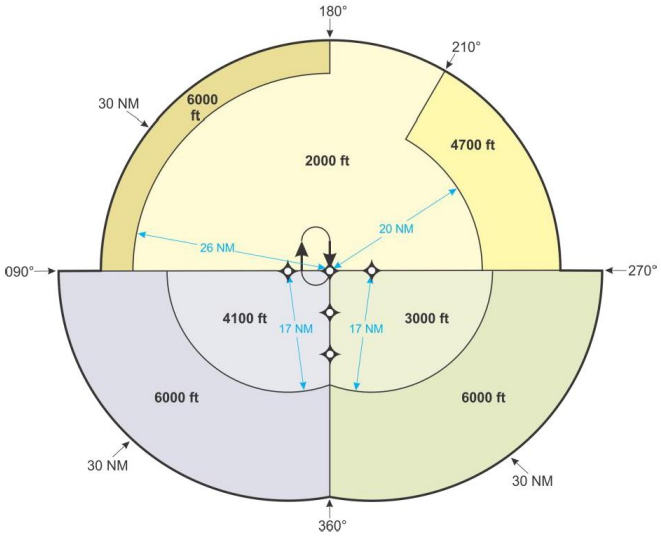


Figure 2-4-9. Area Modification; Radial Sectorization and Stepdown Arcs



(3) Base area elimination. One or both of the basic T initial approach segments and its associated base area may be eliminated [see figure 2-4-10 and figure 2-4-11].

(a) Construction. The straight-in area construction is extended into the area of the eliminated base area(s). Paragraph 2.4.3.b construction applies to a remaining base area. Paragraph 2.4.3.a applies except the outside boundary is a 30-NM arc connecting the base area side boundary line to the intermediate segment track centerline extended. When both base areas are eliminated, the straight-in area is a 30-NM circle centered on the IF/IAF.

Figure 2-4-10. Area Modification; Right Base Area Elimination

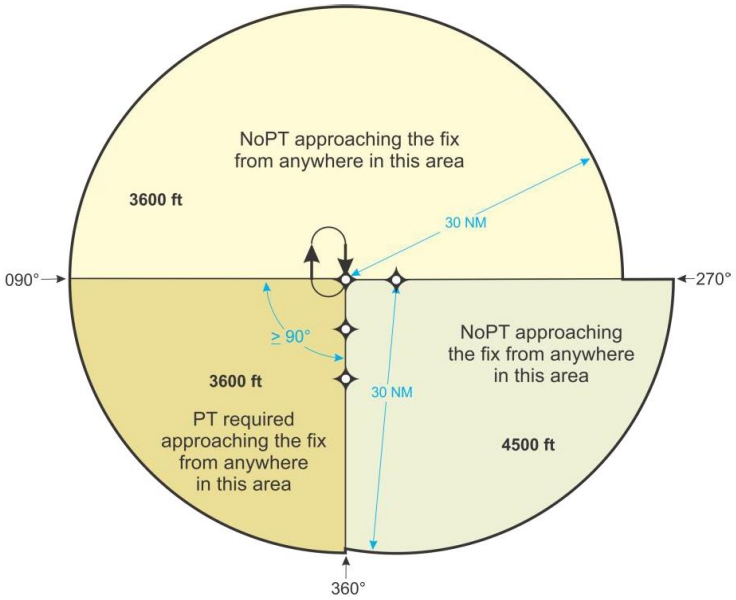
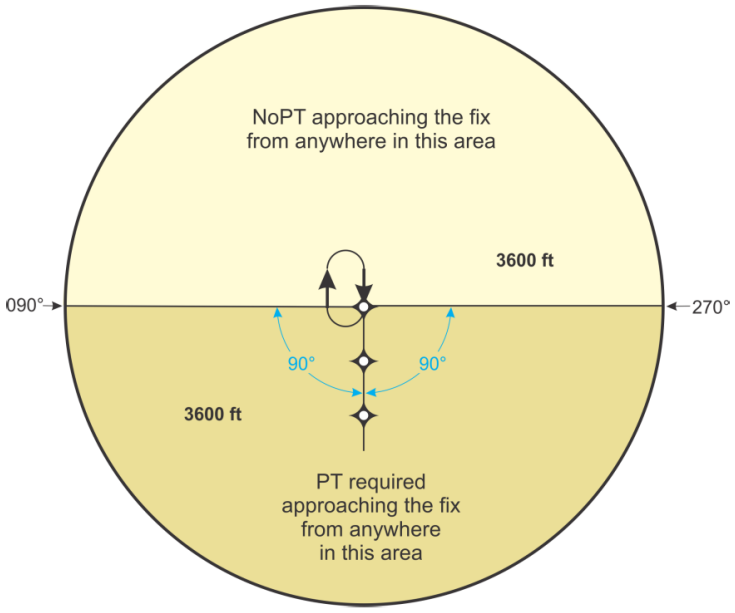
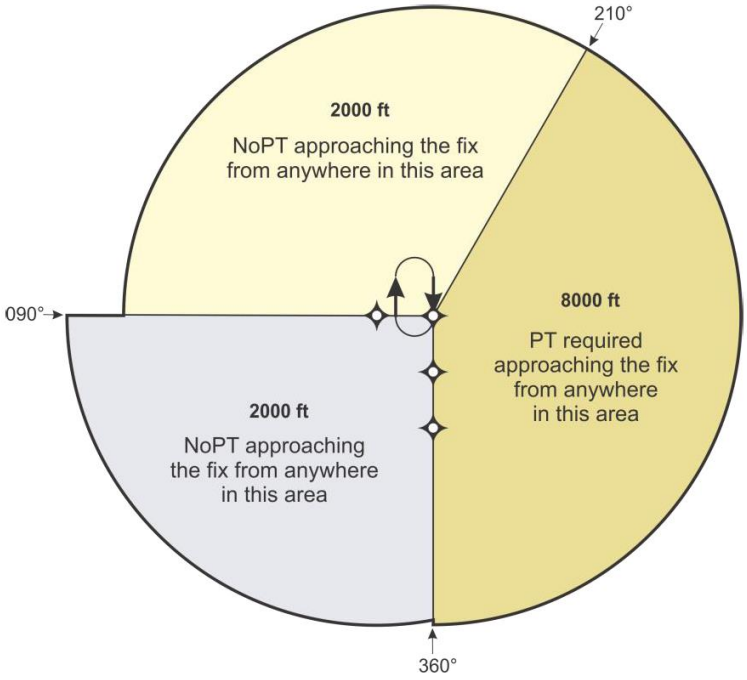


Figure 2-4-11. Area Modification; Both Right and Left Base Area Elimination



(b) No procedure turn (NoPT) exclusion. The sector associated with an eliminated base area must be excluded from a NoPT designation. A NoPT exclusion area may also be extended from an eliminated base area into the straight-in area when required to meet descent gradient standards.

Figure 2-4-12. Area Modification; NoPT Exclusion

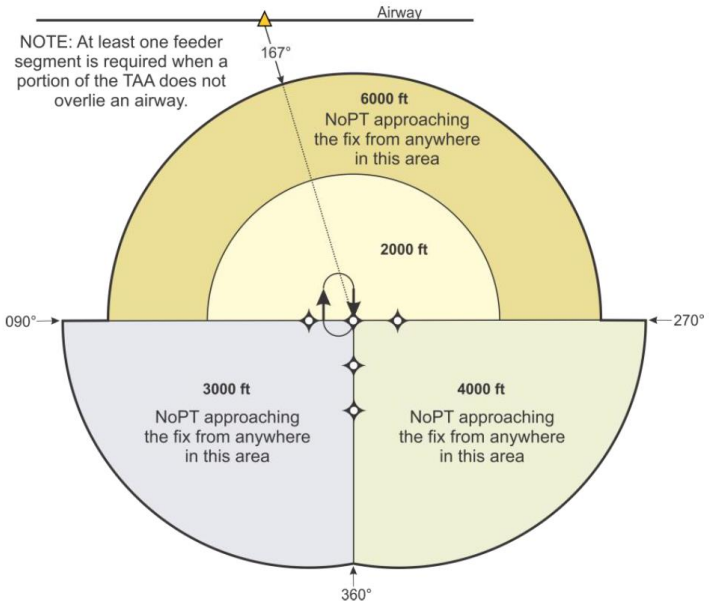


d. Obstacle clearance (see Vol 1, paragraph 1720).

e. Altitude selection. A minimum altitude is specified for each area and sub-sector. Where possible establish a common IAF altitude for the right/left base and straight-in areas. Where not possible, area altitudes must permit establishment of a common altitude at the IF/IAF. Except for areas/sub-sectors excluded from a NoPT designation, the associated IAF altitude may not be lower than the applicable area/sub-sector altitude. Vol 1, paragraph 2.3.5.e applies to area/sub-sectors excluded from a NoPT designation.

2.4.4. Feeder route. Normally one of the TAA areas (excluding obstacle evaluation buffers) will overlie an airway. Where this is not the case, at least one feeder route must be established from the en route structure to the TAA boundary. Vol 1, paragraph 2.2.1 applies except alignment must be a direct course to the IF/IAF or right/left base IAF depending on the location of the feeder fix [see figure 2-4-13].

Figure 2-4-13. TAA with Feeder route



VOLUME 2: PERFORMANCE BASED NAVIGATION (PBN)

CHAPTER 3: RNAV (GNSS) APPROACH

SECTION 3-1: GENERAL CRITERIA

3.1. General Criteria

3.1.1. Applicability. This chapter applies to procedures covered by the RNP APCH NavSpec (LPV, LP, LNAV/VNAV, and LNAV). It also applies to PBN legs that transition to an ILS or GLS final. Incorporation of an RF leg limits IFP availability to some users; therefore, an RNAV (GNSS) approach that requires use of an RF leg in the missed approach, intermediate, or in all initials should be avoided.

3.1.2. Feeder segment. Construct feeder segments as described in chapter 2 using one or more TF or RF legs. The NavSpec is RNAV 1 or RNP 1 (Feeder flight phase with associated XTT of 1). Optional NavSpec may be A-RNP (Feeder flight phase with associated XTT of 1 or 0.3 as appropriate) or RNP 0.3 for helicopters. Use an effective XTT of 2 where applicable per table 1-2-1 footnote 2. The minimum XTT is the result of formula 3-1-1 for A-RNP to LP and LPV/GLS. Secondary areas apply, except for A-RNP.

3.1.3. Initial. Construct initial segments as described in chapter 1 using one or more TF or RF legs. The NavSpec is RNP APCH (Initial flight phase with associated XTT of 1). Optional NavSpec may be A-RNP (Initial flight phase with associated XTT of 1 or 0.3 as appropriate) or RNP 0.3 for helicopters. Use an effective XTT of 2 where applicable per table 1-2-1 footnote 2. The minimum XTT is the result of formula 3-1-1 for A-RNP to LP and LPV/GLS. Secondary areas apply, except for A-RNP.

3.1.4. Intermediate. Construct intermediate segments as described in chapter 1 using one or more TF or RF legs. The NavSpec is RNP APCH (Intermediate flight phase with associated XTT of 1). Optional NavSpec may be A-RNP (Initial flight phase with associated XTT of 1 or 0.3 as appropriate) or RNP 0.3 for helicopters. Secondary areas apply, except for A-RNP. Paragraph 1.2.10.a(1)(d) applies except the ATT at the PFAF is based on the applicable final approach navigation accuracy from table 1-2-1.

a. RF leg. Except when joining an ILS/GLS/LPV final [see appendix C], an RF leg must end at least 2 NM prior to the PFAF.

b. Alignment (maximum course change at the PFAF). Offset alignment is only authorized when the PFAF is a FB fix.

(1). LNAV and LP. Align the intermediate course within 30 degrees of the final approach course.
(2). LNAV/VNAV. Align the intermediate course within 15 degrees of the final approach course.

c. ILS/GLS/LPV. Apply Appendix C for PBN transitions to ILS/GLS/LPV.

d. Area [see figure 3-1-1 and figure 3-1-2].

(1). LNAV and LNAV/VNAV. The intermediate segment primary area tapers uniformly from ±2 NM at a point 2 NM prior to the PFAF to the primary boundary 1 NM past the PFAF. The secondary boundary tapers uniformly from 1 NM at a point 2 NM prior to the PFAF to the secondary boundary 1 NM past the PFAF.

(2). LP and LPV/GLS. The intermediate segment primary area tapers uniformly from ±2 NM at a point 2 NM prior to the PFAF to the primary boundary/X OCS outer boundary abeam the PFAF. The secondary boundary tapers uniformly from 1 NM at a point 2 NM prior to the PFAF to the secondary/Y OCS outer boundary abeam the PFAF. When using a reduced XTT value, use the same XTT value throughout the entire intermediate segment and verify that the final segment supports the selected XTT with formula 3-1-1. Where the selected XTT is less than the minimum, increase the XTT or decrease the length of final. When the PFAF is located more than 50200 feet from LTP, the minimum XTT value is 0.5 NM. The minimum XTT is the result of formula 3-1-1. When an RF to an ILS/GLS/LPV PFAF is used, comply with appendix C and taper relative to the RF track.

Formula 3-1-1. Minimum XTT

$$\mathrm{Min}_{\mathrm{XTT}} = \frac{0.3048 \times \left(\mathrm{FAS}_{\mathrm{Length}} \times 0.10752 + 678.496\right)}{1852 \times 2}$$

Where:

$\mathrm{FAS}_{\mathrm{Length}} = \text{length (feet)of the final approach segment}$

Example:

$$\mathrm{Min}_{\mathrm{XTT}} = \frac{0.3048 \times (50201.07 \times 0.10752 + 678.496)}{1852 \times 2}$$

$$\mathrm{Min}_{\mathrm{XTT}} = 0.5$$

Figure 3-1-1. LNAV, LNAV/VNAV Intermediate

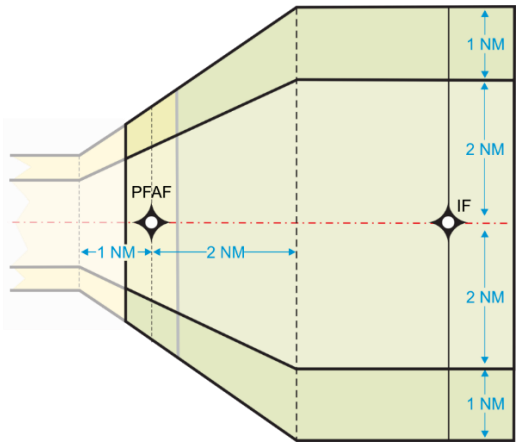
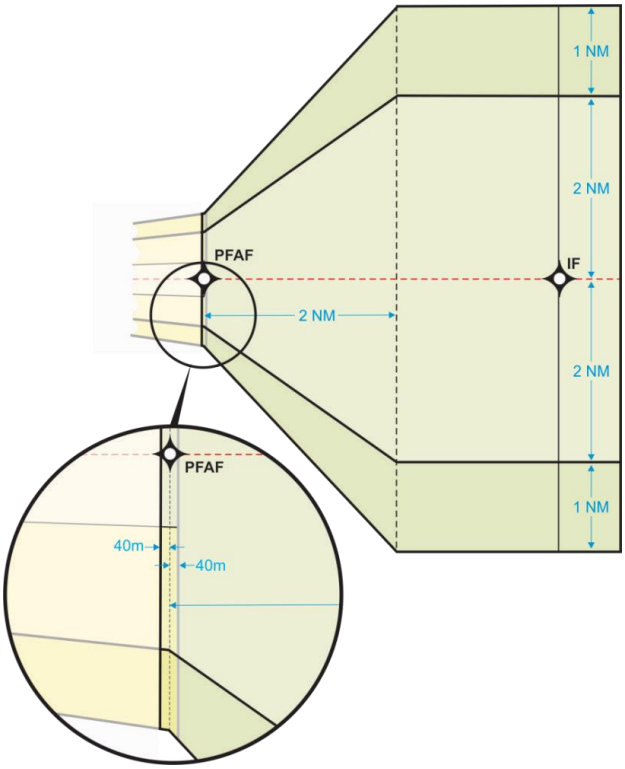


Figure 3-1-2. LP, LPV/GLS Intermediate



(3). Turn at IF or start of aligned leg prior to PFAF. When the standard FB turn construction results in boundaries outside the normal primary/secondary widths at the point 2 NM prior to the PFAF, the inside (turn side) boundaries may be constructed as straight lines from the tangent points on the turning construction arcs to the applicable final segment boundaries [see figure 3-1-3 and figure 3-1-4]. Redesign if straight line

connections result in an area less than normal primary/secondary area width in the leg prior to PFAF.

Figure 3-1-3. Turn at IF, Example LNAV, LNAV/VNAV

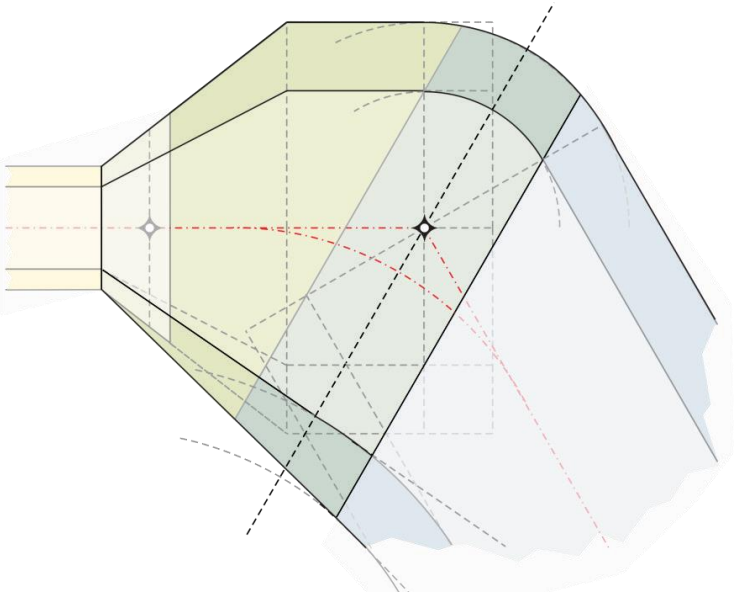
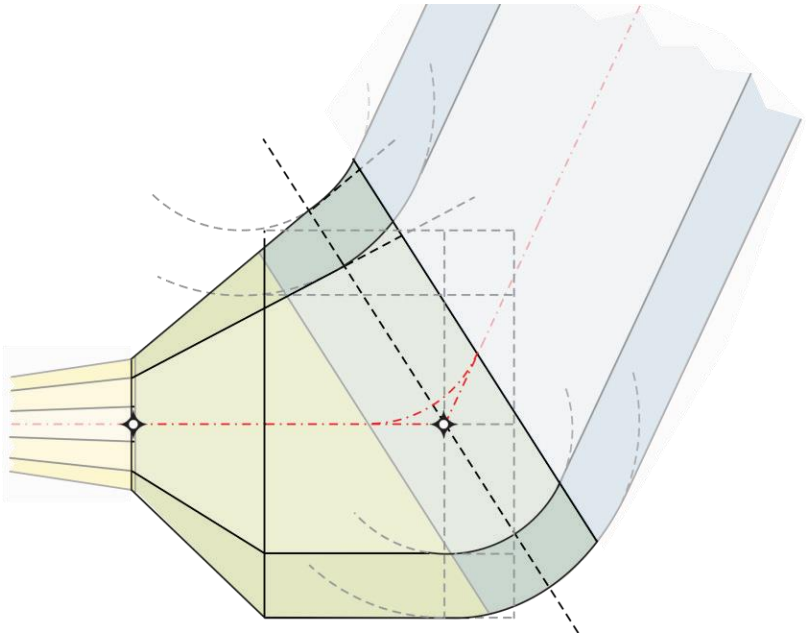


Figure 3-1-4. Turn at IF, Example LP, LPV/GLS



(4). Offset construction. Where the intermediate course is not an extension of the final course, use the following construction techniques.

(a) *Step 1*. Construct line A perpendicular to the intermediate course 2 NM prior to the PFAF.

(b) *Step 2*. Construct line B perpendicular to the intermediate course extended 1 NM past the PFAF.

(c) *Step 3*. Construct the inside turn boundaries by connecting the points of intersection of line A with the turn side intermediate segment boundaries with the intersection of line B with the turn side final segment boundaries.

(d) *Step 4*. This step is dependent on procedure.

1. LNAV and LNAV/VNAV [see figure 3-1-5]. Construct arcs centered on the PFAF of 1 NM and 1.3-NM radius on the non-turn side of the fix.

2. LP and LPV/GLS [see figure 3-1-6]. Connect lines from the point of intersection of line A and the outside primary and secondary intermediate segment boundaries to the final segment primary and secondary final segment lines at a point perpendicular to the final course at the PFAF.

(e) *Step 5* (applicable to LNAV and LNAV/VNAV Only). Connect lines from the point of intersection of line A and the outside primary and secondary intermediate segment boundaries to tangent points on the arcs constructed by *Step 4*.

(f) *Step 6* (applicable to LNAV and LNAV/VNAV Only). Connect lines tangent to the arcs created in *Step 4* that taper inward at 30 degrees relative to the FAC to intersect the primary and secondary final segment boundaries as appropriate.

Figure 3-1-5. Offset Intermediate, Example LNAV

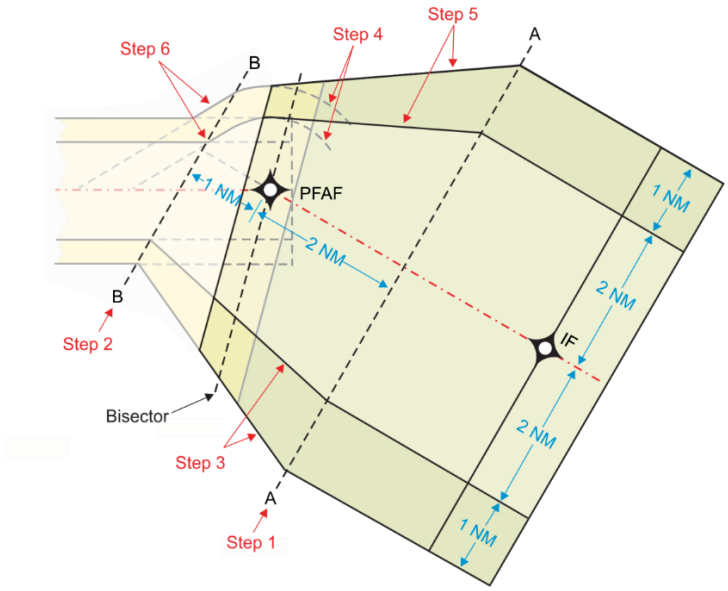
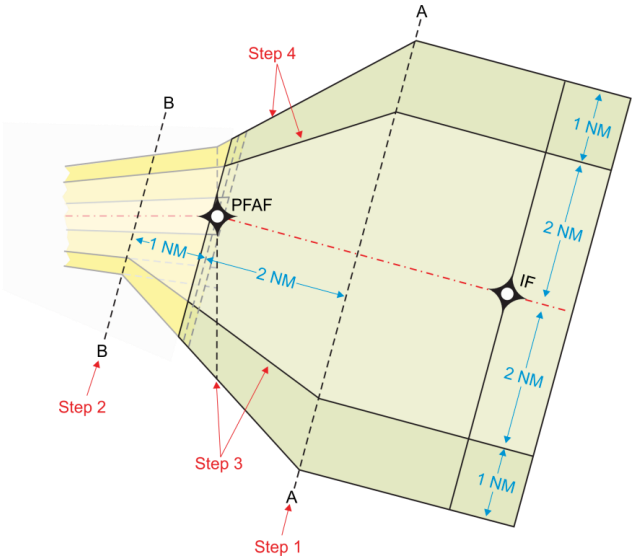


Figure 3-1-6. Offset Intermediate, Example LPV/GLS



3.1.5. Final. Construct final segments as described in section 3-2 using one or more TF legs. RF legs and TF turns are not authorized. The NavSpec is RNP APCH Final flight phase [with associated XTT of 0.3 NM for part A (LNAV and LNAV/VNAV) and 40 meters for part B (LP and LPV/GLS)]. Secondary areas apply.

a. General. Paragraph 1.3.1.f applies except see paragraph 3.4.1 for LPV/GLS exceptions.

b. The final segment OEA primary and secondary boundaries follow the intermediate segment OEA primary and secondary boundaries from ATT prior to the PFAF to the applicable taper connection point and includes offset intermediate construction [see figure 3-1-1, figure 3-1-2, figure 3-1-3, figure 3-1-5, and figure 3-1-6].

c. FAS data block [see figure 3-1-7]. The FAS data block is documentation requirement used to define the lateral and vertical paths unique to SIAPs with LP, LPV, or GLS minimums. FAS data includes the following fields:

(1). Flight path alignment point (FPAP). The FPAP is defined by geodetic coordinates. When the FAC is aligned with the RCL, find the FPAP by extending a geodesic line from the LTP toward the DER a distance equal to the greater of the runway length or 9023 feet. For offset procedures, the FPAP is located on the extension of the desired final approach course at a distance from the FTP that provides the appropriate lateral course width. The FPAP is located 9023 feet from the helipoint/fictitious helipoint (FHP) on the FAC for helicopter procedures.

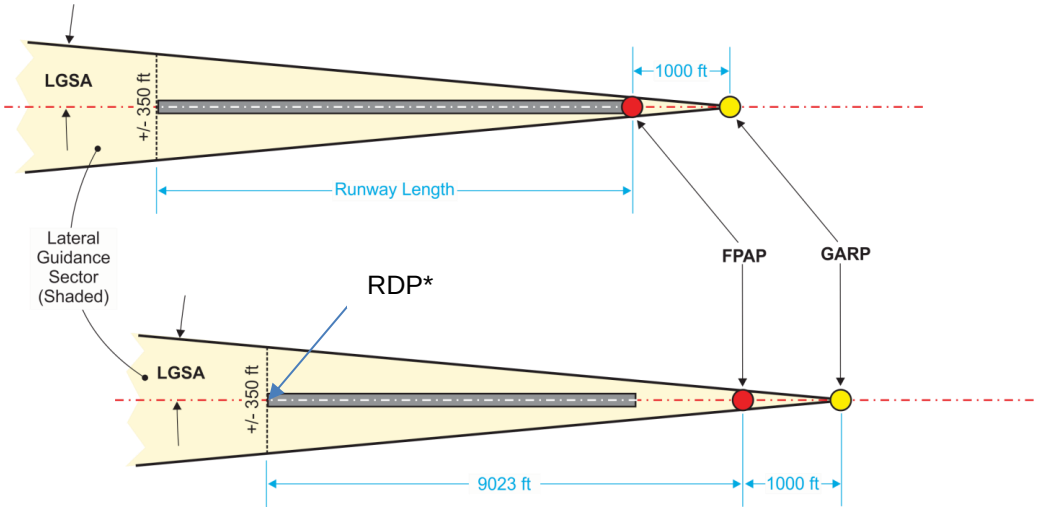
(2). Length offset. The length offset value is the distance between the departure end of runway and the FPAP, rounded to the nearest eight-meter value. It defines the location where lateral sensitivity changes to missed approach sensitivity. The length offset is zero (0) for offset procedures, procedures where the FPAP is located at the departure end of the runway, and helicopter procedures to landing areas that support IFR procedures.

(3). Course width at threshold. The course width at threshold is defined by the GNSS azimuth reference point (GARP) and the lateral guidance sector angle (LGSA) using formula 3-1-2. Convert the result to meters and round to the nearest 0.25-meter increment.

(a) GARP. The GARP is a point located 1000 feet beyond the FPAP on the extension of the FAC/RCL geodesic line. This point is used by the airborne system as the origin of the lateral guidance sector.

(b) LGSA. The LGSA originates at the GARP and is the angular dimension of lateral guidance relative to the FAC. The LGSA angle ranges from not more than ±2 degrees to not less than ±1.5 degrees.

Figure 3-1-7. FAS Data Block



Note: * For helicopter only.

Formula 3-1-2. Course Width At Threshold

$$\text{Course}_{\text{width}} = \text{greater of } 350 \text{ feet or } \tan(1.5) \times \text{d}_{\text{GARP}}$$

Where:

$\text{d}_{\text{GARP}} = distance\ (feet) from\ the\ LTP/FTP\ to\ the\ GARP$

Example:

$\text{Course}_{\text{width}} = \tan(1.5) \times 13560.66$

$\text{Course}_{\text{width}} \approx 355.10$

$\text{Course}_{\text{width}} = 108.23\ meters$ (rounded to 108.25 meters)

SECTION 3-2. GENERAL NON-VERTICALLY GUIDED FINAL SEGMENT

3.2.1. General. This section contains obstacle evaluation criteria for LNAV and LP non-vertically guided approach procedures. LP is not applicable if straight-in minimums are not authorized [see paragraph 3.2.2.b and Vol 1, paragraph 2.5.2]. Do not develop a new LP to a runway where an LNAV/VNAV or LPV can be developed for at least one approach CAT, regardless of minima.

3.2.2. Alignment. Optimum non-vertically guided procedure final segment alignment is with the runway centerline extended through the LTP. When published in conjunction with a vertically-guided procedure, alignment must be identical with the vertically guided final segment. TF-TF turns are not allowed in the FAS. When an LNAV procedure is combined with an APV, the MAP must be located at the LTP/FTP. Helicopter procedures to heliports must be aligned per Vol 1, Chapter 11, paragraph 1111.a and are considered straight-in.

a. Straight-in with offset alignment. When the final course must be offset, it may be offset up to 30 degrees (published separately from vertically guided) when the following conditions are met:

(1) Offset ≤ 5 degrees. Align the course through LTP.

(2) Offset > 5 degrees and ≤ 10 degrees. The course must cross the runway centerline extended at least 1500 feet prior to LTP (5200 feet maximum).

(3) Offset > 10 degrees and ≤ 20 degrees. The course must cross the runway centerline extended at least 3000 feet prior to LTP (5200 feet maximum). For offsets > 15 degrees, CAT C/D minimum published visibility 1 SM, minimum HAT of 300 feet.

(4) Offset > 20 and ≤ 30 degrees (CAT A/B only). The course must cross the runway centerline extended at least 4500 feet prior to the LTP (5200 feet maximum).

Note: Where offset alignment as specified above cannot be attained and the final course does not intersect the runway centerline or intersects the centerline more than 5200 feet from LTP, and an operational advantage can be achieved, the final may be aligned to lie laterally within 500 feet of the extended runway centerline at a point 3000 feet outward from LTP. For the purposes of OEA construction, use the Final End Point (FEP) as the FTP [see Vol 1, paragraph 2.5.4].

b. Circling. The optimum final course alignment is to the center of the landing area, but may be to any portion of the usable landing surface. The latest point the MAP can be located is the FEP. For the purposes of OEA construction, use the FEP as the FTP.

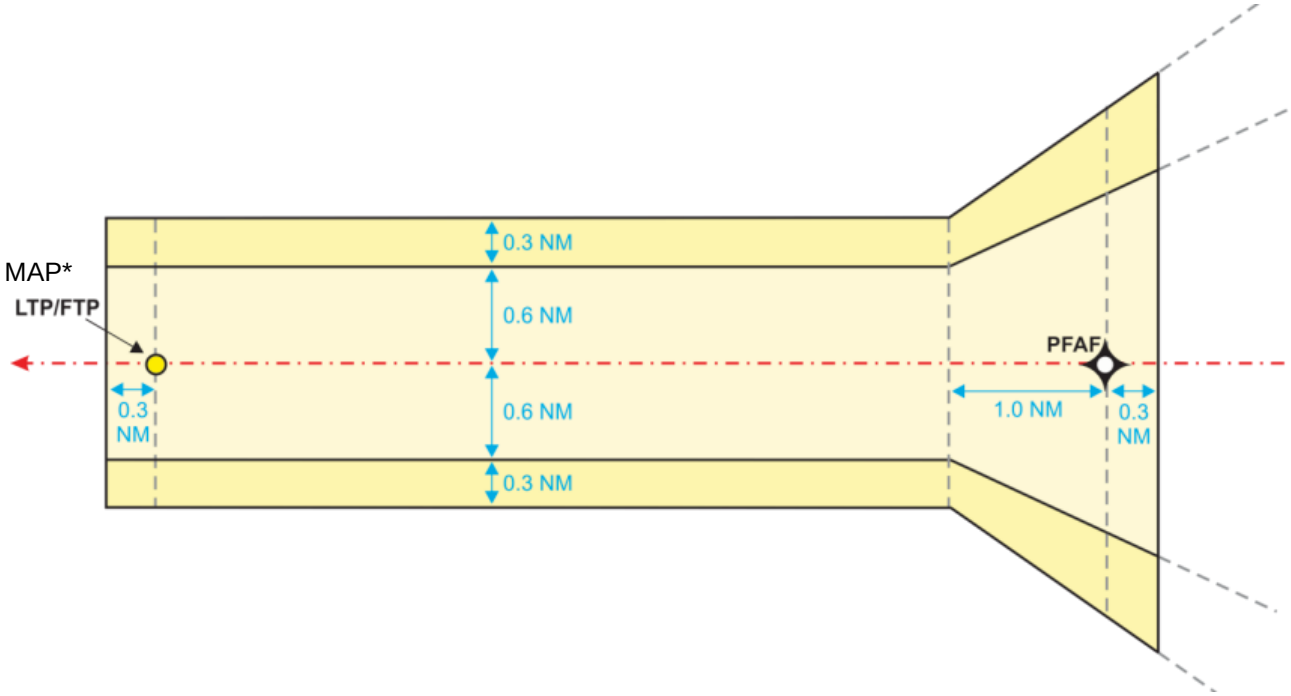
3.2.3. Area.

a. LNAV.

(1) Length. The OEA begins 0.3 NM prior to the PFAF and ends 0.3 NM past the LTP/FTP/(MAP for helicopters). Segment length is the distance from the PFAF location to the LTP/FTP. The maximum length is 10 NM.

(2) Width. The final segment OEA primary and secondary boundaries are coincident with the tapering intermediate segment boundaries from a point 0.3 NM prior to the PFAF to a point 1.0 NM past the PFAF. From this point to 0.3 NM past the LTP/FTP/(MAP for helicopters), the primary OEA boundary is ± 0.6 NM from course centerline. A 0.3 NM secondary area is located on each side of the primary area. Determine the primary and secondary area widths in this tapering area using formula 3-2-1.

Figure 3-2-1. LNAV Final Segment OEA



Note: * Helicopter only.

Formula 3-2-1. Tapering Area Width

$$^1/_2\,W_p = \frac{1.4 \times D_{taper}}{3} + 0.6$$

$$W_s = \frac{0.7 \times D_{taper}}{3} + 0.3$$

Where:

$D_{taper} =$ along track distance (NM) from end of taper in the final segment to the point of interest

Example:

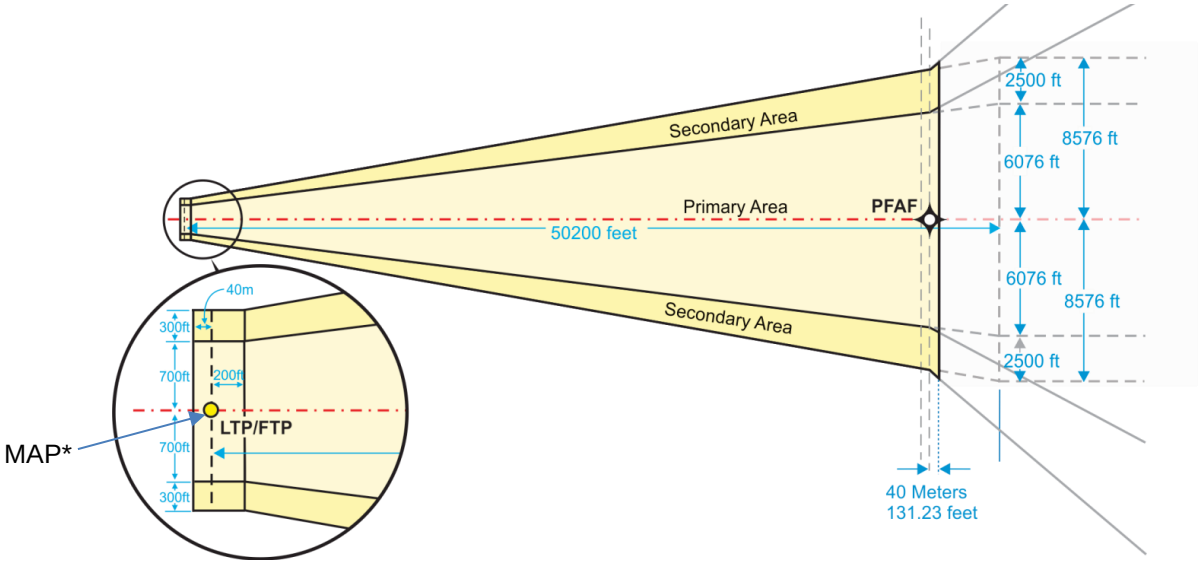
$$^1/_2\,W_p = \frac{1.4 \times 1.3}{3} + 0.6$$
$$^1/_2\,W_p \approx 1.21\ \text{NM}$$

$$W_S = \frac{0{,}7 \times 1.3}{3} + 0.3$$
$$W_S \approx 0.60\ \text{NM}$$

Note: This formula may only be used when the intermediate and final legs are aligned.

b. LP.

Figure 3-2-2. LP Final OEA



Note: * Helicopter only.

(1) Length. The OEA begins 40 meters prior to the PFAF and ends 40 meters past the LTP/FTP (helipoint/FHP for helicopter procedures). Segment length is the distance from the PFAF location to the LTP/FTP(helipoint/FHP for helicopter procedures). The helipoint/FHP is a point on the FAC 2600 feet after the LP MAP for helicopter procedures. The maximum length is 10 NM.

(2) Width.

(a) Primary. The perpendicular distance from the course centerline to the outer boundary of the primary area is a constant 700 feet from a point 40 meters past (inside) the LTP/FTP (helipoint/FHP for helicopter procedures) to a point 200 feet prior to (outside) the LTP/FTP (helipoint/FHP for helicopter procedures). It expands from this point in a direction toward the PFAF. Calculate primary half width from the 200-foot point to a point 50200 feet from LTP (helipoint/FHP for helicopter

procedures) using formula 3-2-2. The value of primary half width beyond the 50200-foot point is 6076 feet.

Formula 3-2-2. Primary Area Half Width

$$^{1}/_{2}\,W_P = 0.10752 \times d_{LTP} + 678.496$$

Where:

d_{LTP} = along track distance (feet) from LTP to point of interest

Note: 200 feet ≤ d_{LTP} ≤ 50200 feet

Example:

$^{1}/_{2}\,W_P$ = 0.10752 × 30308.58 + 678.496

$^{1}/_{2}\,W_P$ ≈ 3937.27 feet

(b) Secondary. The secondary width is a constant 300 feet from a point 40 meters past (inside) the LTP/FTP (helipoint/FHP for helicopter procedures) to a point 200 feet prior to (outside) the LTP/FTP (helipoint/FHP for helicopter procedures). It expands from this point in a direction toward the PFAF. Calculate secondary width from the 200-foot point to a point 50200 feet from LTP (helipoint/FHP for helicopter procedures) using formula 3-2-3. The value of secondary width beyond the 50200-foot point is 2500 feet.

Formula 3-2-3. Secondary Area Width

$$w_s = 0.044 \times d_{LTP} + 291.2$$

Where: d_{LTP} = along track distance (feet) from LTP to point of interest

Note: 200 feet ≤ d_{LTP} ≤ 50200 feet

Example:

w_s = 0.044 × 30308.58 + 291.2

w_s ≈ 1624.78 feet

3.2.4. Obstacle clearance. The minimum ROC in the primary area is 250 feet. The minimum ROC in the secondary area is 250 feet at the primary boundary, tapering uniformly to zero feet at the outer edge. Vol 1, chapter 3 precipitous terrain, remote altimeter, and excessive length of final adjustments apply. Calculate secondary ROC value in accordance with paragraph 1.3.1.b.

3.2.5. Minimum descent altitude. The MDA value is the sum of the controlling obstacle MSL plus the applicable ROC application from paragraph 3.2.4. Round the sum to the next higher 20-foot increment; e.g., 623 rounds to 640. The minimum HAT value is 250 feet.

SECTION 3-3. LATERAL NAVIGATION WITH VERTICAL GUIDANCE (LNAV/VNAV) FINAL SEGMENT

3.3.1. General. An LNAV/VNAV approach is a vertically-guided approach procedure using baro-VNAV or WAAS VNAV for the vertical guidance. Obstacle evaluation is based on the LNAV OEA dimensions, level surface OCS based on ROC, and a sloping baro-VNAV OCS. ROC adjustments for excessive length of final do not apply.

a. Vertical Path restrictions. The true vertical path provided by baro-VNAV is influenced by temperature variations; i.e., during periods of cold temperature, the effective glidepath may be lower than published and during periods of hot weather, the effective glidepath may be higher than published [see paragraph 3.3.4.a(1) and Annex E, paragraph 4.6.8].

b. Other restrictions. LNAV/VNAV approach procedures at airports where Remote Altimeter Setting Source (RASS) is in use, helicopter point-in-space (PinS) approaches, or where the final segment overlies precipitous terrain must be annotated to indicate the approach is not authorized for baro-VNAV systems.

3.3.2. Alignment. Optimum final segment alignment is with the runway centerline extended through the LTP. TF-TF turns are not allowed in the FAS. Where lowest minimums can only be achieved by offsetting the final course, it may be offset up to 15 degrees when the following conditions are met:

a. Offset ≤ 5 degrees. Align the course through LTP.

b. Offset > 5 degrees and ≤ 10 degrees. The course must cross the runway centerline extended at least 1500 feet (5200 feet maximum) prior to LTP.

c. Offset > 10 degrees and ≤ 15 degrees. The course must cross the runway centerline extended at least 3000 feet (5200 feet maximum) prior to LTP.

Note: For paragraphs 3.3.2.b and 3.3.2.c, determine the effective DA distance using formula 3-3-1. This distance can be used in formula 1-3-4 to determine the required altitude.

Formula 3-3-1. Offset Alignment Minimum Effective DA distance

$$d_{DAeffective} = \frac{V_{KIAS}{}^2 \times \tan(a_{offset} \times 0.5) \times 1852}{\tan(18) \times 68625.4 \times 0.3048} + d_{LTP}$$

Where:
V_{KIAS}= indicated final approach airspeed (knots) for applicable category
a_{offset} = degrees of offset between the final course and runway centerline extended
d_{LTP} = distance (feet) from LTP to the final course and runway centerline extended intersection

Example:

$$d_{DAeffective} = \frac{165^2 \times \tan(12.5 \times 0.5) \times 1852}{\tan(18) \times 68625.4 \times 0.3048} + 4300.67$$

$d_{DAeffective}$≈ 5113.16 feet

3.3.3. Area. Apply paragraph 3.2.3.a.

3.3.4. Obstacle clearance surface (OCS). In the primary area, the elevation of the OCS at any point is the elevation of the OCS at the course centerline abeam it. The OCS in the secondary area is a 7:1 surface sloping upward from the edge of the primary area OCS perpendicular to the flight track [see formula 3-3-2 and figure 3-3-1]. The controlling obstacle is the obstacle that having penetrated the sloping OCS requires the highest GPA or most adverse DA or an obstacle that penetrates the level OCS that causes the most adverse DA. See latest version of Vol 1 Section 13-6 for obstacle assessment.

Formula 3-3-2. Secondary Area Adjusted Obstacle Elevation

$$O_{adjusted} = O_{MSL} - \frac{OBS_Y - {}^1/_2 W_P}{7}$$

Where:
O_{MSL} = obstacle MSL elevation
OBS_Y = perpendicular distance (feet) from the final approach centerline to the obstacle
${}^1/_2 W_P$= perpendicular distance (feet) from final approach centerline to primary area boundary

Example:

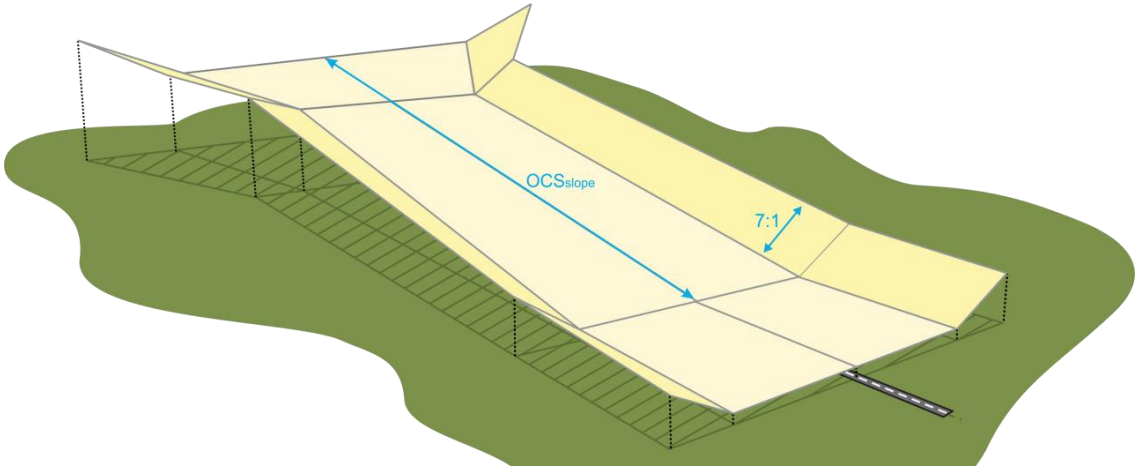
$$O_{adjusted} = O_{MSL} - \frac{OBS_Y - {}^1/_2 W_P}{7}$$

$$O_{adjusted} = 3841.6 - \frac{4253.28 - 3645.67}{7}$$

$$O_{adjusted} \approx 3754.80 \text{ feet}$$

a. Sloping OCS [see Volume 1, paragraph 2-1-4]. The primary area OCS slope varies based on critical temperatures and designed glidepath angle.

Figure 3-3-1. LNAV/VNAV Final Segment OCS



(1) Critical temperatures.

(a) Average cold temperature (ACT). In order to determine the critical low temperature, the ACT must first be established.

1. ACT based on historical temperature data.

a Source. Environment Canada is the official government source for historical temperature data.

b Reporting period. Reporting periods are established in calendar years (January through December) and must have a complete temperature record for the airport for the entire period. Ideally use the five full year period prior to the current year. If temperature data is incomplete, use the longest continuous period with complete data starting not more than six years prior to the current year. The minimum reporting period is not less than three full calendar years.

Example: The current date is in calendar year (CY) 2015. The ideal reporting period is January 1, 2010 to December 31, 2014; however, temperature data is only complete up to November 2014. Since the earliest allowable year for ACT determination is 2009, the specialist chooses a reporting period from January 1, 2009 to December 31, 2013.

c Calculate the ACT as follows:

1 Find the coldest month. For each year in the reporting period, find the month with the lowest average temperature. When two or more months have the same average temperature, chose the month with the lowest single day temperature.

Example: Jan 2009: 45.4°F; Dec 2010: 44.7°F; Dec 2011: 43.4°F; Feb 2012: 42.2°F; Jan 2013: 45.0°F.

2 Find the lowest temperature in the coldest month. Find the lowest reported temperature in each of the coldest months.

Example: Jan 2009: 37°F; Dec 2010: 35°F; Dec 2011: 35°F; Feb 2012: 29°F; Jan 2013: 35°F.

3 Average the lowest temperature. When Fahrenheit values are used, convert the result to Celsius. Round the Celsius value to the next warmer whole degree; e.g., -15.00 remains -15; -14.99 becomes -14. The resultant rounded value is the ACT.

Example:

$$ACT = \frac{37 + 35 + 35 + 29 + 35\ 5}{5}$$

ACT = 34.20°F

ACT = (34.20 -32)/1.8 ≈ 1.22°C

ACT= 2°C

2. ACT based on standard ΔISA. When historical temperature data is not available, determine ACT using a standard cold temperature deviation below airport ISA (ΔISA).

a Calculate airport ISA. Calculate the airport ISA in degrees Celsius using formula 3-3-3:

Formula 3-3-3. Airport ISA

$$ISA_{airport} = 15 - 0.00198 \times apt_{elev}$$

Example:

$ISA_{airport} = 15 - 0.00198 \times 5433.8$

$ISA_{airport} \approx 4.24°C$

b Determine standard ΔISA. Select the standard ΔISA for the airport using table 3-3-1:

Table 3-3-1. Standard ΔISA Values

Airport Location	Value Below Airport ISA°C
Conus	-30°C
Alaska/ Canada	-40°C
Hawaii and US territories	-20°C

c Determine the ACT. Add the standard ΔISA deviation to the airport ISA value and round the calculated value to the next warmer whole degree; e.g., -15.00 remains -15; -15.01 through -15.99 becomes -15. The resultant rounded value is the ACT.

Example:
ACT = −30 + 4.24
ACT ≈−25.76°C
ACT = −25°C

(b) Determining the critical low and high temperatures. Normally, the critical low temperature limit is the calculated ACT. Where the ACT results in an effective glidepath of less

than 2.5 degrees, the temperature limit is raised to achieve the required glidepath angle. The critical high temperature limit is the temp that yields an effective glidepath of 1.13 times the maximum allowed glidepath angle for the fastest designed category (not to exceed 54 degrees Celsius). Use formula 3-3-4, formula 3-3-5, and formula 3-3-6 to find both the critical low and critical high temperature.

Formula 3-3-4. Temperature Induced DA Deviation

$$\Delta \mathrm{DA}_{\mathrm{Temp}} = e^{\frac{\mathrm{d}_{250} \times \tan(\theta_{\mathrm{Temp}})}{\mathrm{r}}} \times (\mathrm{r} + \mathrm{LTP}_{\mathrm{elev}} + \mathrm{TCH}) - (\mathrm{r} + \mathrm{TDZE} + 250)$$

Where:

d_{250} = distance (feet) from LTP to a point 250 feet above TDZE using the designed GPA

θ_{Temp} = 2.5 for low temp deviations or 1.13 × the maximum allowable GPA of the fastest CAT for high temp deviations.

Example:

$$\Delta DA_{Temp} = e^{\frac{3805.69 \times \tan(2.5)}{r}} \times (r + 5321.8 + 55) - (r + 5326.3 + 250)$$

$$\Delta DA_{Temp} \approx -33.26\ feet$$

Note: This calculation is accomplished twice. Once for low and once for high temperature deviations.

Formula 3-3-5. ΔISA Adjusted

$$\Delta \mathrm{ISA}_{\mathrm{adjusted}} = \frac{\Delta \mathrm{DA}_{\mathrm{Temp}} \times [288 - 0.5 \times 0.00198 \times (\mathrm{TDZE} + 250)]}{250 - \Delta \mathrm{DA}_{\mathrm{Temp}}}$$

Where:

$\Delta \mathrm{DA}_{\mathrm{Temp}}$ = calculated maximum DA deviation if flown at the respective critical temperatures

Example:

$$\Delta \mathrm{ISA}_{\mathrm{adjusted}} = \frac{-33.30 \times [288 - 0.5 \times 0.00198 \times (5326.3 + 250)]}{250 - (-33.30)}$$

$$\Delta \mathrm{ISA}_{\mathrm{adjusted}} \approx -33.20°C$$

Note 1: This calculation is accomplished twice. Once for low and once for high temperature deviations.

Formula 3-3-6. Adjusted ACT

$$\mathrm{ACT_{adjusted}} = \mathrm{ISA_{airport}} + \Delta\mathrm{ISA_{adjusted}}$$

Where:

$\mathrm{ISA_{airport}}$= International Standard Atmosphere temperature °C for the airport

$\Delta\mathrm{ISA_{adjusted}}$ = ISA adjustment (°C) required to achieve the respective low or high temp GPA

Example:

$\mathrm{ACT_{adjusted}}$ = 4.24 – 33.20

$\mathrm{ACT_{adjusted}}$ ≈ – 28.96°

$\mathrm{ACT_{adjusted}}$ ≈ – 28°

Note 1: $\mathrm{Critical_{Low}}$ = warmer of ACT or $\mathrm{ACT_{adjusted}}$ rounded to the warmer whole degree.

Note 2: $\mathrm{Critical_{High}}$ = colder of 54° C or $\mathrm{ACT_{adjusted}}$ rounded to the colder whole degree.

Note 3: $\Delta\mathrm{ISA_{Low}} = \mathrm{Critical_{Low}} - \mathrm{ISA_{airport}}$

(c) High temperature descent rate. Use formula 3-3-7 to determine the maximum expected descent rate at standard and critical high temperatures.

Formula 3-3-7. Descent Rate

$$\mathrm{dr} = \frac{(\mathrm{V_{KTAS}} + 10) \times 1852}{0.3048} \times \frac{60 \times \tan(\theta)}{3600}$$

Where:

$\mathrm{V_{KTAS}}$ = KTAS using 250 feet above TDZE and final approach KIAS for fastest CAT

θ = either designed GPA or 1.13 × maximum allowable GPA for the fastest CAT

Example:

$$\mathrm{dr} = \frac{(184.10 + 10) \times 1852}{0.3048} \times \frac{60 \times \tan(3.50)}{3600}$$

dr ≈ 1202.23 feet/minute

(2) OCS slope. The OCS slope and origin are determined using formula 3-3-8, formula 3-3-9, and formula 3-3-10:

Formula 3-3-8. OCS Slope

$$\mathrm{OCS_{slope}} = \frac{1}{\tan(\theta) \times \left[0.928 + 0.0038 \times \left(\mathrm{Critical_{Low}} - \mathrm{ISA_{airport}}\right)\right]}$$

Where:
$\mathrm{Critical_{Low}}$ = calculated temperature (°C) that ensures no less than a 2.5° GPA
$\mathrm{ISA_{airport}}$ = International Standard Atmosphere temperature (°C) for the airport

Example:

$$\mathrm{OCS_{slope}} = \frac{1}{\tan(3) \times \left[0.928 + 0.0038 \times (-28.96 - 4.24)\right]}$$
$$\mathrm{OCS_{slope}} \approx 23.80$$

Formula 3-3-9. Sloping OCS Origin

$$\mathrm{d_{origin}} = \frac{\mathrm{TDZE} + 250 - (\mathrm{LTP_{elev}} + \mathrm{TCH})}{\tan(\theta)}$$

Example:

$$\mathrm{d_{origin}} = \frac{5326.3 + 250 - (5321.8 + 55)}{\tan(3)}$$
$$\mathrm{d_{origin}} \approx 3806.69 \text{ feet}$$

Formula 3-3-10. Distance from LTP that the Sloping OCS Application Begins

$$\mathrm{d_{OCS}} = \mathrm{d_{origin}} + \mathrm{r} \times \mathrm{OCS_{slope}} \times \mathrm{In}\left(\frac{\mathrm{TDZE} + 89 + \mathrm{r}}{\mathrm{r} + \mathrm{LTP_{elev}}}\right)$$

Where:
$\mathrm{d_{OCS}}$ = distance (feet) from LTP to OCS origin

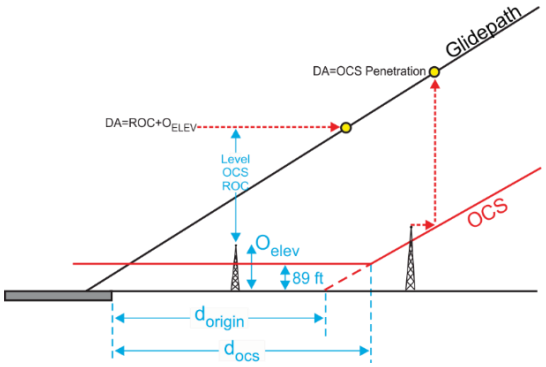
Example:

$$\mathrm{d_{OCS}} = 3806.69 + r \times 23.80 \times \mathrm{In}\left(\frac{5326.3 + 89 + \mathrm{r}}{\mathrm{r} + 5321.8}\right)$$
$$\mathrm{d_{OCS}} \approx 6031.42 \text{ feet}$$

(3) Obstacle accuracies/ROC adjustments. If the controlling obstacle is within the sloping OCS area, apply the non-RNP procedure evaluation sequence based on the sloping surface evaluation method [see Annex E, paragraphs 2.11.3 and 2.11.4]. Do not apply Vol 1, chapter 3 precipitous terrain and/or RASS adjustments when determining preliminary DA.

(4) Sloping OCS DA adjustment [see figure 3-3-2]. The MSL elevation of the sloping OCS at any distance from LTP (beyond the OCS origin) is determined using formula 3-3-11. Where obstacles penetrate the OCS, determine the distance to the adjusted DA by entering the penetrating obstacle's actual or adjusted elevation [see formula 3-3-2] into formula 3-3-12.

Figure 3-3-2. LNAV/VNAV DA Adjustment



Formula 3-3-11. Sloping OCS Elevation

$$OCS_{elev} = e^{\left(\frac{d_{LTP} - d_{origin}}{r \times OCS_{slope}}\right)} \times (r + LTP_{elev}) - r$$

Where:
d_{LTP} = along track distance (feet) from LTP to point of interest
d_{origin} = distance (feet) from LTP to OCS origin

Example:

$$OCS_{elev} = e^{\left(\frac{19747.38 - 3911.63}{r \times 23.42}\right)} \times (r + 1125.4) - r$$

$$OCS_{elev} \approx 1801.61 \text{ feet}$$

Formula 3-3-12. Preliminary DA Distance Based on Sloping OCS Penetration

$$d_{DA} = (r + LTP_{elev}) \times OCS_{slope} \times \ln\left(\frac{r + O_{elev}}{r + LTP_{elev}}\right) + d_{origin}$$

Where:
O_{elev} = obstacle actual or $O_{adjusted}$ elevation (feet)
d_{origin} = distance (feet) from LTP to OCS origin

Example:

$$d_{DA} = (r + 1125.4) \times 23.42 \times \ln\left(\frac{r + 1263.7}{r + 1125.4}\right) + 3911.63$$

$d_{DA} \approx$ 7150.61 feet

b. Level OCS [see Vol 1, paragraph 2.1.3]. A level OCS (89 ft above TDZE) is applied from 0.3 NM past the LTP/FTP to the point of intersection with the sloping OCS. If an obstacle is in the

secondary area (transitional surface), adjust the height of the obstacle using formula 3-3-2, then evaluate it at the adjusted height as if it is in the primary area.

(1) Obstacle clearance. Apply the applicable ROC from table 3-3-2 to the obstacle with the highest effective height to determine the preliminary DA.

(2) Obstacle accuracies/ROC adjustments. If the controlling obstacle is within the level OCS area, apply the non-RNP procedure evaluation sequence based on the level surface evaluation method [see Annex E, paragraphs 2.11.3 and 2.11.4]. Do not apply Vol 1, chapter 3 precipitous terrain and/or RASS adjustments when determining preliminary DA.

Table 3-3-2. Level OCS ROC by Approach Category

Aircraft Category	ROC
A	131
B	142
C	150
D/E	161

3.3.5. Decision altitude (DA). The minimum HAT is 250 feet [see Vol 1, table 3-5]. The DA based on the final segment evaluation is the highest of the following; the DA based on the minimum HAT, the DA based on the minimum offset DA distance [see paragraph 3.3.2], the DA based on the controlling obstacle. APV precipitous terrain and RASS adjustments apply. The DA based on the evaluation of the sloping OCS is not required to be higher than the MDA of an LNAV procedure established on the same chart. Document the controlling obstacle and ROC based on whichever evaluation (level or sloping OCS) results in the highest DA.

3.3.6. Raising GPA or adjusting TCH for penetrating obstructions. The GPA and/or TCH may be raised to eliminate or reduce final segment OCS penetrations.

SECTION 3-4. LPV/GLS FINAL

3.4.1. General. The OEA and associated OCSs are applicable to LPV and GLS final approach segments.

a. Exceptions. Paragraph 1.3.1 vertical path requirements apply except:

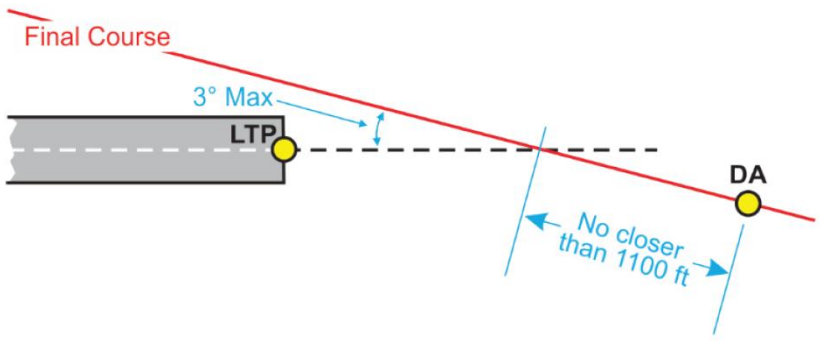
(1) The maximum GPA is 3.5 degrees for procedures with a HAT less than 250.

(2) The maximum TCH is 60 feet regardless of height group.

b. Restrictions. For GLS procedures, final track intercept must occur within 20 NM of the airport.

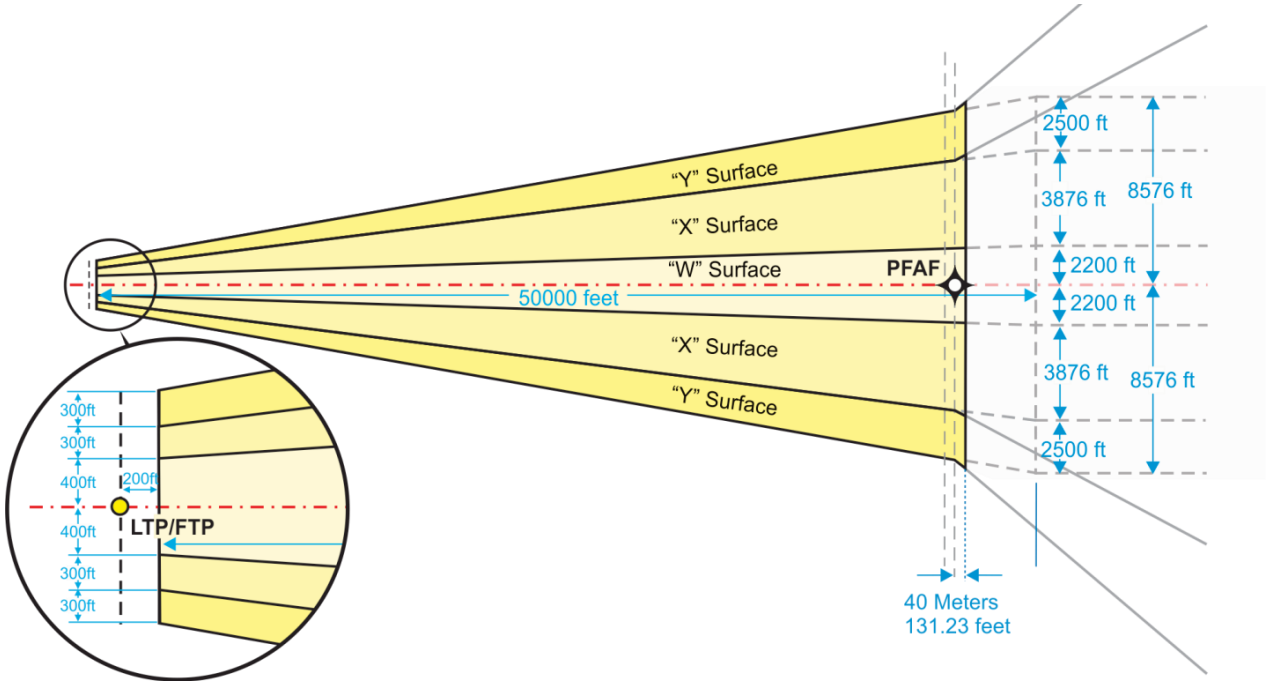
3.4.2. Alignment. The final course is normally aligned with the runway centerline (RCL) (±0.03 degrees) extended through the LTP (± 5 feet). Where an operational requirement necessitates an offset course, the FAC must intersect the RCL extended no closer than 1100 feet inside the DA point and the offset must not exceed three degrees measured from the point of intersection [see figure 3-4-1]. The DA point for this evaluation is the point on the glideslope where the altitude is equal to the published DA less any RASS and precipitous terrain adjustments. Where the course is offset, the minimum HAT is 250. TF-TF turns are not allowed in the FAS.

Figure 3-4-1. Offset Final Alignment



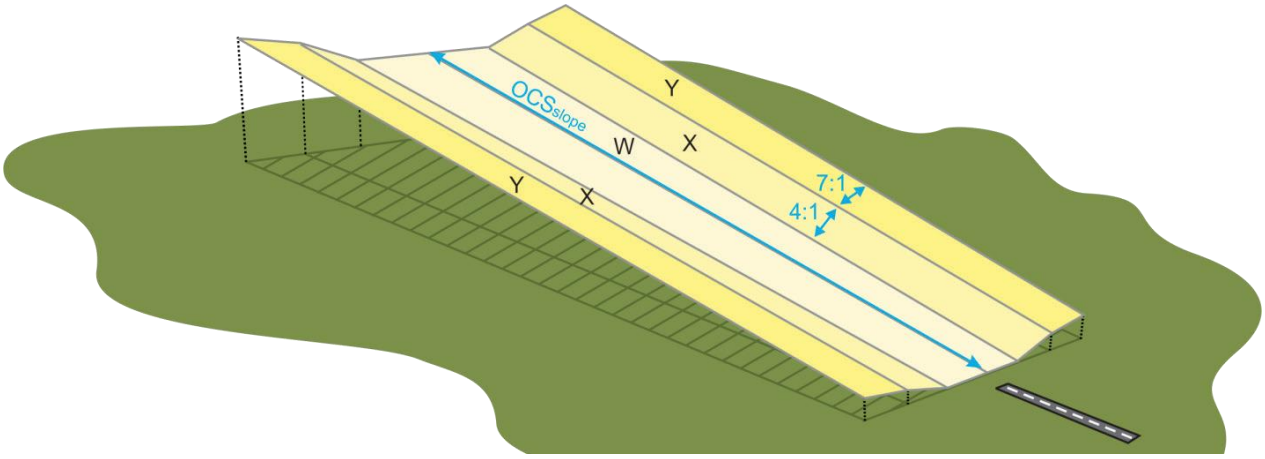
3.4.3. Area. The OEA originates 200 feet from LTP and extends to a point 40 meters beyond the PFAF. It is centered on the final approach course and expands uniformly from its origin to a point 50000 feet from the origin. Where the PFAF must be located more than 50200 feet from LTP, the OEA continues linearly (boundaries parallel to course centerline) beyond that point [see figure 3-4-2].

Figure 3-4-2. LPV/GLS Final OEA



3.4.4. Obstacle clearance surface. The primary area OCS consists of the W and X surfaces. The Y surface is an early missed approach transitional surface. The W surface slopes longitudinally along the final approach track, and is level perpendicular to track. The X and Y surfaces slope upward from the edge of the W surface perpendicular to the final approach track [see figure 3-4-3]. Obstacles located in the X and Y surfaces are adjusted in height to account for perpendicular surface rise and evaluated under the W surface.

Figure 3-4-3. LPV/GLS Final OCSs



a. OCS slope. Determine the OCS slope associated with a specific glidepath angle using formula 3-4-1.

Formula 3-4-1. OCS Slope

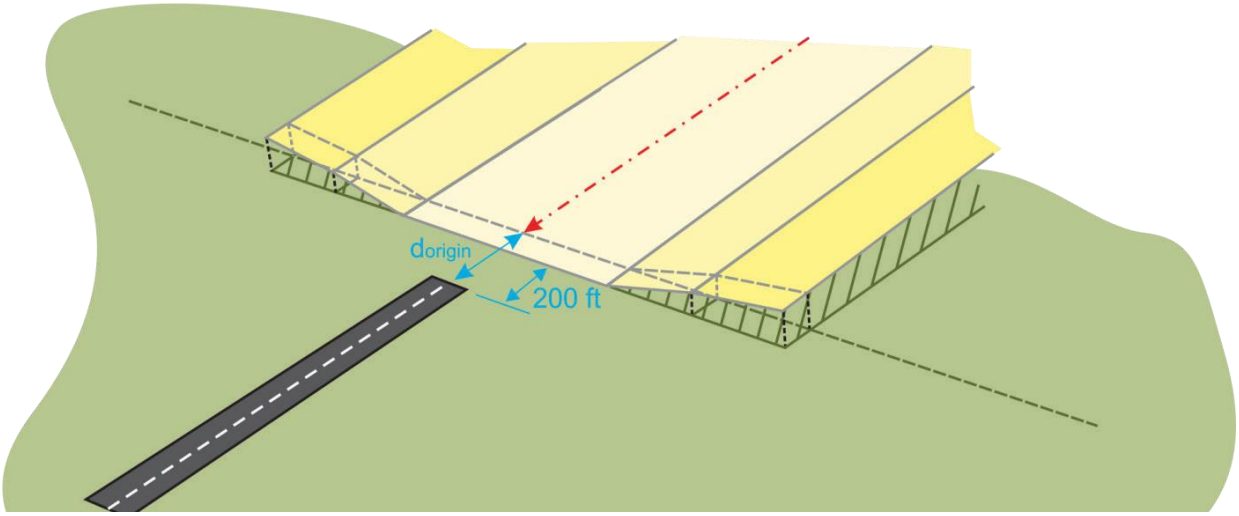
$$\mathrm{OCA}_{\mathrm{slope}} = \frac{102}{\theta}$$

Example:

$\mathrm{OCA}_{\mathrm{slope}} = \frac{102}{3.1}$

$\mathrm{OCA}_{\mathrm{slope}} \approx 32.90$

Figure 3-4-4. OCS Slope Origin



b. OCS origin. All OCS surfaces begin at LTP elevation at a point 200 feet from LTP [see figure 3-4-4] measured along course centerline and extends toward the PFAF. The longitudinal (along-track) rising W surface slope begins at a calculated distance from the LTP [see formula 3-4-2].

Formula 3-4-2. OCS Origin

$$\mathrm{d}_{\mathrm{origin}} = \text{greater of } 200 \text{ or } 1154 - \frac{\mathrm{TCH}}{\tan(\theta)}$$

Example:

$\mathrm{d}_{\mathrm{origin}} = 1154 - \frac{55}{\tan(3.1)}$

$\mathrm{d}_{\mathrm{origin}} \approx 138.45$ feet

$\mathrm{d}_{\mathrm{origin}} = 200$ feet

c. Obstacle effective elevation (O_{EE}). Because the earth curves away from the OCS as distance from course centerline increases, the MSL elevation of an obstacle is reduced to account for this. Use formula 3-4-3 to calculate the O_{EE}.

Formula 3-4-3. Obstacle Effective Elevation

$$O_{EE} = O_{MSL} - \left[(r + LTP_{elev}) \times \left(\cos\left[\frac{OBS_Y \times 180}{r \times \pi}\right]^{-1} - 1\right) + Q\right]$$

Where:
O_{MSL} = obstacle MSL elevation
OBS_Y = perpendicular distance (feet) from the course centerline to the obstacle
Q= obstacle adjustment (feet) for X or Y surface rise. Zero (0) if in the W surface

Example:

$$O_{EE} = 2768.9 - \left[(r + 1125.4) \times \left(\cos\left[\frac{1432.5 \times 180}{r \times \pi}\right]^{-1} - 1\right) + 192.90\right]$$

$O_{EE} \approx 2575.95$ feet

d. W OCS.

(1) Width. The perpendicular distance from course centerline to the boundary is 400 feet at the origin, and expands uniformly to 2200 feet at a point 50200 feet from LTP/FTP. Calculate the OCS half-width using formula 3-4-4.

Formula 3-4-4. W OCS Half Width

$$W_{boundary} = 0.036 \times d_{LTP} + 392.8$$

Where:
d_{LTP} = along track distance (feet) from LTP to point of interest

Note: 200 feet $\leq d_{LTP} \leq$ 50200 feet

Example:

$W_{boundary} = 0.036 \times 5462.03 + 392.8$
$W_{boundary} \approx$ 589.43 feet

(2) OCS elevation. The LPV/GLS glidepath is considered to be a straight line in space extending from TCH. To protect the straight-line glidepath, the OCS is a flat plane (does not follow earth curvature). The elevation of the W OCS at any point is the elevation of the OCS at the course centerline abeam it. Calculate the W OCS angle using formula 3-4-5 and elevation at any distance beyond the OCS origin using formula 3-4-6.

Formula 3-4-5. OCS Angle

$$\mathrm{OCS}_{\mathrm{angle}} = \mathrm{atan}\left(\frac{\theta}{102}\right)$$

Example:

$$\mathrm{OCS}_{\mathrm{angle}} = \mathrm{atan}\left(\frac{3.1}{102}\right)$$
$$\mathrm{OCS}_{\mathrm{angle}} \approx 1.74°$$

Formula 3-4-6. W OCS Elevation

$$OCS_{elev} = \frac{(r + LTP_{elev}) \times cos(OCS_{angle})}{cos\left[\frac{(d_{LTP} - d_{origin}) \times 180}{r \times \pi} + OCS_{angle}\right]} - r$$

Where:
OCS_{angle} = calculated angle of the obstacle clearance surface
d_{LTP} = along track distance (feet) from LTP to point of interest
d_{origin} = distance (feet) from LTP to OCS origin

Example:

$$OCS_{elev} = \frac{(r + 1125.4) \times cos(1.74)}{cos\left[\frac{(5280 - 200) \times 180}{r \times \pi} + 1.74\right]} \text{ -r}$$
$$\mathrm{OCS}_{\mathrm{elev}} \approx 1280.35 \text{ feet}$$

(3) OCS evaluation. Compare the W OCS elevation abeam the obstacle location with the OEE. Lowest minimums are achieved when the W surface is clear. See latest version of Vol 1 Section 13-6 for obstacle assessment. To eliminate or avoid a penetration, take one or more of the following actions:

(a) Remove or adjust the obstruction location and/or height.

(b) Displace the RWT.

(c) Raise GPA within the categorical limits.

(d) Adjust DA.

(e) Raise TCH.

e. X OCS.

(1) Width. The perpendicular distance from the course centerline to the outer boundary of the X OCS is 700 feet at the origin and expands uniformly to 6076 feet at a point 50200 feet from LTP/FTP. Calculate the perpendicular distance from the course centerline to the X surface boundary using formula 3-4-7.

Formula 3-4-7. Perpendicular Distance to X Boundary

$$X_{boundary} = 0.10752 \times d_{LTP} + 678.496$$

Where:
d_{LTP} = along track distance (feet) from LTP to point of interest

Note: 200 feet ≤ d_{LTP} ≤ 50200 feet

Example:

$X_{boundary} = 0.10752 \times 5462.03 + 678.496$

$X_{boundary} \approx 1265.77$ feet

(2) Obstacle adjustment. The X OCS begins at the height of the W surface and rises at a slope of 4:1 in a direction perpendicular to the final approach course. The MSL elevation of an obstacle in the X surface is reduced by the amount of surface rise. Use formula 3-4-8 to determine the obstacle height adjustment (Q) for use in formula 3-4-3. Evaluate the obstacle in accordance with paragraph 3.4.4.d(3).

Formula 3-4-8. X OCS Obstacle Adjustment

$$Q = \frac{OBS_Y - W_{boundary}}{4}$$

Where:
OBS_Y = perpendicular distance (feet) from the course centerline to the obstacle
$W_{boundary}$ = perpendicular distance (feet) from the course centerline to the W surface boundary

Example:

$$Q = \frac{1265.77 - 589.43}{4}$$

Q ≈ 169.09 feet

f. Y OCS.

(1) Width. The perpendicular distance from the course centerline to the outer boundary of the Y OCS is 1000 feet at the origin and expands uniformly to 8576 feet at a point 50200 feet from LTP/FTP. Calculate the perpendicular distance from the course centerline to the Y surface boundary using formula 3-4-9.

Formula 3-4-9. Perpendicular Distance to Y Boundary

$$Y_{boundary} = 0.15152 \times d_{LTP} + 969.696$$

Where:
d_{LTP} = along track distance (feet) from LTP to point of interest

Note: 200 feet ≤ d_{LTP} ≤ 50200 feet

Example:

$Y_{boundary}$=0.15152 × 5462.03 + 969.696

$Y_{boundary}$ ≈ 1797.30 feet

(2) Obstacle adjustment. The Y OCS begins at the height of the X surface and rises at a slope of 7:1 in a direction perpendicular to the final approach course. The MSL elevation of an obstacle in the Y surface is reduced by the amount of X and Y surface rise. Use formula 3-4-10 to determine the obstacle height adjustment (Q) for use in formula 3-4-3. Evaluate the obstacle in accordance with paragraph 3.4.4.d(3).

Formula 3-4-10. Y OCS Obstacle Adjustment

$$Q = \frac{X_{boundary} - W_{boundary}}{4} + \frac{OBS_Y - X_{boundary}}{7}$$

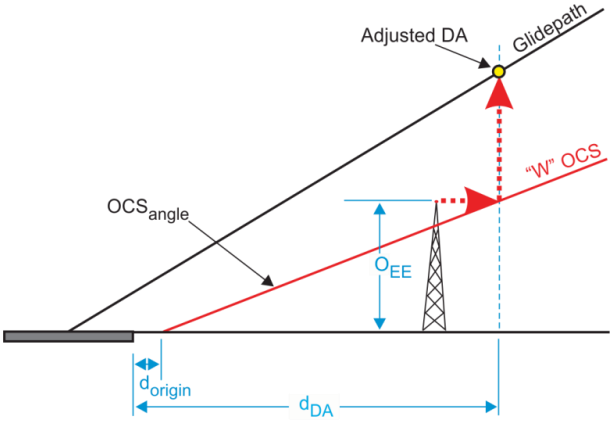
Where:
$X_{boundary}$ = perpendicular distance (feet) from the course centerline to the X surface boundary
$W_{boundary}$ = perpendicular distance (feet) from the course centerline to the W surface boundary
OBS_Y = perpendicular distance (feet) from the course centerline to the obstacle

Example:

$$Q = \frac{1265.77 - 589.43}{4} + \frac{1432.5 - 1265.77}{7}$$
$$Q \approx 192.90 \text{ feet}$$

3.4.5. Decision altitude (DA). When the final OCS is clear, the minimum HAT is 200 feet. When the final OCS is penetrated or when the final course is offset, the minimum HAT is 250 feet. The DA is the highest of the following: the DA based on the applicable minimum HAT; the DA based on GPA [see Vol 1, table 3-5]; and the DA based on evaluation of the final segment OCS. Calculate the adjusted DA distance for OCS penetrations using formula 3-4-11 for input into formula 3-4-12. Calculate the published DA distance from the LTP/FTP using formula 3-4-13. The published DA is not required to be higher than the MDA of an LNAV procedure established on the same chart.

Figure 3-4-5. LPV/GLS DA Adjustment



Formula 3-4-11. Adjusted DA Distance

$$d_{DA} = \frac{r \times \pi}{180} \times \left(90 - OCS_{angle} - \operatorname{asin}\left[\frac{\cos(OCS_{angle}) \times (r + LTP_{elev})}{r + O_{EE}}\right]\right) + d_{origin}$$

Where:
OCS_{angle} = calculated angle of the obstacle clearance surface
d_{origin} = distance (feet) from LTP to OCS origin
O_{EE} = calculated obstacle effective elevation (feet)

Example:

$$d_{DA} = \frac{r \times \pi}{180} \times \left(90 - 1.74 - \operatorname{asin}\left[\frac{\cos(1.74) \times (r + 1125.4)}{r + 1271.5}\right]\right) + 200$$

$d_{DA} \approx$ 4991.01 feet

Formula 3-4-12. Altitude on LPV/GLS Glidepath

$$Z_{LPV} = \frac{(r + alt_b) \times \cos(\theta)}{\cos\left(\frac{d \times 180}{r \times \pi} + \theta\right)} - r$$

Where:
alt_b = beginning altitude (feet) [e.g., LTP elevation + TCH]
d= distance (feet) between the points of interest

Example:

$$Z_{LPV} = \frac{(r + 1125.4) \times \cos(3.1)}{\cos\left(\frac{42041.91 \times 180}{r \times \pi} + 3.1\right)} - r$$

$Z_{LPV} \approx$ 3500 feet

Formula 3-4-13. Distance on LPV/GLS Glidepath

$$d_{LPV} = \frac{r \times \pi}{180} \times \left(90 - \theta - \operatorname{asin}\left[\frac{\cos(\theta) \times (r + alt_b)}{r + alt_e}\right]\right)$$

Where:
alt_b = beginning altitude (MSL)
alt_e = ending altitude (MSL)

Example:

$$d_{LPV} = \frac{r \times \pi}{180} \times \left(90 - 3.1 - \operatorname{asin}\left[\frac{\cos(3.1) \times (r + 1125.4 + 55)}{r + 3500}\right]\right)$$

$d_{LPV} \approx 42041.91$ feet

3.4.6. Raising GPA for OCS penetrations. Raising the GPA may eliminate OCS penetrations. To determine the revised minimum GPA, use formula 3-4-14.

Formula 3-4-14. GPA Adjustment

$$SRD = \sqrt{(r + O_{EE})^2 + (r + LTP_{elev})^2 - 2 \times (r + O_{EE}) \times (r + LTP_{elev}) \times \cos\left[\frac{(d_{LTP} - d_{origin}) \times 180}{r \times \pi}\right]}$$

$$\theta_{adjusted} = \tan\left[\operatorname{acos}\left(\frac{SRD^2 + (r + LTP_{elev})^2 - (r + O_{EE})^2}{2 \times SRD \times (r + LTP_{elev})}\right) - 90\right] \times 102$$

Where:
O_{EE} = calculated obstacle effective elevation (feet)
d_{LTP} = along track distance (feet) from LTP to penetrating obstacle
d_{origin} = distance (feet) from LTP to OCS origin

Example:

$$SRD = \sqrt{(r + 1274.5)^2 + (r + 1125.4)^2 - 2 \times (r + 1274.5) \times (r + 1125.4) \times \cos\left[\frac{(3992.7 - 200) \times 180}{r \times \pi}\right]}$$

$SRD \approx 3795.85$ feet

$$\theta_{adjusted} = \tan\left[\operatorname{acos}\left(\frac{3795.85^2 + (r + 1125.4)^2 - (r + 1274.5)^2}{2 \times 3795.85 \times (r + 1125.4)}\right) - 90\right] \times 102$$

$\theta_{adjusted} \approx 4.00°$

3.4.7. Adjusting TCH to reduce/eliminate OCS penetrations. This paragraph is applicable only where the OCS origin is greater than 200 feet from the LTP. Adjusting TCH is the equivalent to relocating the glide slope antenna in ILS criteria. The goal is to move the OCS origin toward the LTP/FTP (no closer than 200 feet) to raise the OCS at the obstacle location. To determine the maximum W surface vertical relief that can be achieved by adjusting TCH, apply

formula 3-4-15. If the result is greater than the penetration, you may determine the amount to increase TCH by applying formula 3-4-16. If this option is selected, re-evaluate the final segment using the revised TCH value.

Formula 3-4-15. Vertical Relief

$$Z_{TCH} = \frac{d_{origin} - 200}{OCS_{slope}}$$

Where:
d_{origin} = distance (feet) from LTP to OCS origin

Example:

$$Z_{TCH} = \frac{390.75 - 200}{34}$$

$Z_{TCH} \approx 5.61$ feet

Formula 3-4-16. TCH Adjustment

$$\Delta TCH = \tan(\theta) \times OCS_{slope} \times p$$

Where:
p = penetration (feet) of the final OCS

Example:

$\Delta TCH = \tan(3) \times 34 \times 4.04$
$\Delta TCH \approx 7.20$ feet

SECTION 3-5. MISSED APPROACH GENERAL

3.5.1. General. The NavSpec is RNP APCH (Missed flight phase with associated XTT of 1). Exception: For LNAV and LP, apply ATT based on the applicable final flight phase at the beginning of section 1 (line C-D). Optional NavSpec may be A-RNP (Missed flight phase with associated XTT 0.3). Use an effective XTT of 2 where applicable per table 1-2-1 footnote 2. Secondary areas apply where specified, except for A-RNP. Line C-D location and altitude is defined using the base MDA/DA. The base MDA/DA is the lowest value resulting from subtracting any RASS and precipitous terrain adjustments from the lowest final segment MDA/DA (rounded to a publishable value).

3.5.2. Course-to-altitude (CA) leg. A CA leg is used as the first leg of an RNAV missed approach and must be followed by a DF leg. The CA leg must specify a course and altitude. The specified CA course must be an extension of the FAC. The specified CA altitude is determined as follows:

a. When a turning missed approach is based on a “climb-to” altitude before turning, the coded CA altitude is the charted “climb-to” altitude. The lowest permissible climb-to altitude is 400 feet above airport elevation (surface or heliport elevation as applicable for helicopters) (rounded to the nearest foot) plus any final precipitous terrain and primary RASS adjustments.

(1) A climb-to altitude is required for non-LPV/GLS procedures when the first fix after the coded MAP is not within one degree of the FAC extended and the lowest base MDA/DA is less than 400 feet above airport elevation (surface or heliport elevation as applicable for helicopters) (rounded to the nearest foot).

(2) A climb-to altitude is required for LPV/GLS procedures when the first fix after the specified MAP is not within one degree of the FAC extended. Additionally, the climb-to altitude must not be less than the highest Section 2 start altitude [see paragraph 3.7.1.b(2)].

b. When a charted climb-to altitude is not required by the preceding paragraph, the specified CA altitude is the DA, MDA, or 400 feet above the airport elevation (surface or heliport elevation as applicable for helicopters) (rounded to the nearest foot), whichever is lowest. For helicopter point-in-space (PinS) procedures, the specific CA altitude is the DA or MDA, whichever is lower.

3.5.3. MA climb gradient termination. Where the default OCS slope is penetrated and the lowest HAT is required, a greater than standard CG may be required to clear the penetrating obstruction. Calculate the climb gradient termination altitude using formula 3-5-1 for input into the climb gradient formula 1-3-7. If a RASS adjustment is applicable, apply the CG associated with the lowest MDA/DA.

Formula 3-5-1. MA CG Termination Altitude

$$\mathrm{CG_{term}} = 48 \times \mathrm{D_O} + \mathrm{O_{MSL}} - \frac{\mathrm{d_{primary}}}{12} + \mathrm{AC_{Start}} - \mathrm{OCS_{start}} + \mathrm{RASS}$$

Where:
D_O = dist. (NM) from AC_{start} to primary obs. or point from which $d_{primary}$ measured
O_{MSL} = obstacle MSL elevation
$d_{primary}$ = dist. (feet) from edge of primary area to obs. Zero (0) if not in secondary
AC_{start} = starting altitude (feet) of the aircraft (e.g., SOC)
OCS_{start} = starting altitude (feet) of the OCS
RASS = remote altimeter setting source adjustment (feet) for final if applicable

Example:

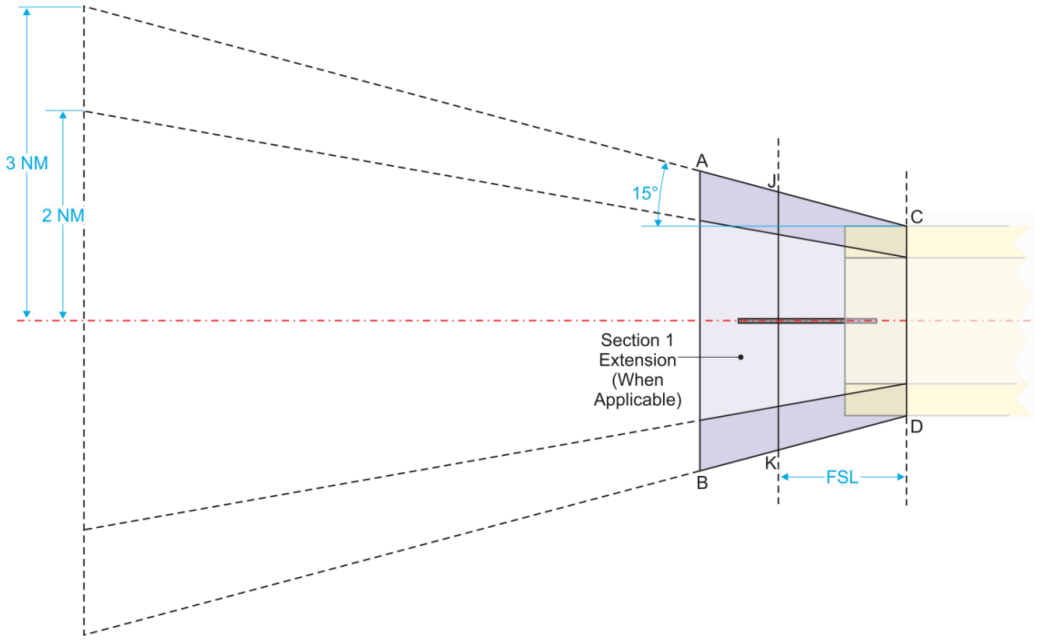
$$\mathrm{CG_{term}} = 48 \times 3.95 + 2147.41 - \frac{537.41}{12} + 1442 - 1217.21$$

$CG_{term} \approx$ 2517.02 feet

SECTION 3-6. MISSED APPROACH SECTION 1

3.6.1. Non-vertically guided. Section 1 begins final segment ATT prior to the MAP (line C-D) along a continuation of the final course and extends to the SOC (line J-K) or the point where the aircraft is projected to cross 400 feet above airport/heliport elevation (rounded to the nearest foot) (line A-B); whichever is the greater distance from the MAP [see figure 3-6-1 and figure 3-6-2].

Figure 3-6-1. LNAV Missed Approach Section 1 Area



a. Length.

(1) Flat surface length (FSL). The section 1 flat surface begins either 0.3 NM for LNAV or 40 meters for LP prior to the MAP and extends the FSL distance to line J-K. Calculate the FSL using formula 3-6-1.

Formula 3-6-1. LNAV/LP Flat Surface Length

$$\mathrm{FSL} = \frac{(\mathrm{V_{KTAS}} + 10) \times 12}{3600} + 2 \times \mathrm{ATT_{NM}}$$

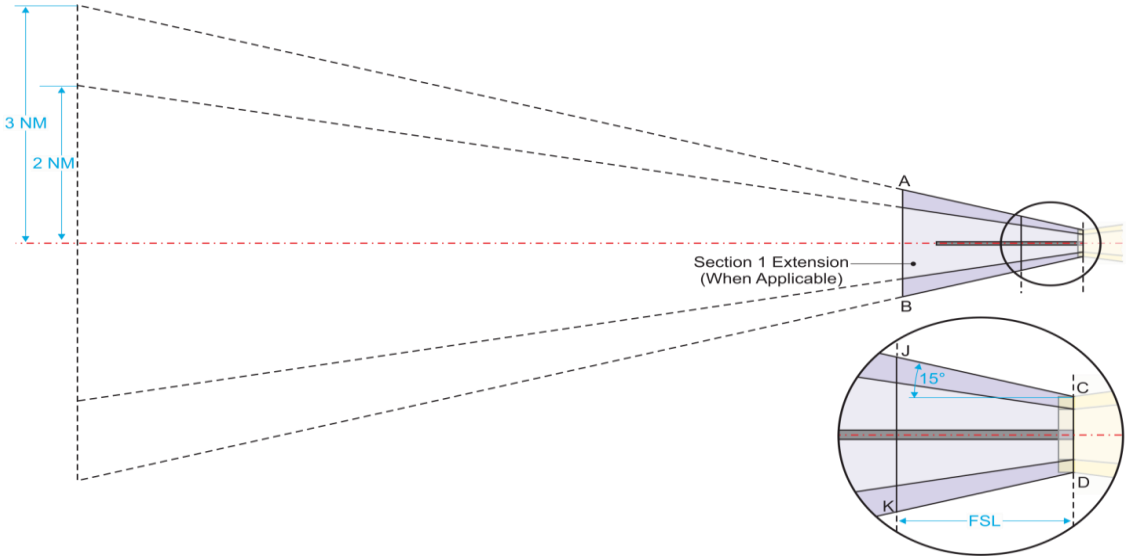
Where:
V_{KTAS} = calculated KTAS using MDA and final approach KIAS
ATT_{NM} = applicable final segment ATT in NM

Example:

$$\mathrm{FSL} = \frac{(171.91 + 10) \times 12}{3600} + 2 \times 0.3$$

FSL ≈ 1.21 NM

Figure 3-6-2. LP Missed Approach Section 1 Area



(2) Section 1 extension.

(a) Base MDA ≥ 400 feet above airport elevation (rounded to the nearest foot). No extension required. Line A-B is coincident with line J-K.

(b) Base MDA < 400 feet above airport elevation (rounded to the nearest foot). Calculate the section 1 extension using formula 3-6-2 and locate line A-B at this distance beyond line J-K.

Formula 3-6-2. Section 1 Extension

$$S1_{extension} = \ln\left(\frac{r + apt_{elev} + 400}{r + alt_b}\right) \times \frac{r}{CG}$$

Where:
apt_{elev} = Airport elevation (MSL)
alt_b = either the Base MDA for LNAV/LP or Base DA for LNAV/VNAV

Example:

$$S1_{extension} = \ln\left(\frac{r + 2900 + 400}{r + 3205}\right) \times \frac{r}{315}$$

$$S1_{extension} \approx 0.30 \text{ NM}$$

b. Width. The secondary area outer boundary starts at the outer edge of the final segment secondary area at line C-D and splays at 15 degrees relative to the missed approach course until reaching 3 XTT width from centerline. The primary area outer boundary starts at the edge of the primary area at line C-D and splays at the angle required to reach a width of 2 XTT from centerline adjacent to the point where secondary outer boundary reaches 3 XTT width.

Calculate the distance from course centerline to the primary and secondary boundary of the OEA at any distance from line C-D using formula 3-6-3 or formula 3-6-4, depending on the final type. For LNAV there is no splay when an A-RNP RNP 0.3 is specified, the OEA remains linear.

Formula 3-6-3. LNAV and LNAV/VNAV MA Primary and Secondary Boundary

$$\mathrm{MAS_{Yprimary}} = \frac{\mathrm{D_{splay}} \times \tan(15) \times 1.4}{2.1} + 0.6$$

$$\mathrm{MAS_{Ysecondary}} = \mathrm{D_{splay}} \times \tan(15) + 0.9$$

Where:
D_{splay} = along track distance (NM) from beginning of MA splay to point of interest

Example:

$\mathrm{MAS_{Yprimary}} = \frac{6.04 \times \tan(15) \times 1.4}{2.1} + 0.6$
$\mathrm{MAS_{Yprimary}}$ ≈ 1.68 NM

$\mathrm{MAS_{Ysecondary}}$ = 6.04 × tan(15) + 0.9
$\mathrm{MAS_{Ysecondary}}$ ≈ 2.52 NM

Formula 3-6-4. LP MA Primary and Secondary Boundary

$$\mathrm{MAS_{Yprimary}} = \frac{\mathrm{D_{splay}} \times \tan(15) \times (2 - {}^{1}/_{2}\,\mathrm{W_p})}{3 - \mathrm{W_s} - {}^{1}/_{2}\,\mathrm{W_p}} + {}^{1}/_{2}\,\mathrm{W_p}$$

$$\mathrm{MAS_{Ysecondary}} = \mathrm{D_{splay}} \times \tan(15) + \mathrm{W_s} + {}^{1}/_{2}\,\mathrm{W_p}$$

Where:
D_{splay} = along track distance (NM) from beginning of MA splay to point of interest
${}^{1}/_{2}\,W_p$ = perpendicular dist.(NM) from FAS centerline to FAS primary boundary
W_s = final secondary area width (NM)

Example:

$\mathrm{MAS_{Yprimary}} = \frac{6.04 \times \tan(15) \times (2 - 0.20)}{3 - 0.09 - 0.20} + 0.20$
$\mathrm{MAS_{Yprimary}}$ ≈ 1.27 NM

$\mathrm{MAS_{Ysecondary}}$ = 6.04 × tan(15) + 0.09 + 0.20
$\mathrm{MAS_{Ysecondary}}$ ≈ 1.91 NM

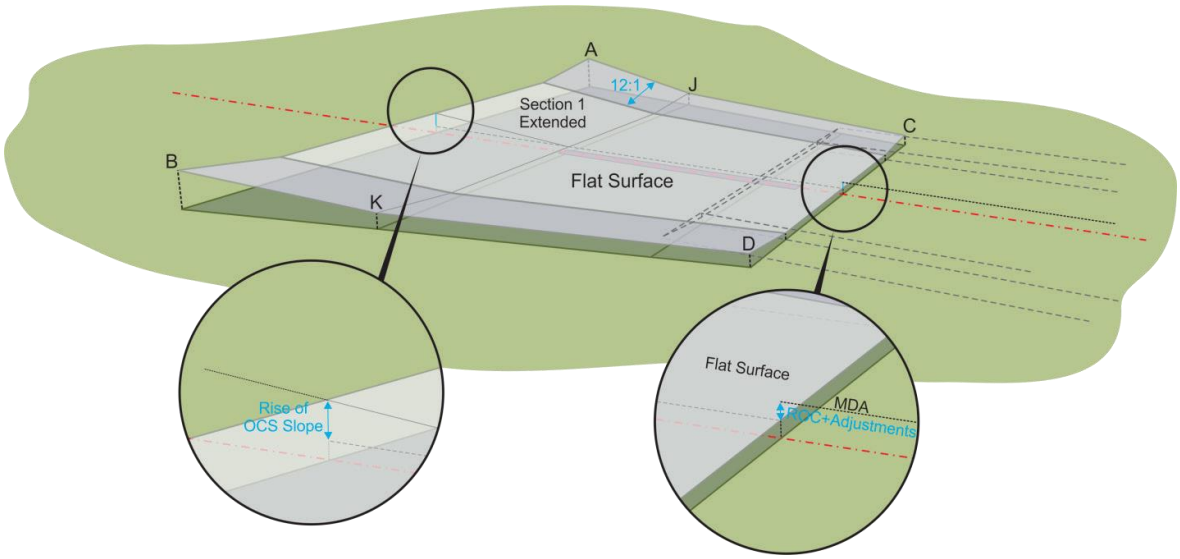
c. Obstacle clearance. Section 1 OCS consists of a flat surface and sloping surface extension [see figure 3-6-3]. The MSL height at the start of the missed approach surface (HMAS) is equal to the base MDA less 100 feet, and excessive length of final adjustments. When obstacles are mitigated by one of the following, re-evaluate the missed approach segment.

(1) Flat surface. The missed approach primary surface remains flat from line C-D to line J-K. Obstacles must not penetrate the flat surface. Where obstacles penetrate the flat surface, raise the MDA by the amount of penetration.

(2) Section 1 extension. From line J-K to line A-B, a sloping OCS surface rises along the missed approach course centerline at a slope ratio commensurate with the obstructions [see paragraph 1.3.1.g(1)]. Where obstacles penetrate this OCS, either adjust the MDA by the amount of penetration or apply a climb gradient to clear the obstacle [see paragraph 1.3.1.g(2)].

(3) Secondary areas apply from the edge of both the flat surface and section 1 extended with a 12:1 slope measured perpendicular to centerline.

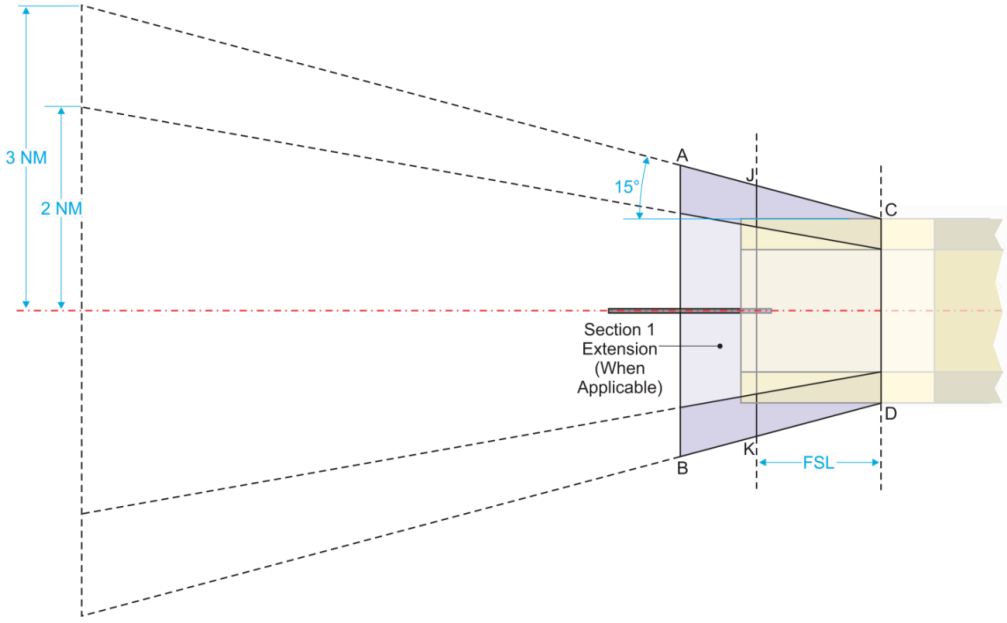
Figure 3-6-3. LNAV Missed Approach Section 1 OCS



3.6.2. LNAV/VNAV. The same criteria specified for non-vertically guided procedures apply with the following exceptions [see figure 3-6-4].

a. Line C-D is at the base DA point.

Figure 3-6-4. LNAV/VNAV Missed Approach Section 1 Area



b. Length. LNAV/VNAV FSL is based on 15 seconds at KTAS + 10 Kts tailwind without ATT. Calculate FSL using formula 3-6-5. Section 1 extension length is the same as non-vertically guided procedures [see formula 3-6-2].

Formula 3-6-5. LNAV/VNAV Flat Surface Length

$$\mathrm{FSL} = \frac{(\mathrm{V_{KTAS}} + 10) \times 15}{3600}$$

Where:
V_{KTAS} = calculated KTAS using DA and final approach KIAS

Example:

$$\mathrm{FSL} = \frac{(173.02 + 10) \times 15}{3600}$$

$\mathrm{FSL} \approx 0.76$ NM

c. Width. The 15-degree OEA splay begins at the outer edge of the final segment secondary area at the base DA point (line C-D). Calculate the distance from course centerline to the primary and secondary boundary of the OEA at any distance from line C-D using formula 3-6-3. There is no splay when an A-RNP RNP 0.3 is specified, the OEA remains linear.

d. Obstacle clearance. The HMAS is determined by subtracting the applicable flat surface ROC for the CAT [see table 3-3-2] and applicable adjustments from the base DA. Where obstacles penetrate the flat surface, raise the DA by the amount of penetration. Where obstacles penetrate the sloping OCS, either calculate the DA adjustment with formula 3-6-6

or apply a higher than standard climb gradient to clear the obstruction [see paragraph 1-3-1.g(2)]. In any case, obstacle mitigation requires the missed approach to be re-evaluated.

Formula 3-6-6. LNAV/VNAV DA Adjustment Value

$$\Delta DA = r \times e^{\left(\frac{p \times MA_{slope} \times \tan(\theta)}{r \times [1 + MA_{slope} \times \tan(\theta)]}\right)} - r$$

Where:
p= penetration (feet) of the MA OCS
MA_{slope} = missed approach OCS slope ratio

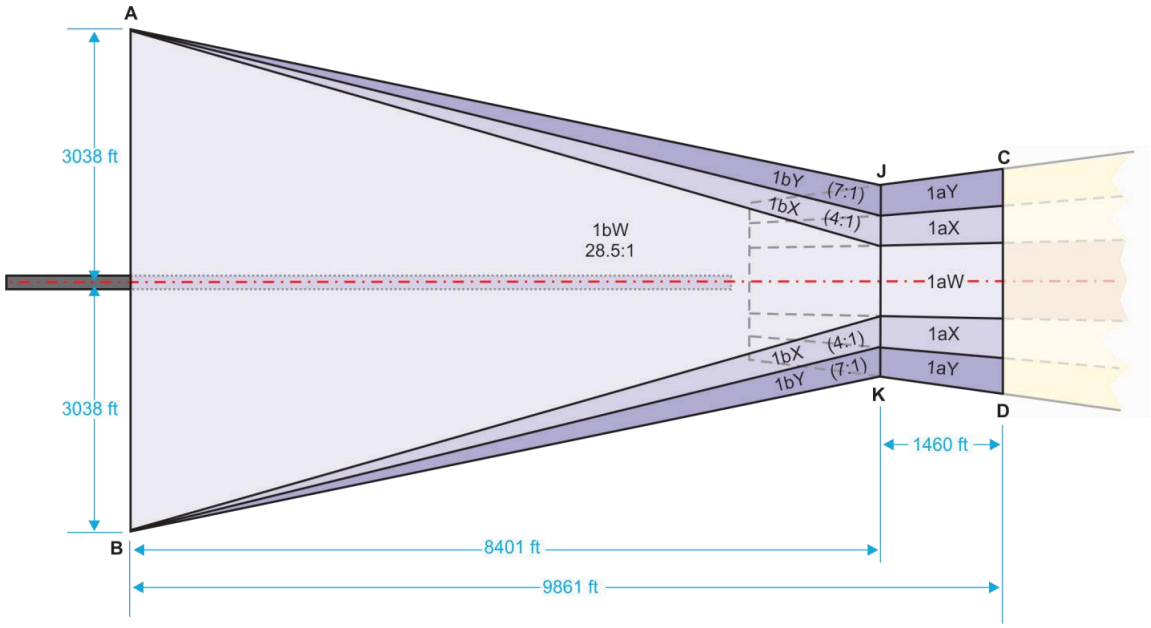
Example:

$$\Delta DA = r \times e^{\left(\frac{19.3 \times 40 \times \tan(3)}{r \times [1 + 40 \times \tan(3)]}\right)} - r$$

Δ DA ≈ 13.07 feet

3.6.3. LPV/GLS. Section 1 begins at the base DA (line C-D) and ends at the SOC (line A-B). It accommodates height loss and establishment of missed approach climb gradient. Section 1 is centered on a continuation of the final approach track and is subdivided into sections 1a and 1b [see figure 3-6-5].

Figure 3-6-5. LPV/GLS Missed Approach Section 1 Area



a. Section 1a area/OCS elevation. Section 1a is a 1460 feet continuation of the FAS OCS beginning at the base DA point to accommodate height loss. The portion consisting of the continuation of the W surface is identified as section 1aW. The portions consisting of the continuation of the X or Y surfaces are respectively identified as section 1aX or 1aY. Calculate

the width and elevation of the section 1aW, 1aX, and 1aY surfaces at any distance from LTP using the final segment formulas.

b. Section 1b areas. The section 1b area extends from line J-K at the end of section 1a for a distance of 8401 feet to line A-B. Section 1b is subdivided into sections 1bW, 1bX, and 1bY. Calculate the distance from course centerline to the boundary of these surfaces at any distance from the end of section 1a using formula 3-6-7.

(1) Section 1bW. Section 1bW extends from the end of section 1aW for a distance of 8401 feet. Its lateral boundaries splay from the width of the end of 1aW surface to a width of ±3038 feet either side of the missed approach course at the 8401 foot-point.

(2) Section 1bX. Section 1bX extends from the end of section 1aX for a distance of 8401 feet. Its inner boundary is the outer boundary of the 1bW surface. Its outer boundary splays from the end of the 1aX surface to a width of ±3038 feet either side of the missed approach course at the 8401-foot point.

(3) Section 1bY. Section 1bY extends from the end of section 1aY for a distance of 8401 feet. Its inner boundary is the outer boundary of the 1bX surface. Its outer boundary splays from the outer edge of the 1aY at the surface at the end of section 1a to a width of ± 3038 feet either side of the missed approach course at the 8401-foot point.

Formula 3-6-7. Section 1bW/X/Y Boundary

$$1b_{boundary} = \frac{d_{1aEnd} \times (3038 - 1a_{boundary})}{8401} + 1a_{boundary}$$

Where:
d_{1aEnd} = along track distance (feet) from end of section 1a to the point of interest
$1a_{boundary}$ = perpendicular dist. (feet) from centerline to respective ending 1a outer boundary

Example:

$$1b_{boundary} = \frac{2591.8 \times (3038 - 481.06)}{8401} + 481.06$$

$1b_{boundary}$ ≈ 1269.90 feet

c. Section 1b OCS elevations.

(1) Section 1bW. The surface rises from the elevation of the 1aW surface at the end of section 1a at a slope ratio of 28.5:1. Calculate the section 1bW surface elevation with formula 1-3-6 for input into formula 3-6-8.

(2) Section 1bX. The surface rises at a slope ration of 4:1 perpendicular to the missed approach course from the edge of the 1bW surface. Calculate the adjustment (Q) for X surface obstacles using formula 3-4-8.

(3) Section 1bY. The surface rises at a slope ratio of 7:1 perpendicular to the missed approach course from the edge of the 1bX surface. Calculate the adjustment (Q) for Y surface obstacles using formula 3-4-10.

Formula 3-6-8. Section 1b Surface Penetration

$$p = O_{MSL} - Q - 1bW_{elev}$$

Where:
O_{MSL}= obstacle MSL elevation
Q= obstacle adjustment (feet) for X or Y surface rise. Zero (0) if in the W surface
$1bW_{elev}$ = elevation (feet) of the 1bW surface abeam the obstacle

Example:

p = 1325.8 − 24.22 − 1282.70

p ≈ 18.88 feet

d. OCS penetration mitigation. To eliminate or avoid a penetration, take one or more of the following actions:

(1) Removing or adjusting the obstruction location and/or height.

(2) Raising GPA within categorical limits.

(3) Raising TCH [see paragraph 3.4.7].

(4) Adjusting DA. For a surface 1b penetration of p feet, the DA point must move Δd_{DA} [see formula 3-6-9] feet further from the LTP to raise the surface above the penetration.

Formula 3-6-9. Along-track DA Adjustment

$$\Delta d_{DA} = \frac{p \times 28.5 \times FAS_{slope}}{28.5 + FAS_{slope}}$$

Where:
p= penetration (feet) of the 1b OCS
FAS_{slope} = final approach segment OCS slope ratio

Example:

$$\Delta d_{DA} = \frac{18.88 \times 28.5 \times 34}{28.5 + 34}$$

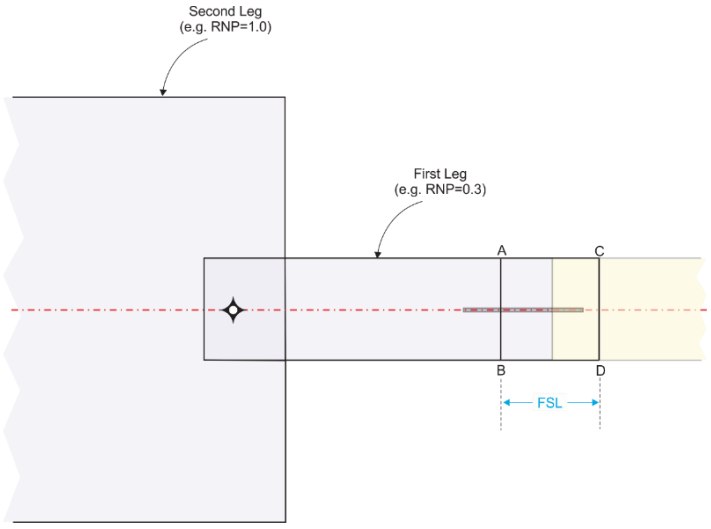
Δd_{DA}≈ 292.72 feet

SECTION 3-7. MISSED APPROACH SECTION 2

3.7.1. General.

a. Obstacle evaluation area (OEA). The section 2 OEA begins at the end of section 1, and splays at least 15 degrees relative to the nominal track to reach full width. Refer to individual chapters for MA section 1 information. Once full OEA width has been obtained with an A-RNP reduced XTT, the OEA remains linear and width changes occur abruptly at the start fix of a leg with a new RNP. Use a reduced XTT only where operationally required and only for the distance necessary to achieve the desired ground track [see figure 3-7-1]. Use of A-RNP missed approach XTT less than 1 should be avoided because it will limits the IFP availability to some users.

Figure 3-7-1. A-RNP Reduced XTT Area



b. Section 2 start altitude.

(1) Non-LPV/GLS.

(a) When line J-K and line A-B are coincident, the section 2 start altitude is the MDA/DA as appropriate.

(b) When line J-K and line A-B are not coincident, the section 2 start altitude is airport elevation + 400 feet + adjustments (final precipitous terrain and RASS).

(2) LPV/GLS. Use formula 3-7-1 to calculate the section 2 start altitude.

Formula 3-7-1. LPV/GLS Section 2 Start Altitude

$$\text{Section 2 start altitude} = DA - \tan(\theta) \times 1460 + \frac{8401 \times 0.3048 \times 200}{1852}$$

Example:

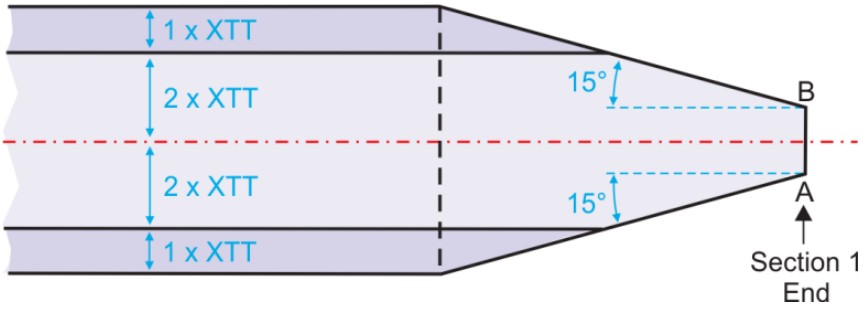
$$\text{Section 2 start altitude} = 1225 - \tan(3.1) \times 1460 + \frac{8401 \times 0.3048 \times 200}{1852}$$

Section 2 start altitude ≈ 1422.45 feet

c. Obstacle clearance surface (OCS) slope and origin. The section 2 OCS slope [see formula 1-3-5] begins at line A-B. Where a higher than standard CG is required, apply the associated OCS from the SOC to the CG termination altitude, then revert to the default OCS.

3.7.2. Straight missed approach. The straight course is a continuation of the FAC. The straight MA section 2 OEA begins at the end of section 1 and splays at 15 degrees relative to the nominal track until reaching full primary and secondary width [see figure 3-7-2].

Figure 3-7-2. Missed Approach Section 2 Straight Area



3.7.3. Turning missed approach.

a. Early and inside turn construction.

(1) First turn. The first MA turn may be specified at an altitude or be specified at a FB or FO fix.

(a) Turn-at-altitude or as soon as practicable. A turn-at-altitude is followed by a DF leg usually ending with a DF-TF connection or holding pattern entry.

1. Turn initiation area (TIA). The TIA includes the applicable section 1 area starting at line C-D and ends where the specified turn altitude is reached (line L-L'). Construct the TIA from the end of section 1 to line L-L' using straight MA criteria. Evaluate section 2 obstacles by applying the prescribed OCS slope along the shortest distance from the TIA boundary to the obstacle. The obstacle-based turn altitude is the sum of starting ROC and OCS elevation at the TIA boundary needed to clear section 2 obstacles. Because TIA length and the OCS elevation at the end of the TIA is dependent on aircraft altitude, establishing an

obstacle-based turn altitude may be an iterative process. Calculate lengths from line C-D using formula 3-7-2, formula 3-7-3, and formula 3-7-5.

a Non-LPV/GLS TIA. Calculate the TIA length using the appropriate FSL value [see section 3-5.]. Where an increased CG terminates below the turn altitude, apply formula 3-7-2, otherwise apply formula 3-7-3.

Formula 3-7-2. TIA Length CG Termination Below Turn Altitude (Non LPV/GLS)

$$\mathrm{TIA_{length}} = \frac{\mathrm{FSL} \times \mathrm{r}}{\mathrm{r} + \mathrm{alt_b}} + \mathrm{D_{climb_i}} + \mathrm{D_{climb_{ii}}}$$

Where:
FSL = length (NM) of the missed approach flat surface
alt_b = beginning altitude (feet) (i.e., the MDA for LNAV/LP or DA for LNAV/VNAV)
D_{climb_i} = climb distance (NM) required to reach the first CG_{term} from MDA or DA
$D_{climb_{ii}}$ = climb distance (NM) required to reach the turn altitude from the first CG_{term}

Example:

$$\mathrm{TIA_{length}} = \frac{1.21 \times \mathrm{r}}{\mathrm{r} + 1900} + 4.44 + 3.26$$

$\mathrm{TIA_{length}} \approx$ 8.91 NM

Formula 3-7-3. TIA Length Standard CG or CG Termination at or above Turn Altitude (Non-LPV/GLS)

$$\mathrm{TIA_{length}} = \frac{\mathrm{FSL} \times \mathrm{r}}{\mathrm{r} + \mathrm{alt_b}} + \mathrm{D_{climb}}$$

Where:
FSL = length (NM) of the missed approach flat surface
alt_b = beginning altitude (feet)(i.e., either the MDA for LNAV/LP or DA for LNAV/VNAV)
D_{climb} = climb distance (NM) required to reach the turn altitude from MDA or DA

Example:

$$\mathrm{TIA_{length}} = \frac{1.21 \times \mathrm{r}}{\mathrm{r} + 1900} + 6.67$$

$\mathrm{TIA_{length}} \approx$ 7.88 NM

b LPV/GLS TIA. Where an increased CG terminates below the turn altitude, apply otherwise apply formula 3-7-5.

Formula 3-7-4. TIA Length CG Termination Below Turn Altitude (LPV/GLS)

$$\mathrm{TIA_{length}} = \frac{9861 \times 0.3048}{1852} + \mathrm{D_{climb_i}} + \mathrm{D_{climb_{ii}}}$$

Where:
D_{climb_i} = climb distance (NM) required to reach the first CG_{term} from SOC
$D_{climb_{ii}}$ = climb distance (NM) required to reach the turn altitude from the first CG_{term}

Example:

$$\mathrm{TIA_{length}} = \frac{9861 \times 0.3048}{1852} + 3.79 + 3.26$$
$\mathrm{TIA_{length}}$ ≈ 8.67 NM

Formula 3-7-5. TIA Length Standard CG or CG Termination at or above Turn Altitude (LPV/GLS)

$$\mathrm{TIA_{length}} = \frac{9861 \times 0.3048}{1852} + \mathrm{D_{climb}}$$

Where:
D_{climb} = climb distance (NM) required to reach the turn altitude from SOC

Example:

$$\mathrm{TIA_{length}} = \frac{9861 \times 0.3048}{1852} + 6.01$$
$\mathrm{TIA_{length}}$ ≈ 7.63 NM

2. OEA construction after TIA [see table 3-7-1 and figure 3-7-3].

Table 3-7-1. Early/Inside Turn Tie-Back Points

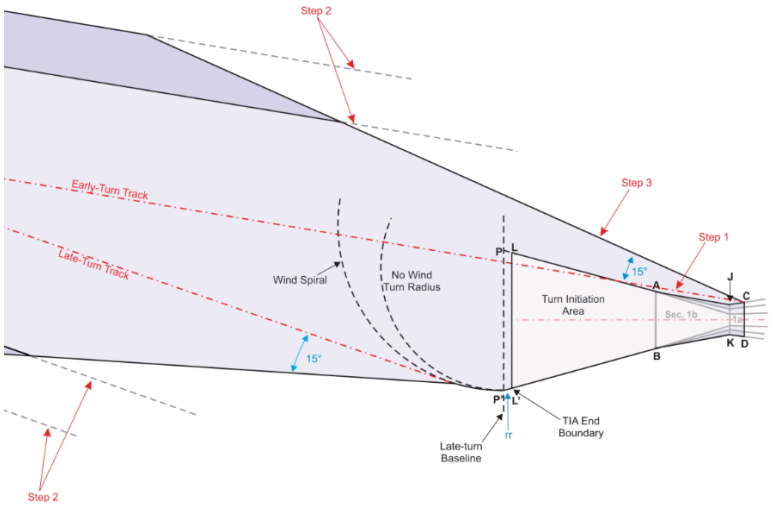
Turn Angle (measured from FAC/line C-D intersection)	Tie-Back Point
≤ 75 degrees	Point C
> 75 degrees	Point D
> 165 degrees	Point P’

a *Step 1*. Construct a line (representing the early-turn flight track) from the tie-back point, to the fix.

b *Step 2***.** Construct the inside turn primary and secondary OEA boundary lines parallel to this line.

c *Step 3*. From the tie-back point, construct a line slaying at 15 degrees to intersect the parallel boundary lines or leg end, whichever occurs earlier. Apply inside turn secondary areas only after the 15-degree splay line intersects the primary boundary line.

Figure 3-7-3. Early/Inside Turn Turn-at-Altitude Construction after TIA



(b) Turn-at-fix (FO or FB). TF legs are followed by a TF leg ending with holding pattern entry or TF-TF connection when the initial straight leg is less than full width. May be followed by an RF leg when the initial straight leg has reached full width, ending with an RF-TF or RF-RF connection. The recommended turn magnitude is 70 degrees; the maximum is 90 degrees. Use FB unless a FO is required for obstacle avoidance or where mandated by specific operational requirements. Use paragraph 1.2.5.d in cases where full primary and secondary width is achieved at a sufficient distance prior to the turn fix to permit construction. Otherwise, construct as follows:

1- Fix location. The first turn fix must be located on the final approach track extended. The distance to the turn fix must be sufficient to result in an early turn baseline at or beyond the end of section 1. Where the first fix must be located at the point the aircraft reaches or exceeds a specific altitude, calculate fix distance from line A-B with formula 1-3-9 using the standard or increased CG. If a fix is already established, calculate the aircraft altitude at the fix using formula 1-3-8. Calculate the aircraft SOC per paragraph 3.7.1.b.

2- Early turn baseline (line L – L'). The early turn baseline is established prior to the turn fix perpendicular to the inbound leg at the appropriate distance.

Table 3-7-2. Early turn Baseline Distance from Turn Fix

Fix Type	Distance
FB Fix	ATT + DTA*
FO Fix	ATT

*DTA = 0 for turns 10 degrees or less

3- Construction points. Inside turn construction uses points PI (primary intersection) and SI (secondary intersection). When defining these points, the leg prior to the turn fix is the inbound leg and the leg following the turn fix is the outbound leg.

a Point SI. This is the connection point for the secondary area boundary and is the intersection of line L-L' and the inbound leg secondary area boundary. When inbound leg has no secondary, points PI and SI are coincident.

b Point PI. This is the connection point for the primary area boundary and is the intersection of line L-L' and the inbound leg primary area boundary.

4- Inside turn construction. Primary/Secondary boundary expansion depends on the location of points PI and SI in relation to the outbound leg OEA boundary lines (extended when necessary) [see table 3-7-3 and figure 3-7-4, figure 3-7-5, and figure 3-7-6]. Where standard expansion is suitable for one, but not both splays, find the outbound connection point for the non-standard splay abeam the standard connection point. If the table 3-7-3 expansion line results in smaller primary areas than those resulting from the 15-degree inbound leg splay, relocate point PI and/or increase the splay angle to maintain or increase the size of the inbound and outbound leg primary areas. Construct as follows:

Table 3-7-3. Inside Turn Expansion

Construction Point	External to Outbound leg OEA (both primary and secondary)	Internal to Outbound leg Secondary area	Internal to Outbound leg Primary area
Point PI	Greater of ½ Turn-angle or Inbound leg Splay	Greater of ½ Turn-angle or Inbound leg Splay	15 degrees relative outbound track
Point SI	Greater of ½ Turn-angle or Inbound leg Splay	15 degrees relative outbound track	15 degrees relative outbound track

a Step 1. Construct line L-L' at the appropriate table 3-7-2 distance.

b Step 2. Construct secondary area boundary.

1 Case 1. SI is external to the outbound leg OEA. Construct an expansion line from SI to the outbound leg secondary boundary.

2 Case 2. SI is internal to either the outbound leg secondary or primary area. In this case, an alternative construction point (point SI') may be required depending on turn magnitude. Point SI' is defined as the intersection of line L-L' and the outside-turn secondary area boundary. Construct the expansion line from either point SI or SI' to the outbound leg secondary boundary whichever results in the larger area. When the expansion line reaches the outbound secondary boundary before reaching the point of intersection of the inbound and outbound leg secondary boundaries, no expansion is required and the area is a simple connection of the inbound and outbound leg secondary boundaries.

c Step 3. Construct the primary area boundary. Construct an expansion line from point PI to the outbound leg primary boundary. When the Step 2 expansion line reaches the outbound leg primary boundary before reaching point of intersection of the inbound and outbound leg primary boundaries, no expansion is required and the area is a simple connection of the inbound and outbound leg primary boundaries.

Figure 3-7-4. Early/Inside Turn, First Turn, Turn at Fix: PI and SI Collocated and External to Outbound Primary and Secondary

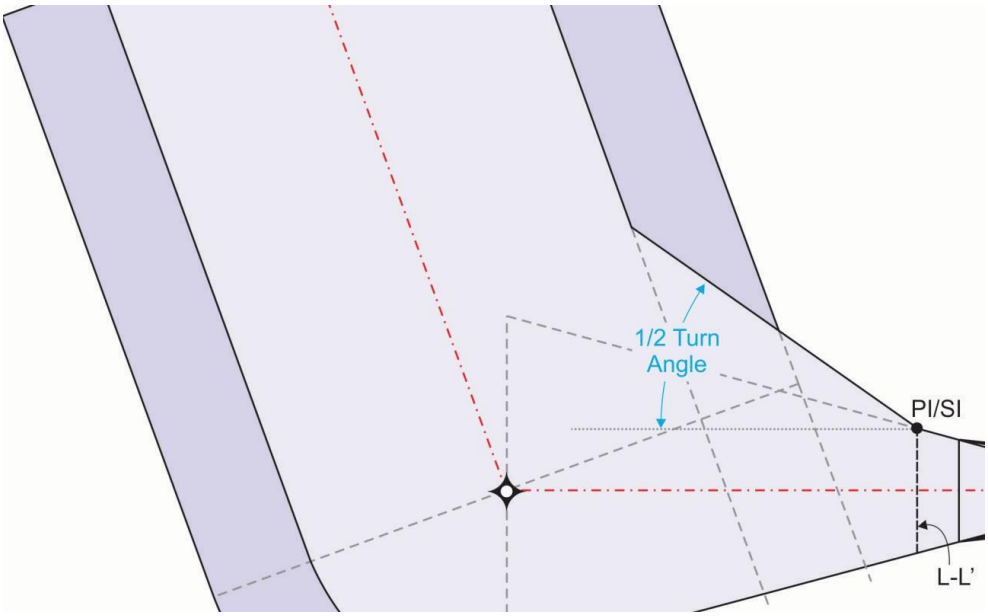


Figure 3-7-5. Early/Inside Turn, First Turn, Turn at Fix: PI and SI Internal to Outbound Primary

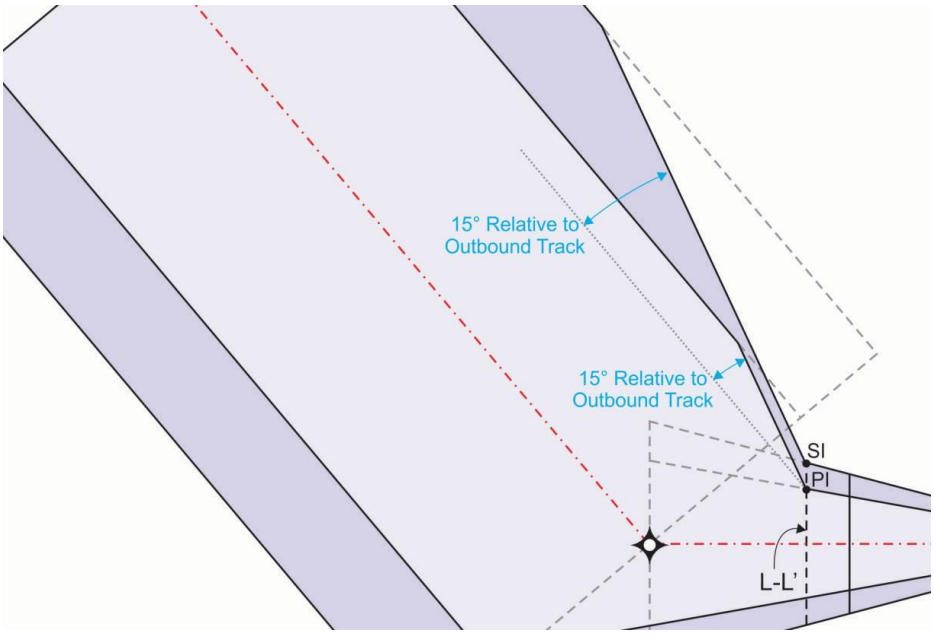
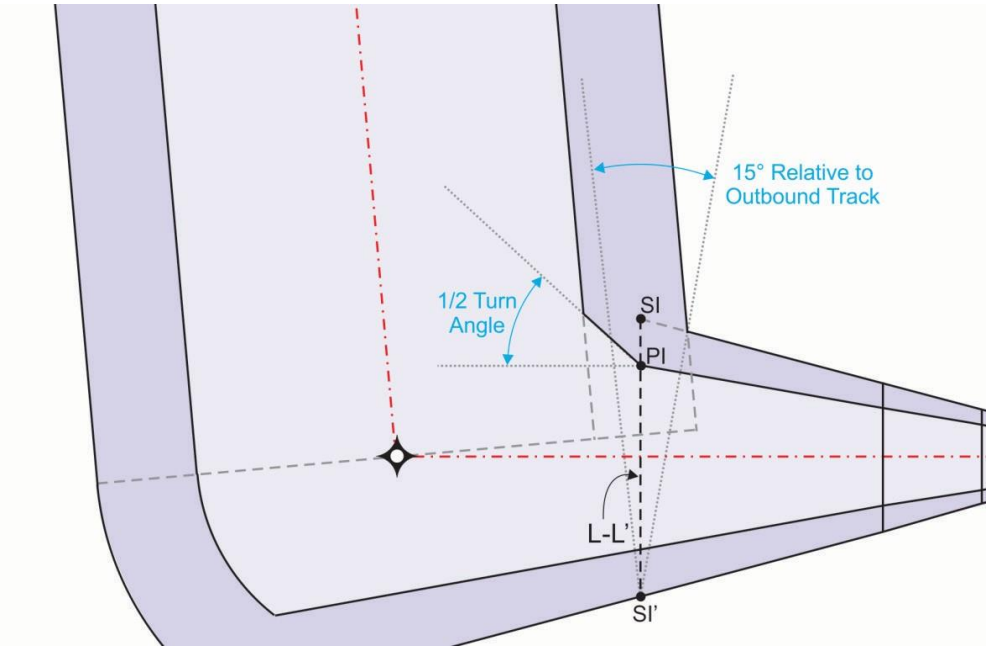


Figure 3-7-6. Early/Inside Turn, First Turn, Turn at Fix: PI and SI Internal to Outbound Secondary, splay from point SI'



(2)Second turn. The second MA turn is specified at either a FB or FO fix [see figure 3-7-7].

(a)DF-TF. This applies to a DF-TF connection following a turn-at-altitude.

1. Construct in accordance with paragraph 3.7.3.a(1)(b) with the following exceptions:

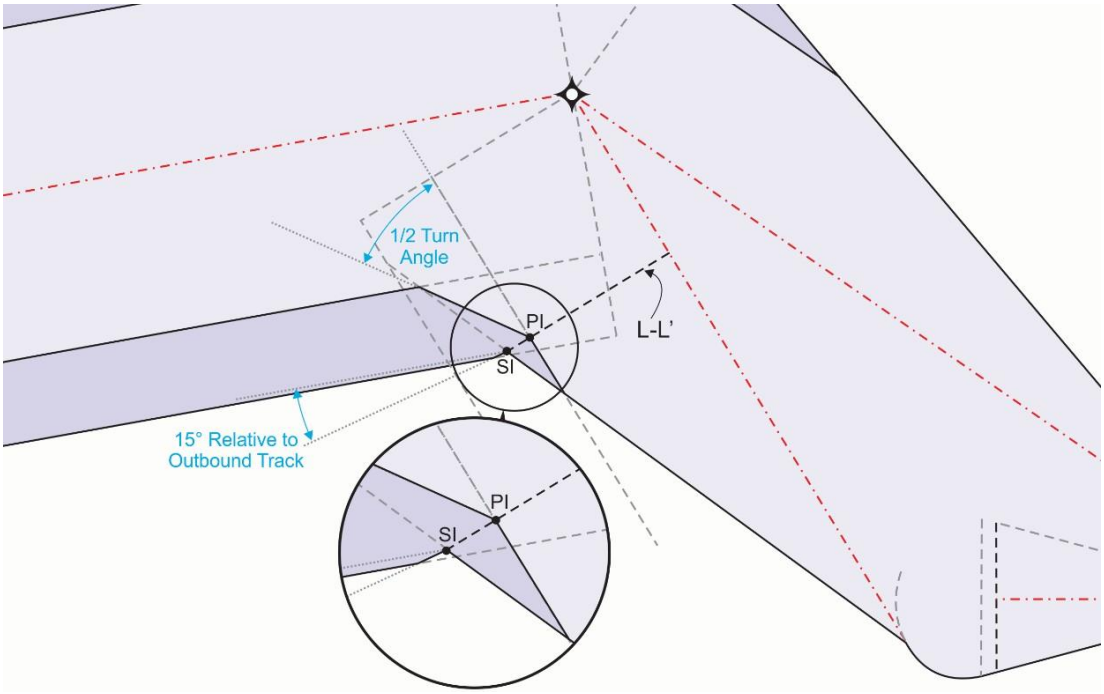
a Paragraph 3.7.3.a(1)1 does not apply.

b Line L-L' is established perpendicular either on the early-or late-turn track, whichever is on the inside of the turn.

c When full primary-and secondary-width is reached at the early-turn baseline (L-L') construct in accordance with paragraph 1.2.5.d.

(b) Other than DF–TF connections. Construct in accordance with paragraph 1.2. 5.d.

Figure 3-7-7. Early/Inside Turn, Second Turn, Turn at FB Fix DF-TF connection



b. Late and outside turn construction.

(1) Wind spiral application. Wind spiral (WS) construction applies to late and outside turns for turn-at-altitude, turn-at-fix (FO) for the first turn, and DF-TF (FO) for the second turn. See paragraph 1.3.1.g for design parameters.

(a) WS number and baselines. Baseline locations for WS construction may be dependent on Reaction and Roll distance [see formula 1-2-12 and table 3-7-4].

Table 3-7-4. Wind Spiral Number and Distance to Late Turn Baseline

WS/Baseline Parameters	Turn-at-Fix (FO)	Turn-at-Altitude
WS Number	1 or 2	1, 2, or 3
WS1 & WS2 Distance Late-Turn Baseline from turn fix/point	ATT+Drr	TIA+ Drr
WS3 Baseline	Not applicable	Parallel to line C-D

1- First turn baseline. For first turn construction, the late-turn baseline (line P-P') marks the construction line for wind spirals. Line P-P' is located at the table 3-7-4 distance with points P and P' placed at the continuation of the inbound leg's outer boundary [see paragraph 1.3.1.g(4)]. The no-wind turn radius for the outside turn wind spiral (WS1) and inside turn wind spiral (WS2) will be measured perpendicular to the inbound track from their respective point P. If a third wind spiral is used (WS3), the baseline will be parallel to line C-D with the no-wind turn radius measured inward from point C.

2- Second turn baseline [see figure 3-7-15]. To accommodate both inbound tracks, the second MA turn construction uses two WS baselines, line P'-P" for WS1 and line P-P' for WS2. Each late turn baseline is oriented perpendicular to the early-and late-turn tracks at the table 3-7-4 distance. The baseline for the inbound track nearer the outside-turn boundary is designated line P'-P", with point P" placed on the extended outer boundary and point P' placed at the no-wind turn radius inward along the baseline from point P". The baseline for the inbound track nearer the inside-turn boundary is designated line P-P', with point P' placed on inbound track and point P placed on the extended outer boundary. The no-wind turn radius for the inside turn wind spiral is measured inward along the baseline from point P.

(b) WS connection point and outside turn OEA boundary [see figure 3-7-8]. Each WS has various connection options along its path, which predicate the outside turn OEA boundary. The chosen connection must provide the most reasonably conservative track and protection area. Where excessive splay is required to reach full-width protection, consider lengthening the leg, restricting the speed, category, etc. to avoid protection and/or construction difficulties. Consider full-width protection to exist at the fix where the splay line is tangent to a full-width-radius circle about the fix [see figure 3-7-11].

1- Turn-at-altitude connection point. For turn-at-altitude, the 15-degree or greater splay line that joins the outbound leg outer boundaries may originate from the WS/directto-fix tangent point (point 1), the WS to WS tangent line origin (point 2) or the WS to WS tangent line end (point 3). Where the turn angle is ≤ 105 degrees, or the divergence angle between the WS to WS tangent line and the direct-to-fix line is ≤ 15 degrees, apply the splay line from the WS to WS tangent line origin. DF secondary areas begin/exist only where full width primary exists.

2- Turn-at-fix (FO) Connection Point. For turns at a fix, the connection point and the OEA boundary is dependent on the WS boundary relative to the outbound leg OEA (extended). The connection point is the point of tangency on the WS in both cases. When the WS is not contained in the outbound leg OEA, the outside boundary is a 30-degree converging line relative to the outbound course [see figure 3-7-9].When the WS is contained in the outbound leg OEA, the outside boundary is a 15-degree or greater splaying line relative to the outbound course from the WS/outbound leg parallel point until reaching the outbound leg boundaries [see figure 3-7-10].

Figure 3-7-8. Late/Outside Turn, WS Connection Points and Outside Turn OEA

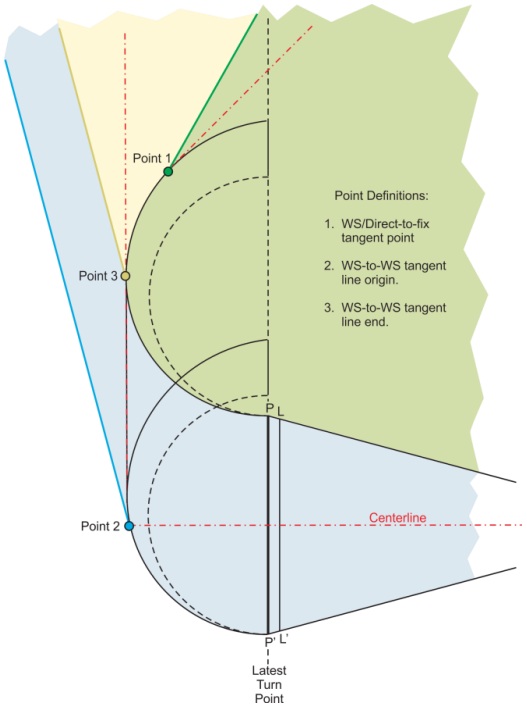


Figure 3-7-9. Late/Outside Turn, Wind Spiral, WS not contained in Outbound OEA

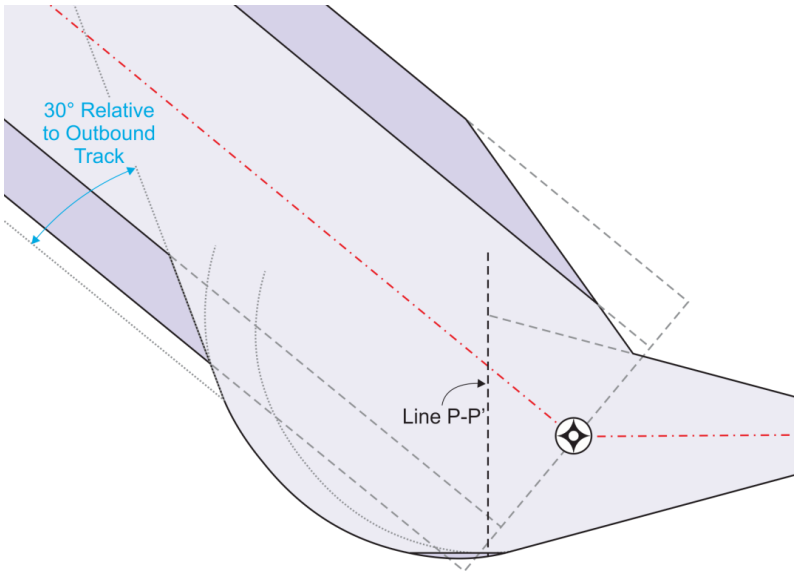
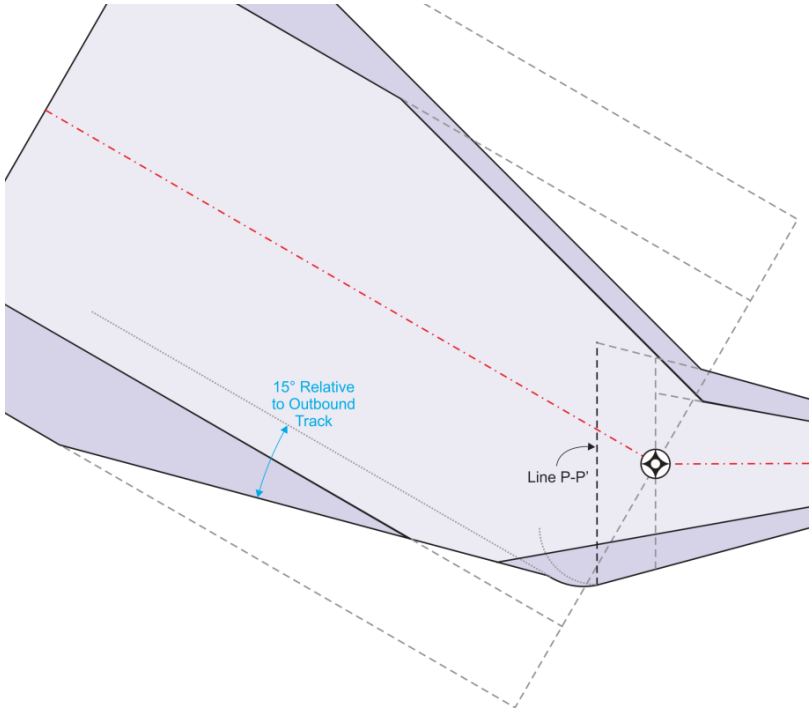


Figure 3-7-10. Late/Outside Turn, Wind Spiral, WS contained in Outbound OEA



(c) Determining multiple WS necessity. To determine multiple wind spiral necessity, construct the additional WS in the direction of turn from its prescribed location to its connection point. Where the additional WS intersects the preceding WS construction (including the connecting and expansion lines), connect the wind spirals with a tangent line that is parallel to the WS center points. Otherwise, revert to the previous WS construction.

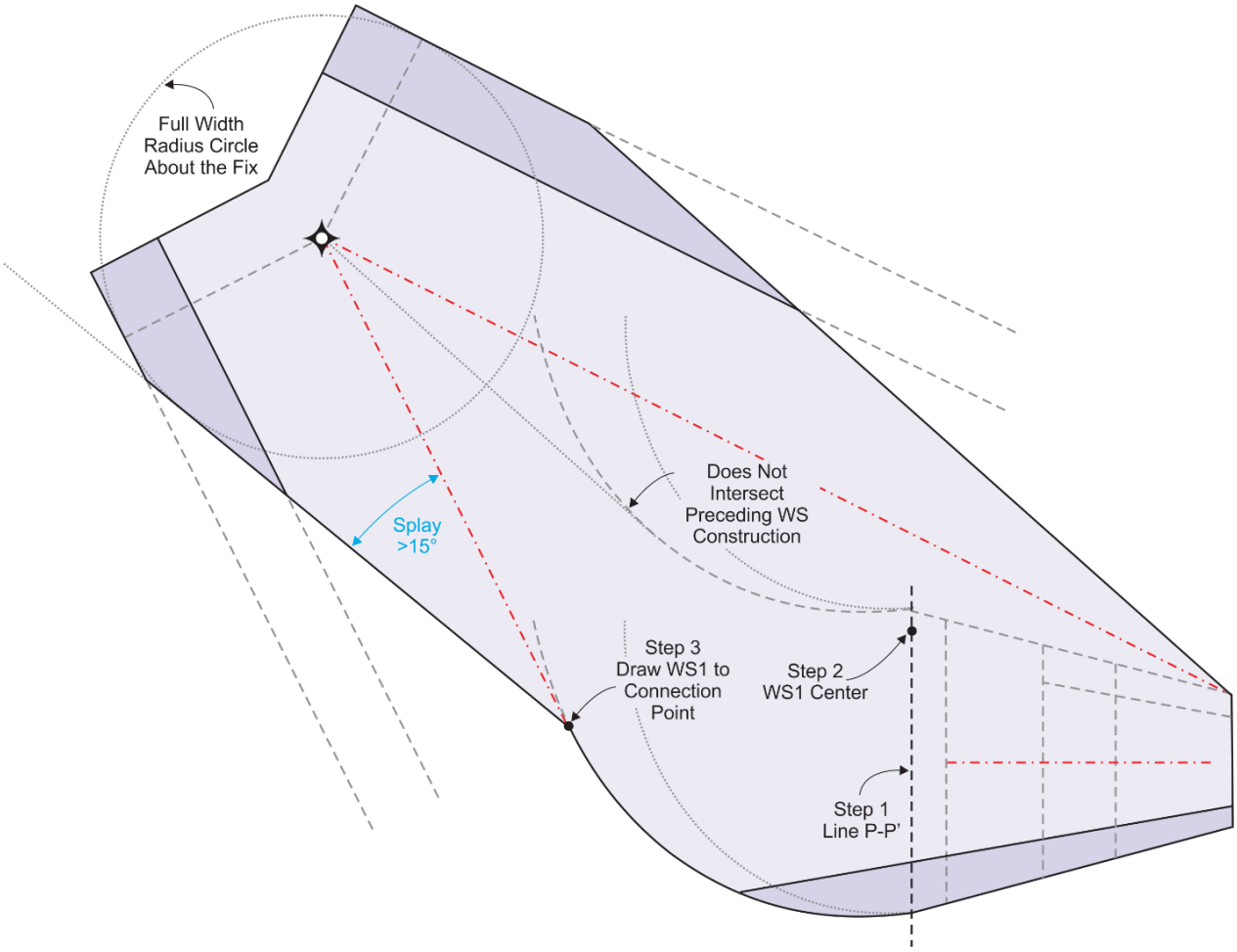
(2) First turn.

(a) Turn-at-altitude or turn-at-fix (FO).

1. *Step 1*. Construct the late-turn baseline (P-P') perpendicular to the straight missed approach track at the late-turn-point.

2. *Case 1*. Small turns using one WS [see figure 3-7-11].

Figure 3-7-11. Late/Outside Turn, First Turn, Case 1,Turn-at-Altitude or FO fix with 1 WS



a *Step 2*. Locate the WS1 center on line P-P' at no-wind turn radius distance from point P'.

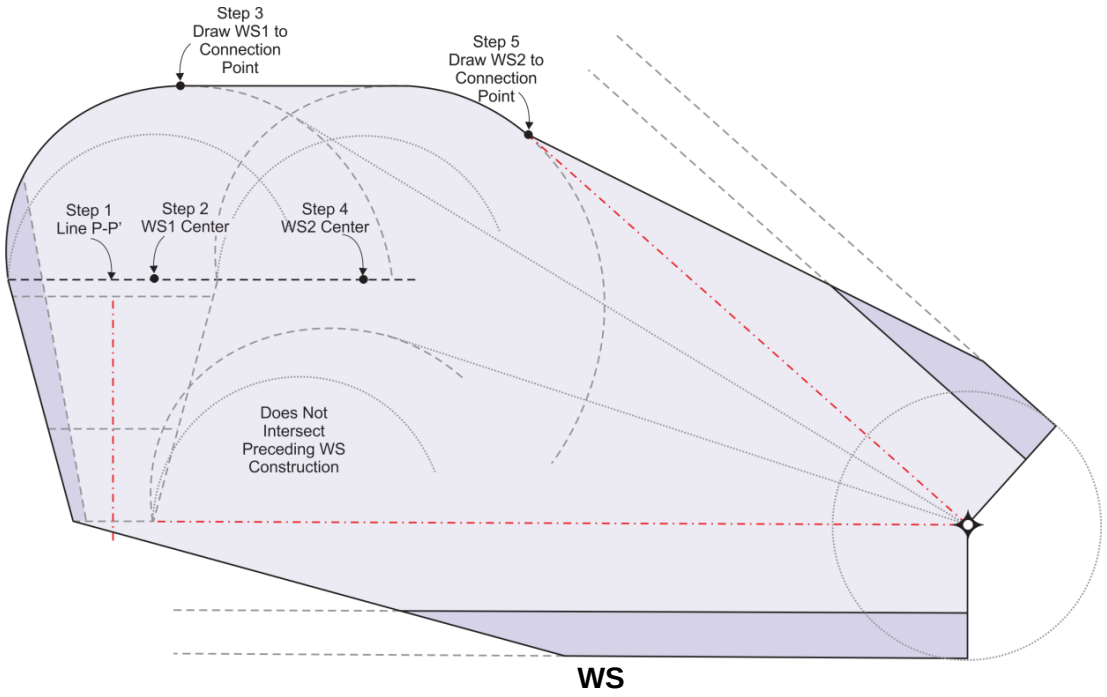
b *Step 3*. Construct WS1 from the outside-turn point in the direction of turn until reaching its connection point.

3. *Case 2*. Turns nearing or greater than 90 degrees using more than one WS [figure 3-7-12]. Apply *Steps 1-3* above, then:

a *Step 4*. Locate the WS2 center on P-P' at no-wind turn radius distance from point P.

b *Step 5*. Construct WS2 from the inside turn point in the direction of turn until reaching its connection point.

Figure 3-7-12. Late/Outside Turn, First Turn, Case 2, Turn-at-Altitude or FO fix with 2



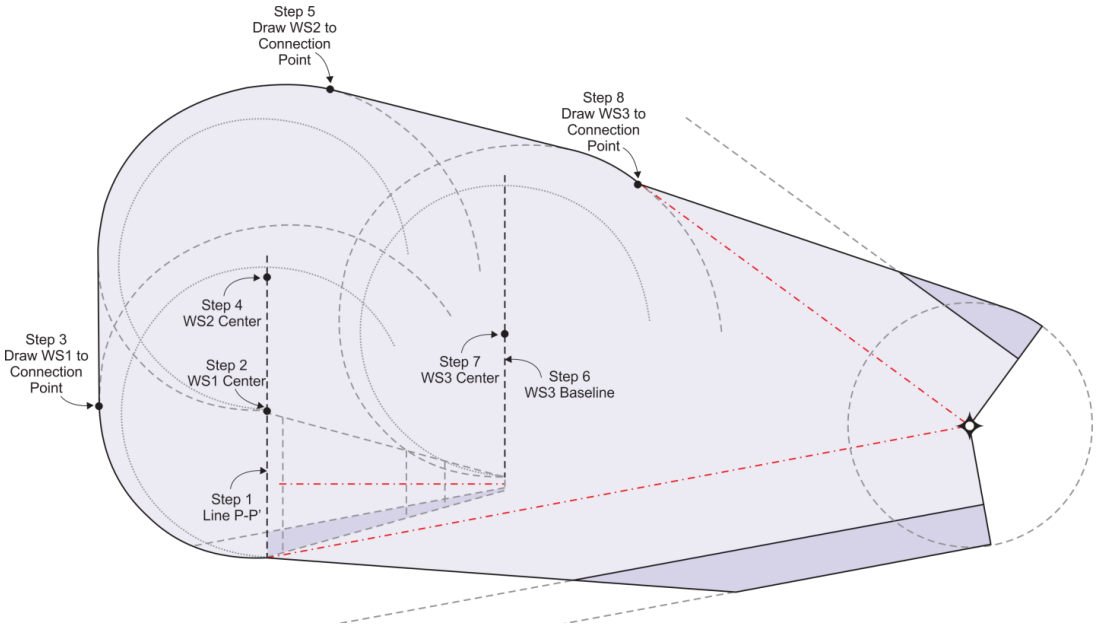
4. *Case 3*. Turns nearing or greater than 180 degrees using more than two WS [see figure 3-7-13]. Apply *Steps 1-5* above, then:

a *Step 6*. Construct the WS3 baseline perpendicular to the straight missed approach track along line C-D extended toward the turn side.

b *Step 7*.Locate the WS3 center on the baseline at no-wind turn radius distance from point C.

c *Step 8*. Construct WS3 from this point in the direction of turn until reaching its connection point.

Figure 3-7-13. Late/Outside Turn, First Turn, Case 3, Turn-at-Altitude or FO fix with 3

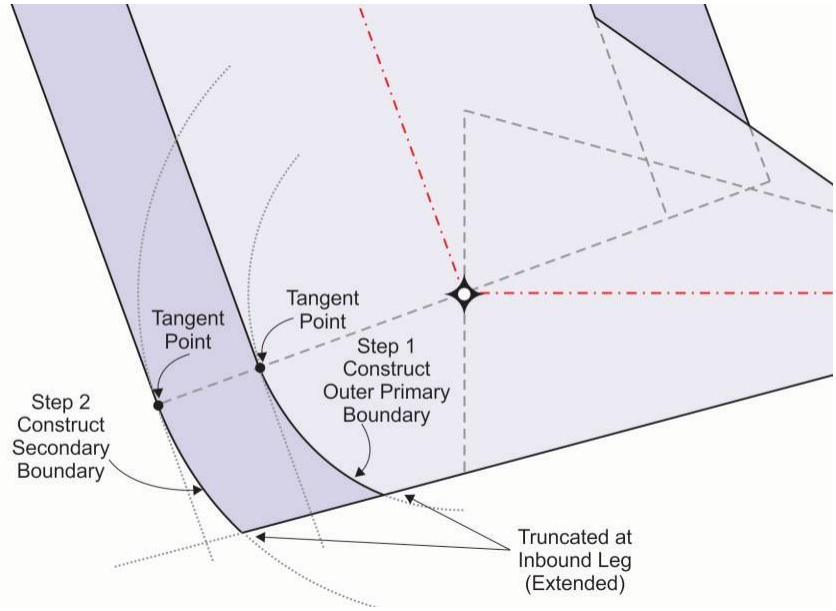


(b) Turn-at-fix (FB) [see figure 3-7-14].

1- *Step 1*. Construct the outer primary boundary using a radius equal to 2 × segment XTT centered on the plotted fix position, truncated at the inbound leg extended outer boundary until tangent to the outbound leg primary boundary.

2- *Step 2*. Construct the secondary boundary using a radius equal to 3 × segment XTT centered on the plotted fix position, truncated at the inbound leg extended outer boundary until tangent to the outbound leg secondary boundary.

Figure 3-7-14. Late/Outside Turn, First Turn, Turn-at-Fix (FB)



(3) Second turn.

(a)Turn-at-fix (FO) [see figure 3-7-15].

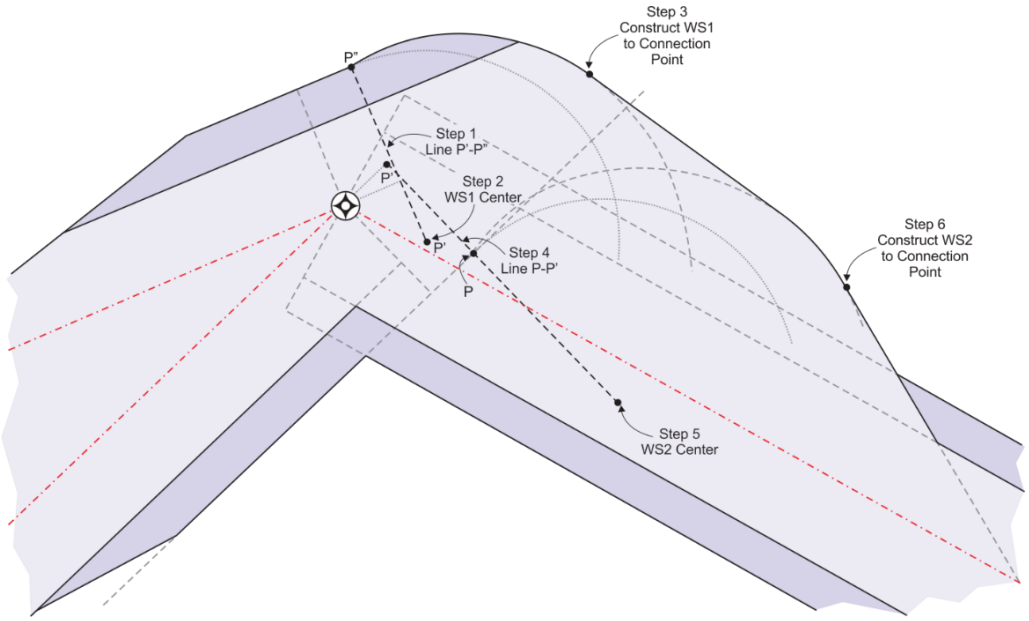
1- *Step 1.* Construct the WS1 baseline, (line P'-P") perpendicular to the DF track nearer the outside of the DF-TF turn, at the late turn point.

2- *Step 2.* Locate the WS1 center on line P'-P" at no-wind turn radius distance from point P."

3- *Step 3*. Construct WS1 from the outside turn point in the direction of turn until reaching its connection point.

4- *Step 4.* Construct the WS2 baseline, (line P-P') perpendicular to the DF track nearer the inside of the DF-TF turn, at the late turn point.

Figure 3-7-15. Late/Outside Turn, Second Turn, Turn-at-fix, FO



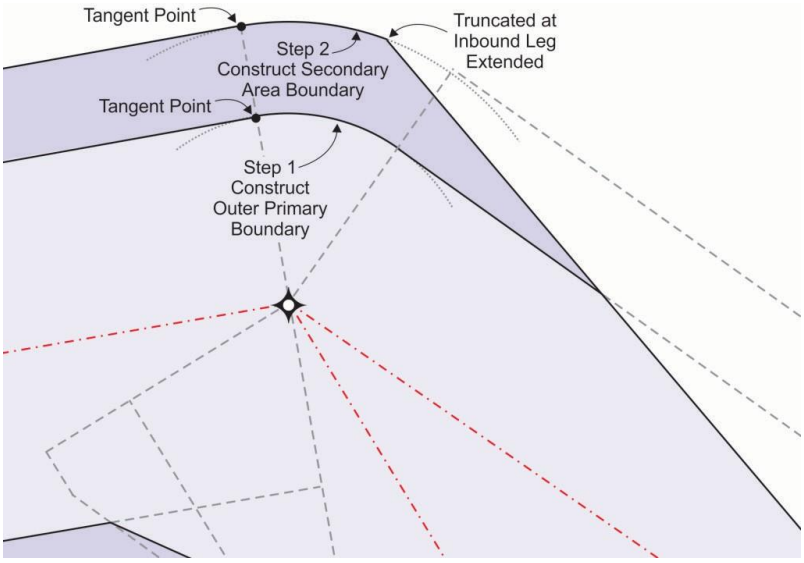
5- *Step 5.* Locate the WS2 center on line P-P' at no-wind turn radius distance from point P.

6- *Step 6.* Construct WS2 from the inside turn point in the direction of turn until reaching its connection point.

(b)Turn-at-fix (FB).

1- When the inbound leg outside boundary is less than full primary and secondary width reached perpendicular to the fix, construct in accordance with paragraph 3.7.3.b(2)(b) [see figure 3-7-16].

Figure 3-7-16. Late/Outside, Second Turn, Turn at FB fix, less than full OEA width



2. When the inbound leg outside boundary is full primary and secondary width perpendicular to the fix, construct in accordance with paragraph 1.2.5.d.

3.7.4. Obstacle Clearance Surface. Apply a sloping OCS [see paragraph 1.3.1.g and paragraph 3.7.1.c]. Calculate the aircraft SOC in accordance with paragraph 3.7.1.b. Where multiple measurements are required (e.g., a point of interest is equidistant from multiple primary boundaries, it lies along perpendiculars from multiple primary boundaries, etc.), apply the most adverse result from each of the combined primary/secondary measurements.

a. Primary area.

(1) Straight MA/TIA. Measure and apply the OCS slope from line A-B along the track distance to the point or abeam the point of interest [see figure 3-7-17].

(2) Turn-at-altitude (single and multiple legs). Apply the OCS slope along the shortest primary area distance from the TIA boundary to the point of interest [see figure 3-7-17 and figure 3-7-18, and figure 3-7-19].

(3) Turn-at-a-fix (single and multiple legs). Apply the OCS slope from line A-B (parallel to track) to L-L', then along the shortest primary distance to the point of interest [see figure 3-7-20]. A-RNP obstacle distance is measured as the along-track distance from line A-B to a point abeam the obstruction.

Note: The shortest primary area distance is the length of the shortest line kept within the primary area that passes through the early-turn baseline of all preceding legs.

Figure 3-7-17. OCS, Primary Area, Turn-at-Altitude, Single leg, Small Turn

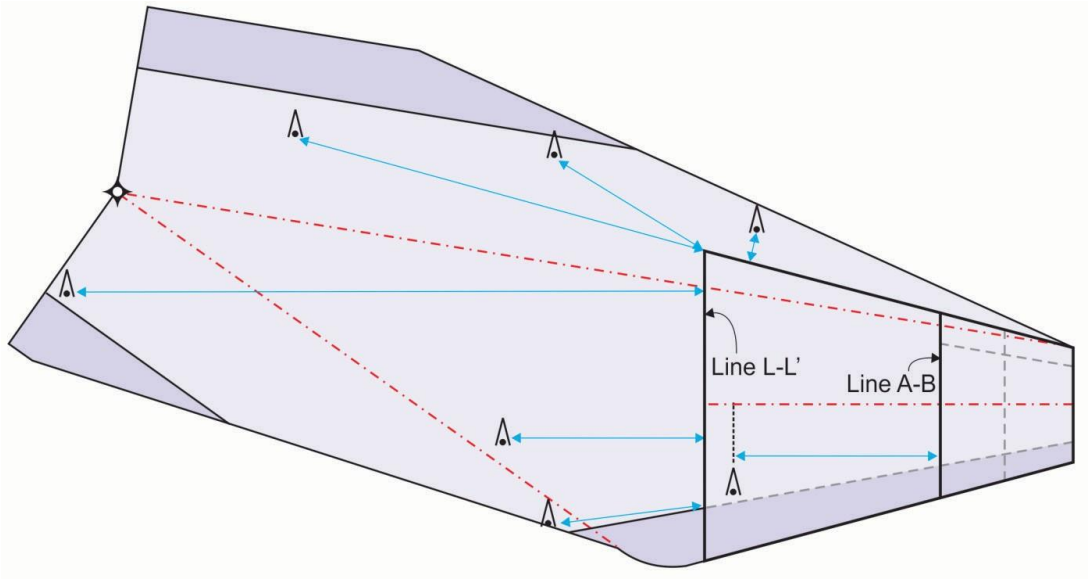


Figure 3-7-18. OCS Primary Area, Turn-at-Altitude, Single Leg, Large Turn

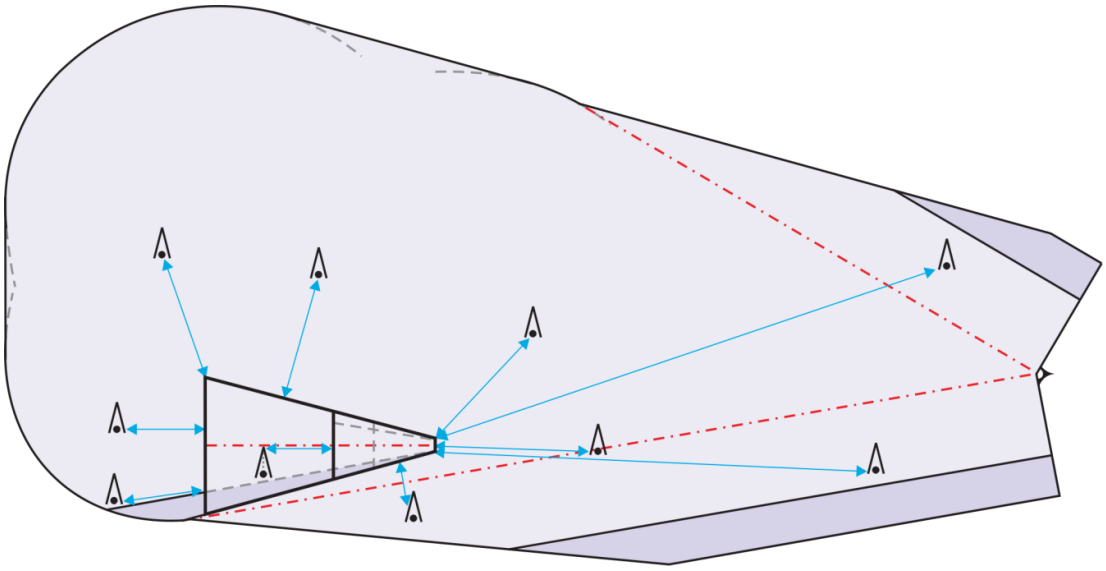


Figure 3-7-19. OCS, Primary Area, Turn-at-Altitude, Multiple legs

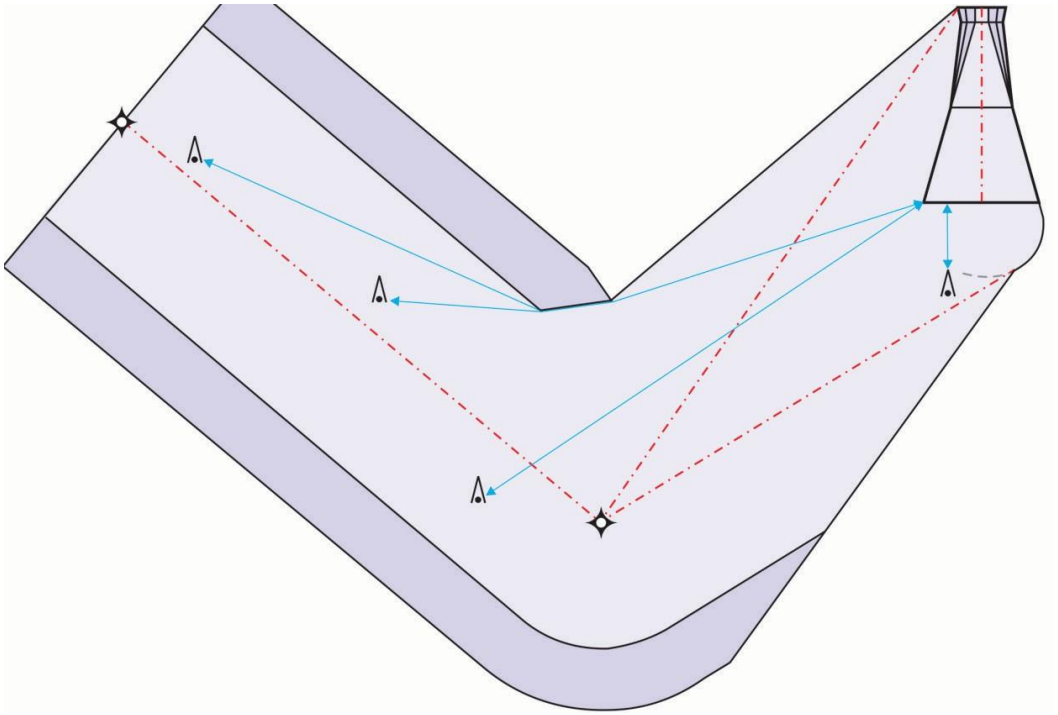
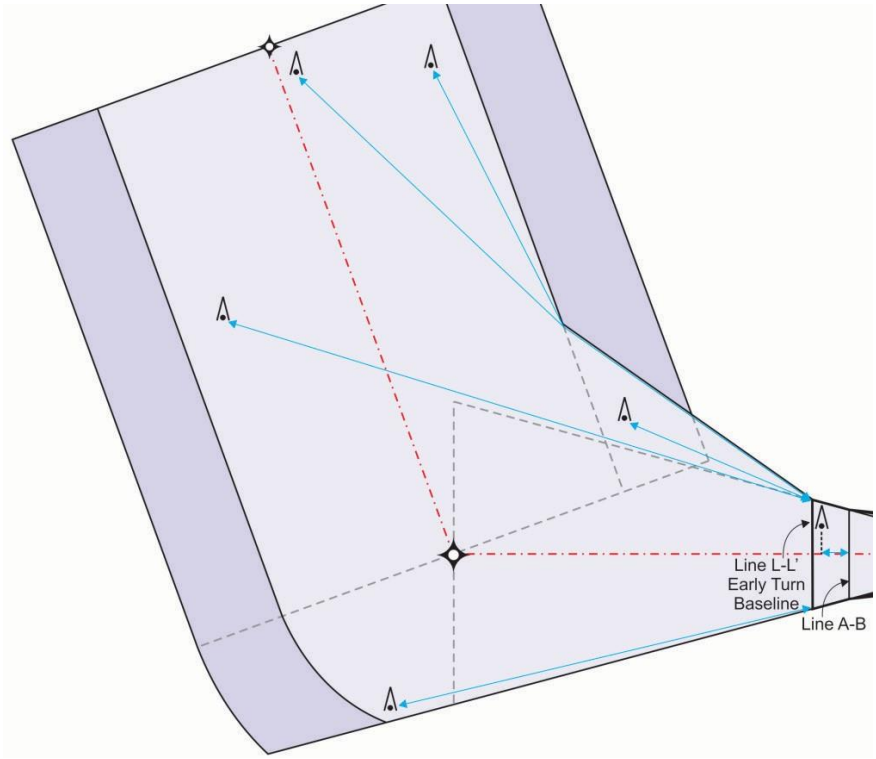
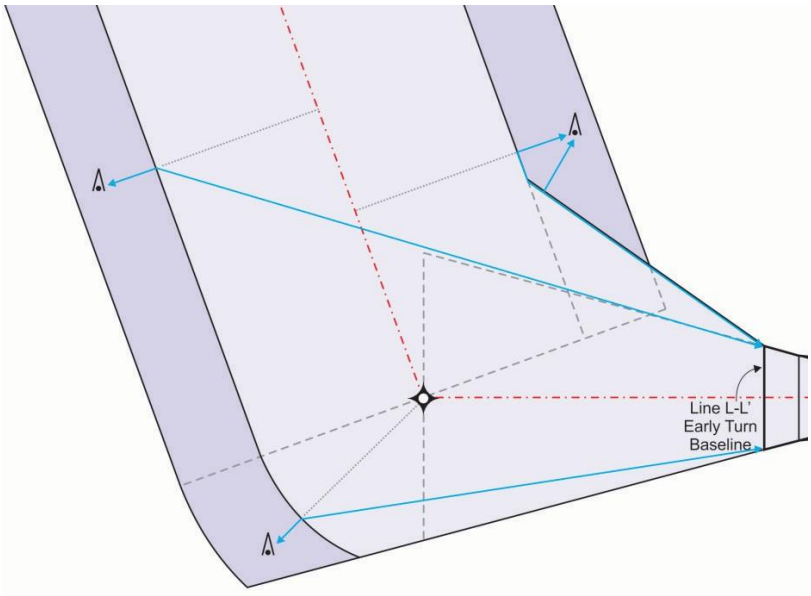


Figure 3-7-20. OCS, Primary Area, Turn at Fix



b. Secondary area. For secondary areas, calculate the primary OCS elevation as stated then apply a 12:1 OCS slope along the shortest secondary distance to the point of interest. In straight legs, this is normally perpendicular to the nominal track. In expansion areas, the slope rises in a direction perpendicular to the primary boundary (arc, diagonal corner-cutter, etc.) [see figure 3-7-21].

Figure 3-7-21. OCS, Secondary Area



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VOLUME 2: PERFORMANCE BASED NAVIGATION (PBN)

CHAPTER 4: RNAV (RNP) APPROACH

SECTION 4-1: GENERAL CRITERIA

4.1. Basic Criteria Information.

4.1.1. Concept and design. This chapter applies to procedures covered by the RNP AR APCH NavSpec. RF legs are preferred for turns but TF legs may be used for procedure simplification, or improved flyability (e.g. a small magnitude turn where the closeness of the waypoints leads to difficulty in charting). FO fixes that require turn construction are not authorized in RNP AR APCH segments.

a. OEA construction. Apply paragraph 1.2.5 with the following exceptions.

(1) Apply the largest RNP for the flight phase from table 1-2-1 unless a smaller value is required to achieve a desired ground track or is operationally required.

(2) RNP changes must occur at a fix and are linear (i.e., do not splay/taper 30 degrees relative to the course). RNP may be decreased as needed prior to the FAS. RNP changes must not occur in the FAS. After crossing the LTP/FTP, RNP values may only increase. See figure 1-2-1, figure 1-2-2, and figure 1-2-3 for illustrations of RNP changes.

(3) The length of any leg between the initial approach fix and the missed approach point may be reduced to not less than 0.2 NM (regardless of RNP) when there are no more than three waypoints within 1 NM along-track distance and there is no leg shorter than 1 NM prior to a change in RF turn direction. No turns (> 0.03 degrees) allowed when applying this to TF-TF connections. Avoid establishing reduced length legs in sequence to avoid negative impact on chart/display readability.

b. Use of NAVAIDS. Do not incorporate a VOR/DME or VORTAC into an RNP AR procedure if the geodetic coordinates of the VOR and DME source are not identical to 0.01 seconds, regardless whether the facilities are considered collocated.

c. Lines of minima. No more than four lines may be established. Circling minimums are not established.

(1) Establish a default line. The default line should be based on RNP 0.3 in the FAS and either a default RNP AR APCH [see paragraph 4.3.1.a(1)] or RNAV 1 [see paragraph 4.3.1.a(2)] missed approach. When RNP 0.3 line isn't possible, then the default line should be the largest value possible.

(2) When the HAT value of the default line is ≥ 300 or no-lights visibility ≥ 1 SM.

(a) Additional lines may be established when at least a 50-foot reduction in HAT or ¼ SM reduction in visibility can be achieved using one or more of the following (as appropriate);

1- Reduced FAS RNP (values < 0.3 but ≥ 0.10).

2- Reduced RNP MAS [see paragraph 4.3.1.a(3)].

3- MAS CG.

(b) Additional lines based on reduced RNP may also be established to meet operational requirements, e.g., to achieve track-to-airspace or track-to-track separation when these minima reductions cannot be achieved.

(c) When applying paragraph 4.1.1.c(2)(a) or 4.1.1.c(2)(b), a default line must still be published.

(3) A line based on reduced FAS RNP may be established to achieve minimum DA to FROP distance. A default line is not required in this case.

d. Use these criteria to develop RNP AR instrument approach procedures. The following basic conditions are considered in the development of obstacle clearance criteria for RNP approach procedures: The aircraft descends and decelerates from the en route environment or a terminal transition route through the initial/intermediate approach segments to the PFAF. The aircraft arrives at the DA and continues with visual reference to a landing on the runway or initiates a missed approach. The design of the instrument procedure defines the boundaries of the airspace within which the instrument operation will be conducted. This is the airspace that will “contain” (account for) all of the major factors influencing RNP: System accuracy, flight technical error, navigation system error, and error values that provide an acceptable level of continuity, availability, and integrity.

e. Visibility Minimums: See TP308/GPH209 Volume 1, chapter 3.

4.1.2. Feeder segment. Construct feeder segments as described in chapter 2 using one or more TF or RF legs. The NavSpec may be RNAV 1 (STAR/Feeder/Arrival flight phase with associated XTT of 1). When RF is used, the NavSpec is RNP 1 (STAR/Feeder/Arrival flight phase with associated XTT of 1). Optional NavSpec may be A-RNP (STAR/Feeder/Arrival flight phase with associated XTT of 2 or 1 as appropriate). Use an effective XTT of 2 where applicable per table 1-2-1 footnote 2. Secondary areas apply, except for A-RNP.

4.1.3. Initial segment. Construct initial segments as described in chapter 1 using one or more TF or RF legs. The NavSpec is RNP AR APCH (Initial flight phase with associated XTT of 1 – 0.1). Secondary areas do not apply.

4.1.4. Intermediate segment. Construct intermediate segments as described in chapter 1 using one or more TF or RF legs. The NavSpec is RNP AR APCH (Intermediate flight phase with associated XTT of 1 – 0.1). Secondary areas do not apply. FB turns at the PFAF are limited to a maximum of 15 degrees. See Appendix C for RF transition to ILS/GLS/LPV.

SECTION 4-2. FINAL APPROACH SEGMENT (FAS)

4.2. Final Approach Segment (FAS)

4.2.1. General. The NavSpec is RNP AR APCH (Final flight phase with associated XTT of 0.3 – 0.1). Secondary areas do not apply. RNP AR APCH ops are 3D procedures in which the aircraft provides the pilot with lateral and vertical path guidance and deviation information throughout the procedure. During the FAS, the aircraft provides either baroVNAV vertical guidance or SBAS LPV lateral and vertical guidance. The minimum HAT value is 250 feet.

a. Vertical path. Chapter 1 applies with the following additional guidance determining a PFAF on an RF leg.

(1) Use formula 4-2-1 and formula 4-2-2 to determine the PFAFs Cartesian coordinates relative to the LTP/FTP. The location of the PFAF may be calculated geodetically from these Cartesian values.

(a) *Step 1.* Determine the flight track distance from LTP/FTP to PFAF using formula 1-3-3.

(b) *Step 2*. Determine the distance from LTP/FTP to the FROP [see paragraph 4.2.2.b.].

(c) *Step 3*. Subtract *Step 2* from *Step 1* to calculate the distance around the arc to the PFAF from the FROP. Use formula 1-2-4 to determine number of degrees of arc; conversely, use formula 1-2-3 to convert degrees of arc to length.

Formula 4-2-1. PFAF on an RF Leg, Cartesian Coordinate "X" Value

$$X = d_{FROP} + R \times \sin(\alpha)$$

Where:
d_{FROP} = distance from LTP to final rollout point
α = degrees of arc
R= arc radius

Note: This formula works with any unit so long as d_{FROP} & R share the same unit.

Example:

X = 9420.55 + 19079 × sin(98.9)
X ≈ 28269.84

Formula 4-2-2. PFAF on an RF Leg, Cartesian Coordinate "Y" Value

$$Y = R - [R \times \cos(\alpha)]$$

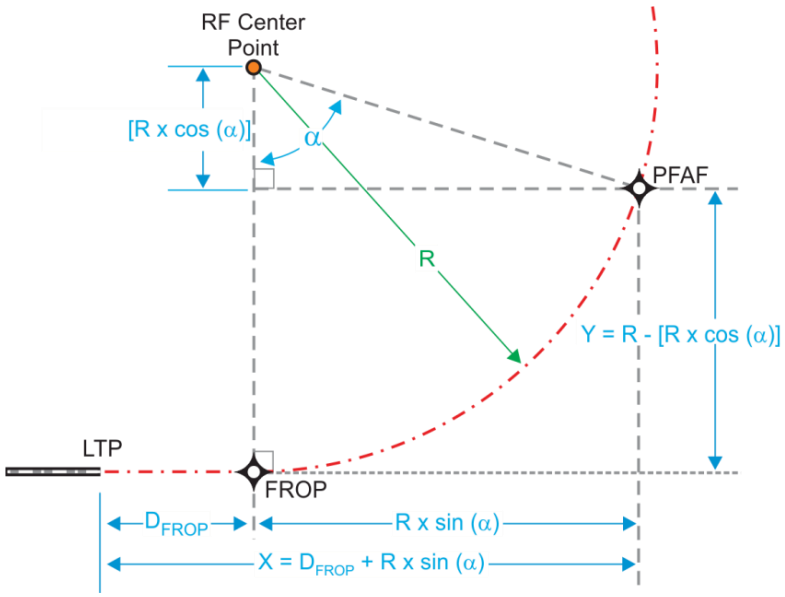
Where:
α = degrees of arc
R= arc radius

Note: This formula produces a value with the same unit as R.

Example:

$Y = 19079 - [19079 \times \cos(98.9)]$
$Y \approx 22030.72$

Figure 4-2-1. Calculating Cartesian Coordinates, PFAF on an RF leg



b. Restrictions. The true vertical path provided by baro-VNAV is influenced by temperature variations; i.e., during periods of cold temperature, the effective glidepath may be lower than published and during periods of hot weather, the effective glidepath may be higher than published. Because of this phenomenon, minimum and maximum temperature limits (for aircraft that are not equipped with temperature compensating systems) are published on the approach chart. Additionally, RNP AR approach procedures are not authorized where a remote altimeter setting source (RASS) is in use. See paragraph 3.3.4.a(1) to determine the critical temperatures and ΔISA_{LOW} for VEB calculations.

c. Precipitous terrain. Do not apply the 10 percent HAT increase identified in Vol 1 paragraph 3.2.2.b to RNP AR procedures.

4.2.2. Alignment.

a. The optimum alignment is a TF leg straight in from PFAF to LTP on runway centerline extended. If necessary, the TF course may be offset by up to three degrees. Where the course is offset, it must cross runway centerline extended at least 1500 feet (5200 feet maximum) out from LTP.

b. Turns in the FAS and final rollout point (FROP). TF-TF turns are not allowed in the FAS. Where turns are necessary in the FAS an RF leg must be established. The RF leg must terminate and be followed by a TF leg meeting FAS alignment at or prior to reaching the minimum FROP distance. The *minimum* FROP distance is the greater of the point on the vertical path 500 feet above LTP/FTP elevation (rounded to the nearest foot) or the point in the FAS at distance equal to 0.5 NM prior to the DA point. If an RF leg is the last leg in the intermediate segment, the PFAF must meet the minimum FROP distance. Use Formula 4-2-3 to determine FROP distance.

Formula 4-2-3. Minimum FROP distance

$$d_{500} = \frac{500 - \mathrm{TCH}}{\tan(\theta)}$$

$$d_{\mathrm{FROP}} = \text{greater of } d_{500} \text{ or } 0.5 \text{ NM} + \text{distance from LTP/FTP to DA}$$

Example:

$$d_{500} = \frac{500 - 47}{\tan(3)}$$

$d_{500} \approx 8643.75$ feet

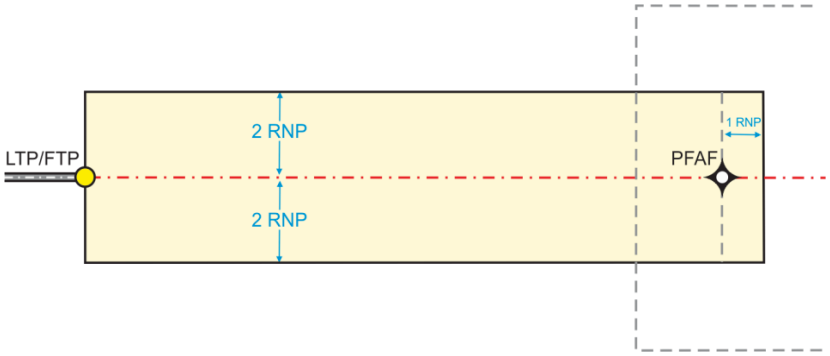
$d_{FROP} \approx 8643.75$ feet

4.2.3. Area.

a. Length. The final segment OEA begins 1 × RNP prior to the PFAF and extends to the LTP/FTP.

b. Width. The final segment OEA width is 2 × RNP either side of designed path [see figure 4-2-2].

Figure 4-2-2. Final Segment OEA



4.2.4. Obstacle clearance. An OCS based on the Vertical Error Budget (VEB) is applied. The VEB origin varies depending on whether the procedure is designed for aircraft with wingspans ≤ 262 feet (wide body) or aircraft with wingspans ≤ 136 feet (narrow body). Design for wide body aircraft by default. When the DA can be reduced by at least 50 feet or visibility reduced by ¼ mile or where wide body operations are not anticipated (e.g., where the airport/runway infrastructure cannot support wide body aircraft) the approach may be designed for narrow body aircraft. In either case, the procedure must be properly annotated [see Annex E, paragraph 4.6.10]. The VEB origin also varies depending on whether evaluating a TF or RF leg (with corresponding changes to the OCS height when both leg types are in the FAS).

a. Calculating the VEB. Total VEB is calculated by adding bias errors to four thirds times the standard deviation variations combined via the root sum square method. This is completed for both the PFAF and 250 feet above TDZE to determine the OCS slope and origin.

(1) Bias errors are:

(a) Body geometry error accounts for the low point of the aircraft below the altimeter reference point. This may be the landing gear for aircraft on straight legs, but it could be a wing tip for aircraft on RF legs.

1. Narrow body (BG_{NB}). Wingspan less than or equal to 136 feet.

a Straight legs: fixed at 15 feet

b RF legs: greater of 15 feet or $\frac{136}{2} \times \sin(\phi)$

2. Wide body (BG_{WB}). Wingspan less than or equal to 262 feet.

a Straight legs: fixed at 25 feet

b RF legs: greater of 25 feet or $\frac{262}{2} \times \sin(\phi)$

(b) International standard atmosphere temperature deviation (ISAD) is attributed to temperature induced altimeter error at the specified critical low temperature in relation to the airport ISA (ΔISA_{Low}) [see paragraph 4.2.1.b].

(c) Example bias error calculations.

$BG_{NB} = \frac{136}{2} \times \sin(\phi)$

$BG_{NB} = \frac{136}{2} \times \sin(18)$

$BG_{NB} \approx 21.01$ feet

$ISAD_{PFAF} = \frac{(PFAF_{alt} - LTP_{elev}) \times \Delta ISA_{Low}}{288 + \Delta ISA_{Low} - 0.5 \times 0.00198 \times PFAF_{alt}}$

$ISAD_{PFAF} = \frac{(4500 - 1200) \times (-20)}{288 + (-20) - 0.5 \times 0.00198 \times 4500}$

$ISAD_{PFAF} \approx -250.43$ feet

$ISAD_{250} = \frac{(TDZE + 250 - LTP_{elev}) \times \Delta ISA_{Low}}{288 + \Delta ISA_{Low} - 0.5 \times 0.00198 \times (TDZE + 250)}$

$ISAD_{250} = \frac{(1202 + 250 - 1200) \times (-20)}{288 + (-20) - 0.5 \times 0.00198 \times (1202 + 250)}$

$ISAD_{250} \approx -18.91$ feet

(2) Standard deviation variations are:

(a) Actual navigation performance error (ANPE). An aircraft is expected to be within a radius equal to the required navigation performance (RNP) for the leg 95% of the time. This additive accounts for the 5th percentile that may be operating outside of RNP.

(b) Waypoint precision error (WPR) contains the horizontal position error associated with the coordinate resolution stored in the database and flight management system (FMS) computational accuracy.

(c) Flight technical error (FTE), fixed at 75 feet, is a measure of the pilot and/or autopilot's ability to track the intended flight path.

(d) Altimetry system error (ASE) is the difference between the pressure altitude displayed to the pilot when referencing ISA and the free stream pressure altitude.

(e) Vertical angle error (VAE) relates to the ability of the FMS to determine incremental height above the reference point using distance and intended flight path angle.

(f) Automatic terminal information system (ATIS), fixed at 20 feet, is a conservative assumption that the reported altimeter setting is within 0.02 inches of mercury of the actual pressure value.

(g) Example standard deviation calculations.

$$\text{ANPE} = 1.225 \times \text{RNP} \times \frac{1852}{0.3048} \times \tan(\theta)$$

$$\text{ANPE} = 1.225 \times 0.14 \times \frac{1852}{0.3048} \times \tan(3)$$

ANPE ≈ 54.61 feet

$$\text{WPR} = 60 \times \tan(\theta)$$

$$\text{WPR} = 60 \times \tan(3)$$

WPR ≈ 3.14 feet

FTE = 75 feet

$$\text{ASE}_{\text{PFAF}} = -8.8 \times 10^{-8} \times \text{PFAF}_{\text{alt}}{}^2 + 6.5 \times 10^{-3} \times \text{PFAF}_{\text{alt}} + 50$$

$$\text{ASE}_{\text{PFAF}} = -8.8 \times 10^{-8} \times 4500^2 + 6.5 \times 10^{-3} \times 4500 + 50$$

$$\text{ASE}_{\text{PFAF}} \approx 77.47 \text{ feet}$$

$$\text{ASE}_{250} = -8.8 \times 10^{-8} \times (\text{TDZE} + 250)^2 + 6.5 \times 10^{-3} \times (\text{TDZE} + 250) + 50$$

$$\text{ASE}_{250} = -8.8 \times 10^{-8} \times (1202 + 250)^2 + 6.5 \times 10^{-3} \times (1202 + 250) + 50$$

$$\text{ASE}_{250} \approx 59.25 \text{ feet}$$

$$\text{VAE}_{\text{PFAF}} = \frac{\text{PFAF}_{\text{alt}} - \text{LTP}_{\text{elev}}}{\tan(\theta)} \times (\tan(\theta) - \tan(\theta - 0.01))$$

$$\text{VAE}_{\text{PFAF}} = \frac{4500 - 1200}{\tan(3)} \times (\tan(3) - \tan(3 - 0.01))$$

$$\text{VAE}_{\text{PFAF}} \approx 11.02 \text{ feet}$$

$$\text{VAE}_{250} = \frac{\text{TDZE} + 250 - \text{LTP}_{\text{elev}}}{\tan(\theta)} \times \big(\tan(\theta) - \tan(\theta - 0.01)\big)$$

$$\text{VAE}_{250} = \frac{1202 + 250 - 1200}{\tan(3)} \times \big(\tan(3) - \tan(3 - 0.01)\big)$$

$$\text{VAE}_{250} \approx 0.84 \text{ feet}$$

ATIS = 20 feet

(3) Example VEB calculations.

$$\text{VEB} = \text{BG} - \text{ISAD} + \frac{4}{3}\sqrt{\text{ANPE}^2 + \text{WPR}^2 + \text{FTE}^2 + \text{ASE}^2 + \text{VAE}^2 + \text{ATIS}^2}$$

$$\text{VEB}_{\text{PFAF}} = 21.01 + 250.43 + \frac{4}{3}\sqrt{54.61^2 + 3.14^2 + 75^2 + 77.47^2 + 11.02^2 + 20^2}$$

$$\text{VEB}_{\text{PFAF}} \approx 435.50 \text{ feet}$$

$$\text{VEB}_{250} = 21.01 + 18.91 + \frac{4}{3}\sqrt{54.61^2 + 3.14^2 + 75^2 + 59.25^2 + 0.84^2 + 20^2}$$

$$\text{VEB}_{250} \approx 189.16 \text{ feet}$$

b. Calculating the OCS slope. The OCS slope is calculated using formula 4-2-4.

Formula 4-2-4. VEB OCS Slope

$$\mathrm{OCS_{slope}} = \frac{(\mathrm{PFAF_{alt}} - \mathrm{TDZE} - 250) \times \tan(\theta)^{-1}}{\mathrm{PFAF_{alt}} - \mathrm{TDZE} - \mathrm{VEB_{PFAF}} - 250 + \mathrm{VEB_{250}}}$$

Where:
VEB_{PFAF} = amount of vertical error budget (feet) at the PFAF
VEB_{250} = amount of vertical error budget (feet) at a point 250 feet above TDZE

Example:

$$\mathrm{OCS_{slope}} = \frac{(4500 - 1202 - 250) \times \tan(3)^{-1}}{4500 - 1202 - 435.50 - 250 + 189.16}$$

$\mathrm{OCS_{slope}} \approx 20.76$

c. Calculating the OCS LTP/FTP to origin distance (d_{VEB}). The d_{VEB} is calculated with formula 4-2-5 by subtracting the distance required for the OCS to reach VEB_{250} below glidepath from the along glidepath distance projected from the threshold to a point 250 feet above TDZE.

Formula 4-2-5. VEB OCS Origin

$$\mathrm{d_{VEB}} = \frac{\mathrm{TDZE} + 250 - \mathrm{LTP_{elev}} - \mathrm{TCH}}{\mathrm{TAN}(\theta)} - (\mathrm{TDZE} + 250 - \mathrm{VEB_{250}} - \mathrm{LTP_{elev}}) \times \mathrm{OCS_{slope}}$$

Where:
VEB_{250} = amount of vertical error budget (feet) at a point 250 feet above TDZE

Example:

$$\mathrm{d_{VEB}} = \frac{1202 + 250 - 1200 - 55}{\mathrm{TAN}(3)} - (1202 + 250 - 189.16 - 1200) \times 20.76$$

$d_{VEB} \approx 2454.43$ feet

Formula 4-2-6. VEB OCS Elevation

$$\mathrm{OCS_{elev}} = \mathrm{LTP_{elev}} + \frac{\mathrm{d_{LTP}} - \mathrm{d_{VEB}}}{\mathrm{OCS_{slope}}}$$

Where:
d_{LTP} = along-track distance (feet) from LTP to the point of interest
d_{VEB} = distance (feet) from LTP to VEB OCS origin as per leg type

Example:

$$\mathrm{OCS_{elev}} = 1125.4 + \frac{19747.38 - 4063.28}{21.67}$$

$\mathrm{OCS_{elev}}$ ≈ 1849.17 feet

d. Obstacle evaluation. Use formula 4-2-6 to determine the VEB OCS elevation. Apply the OCS applicable to the leg type to the entire leg [see paragraph 1.2.5.b(1)(b) and Figure 4-2-3]. Obstacles that penetrate an OCS may be mitigated by one of the following:

(1) Reduce the RNP value for the leg or change the lateral path.

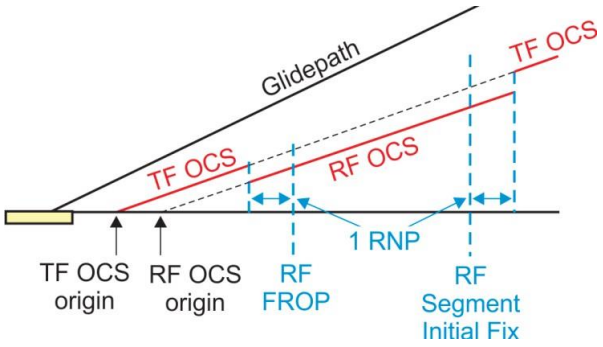
(2) Raise GPA.

(3) Raise TCH.

(4) Adjust the DA [see formula 4-2-7].

Note: The VEB slope and origin is impacted by changes to RNP, GPA, and/or TCH. When paragraphs 4.2.4.d(1), 4.2.4.d(2), and/or 4.2.4.d(3) are applied, the VEB must be recalculated and the OCS re-evaluated.

Figure 4-2-3. Final Segment OCS Elevation



Formula 4-2-7. DA Distance Based on VEB OCS Penetration

$$d_{DA} = d_{LTP} + p \times OCS_{slope}$$

Where:
p= penetration (feet) of the OCS
d_{LTP} = along track distance (feet) from the LTP/FTP to obstacle

Example:

$d_{DA} = 4514.5 + 8.3 \times 23.42$
$d_{DA} \approx 4708.89$ feet

e. Published decision altitude. If the FAS OCS is not penetrated, the minimum HAT value of 250 feet applies. Except when using an RNAV MAS [see paragraph 4.3.1.a(2)], the DA distance from LTP/FTP must also not be less than missed approach $d_{heightloss}$ [see formula 4-3-4] plus d_{VEB}.

SECTION 4-3. MISSED APPROACH SEGMENT (MAS)

4.3.1. General. The NavSpec is RNP AR APCH (Missed flight phase with associated XTT of 1 – 0.1). Secondary areas do not apply. Optional NavSpec may be RNAV 1 or A-RNP (Missed flight phase with associated XTT of 1 or 0.3) with secondary areas (except for A-RNP). Use of A-RNP missed approach XTT less than 1 should be avoided because it will limits the IFP availability to some users.

a. MAS RNP. Use of RNP < 1.0 in the missed approach may limit availability of the procedure. In order to serve the largest number of users, specify a default or RNAV MAS where possible.

(1) Default MAS (RNP AR APCH with RNP 1.0). Use except where not operationally beneficial. The construction is a continuation of the FAC. The OEA expands from the FAS RNP to an RNP value of 1.0.

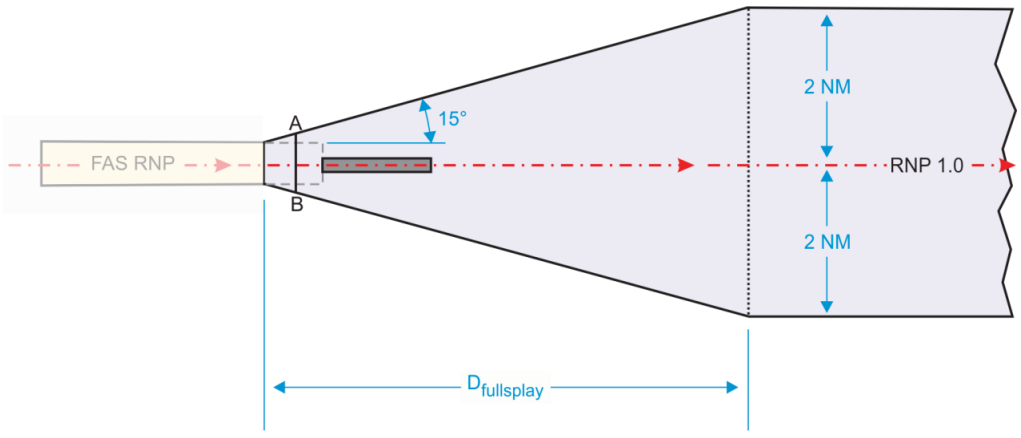
(2) RNAV MAS (RNAV 1 Missed flight phase). Use where operationally beneficial (i.e., turn-at-altitude construction to allow a turn earlier than permitted by default MAS construction).

(3) Reduced RNP MAS (RNP AR APCH with RNP <1.0). Use when previous options are not practical. Construct straight or turning (using RF legs) missed approach.

4.3.2. Default MAS OEA construction. Establish the MAS using TF and/or RF legs.

a. Straight. The MAS leg expands from the FAS OEA DA at an angle of at least 15 degrees relative to course centerline until reaching a width of ± 2 NM (RNP 1.0) [see figure 4-3-1]. RNP 1.0 width must be achieved at or prior to reaching the first missed approach fix or the clearance limit if no other fix exists beyond the DA. The along-track distance (NM) required to complete the splay ($D_{fullsplay}$) may be calculated using formula 4-3-1. When RNP 1.0 is not reached using a 15-degree splay, establish an RNAV MAS or splay at the angle required to reach ± 2 NM at the turn point/fix (S_{angle}).

Figure 4-3-1. Default MAS OEA, Straight



Formula 4-3-1. Along-Track Distance to Complete Splay

$$D_{fullsplay} = \frac{2 \times (1 - RNP_{FAS})}{\tan(S_{angle})}$$

Where:
RNP_{FAS}= RNP value (NM) of the final segment
S_{angle} = Missed approach OEA splay angle relative to the course centerline

Example:

$$D_{fullsplay} = \frac{2 \times (1 - 0.3)}{\tan(15)}$$

$$D_{fullsplay} \approx 5.22 \text{ NM}$$

b. Turning missed approach. Apply paragraph 4.3.2.a in conjunction with the following paragraphs.

(1) TF-TF connection. Use paragraph 1.2.5.d(1) in cases where RNP 1.0 width is achieved at a sufficient distance prior to the turn fix to permit construction. Otherwise, construct as follows:

(a) *Step 1*. Construct the leg following the turn fix (outbound leg) at full width.

(b) *Step 2*. Determine the DTA using formula 1-2-1. Establish point EB at the turn-side boundary of the inbound leg abeam the DTA. Establish point EE at the turn-side boundary of the outbound leg abeam the DTA.

(c) *Step 3.*

1. Case 1 [see figure 4-3-2]. Point EB is internal to the outbound leg OEA. In this case, no expansion is required. The area is a simple connection of the inbound and outbound leg boundaries.

2. Case 2 [see figure 4-3-3]. Point EB is external to the outbound leg OEA. In this case, expand the boundaries with a line connecting points EB and EE.

(2) TF-RF and RF-RF connections. Paragraph 1.2.5.d(3) applies.

Figure 4-3-2. Default MAS OEA Construction, Turning TF-TF Connection, Splay Greater than 15 degrees, Case 1

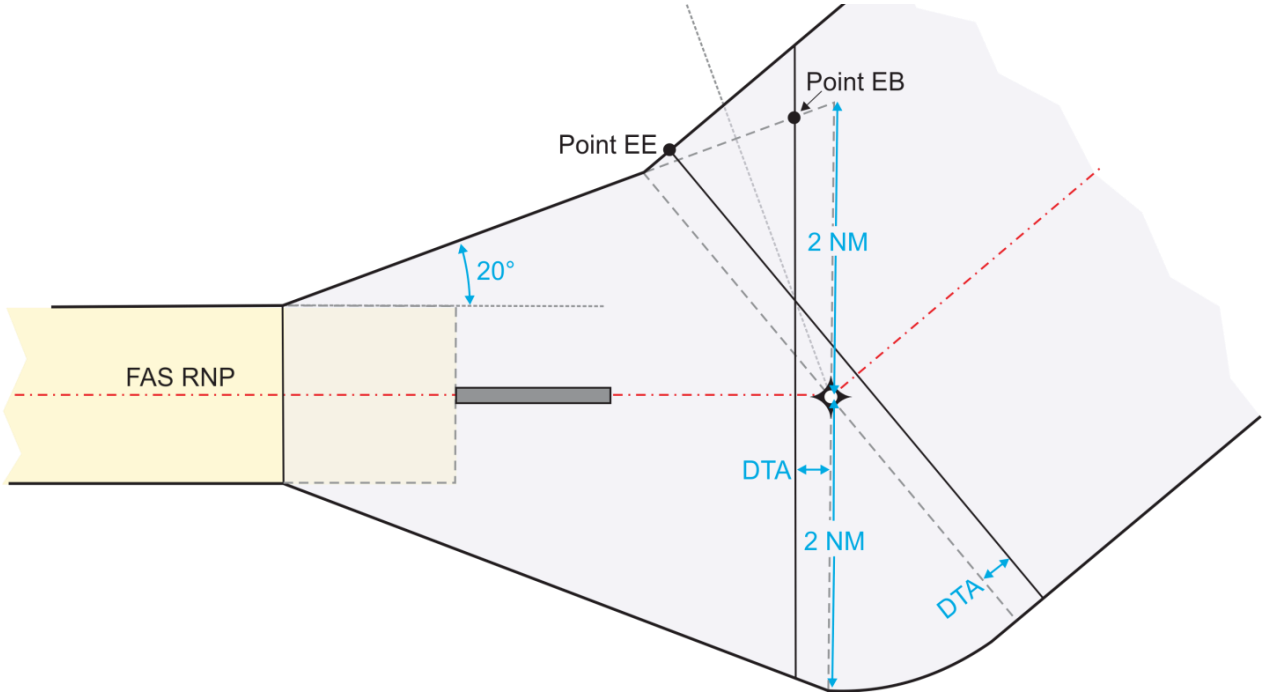
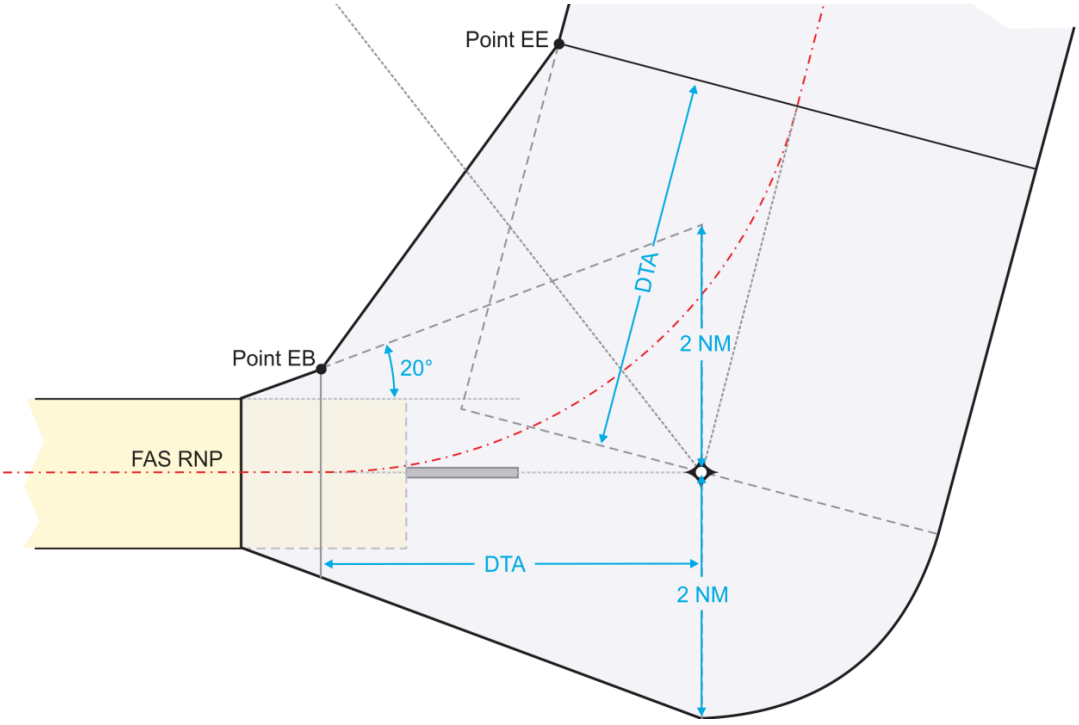


Figure 4-3-3. Default MAS OEA Construction, Turning TF-TF Connection, Splay Greater than 15 degrees, Case 2



4.3.3. RNAV MAS OEA construction [see figure 4-3-4]. Use LNAV/VNAV construction in accordance with section 3-5 and section 3-7 with the following exceptions;

a. DA must be no closer to LTP than the VEB OCS origin.

b. Paragraph 3.6.2 applies except the 15-degree OEA splay begins at the outer edge of the final OEA at the DA point instead of the final secondary area (i.e., the secondary start width is zero). Calculate the distance from course centerline to the primary and secondary boundary of the OEA at any distance from line C-D using formula 4-3-2.

Formula 4-3-2. RNP AR RNAV MAS Primary and Secondary Boundary

$$\mathrm{MAS_{Yprimary}} = \frac{\mathrm{D_{splay}} \times \tan(15) \times \ (1 - \mathrm{RNP_{FAS}})}{1.5 - \ \mathrm{RNP_{FAS}}} + 2 \ \times \mathrm{RNP_{FAS}}$$

$$\mathrm{MAS_{Ysecondary}} = \ \mathrm{D_{splay}} \times \tan(15) + 2 \ \times \mathrm{RNP_{FAS}}$$

Where:
$\mathrm{D_{splay}}$ = along-track distance (NM) from beginning of MAS splay to point of interest
$\mathrm{RNP_{FAS}}$ = RNP value (NM) of the final segment

Example:

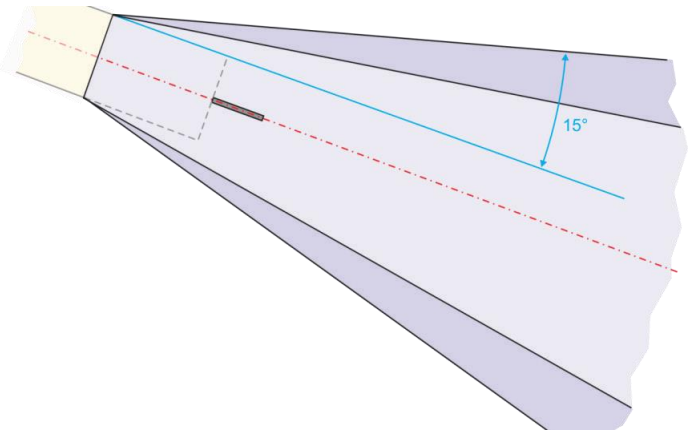
$$\mathrm{MAS_{Yprimary}} = \frac{4.48 \ \times \tan(15) \times \ (1 - 0.3)}{1.5 - \ 0.3} + 2 \ \times 0.3$$

$$\mathrm{MAS_{Yprimary}} \approx 1.3 \ \mathrm{NM}$$

$$\mathrm{MAS_{Ysecondary}} = \ 4.48 \ \times \tan(15) + 2 \ \times 0.3$$

$$\mathrm{MAS_{Ysecondary}} \approx 1.8 \ \mathrm{NM}$$

Figure 4-3-4. Missed Approach Segment, RNAV MAS Area



4.3.4. Reduced RNP MAS. Establish using TF and/or RF legs. See paragraph 1.2.5.b for OEA construction. Where turns are necessary, the turn must occur after passing 500 feet above airport elevation (rounded to the nearest foot) and where possible, not prior to the DER. At no point may the turn be specified prior to $D_{MASturn}$ from DA [see formula 4-3-3].

Formula 4-3-3. Reduced RNP MAS, Minimum Distance DA to Turn

$$D_{MASturn} = \frac{(V_{KTAS} + 15) \times 10}{3600}$$

Where:
V_{KTAS} calculated KTAS using DA and final segment KIAS for the fastest CAT

Example:

$$D_{MASturn} = \frac{(170.38 + 15) \times 10}{3600}$$

$$D_{MASturn} \approx 0.51 \text{ NM}$$

4.3.5. OCS evaluation. The following applies to default and reduced RNP missed approaches. For RNAV missed approaches see sections 3-5, 3-6, and 3-7.

a. General. The OCS is composed of sections 1a and 1b, which are separated by line A-B.

(1) Section 1a. The OCS extends from the DA point downward at the VEB OCS slope ratio for a distance of $d_{heightloss}$ using formula 4-3-4 measured along the final course track to line A-B.

Formula 4-3-4. Height Loss Distance

$$d_{heightloss} = \frac{50}{\tan(\theta)}$$

Example:

$$d_{heightloss} = \frac{50}{\tan(3)}$$

$$d_{heightloss} \approx 954.06 \text{ feet}$$

(2) Section 1b OCS. From line A-B, section 1b OCS rises at a 40:1 slope Calculate the HMAS at line A-B using formula 4-3-5. Obstacle distance is measured as the along-track distance from line A-B to a point abeam the obstruction.

Formula 4-3-5. HMAS at line AB

$$\mathrm{HMAS} = \mathrm{LTP_{elev}} + \frac{\mathrm{d_{DA}} - \mathrm{d_{VEB}} - \mathrm{d_{heightloss}}}{\mathrm{OCS_{slope}}}$$

Where:
$\mathrm{d_{DA}}$ = distance (feet) from LTP to DA
$\mathrm{d_{VEB}}$ = distance (feet) from LTP to VEB OCS origin
$\mathrm{d_{heightloss}}$ = distance (feet) required to lose 50 feet on glidepath

Example:

$$\mathrm{HMAS} = 1200 + \frac{3758.74 - 2454.55 - 954.06}{20.76}$$

$$\mathrm{HMAS} \approx 1216.87 \text{ feet}$$

b. OCS penetrations. Obstacles must not penetrate the OCS. Where obstructions penetrate the OCS, mitigate using one or more of the following actions:

(1) Revise the MAS course.

(2) Specify a MAS climb gradient [see paragraph 1.3.1.g(2)].Calculate the altitude above which the climb gradient is no longer required using formula 4-3-6. This altitude is used in formula 1-3-7 to calculate the required climb gradient.

Note: If the climb gradient exceeds 425 ft/NM, evaluate the MAS using the OCS slope appropriate for 425 ft/NM (18.82:1) and adjust DA for the remaining penetration per paragraph 4.3.5.b(3).

Formula 4-3-6. CG Termination Altitude

$$\mathrm{CG_{term}} = \frac{(\mathrm{O_{MSL}} - \mathrm{OCS_{start}}) \times 8000 \times 0.3048}{1852} + \mathrm{AC_{start}}$$

Where:
$\mathrm{O_{MSL}}$ = obstacle MSL elevation
$\mathrm{OCS_{start}}$ = starting altitude (feet) of the OCS
$\mathrm{AC_{start}}$ = starting altitude (feet) of the aircraft (e.g., SOC)

Example:

$$\mathrm{CG_{term}} = \frac{(2147.41 - 1217.37) \times 8000 \times 0.3048}{1852} + 1402$$

$$\mathrm{CG_{term}} \approx 2626.52 \text{ feet}$$

(3) Adjust DA. To determine the DA required for an OCS penetration, calculate the HAT adjustment using formula 4-3-7 and add the result to the original DA. Use formula 1-3-3 to determine adjusted DA distance from the LTP/FTP.

Formula 4-3-7. HAT Adjustment for MAS OCS Penetration

$$\Delta DA = \frac{p \times \tan(\theta) \times MAS_{slope} \times FAS_{slope}}{MAS_{slope} + FAS_{slope}}$$

Where:
$p =$ penetration (feet) of the MAS OCS
$MAS_{slope} =$ missed approach OCS slope ratio
$FAS_{slope} =$ final approach OCS slope ratio

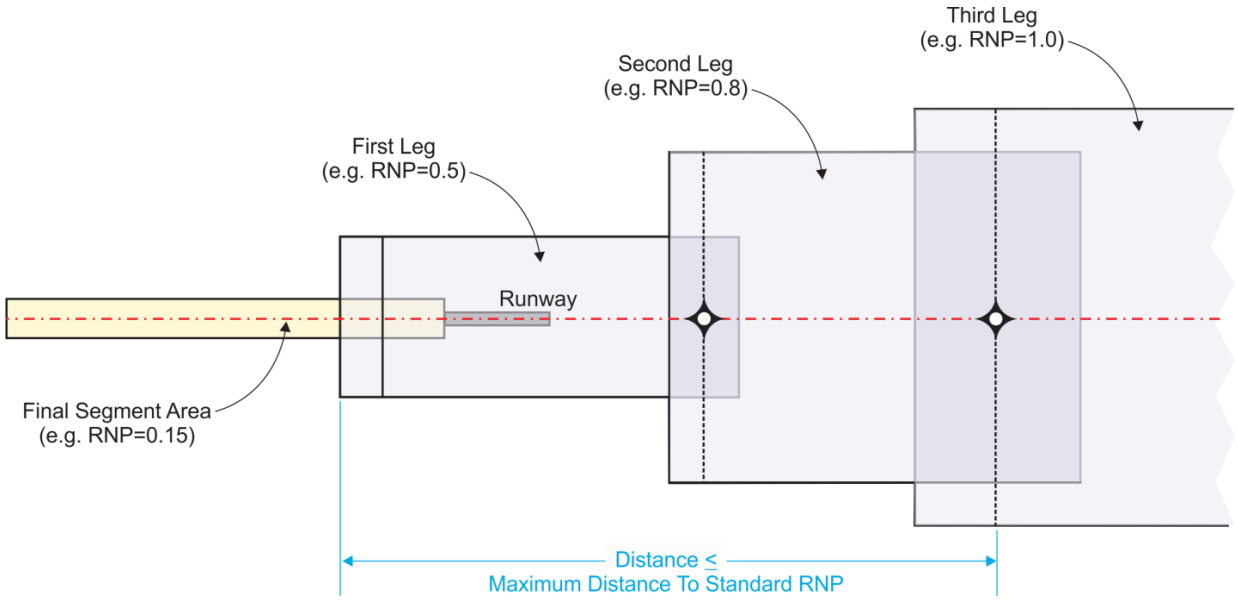
Example:

$$\Delta DA = \frac{19.3 \times \tan(3) \times 40 \times 23.42}{40 + 23.42}$$

$\Delta DA \approx 14.94$ feet

(4) Specify a reduced RNP MAS leg [see paragraph 4.3.1.a(3)].Apply the reduced RNP MAS leg only as far as needed to clear the penetrating obstruction(s) and specify the largest RNP value possible. Calculate the maximum length of the reduced RNP leg using formula 4-3-8 [see figure 4-3-5]. A reduced RNP MAS leg must be a TF or RF leg.

Figure 4-3-5. Maximum Length Reduced RNP MAS



Formula 4-3-8. Max Length Reduced RNP MAS Leg

$$D_{MASRNP} = (RNP_{MAS} - 0.05) \times \frac{V_{KTAS} - 10}{8}$$

Where:
RNP_{MAS} = RNP value (NM) of the missed approach segment
V_{KTAS} = calculated KTAS using DA and final approach KIAS for the slowest CAT

Example:

$$D_{MASRNP} = (0.5 - 0.05) \times \frac{92.93 - 10}{8}$$

$$D_{MASRNP} \approx 4.66 \text{ NM}$$

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VOLUME 2: PERFORMANCE BASED NAVIGATION (PBN)

CHAPTER 5: DEPARTURE PROCEDURES

SECTION 5-1: GENERAL CRITERIA

5.1. General Criteria.

5.1.1. General. The NavSpec is RNAV 1 or RNP 1 (Departure flight phase with associated XTT of 1). Optional NavSpec may be A-RNP (Departure flight phase with associated XTT of 1 or 0.3) or RNP AR DP (Departure flight phase with associated XTT of 1 - 0.3). Use of A-RNP departure XTT less than 1 is not authorized. RNP AR DPs are established using TF and/or RF legs. Secondary areas apply, except for RNP AR DP and A-RNP.

a. ICA. Departure procedures begin with an ICA constructed in accordance with Vol 1, paragraph 12.1.6, except where modified by this order.

(1) The ICA must be long enough to allow LNAV engagement (500 feet above airport elevation (rounded to the nearest foot)).

(2) Use formula 1-3-9 to determine ICA length. Where a higher than standard climb gradient terminates prior to the minimum turning altitude, the ICA length will be the distance required to reach the CG termination altitude plus the distance between that altitude and the turning altitude at the reduced CG.

(3) An RNP AR departure with an RF turn at DER has no ICA. The OEA is constructed using a 15-degree splay relative to RF track originating from +/- 500 feet either side of DER (ICAB) [see figure 5-3-8].

b. Leg type limitations. See Annex E, paragraph 4.6.7.k for permissible leg types.

Note: The ‘AER’ in Annex E, table 4-1-1 is for coding purposes. Bearings and distances used for OEA construction and leg length analysis are not measured from the AER.

(1) VA leg. VA legs are all-primary area and the initial departure course is aligned within 15 degrees of the extended runway centerline [see paragraph 5.2.1].

(2) VI leg. VI legs are all-primary area and the initial departure course is aligned with extended runway centerline [see paragraph 5.2.1]. VI legs are associated with CF legs and due to possible Flight Management System route discontinuity, course changes of less than 10 degrees to intercept the CF leg are not authorized.

(3) DF leg. Secondary areas apply once the 15-degree splay from course line (early and late) have reached full primary width. DF-DF is only authorized when the first DF fix is within 15 degrees of the extended runway centerline.

(4) CF leg. Secondary areas apply once the 15-degree splay from course has reached full primary width or as defined in the turning departure section.

c. Leg length. Comply with paragraph 1.2.5.b(1) with the following exceptions.

(1) Do not develop legs exceeding 260 NM to ensure the geodesic path does not exceed the protected airspace for a great circle path.

(2) For LNAV engagement, the first leg must be designed to end at least 500 feet above airport elevation (rounded to the nearest foot). Only use a higher than standard CG for LNAV engagement when there is an operational need to bring the first turn closer to DER.

(3) The maximum allowable VA or VI leg length is 10 NM.

(4) For FO DF leg length feasibility check see appendix B.

SECTION 5-2. STRAIGHT DEPARTURE

5.2. Straight departure.

5.2.1. General.

a. VI is a straight departures leg and is aligned with runway centerline extended. VA, DF, CF, and TF are straight departure legs and are aligned within 15 degrees of the runway centerline. Evaluate straight departure legs in accordance with Vol 1, paragraph 12.3.1 with the following provisions:

(1) The ICA is aligned along the runway centerline (departure course for helicopter departures from a takeoff area that supports IFR procedures) for the distance required for a climb to 500 feet above airport/heliport elevation (rounded to the nearest foot).

(2) Continue splay until reaching basic area width as defined in chapter 1. If an A-RNP or RNP AR DP value is selected that results in an OEA narrower than the ending ICA width, taper inward at 30 degrees relative to course to join edge of primary area [see figure 5-2-2].

(3) The departure may not be offset from runway centerline when the first turn is an RF and the straight segment hasn't reached full OEA width construction [see paragraph 1.2.5.d].

(4) Straight route departure criteria apply only to the first course from DER. Any turn after the first departure course must be evaluated using turning criteria.

Figure 5-2-1. Straight Departure

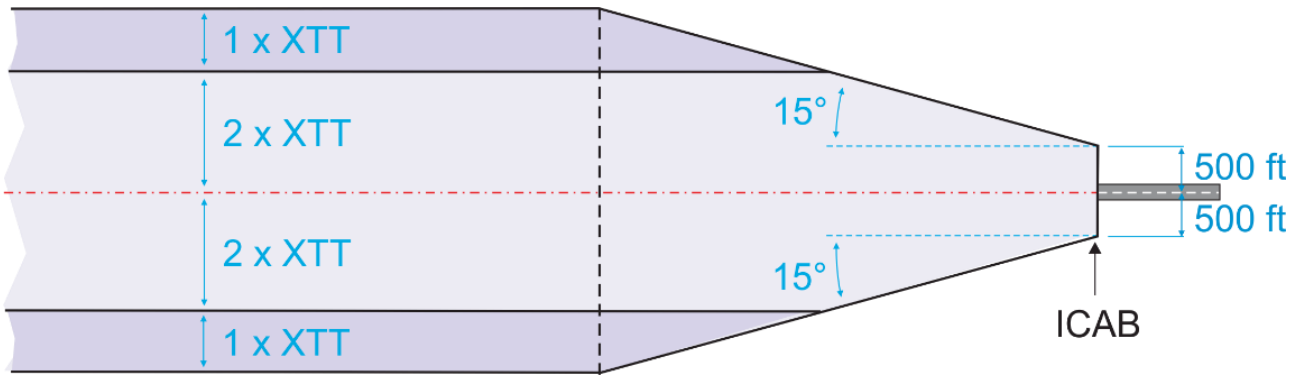


Figure 5-2-2. Straight Departure with 30-Degree Inward Taper

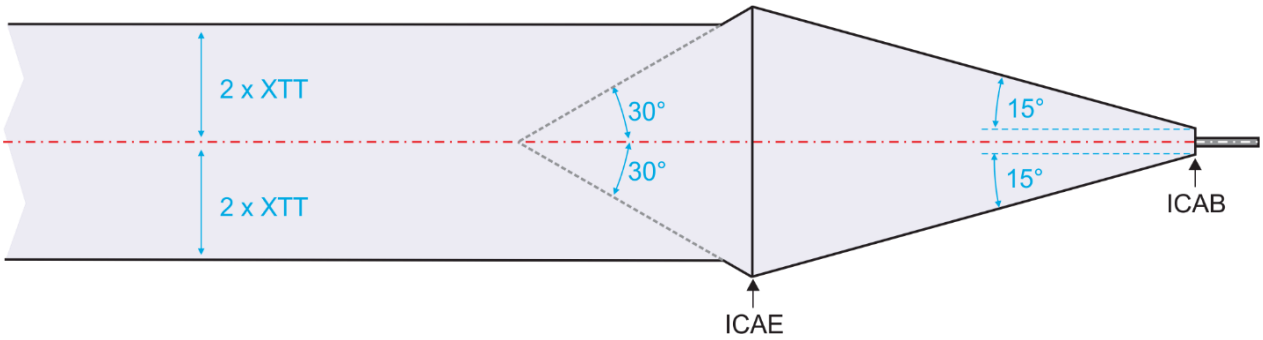
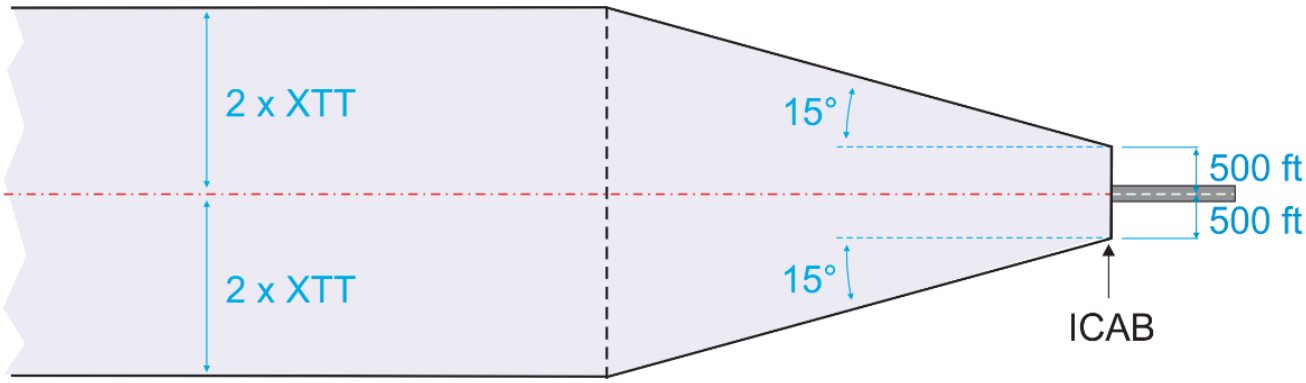


Figure 5-2-3. Straight RNP AR DP



SECTION 5-3. TURNING DEPARTURES

5.3. Turning departure.

5.3.1. General.

a. Early and inside turn construction.

(1) First turn. The first turn may be a FB or FO fix or may follow a VA or VI leg.

(a) Turn following VA leg (turn-at-altitude). The turn altitude will either be the minimum required altitude, operationally specified, or determined by obstacle evaluation. The specified turn altitude must equal or exceed the ICA end aircraft altitude.

1- The OEA consists of the ICA/straight segment, section 1, and section 2. Excluding the ICA, section 1 is defined as the OEA on the DER side of the DRL. Section 2 is the OEA on the SER side of the DRL
.

2- Construct the ICA/straight segment from the ICAB to line L-L'. Because straight segment length and the OCS elevation at L-L' are dependent on aircraft altitude, establishing an obstacle-based turn altitude may be an iterative process. If an A-RNP value is selected that results in an OEA narrower than the ending ICA/straight segment width, taper inward at 30 degrees relative to course.

3- OEA construction after ICA/straight segment [see table 5-3-1 and figure 5-3-1].

Table 5-3-1. Early-Turn Tie-Back Points

Turn Angle (measured from RWY C/L ICAE intersection)	Tie-Back Point
≤ 165 degrees	DRP
> 165 degrees	Point P'

a *Step 1.* Construct a line (representing the early-turn flight track) from the tie-back point, to the fix.

b *Step 2.* Construct the inner primary and secondary OEA boundary lines parallel to this line.

c *Step 3.* From the tie-back point, construct a line splaying at 15 degrees to intersect the parallel boundary lines or segment end, whichever occurs earlier. Apply secondary areas only after the 15-degree splay line intersects the primary boundary line. Where the inside turn boundary intersects the ICA inside 15-degree splay line the boundary must be a line connecting the DRP, point A, and full width point or original splay width abeam fix if full width has not been reached [see figure 5-3-2].

Figure 5-3-1. VA-DF Early/Inside Turn Construction after ICA

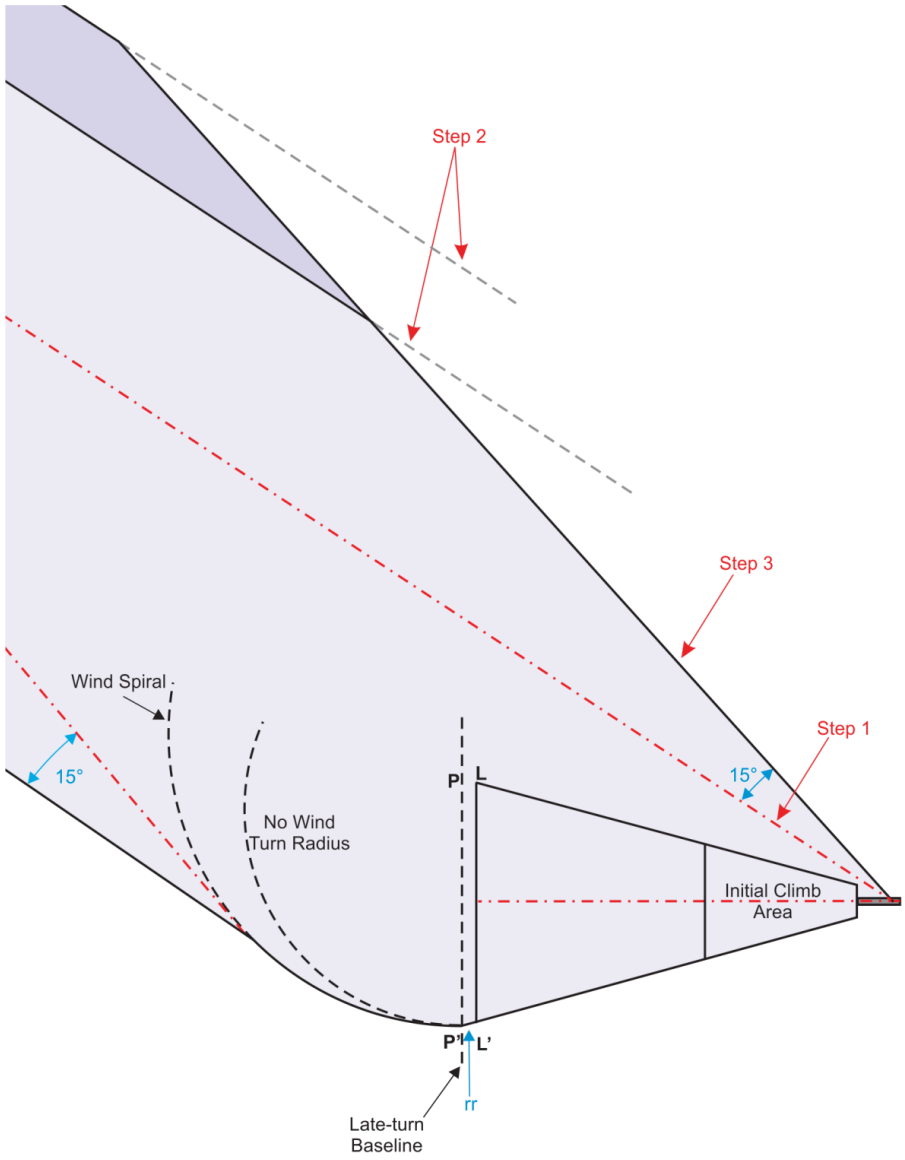
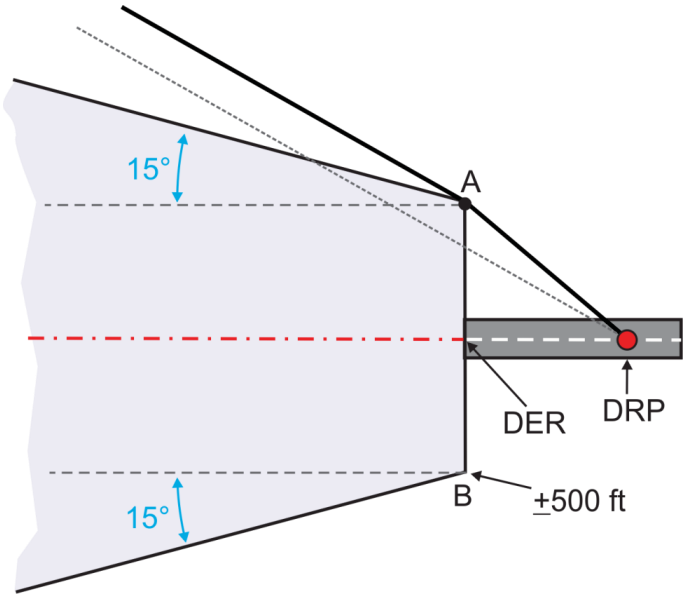


Figure 5-3-2. VA Leg Construction Alternate Inside Boundary



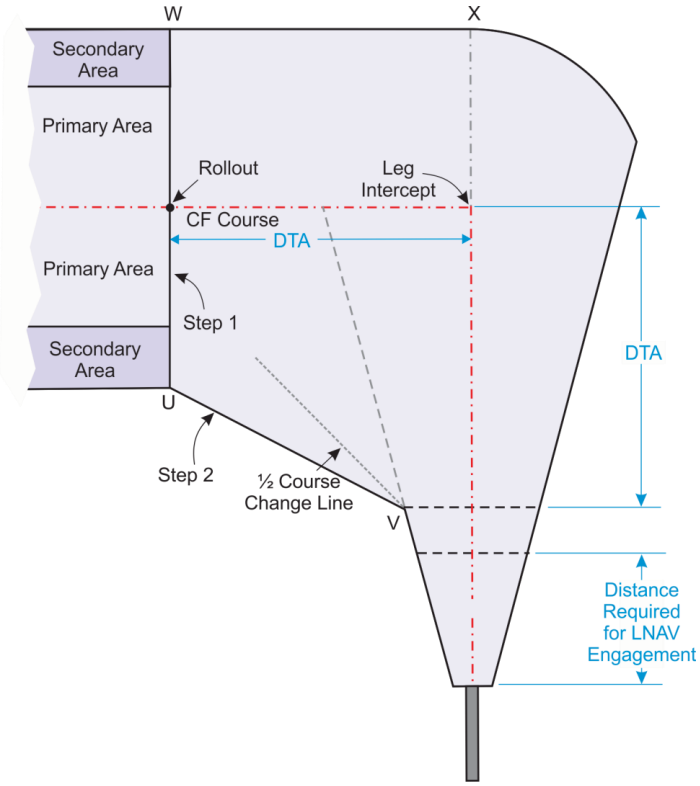
(b) Turn following VI leg. The VI leg contains an ICA constructed in accordance with paragraph 5.1.1.a terminating where LNAV engagement is reached (500 feet above airport elevation (rounded to the nearest foot)). The VI leg OEA is all primary area; secondary area may be applied in the CF leg at the rollout point.

1- OEA construction. Inside expansion starts where the VI DTA area begins (point V) with an angle drawn at one-half of the course change at leg intercept and ends where the angle converges with CF leg secondary boundary. Where the angle does not converge with secondary boundary, draw a line from point V to the inside secondary area boundary abeam the rollout (point U) for area completion [see figure 5-3-3].

a *Step 1.* Along the CF leg course, construct a line perpendicular to the CF leg at a distance from the intercept point equal to the calculated DTA based on the altitude at leg intercept. At the rollout point, the CF leg OEA is the full combined width of the primary and secondary areas.

b *Step 2.* Construct a line (representing the early-turn flight track) from the VI DTA (point V), to the CF leg full width abeam the rollout point.

Figure 5-3-3. Standard VI-CF Construction, 90-Degree Turn



2- Minimum VI-CF leg combination construction. Where a short initial departure leg must be developed, the VI leg length may be designed to the greater of 1 NM from DER or the distance required to climb 500 feet above airport elevation (rounded to the nearest foot). For this early turn, the OEA is modified to be somewhat like a FB fix turn for inside expansion and additional protection is also provided for outside area expansion built similarly to a FO fix turn.

a For turns of 30 degrees or less, splay 15 degrees relative to the CF leg course from point ICAB and continue this line until intersecting the CF leg secondary area boundary [see figure 5-3-4]. The secondary area begins where this line crosses the primary area boundary.

b For turns of more than 30 degrees, the inside boundary is from the DRP to the inside secondary area boundary abeam the rollout (point R). From point R, the secondary area tapers 30 degrees inward relative to the CF leg course until the CF leg standard primary area boundary [see figure 5-3-5 thru figure 5-3-7].

c CF leg construction. Along the CF leg course, a rollout point is established from leg intercept at a distance of the calculated DTA, based on the altitude at leg intercept. Establish a full primary and secondary width OEA at the rollout point; the area may or may not be fully utilized based upon the leg intercept turn.

Figure 5-3-4. Minimum VI-CF Construction, Turn 30 Degrees or Less

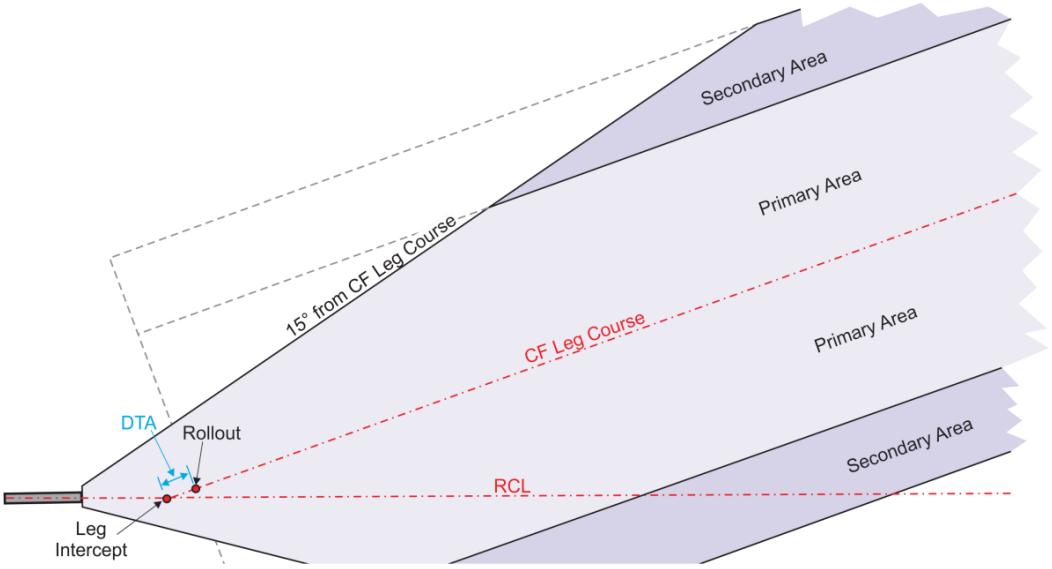


Figure 5-3-5 Minimum VI-CF Construction, Greater than 30-degree Turn

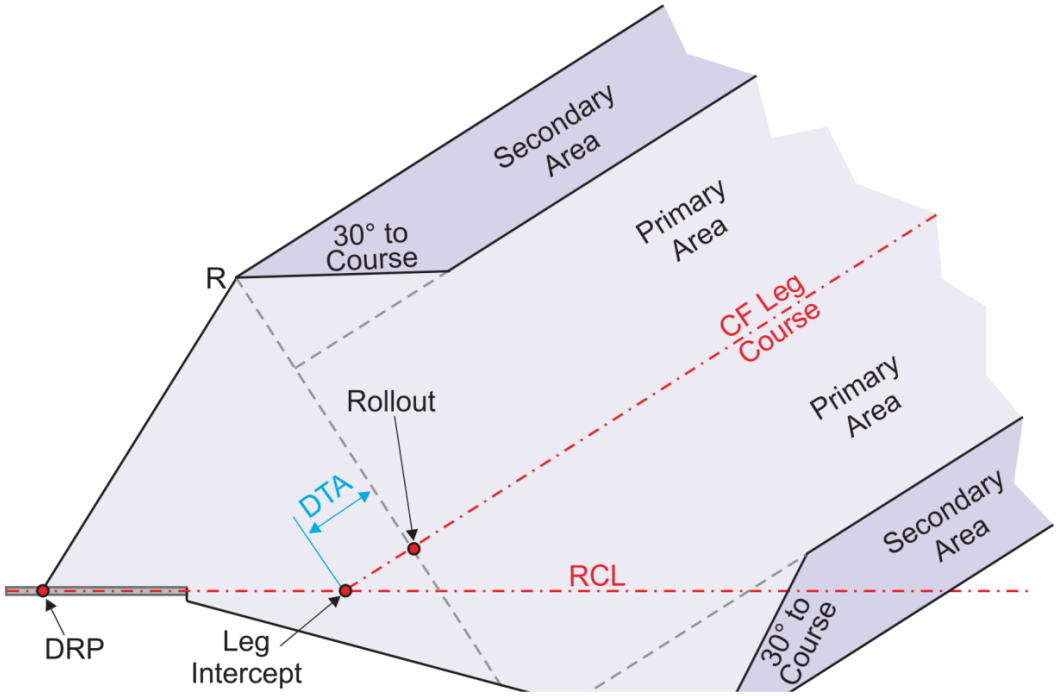


Figure 5-3-6. Minimum VI-CF Construction, 75-degree Turn

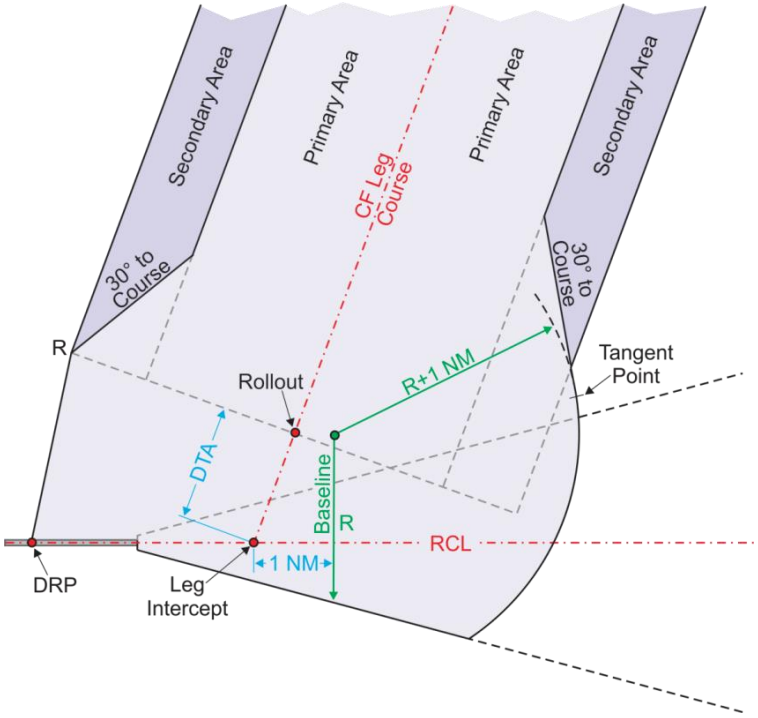
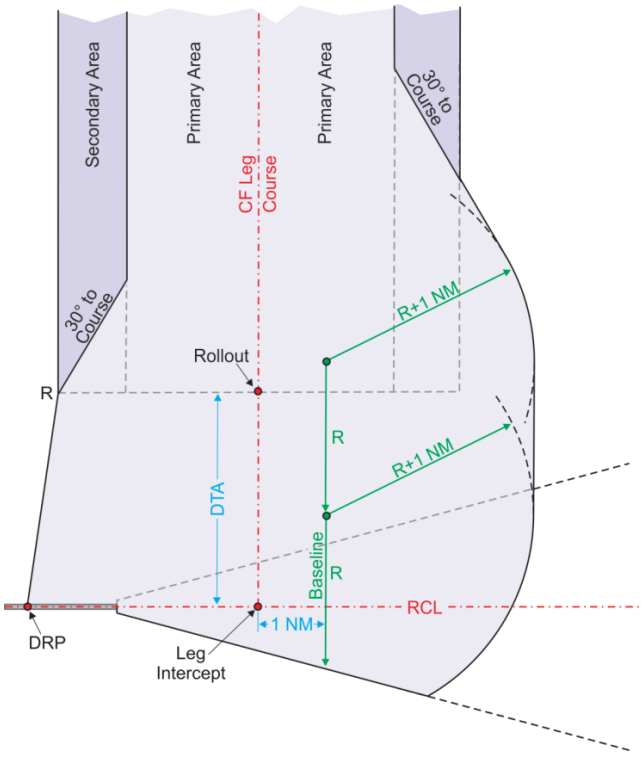


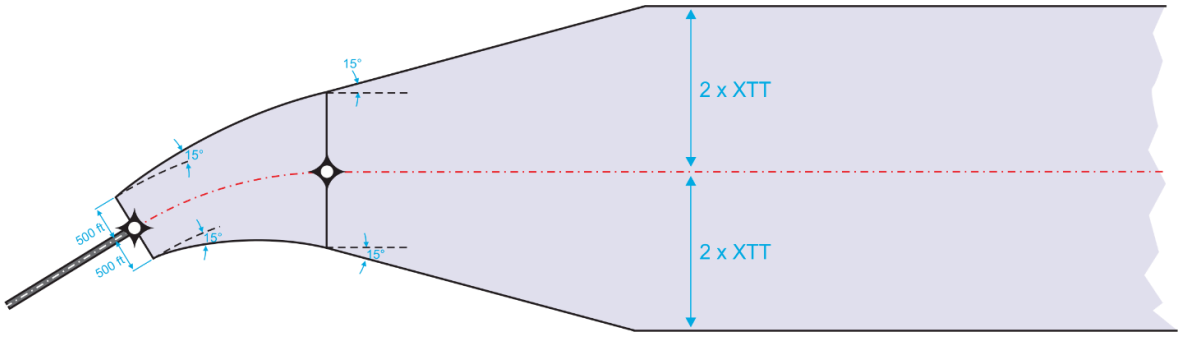
Figure 5-3-7. Minimum VI-CF Construction, 90-degree Turn



(c) Turn-at-fix (FO or FB). Use paragraph 1.2.5.d in cases where full primary and secondary width is achieved at a sufficient distance prior to the turn fix to permit construction. If an A-RNP or RNP AR DP value is selected that results in an OEA narrower at an RF start point than the ending ICA width, taper inward at 30 degrees relative to course to join edge of primary area. Otherwise, construct as follows:

1- Fix location. The first turn fix must be located on the runway centerline extended (or course line for paragraph 5.2.1.a construction). The distance to the turn fix must be sufficient to result in an early turn baseline at or beyond LNAV engagement (500 feet above airport elevation (rounded to the nearest foot)). Where the first fix must be located at the point the aircraft reaches or exceeds a specific altitude, calculate fix distance from DER with formula 1-3-9 using the standard or assigned CG. If a fix is already established, project the aircraft altitude at the fix in accordance with chapter 1. For RNP-1 or A-RNP departures, an RF start point may be located no closer to DER than the greater of 1NM or LNAV engagement (500 feet above airport elevation (rounded to the nearest foot)). For RNP AR departure procedures, an RF start point may be located up to and including at the DER. If the RF start point is at DER or less than 1 NM from DER, chart restrictions to cross DER at or above 500 feet above airport elevation (rounded to the nearest foot) and a max airspeed of 210 KIAS at/until the RF start waypoint. If the RF start point is not at DER but is less than 1 NM from DER, publish a waypoint at DER (may be opposite end threshold if the coordinates are the same) this is to provide reference for the 500-ft crossing restriction. The RF must be tangent to the runway centerline (extended).

Figure 5-3-8. RF at DER



2- Early turn baseline (line L – L'). The early turn baseline is established perpendicular to the inbound leg at the appropriate table 5-3-2 distance prior to the fix. For RF turn construction, ATT need not be applied until sufficient distance from DER for OEA to reach full width.

Table 5-3-2. Early turn Baseline Distance Prior to Turn Fix

Fix Type	Distance
FB Fix	ATT + DTA*
FO Fix	ATT

*DTA = 0 for turns 10 degrees or less

3- Construction points. Inside turn construction uses points PI (primary intersection) and SI (secondary intersection). When defining these points, the leg prior to the turn fix is the inbound leg and the leg following the turn fix is the outbound leg.

a Point SI. This is the connection point for the secondary area boundary and is the intersection of line L-L' and the inbound leg secondary area boundary. When inbound leg has no secondary, points PI and SI are coincident.

b Point PI. This is the connection point for the primary area boundary and is the intersection of line L-L' and the inbound leg primary area boundary.

4- Inside turn expansion. Primary/Secondary boundary expansion depends on the location of points PI and SI in relation to the outbound leg OEA boundary lines (extended when necessary) [see table 5-3-3]. Where standard expansion is suitable for one, but not both splays, find the outbound connection point for the non-standard splay abeam the standard connection point. If the primary expansion line would result in a smaller primary area, continue the inbound leg splay until full primary width is reached or until intersecting the angle bisector line whichever occurs first, then splay per table 5-3-3. For RF legs, splay 15 degrees relative to RF path beginning at points PI and SI on an early turn baseline L-L' abeam the RF start point. Where the splay doesn't reach full OEA width at a point that supports standard construction then connect points PI and SI on an early turn baseline L-L' abeam the RF start point to the outbound leg OEA boundary lines perpendicular to the RF end point [see figure 5-3-12].

Table 5-3-3. Standard Inside Turn Expansion

Construction Point	External to Outbound leg OEA (both primary and secondary)	Internal to Outbound leg Secondary area	Internal to Outbound leg Primary area
Point SI	Greater of ½ Turn-angle or Inbound leg Splay	15-degrees relative outbound track	
Point PI	Greater of ½ Turn-angle or Inbound leg Splay		15-degrees relative outbound track

5- Reserved.

6- Construction steps.

a Step 1. Construct line L-L' at the appropriate table 5-3-2 distance.

b Step 2. Construct secondary area boundary.

1- *Case 1.* SI is external to the outbound leg OEA. Construct an expansion line from SI to the outbound leg secondary boundary.

2- *Case 2.* SI is internal to either the outbound leg secondary or primary area. In this case, an alternative construction point (point SI') may be required depending on magnitude. Point SI' is the intersection of line L-L' and the outside-turn secondary area boundary. Construct the expansion line from either point SI or SI' to the outbound leg secondary boundary whichever results in the larger area. When the expansion line

reaches the outbound secondary boundary before reaching the point of intersection of the inbound and outbound leg secondary boundaries, no expansion is required and the area is a simple connection of the inbound and outbound leg secondary boundaries.

c Step 3. Construct the primary area boundary. Construct an expansion line from point PI to the outbound leg primary boundary. When the Step 2 expansion line reaches the outbound leg primary boundary before reaching point of intersection of the inbound and outbound leg primary boundaries, no expansion is required and the area is a simple connection of the inbound and outbound leg primary boundaries.

Figure 5-3-9. Early/Inside Turn, First Turn, Turn at Fix: PI and SI Collocated and External to Outbound Primary and Secondary

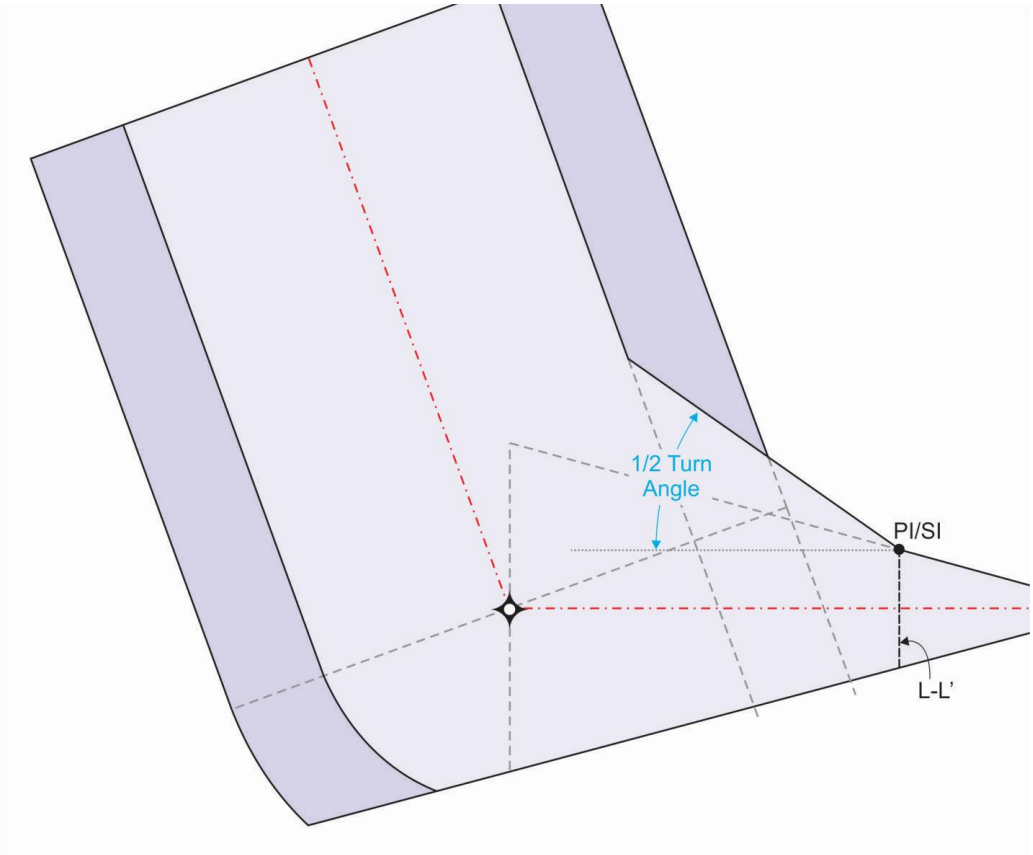


Figure 5-3-10. Early Inside Turn, First Turn, Turn at Fix: PI and SI internal to Outbound Primary

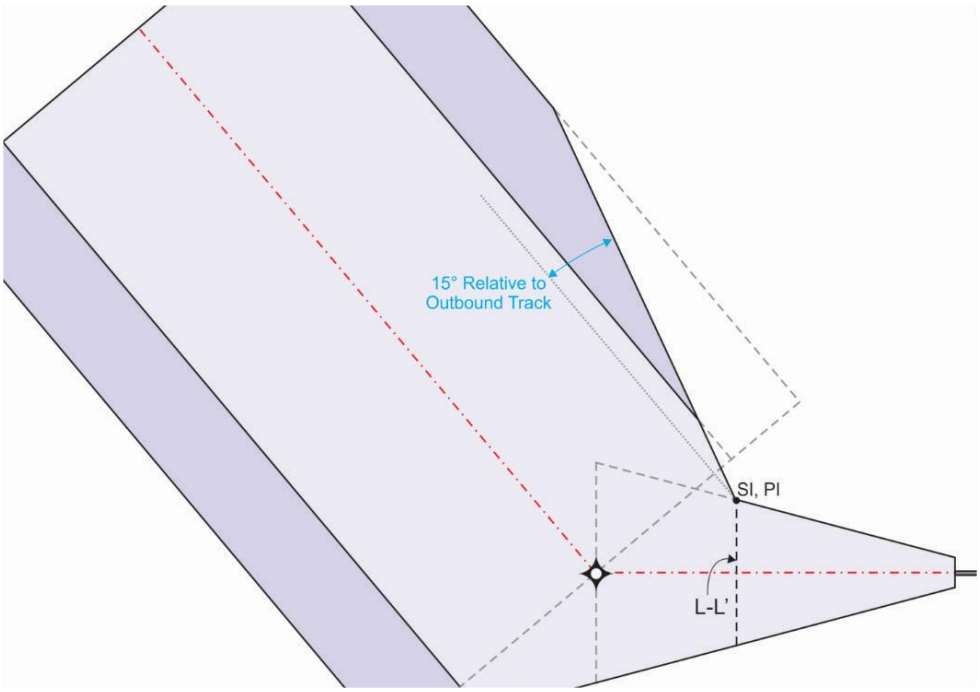


Figure 5-3-11. Early/Inside Turn, First Turn, Turn at Fix: PI and SI internal to Outbound Secondary, splay from point SI'

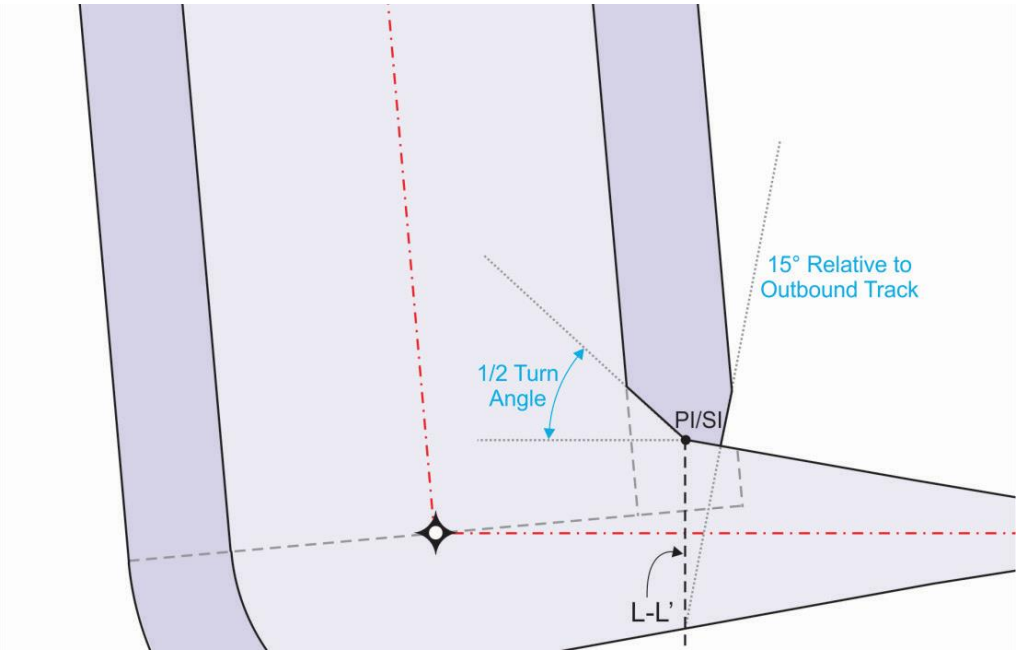


Figure 5-3-12. First Turn, Turn at Fix: PI and SI connecting to abeam RF end point

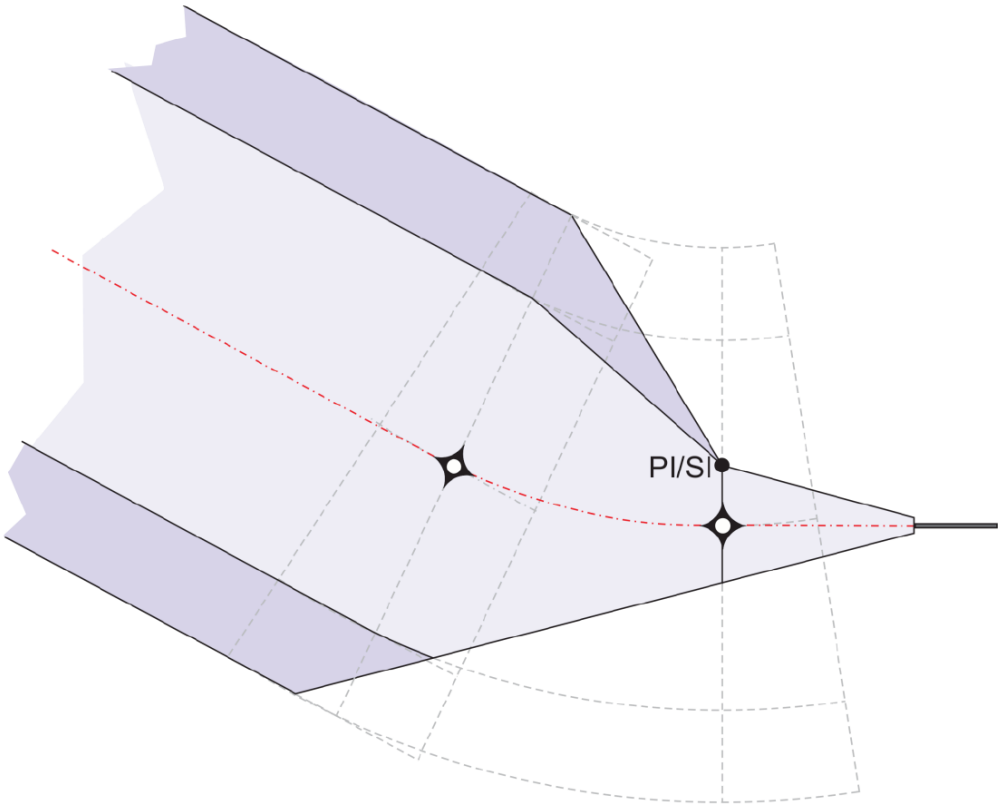
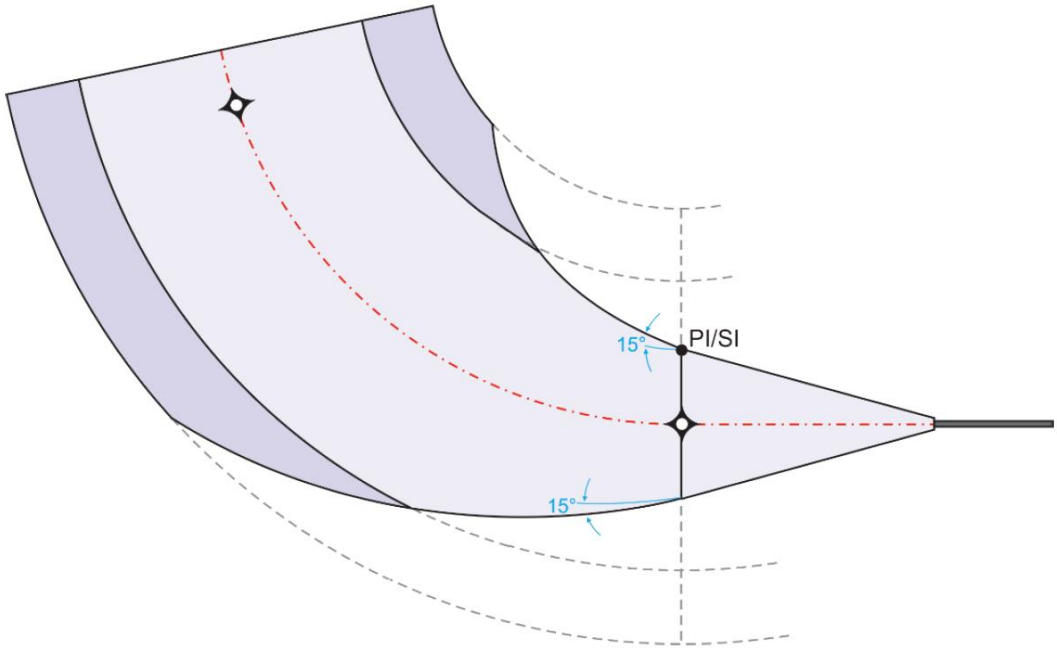


Figure 5-3-13. First Turn, Turn at Fix, RF



(2) Second turn. The second turn is specified at either a FB or FO fix.

(a) DF-TF or CF-TF.

1- Construct in accordance with paragraph 5.3.1.a(1)(c) with the following exceptions:

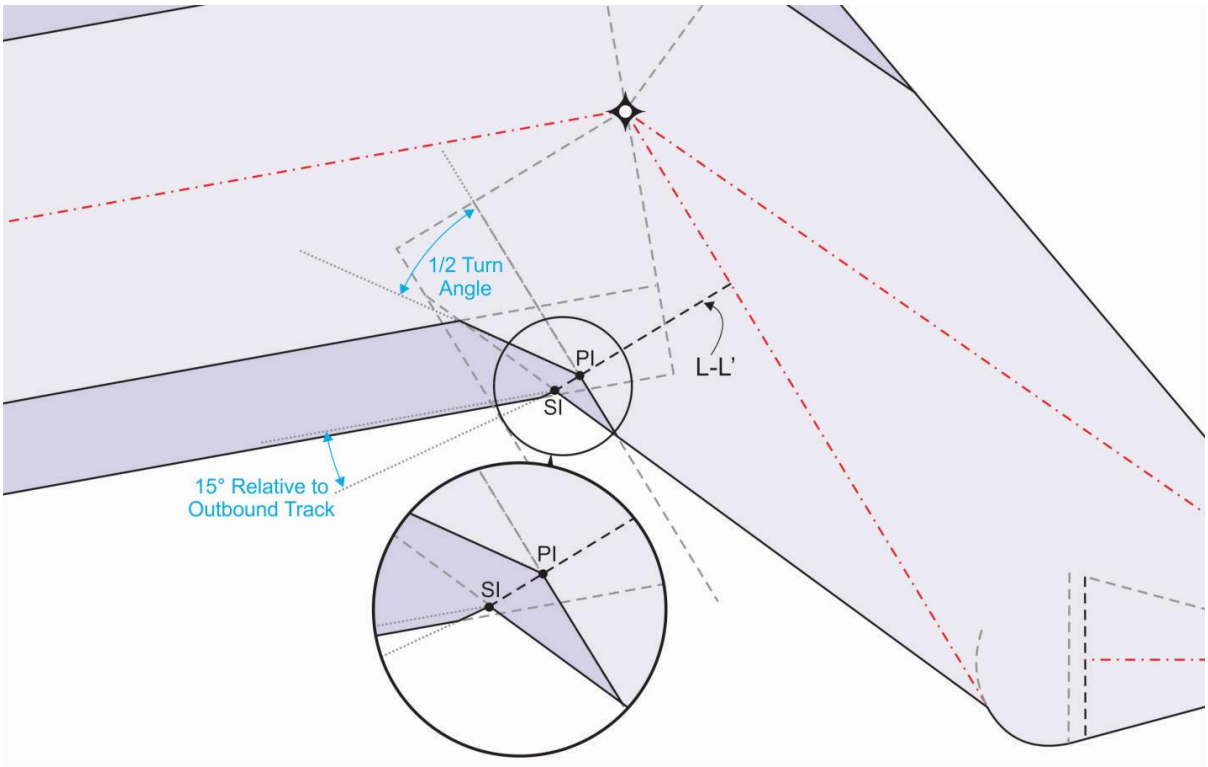
a Paragraph 5.3.1.a(1)(c)1 does not apply.

b For DF-TF, line L-L' is established perpendicular either on the early- or late-turn track, whichever is on the inside of the turn.

c When full primary and secondary width is reached at the early-turn baseline (L-L') construct in accordance with paragraph 1.2.5.

(b) Other connections. Construct in accordance with paragraph 1.2.5.

Figure 5-3-14. Early/Inside Turn, Second Turn, Turn at FB Fix DF-TF connection



b. Late and outside turn construction.

(1) Wind spiral application. Wind spiral (WS) construction applies to late and outside turns for turn-at-altitude, turn-at-fix (FO). See paragraph 1.3.1.g for design parameters.

(a) WS number and baselines. Baseline locations for WS construction may be dependent on Reaction and Roll distance [see formula 1-2-12 and table 5-3-4].

Table 5-3-4. Wind Spiral Number and distance to Late Turn Baseline

WS/Baseline Parameters	Turn-at-Fix (FO)	Turn-at-Altitude
WS Number	1 or 2	1, 2, or 3
WS1 & WS2 Distance Late-Turn Baseline (Line P-P') from turn fix/point	ATT + D_{rr}	ICA + D_{rr}
WS3 Baseline	ATT (early) for FO DF, otherwise not applicable	Parallel to DRL

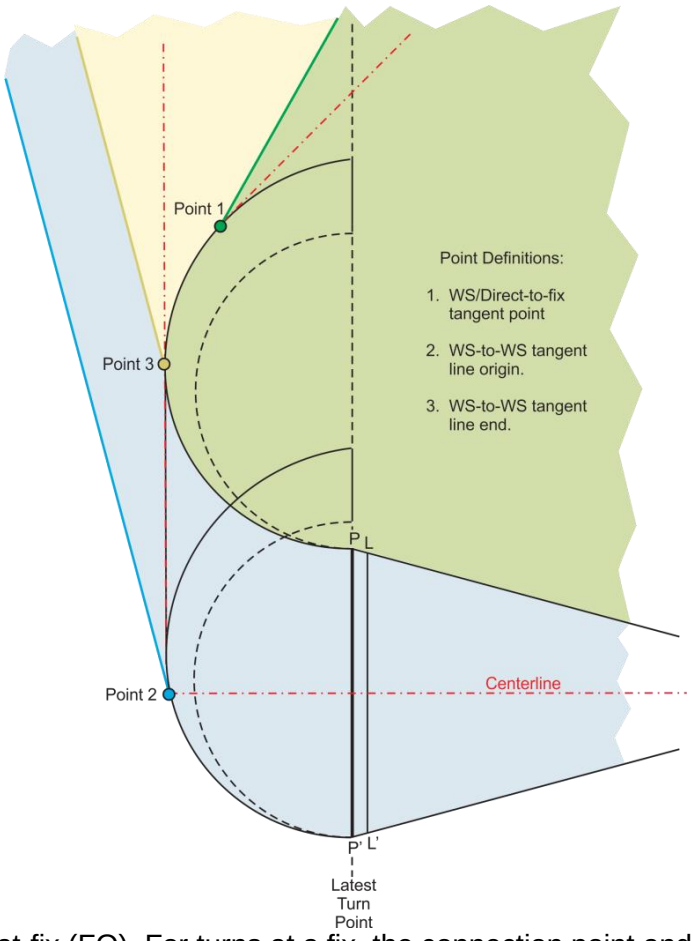
1- First turn baseline. For first turn construction, the late-turn baseline (line P-P') marks the construction line for wind spirals. Line P-P' is located at the table 5-3-4 distance with points P and P' placed at the continuation of the inbound leg's outer boundary [see paragraph 1.3.1.g(4)]. The no-wind turn radius for the outside turn wind spiral (WS1) and inside turn wind spiral (WS2) will be measured perpendicular to the inbound track from their respective point P. If a third wind spiral is used (WS3), the baseline will be parallel to DRL with the no-wind turn radius measured inward from DRP, for DF-DF baseline will be line L-L'.

2- Second turn baseline [see figure 5-3-22]. To accommodate the two inbound tracks in the DF leg, the second turn construction uses two WS baselines, line P-P' for WS1 and line P'-P" for WS2. Each late turn baseline is oriented perpendicular to the early- and late-turn tracks at the table 5-3-4 distance. The baseline for the inbound track nearer the outside-turn boundary is designated line P'-P", with point P" placed on the extended outer boundary and point P' placed at the no-wind turn radius inward along the baseline from point P". The baseline for the inbound track nearer the inside-turn boundary is designated line P-P', with point P' placed on inbound track and point P placed on the extended outer boundary. The no-wind turn radius for the inside turn wind spiral is measured perpendicular to the inside track inward along the baseline from point P.

(b) WS connection point and outside turn OEA boundary. Each WS has various connection options along its path, which predicate the outside turn OEA boundary. The chosen connection must provide the most reasonably conservative track and protection area. Where excessive splay is required to reach full-width protection, consider lengthening the leg, restricting the speed, category, etc. to avoid protection and/or construction difficulties. Consider full-width protection to exist at the fix where the splay line is tangent to a full-width-radius circle about the fix.

1- Turn-at-altitude. For turns at an altitude, the 15-degree or greater splay line that joins the outbound leg outer boundaries may originate from the WS/direct-to-fix tangent point (point 1), the WS to WS tangent line origin (point 2) or the WS to WS tangent line end (point 3). Where the turn angle is ≤ 105 degrees, or the divergence angle between the WS to WS tangent line and the direct-to-fix line is ≤ 15 degrees, apply the splay line from the WS to WS tangent line origin. DF secondary areas begin/exist only where full width primary exists.

Figure 5-3-15. WS Connection Points, Turn-at-Altitude



2- Turn-at-fix (FO). For turns at a fix, the connection point and the OEA boundary is dependent on the WS boundary relative to the outbound leg OEA (extended). The connection point is the point of tangency on the WS in both cases. When the WS is not contained in the outbound leg OEA, the outside boundary is a 30-degree converging line relative to the outbound course (see Figure 5-3-16). When the WS is contained in the outbound leg OEA, the outside boundary is a 15-degree or greater splaying line relative to the outbound course from the WS/outbound leg parallel point until reaching the outbound leg boundaries (see Figure 5-3-17).

Figure 5-3-16. Late/Outside Turn, Wind Spiral, WS not contained in Outbound OEA

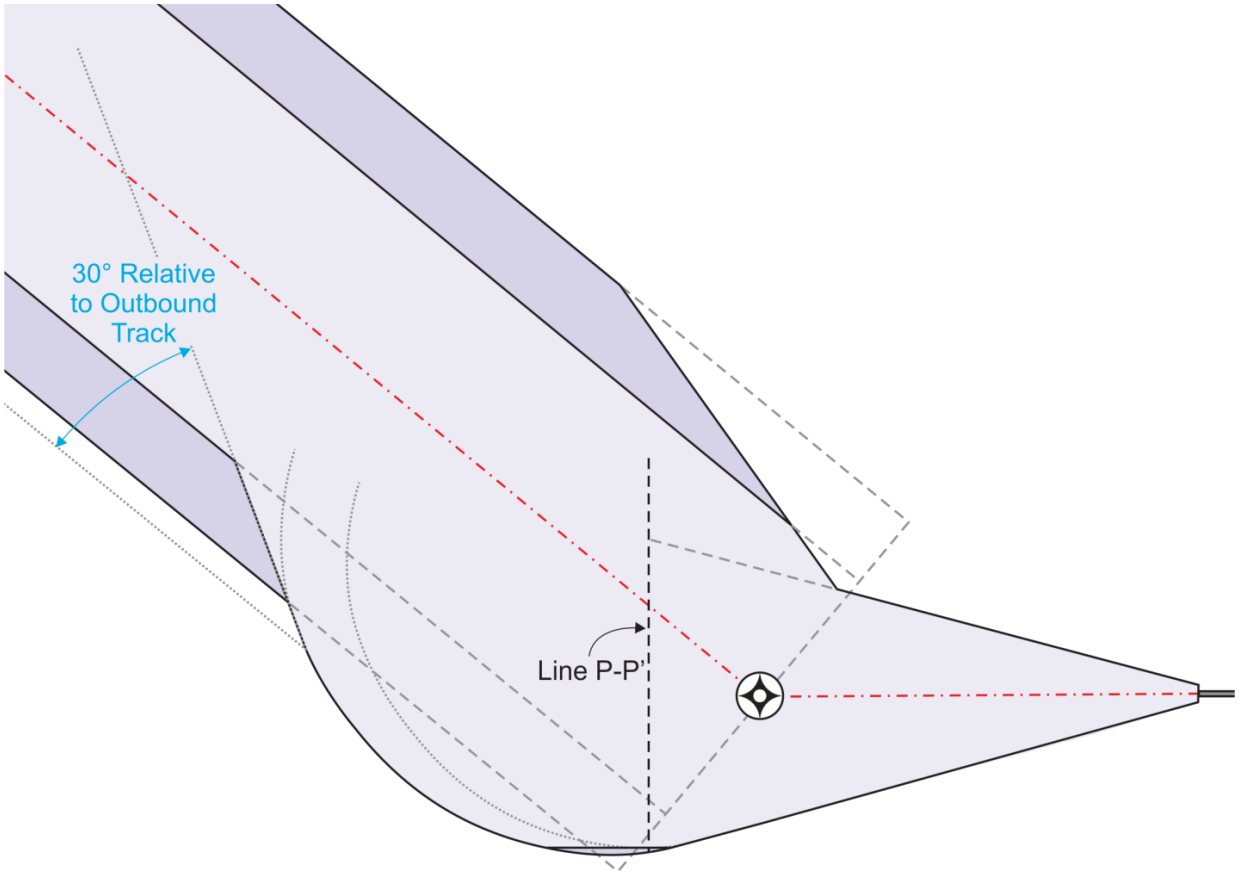
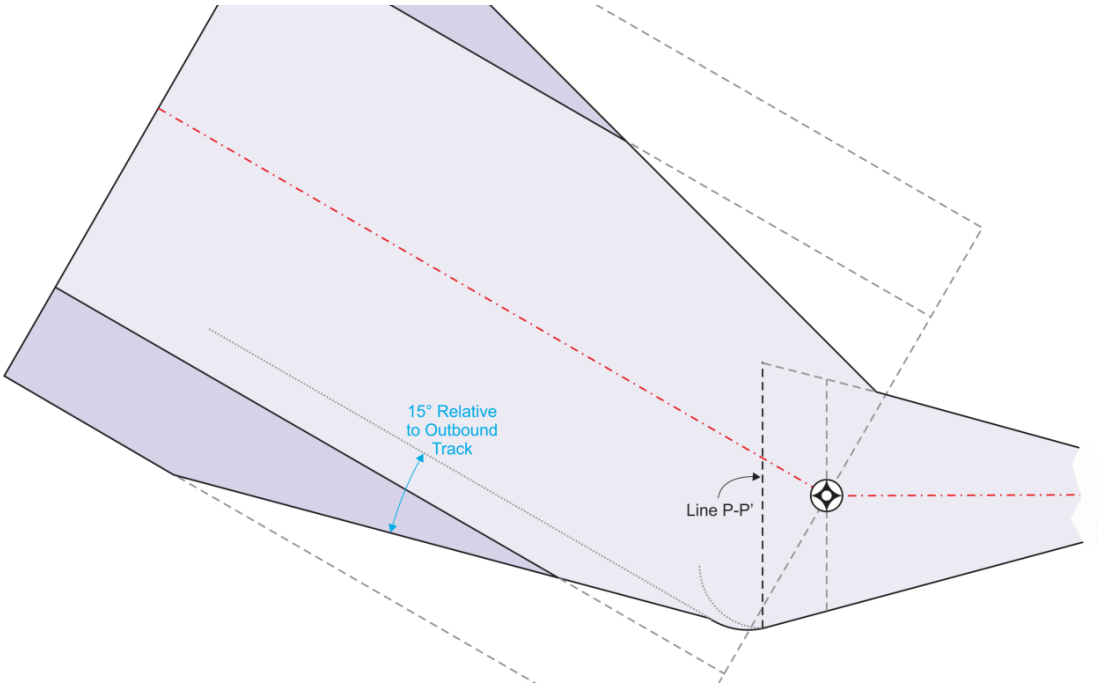


Figure 5-3-17. Late/Outside Turn, Wind Spiral, WS contained in Outbound OEA



(c) Determining multiple WS necessity. To determine multiple wind spiral necessity, construct the additional WS in the direction of turn from its prescribed location to its connection point. Where the additional WS intersects the preceding WS construction (including the connecting and expansion lines), connect the wind spirals with a tangent line that is parallel to the WS center points. Otherwise, revert to the previous WS construction.

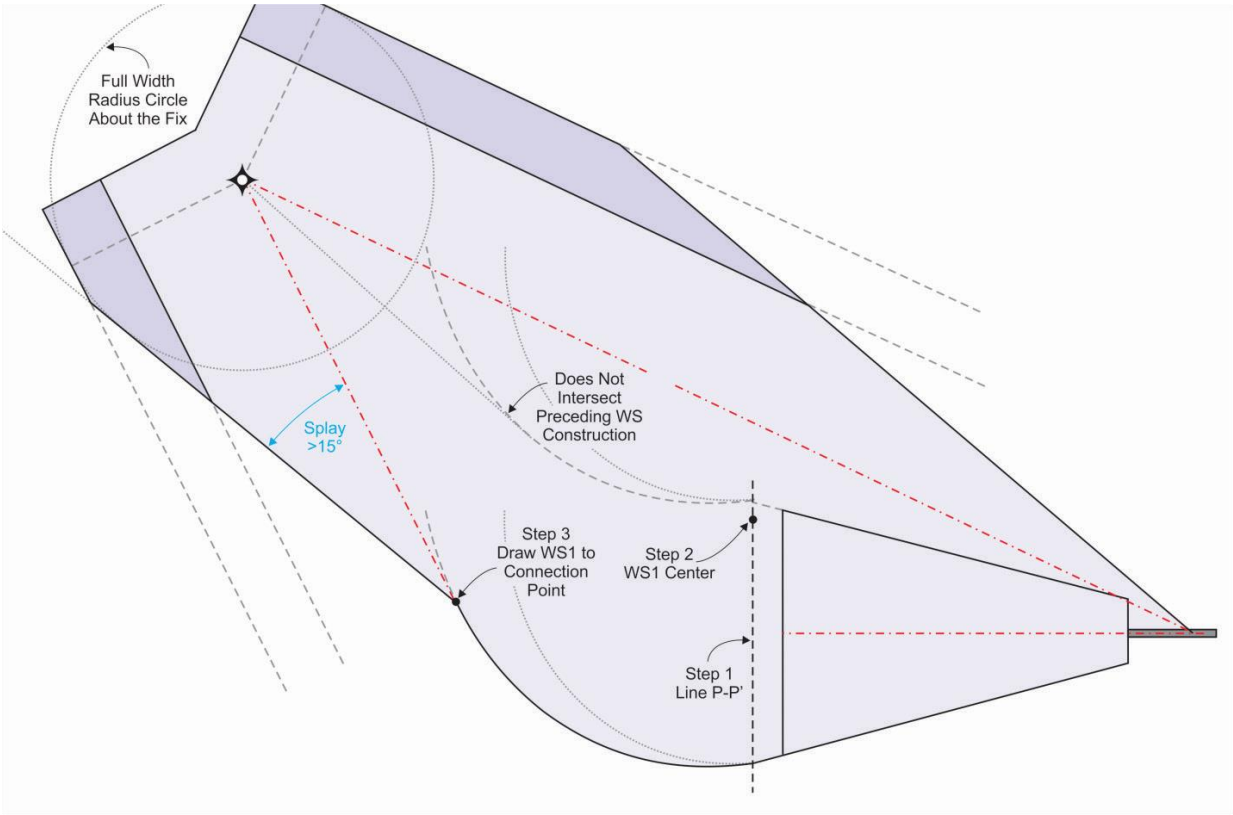
(2) First turn.

(a) Turn-at-altitude, turn-at-fix (FO), and minimum VI-CF construction.

1- Step 1. Construct the late-turn baseline (P-P') perpendicular to the runway centerline extended (or offset course if paragraph 5-2-1.a is used) at the late-turn-point. For minimum VI-CF construction late-turn point is 1 NM past the intercept point.

2- Case 1. Small turns using one WS.

Figure 5-3-18. Late/Outside Turn, First Turn, Case 1, Turn-at-Altitude or FO fix with 1 WS

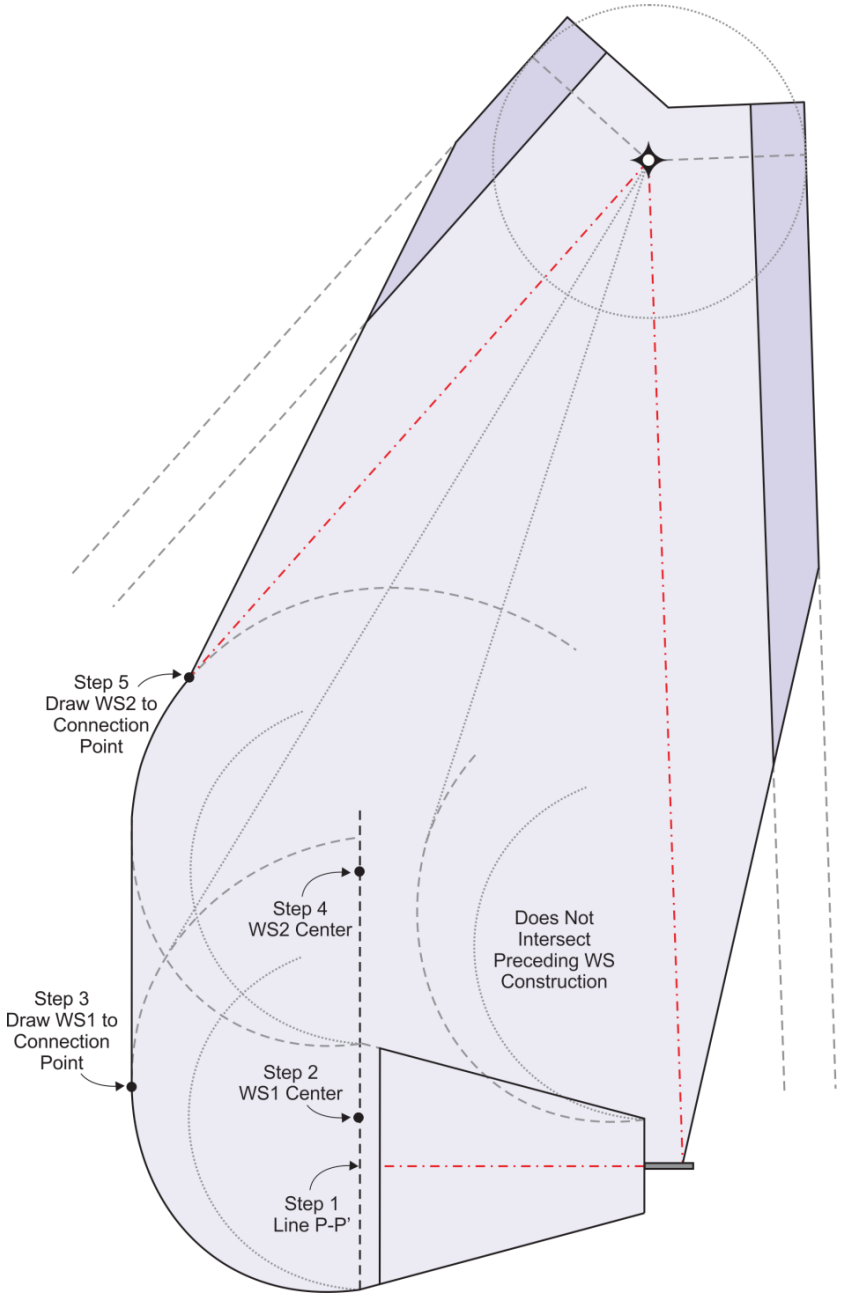


a Step 2. Locate the WS1 center on line P-P' at no-wind turn radius distance from point P'.

b Step 3. Construct WS1 from the outside turn point in the direction of turn until reaching its connection point. For minimum VI-CF construction use R (based on the highest projected turn altitude), place an arc center point at R distance from the outside turn point, construct an arc at distance R+ 1 NM (this will result in a circle instead of a WS) [see figure 5-3-6].

3. Case 2. For turns nearing or greater than 90 degrees using more than one WS, complete Steps 1-3 then:

Figure 5-3-19. Late/Outside Turn, First Turn, Case 2, Turn-at-Altitude or FO fix with 2 WS

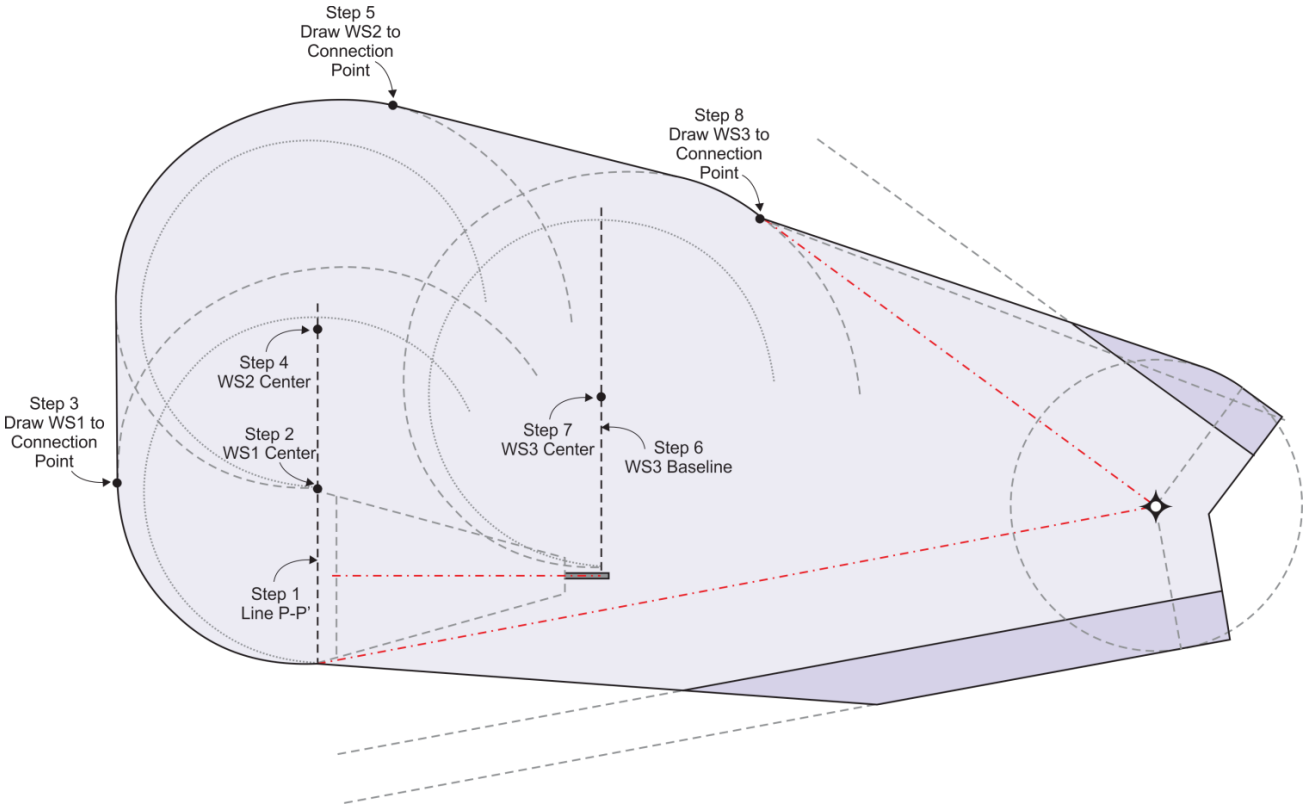


a Step 4. Locate the WS2 center on P-P' at no-wind turn radius distance from point P.

b Step 5. Construct WS2 from the inside turn point in the direction of turn until reaching its connection point. For minimum VI-CF construction use R (based on the highest projected turn altitude), place an arc center point at 2 X R distance from the outside turn point, construct an arc at distance R + 1 NM (this will result in a circle instead of a WS) [see figure 5-3-7].

4- Case 3. Turns nearing or greater than 180 degrees using more than two WS, complete Steps 1-5 then:

Figure 5-3-20. Late/Outside Turn, First Turn, Case 3, Turn-at-Altitude with 3 WS



a Step 6. Construct the WS3 baseline perpendicular to the runway centerline along DRL extended toward the turn side. For FO DF the WS3 baseline is on line L-L' perpendicular to the runway centerline extended toward turn side.

b Step 7. Locate the WS3 center on the baseline at no-wind turn radius distance from DRP.

c Step 8. Construct WS3 from this point in the direction of turn until reaching its connection point.

(b) Turn-at-fix (FB) and standard VI-CF construction.

1- Step 1. Construct the outer primary boundary using a radius of 1 × segment XTT centered on the plotted fix position, truncated at the inbound leg extended primary boundary until tangent to the outbound leg primary boundary (not applicable to VI-CF).

2- Step 2. Construct the secondary boundary using a radius of 3 × segment XTT entered on the plotted fix position, truncated at the inbound leg extended outer boundary until tangent to the outbound leg outer boundary. For VI-CF this will be

the outer primary boundary connecting to point X then parallel to CF course to point W [see figure 5-3-3].

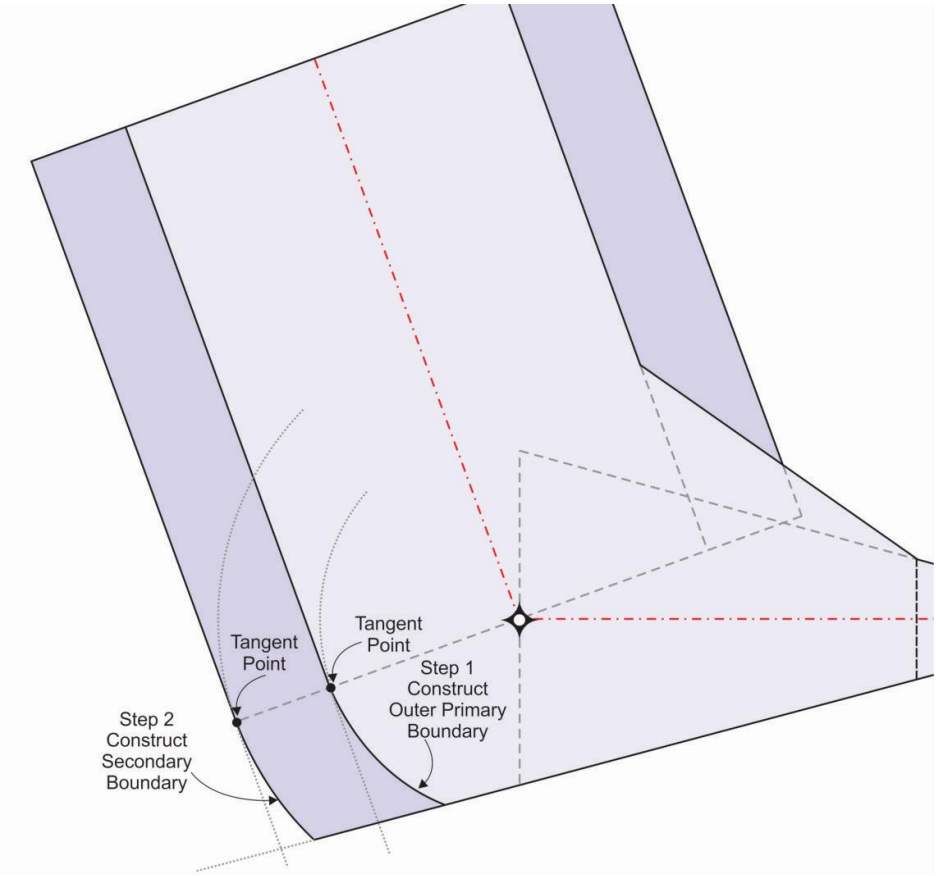
(c) Turn-at-fix, RF construction.

1- Step 1. Construct the outer primary boundary by splaying at 15 degrees relative to RF path from point abeam RF start point. Where the splay doesn't reach full OEA width at a point that supports standard construction, then construct by truncating the RF full width primary area at the initial straight leg extended splay line [see figure 5-3-13].

2- Step 2. Construct the secondary boundary by splaying at 15 degrees relative to RF path from point abeam RF start point. Where the splay doesn't reach full OEA width at a point that supports standard construction, then construct by truncating the RF full width secondary area at the initial straight leg extended splay line [see figure 5-3-13].

3- Where the initial straight leg splay hasn't reached a width of 3 × segment XTT by the end of the first RF and the succeeding legs is a TF or RF with same direction turn, the initial straight leg splay may continue into the next leg until full width is reached [see figure 5-3-12]; otherwise, increase splay as necessary to reach full OEA width by the end point of the first RF.

Figure 5-3-21. Late/Outside Turn, First Turn, FB fix



(3) Second turn. (a) Turn-at-fix (FO) (see Figure 5-3-22).

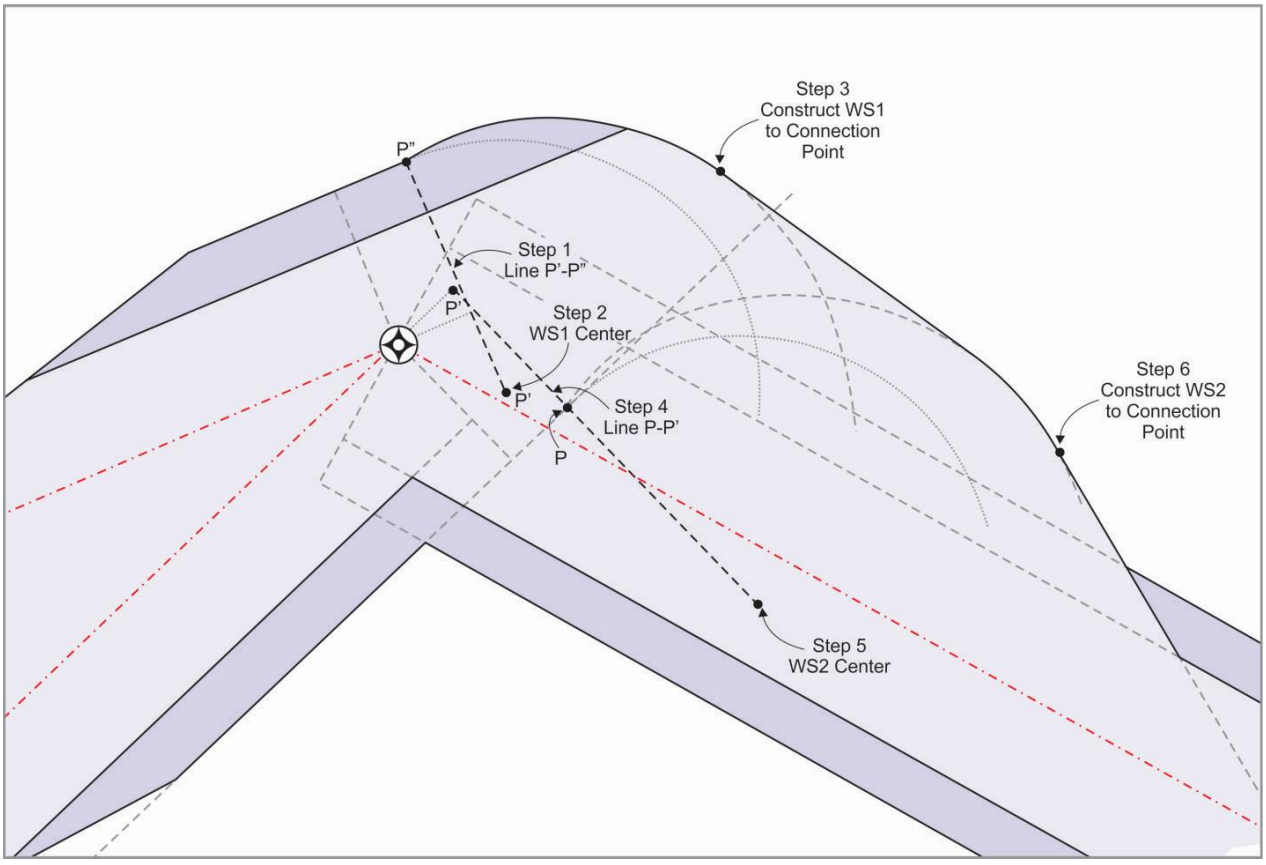
1- Step 1. Construct the WS1 baseline, (line P'-P") perpendicular to the DF track nearer the outside of the DF-TF turn at the late turn point.

2- Step 2. Locate the WS1 center on line P'-P" at no-wind turn radius distance from point P."

3- Step 3. Construct WS1 the outside point in the direction of turn until reaching its connection point.

4- Step 4. Construct the WS2 baseline, (line P-P') perpendicular to the DF track nearer the inside the DF-TF at the late turn point.

Figure 5-3-22. Late/Outside Turn, Second Turn, FO fix



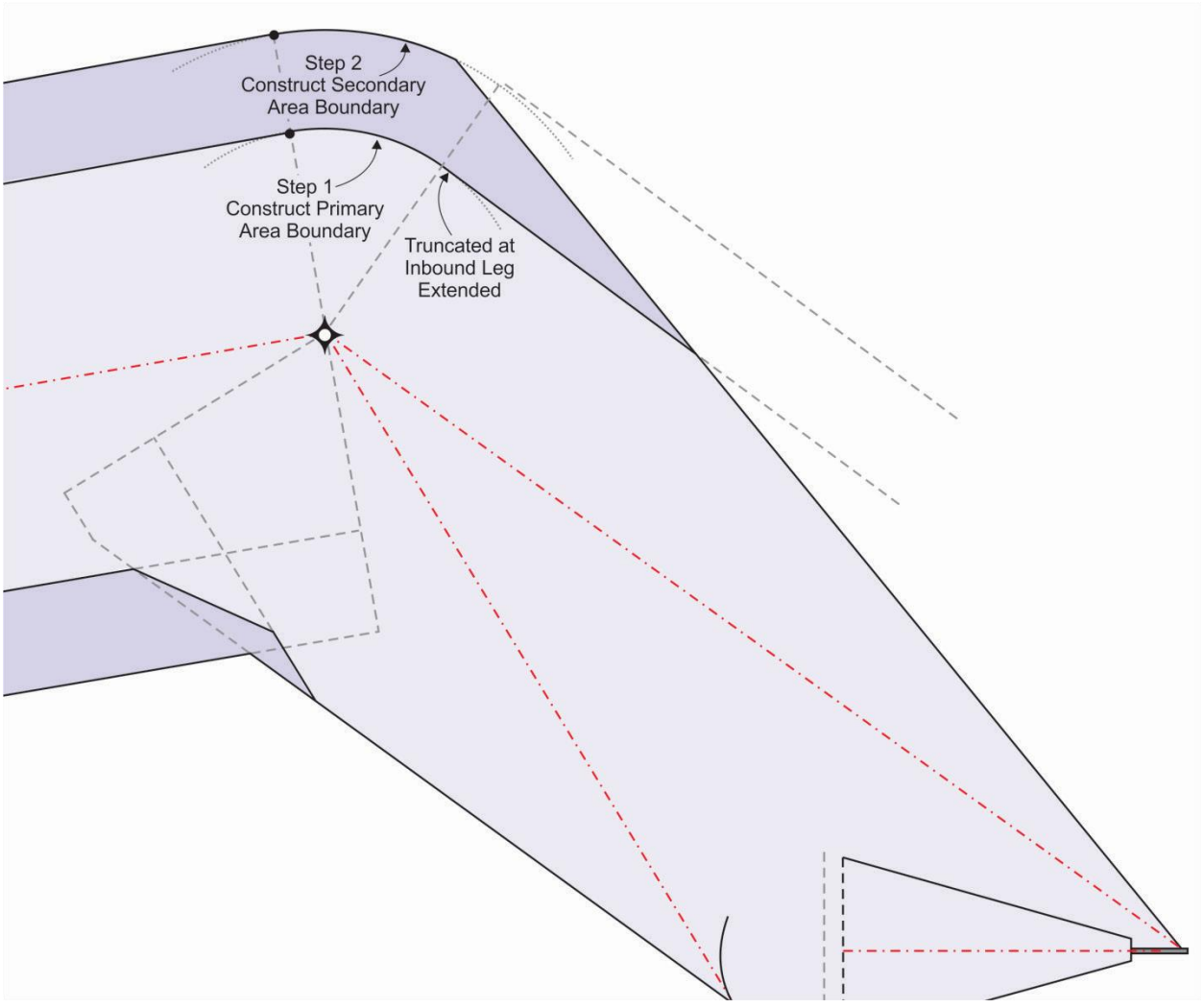
5- Step 5. Locate the WS2 center on line P-P' at no-wind turn radius distance from point P.

6- Step 6. Construct WS2 from the inside turn point in the direction of turn until reaching its connection point.

(b) Turn-at-Fix (FB).

1- When the inbound leg outside boundary is less than full primary and secondary width reached perpendicular to the fix, construct in accordance with paragraph 5.3.1.b(2)(b) [see figure 5-3-17].

Figure 5-3-23. Late/Outside Turn, Second Turn, Turn at FB fix, less than full OEA width perpendicular to fix



2- When the inbound leg outside boundary is full primary and secondary width perpendicular to the fix, construct in accordance with paragraph 1.2.5.

SECTION 5-4. OBSTACLE EVALUATION

5.4. Obstacle evaluations.

5.4.1. General.

a. Utilize the general concepts from paragraph 1.3.1.g. Where an obstacle requires multiple measurements (an obstacle is equidistant from multiple primary boundary points, it lies along perpendiculars from multiple primary boundary points, etc.), apply the most adverse result from each of the combined primary/secondary measurements [see figure 5-4-1 through figure 5-4-7]. For RNP AR DP apply horizontal and vertical accuracy adjustments to obstacles except for those excluded obstacles in Annex E, paragraph 2.11.4.

b. Primary OCS.

(1) ICA. Measure distance to obstacles using the distance from ICAB along runway centerline extended. The ICA OCS begins at the MSL elevation of the ICAB [see formula 1-3-5 to determine OCS slope].

(2) Straight departure. Measure and apply the OCS slope along the shortest primary area distance from the ICA to a point at/abeam the obstacle. For RNP AR DP, obstacle distance is measured as the along track distance from the ICAB to a point abeam the obstruction.

(3) Turn-at-altitude (single and multiple legs). Apply the OCS slope along the shortest primary area distance from the ICA/straight segment boundary to a point at/abeam the obstacle.

(a) Section 1. For obstacles past the ICAB, measure from the closest point on the ICA/straight segment boundary. For obstacles between the DRL and ICAB, take the lesser of the distance from runway centerline and the closest point on the ICA boundary. The section 1 OCS begins at the MSL elevation of the OCS at ICAE.

(b) Section 2. Measure from DRP. The section 2 OCS begins at the specified turn altitude.

(4) Turn-at-a-fix (single and multiple legs). Apply the OCS slope along the shortest primary area distance from the ICA to a point at/abeam the obstacle. For RNP AR DP, obstacle distance is measured as the along track distance from the ICAB to a point abeam the obstruction. When the RNP AR DP has a DER crossing restriction of 500 ft above airport elevation (rounded to the nearest foot), the OCS begins 380 feet above DER.

(5) VI-CF.

(a) VI-CF standard construction and minimum VI-CF with turns of 30 degrees or less. Apply the OCS slope along the shortest primary area distance from the ICA boundary to a point at/abeam the obstacle.

(b) Minimum VI-CF with turns of more than 30 degrees. For obstacles past the DER, measure from the closest point on the ICA boundary. For obstacles between the DRP

and DER, take the lesser of the distance from runway centerline and the closest point on the ICA boundary.

(6) Routes. Apply ICA, section 1 and section 2 methodology where applicable, then measure along the shortest primary area distance that passes through the early-turn baseline of all preceding legs.

Note: The shortest primary area distance is the length of the shortest line kept within primary area that passes through the early-turn baseline of all preceding legs.

c. Secondary OCS. For obstacles located in secondary areas, calculate the primary OCS elevation as stated, then apply a 12:1 OCS slope along the shortest secondary distance to the obstacle. In straight legs, this is normally perpendicular to the nominal track. In expansion areas, the slope rises in a direction perpendicular to the primary boundary (arc, diagonal corner-cutter, etc.).

d. Maximum Altitude Restrictions. Apply Vol 1, paragraph 12.6.1, for fix error use ATT. For RF legs, late ATT lies along the RF track and on the construction line anchored at the RF center point [see figure 5-4-8].

Figure 5-4-1. VA-DF Obstacle Distance Measurements, Primary and Secondary Area, large turn

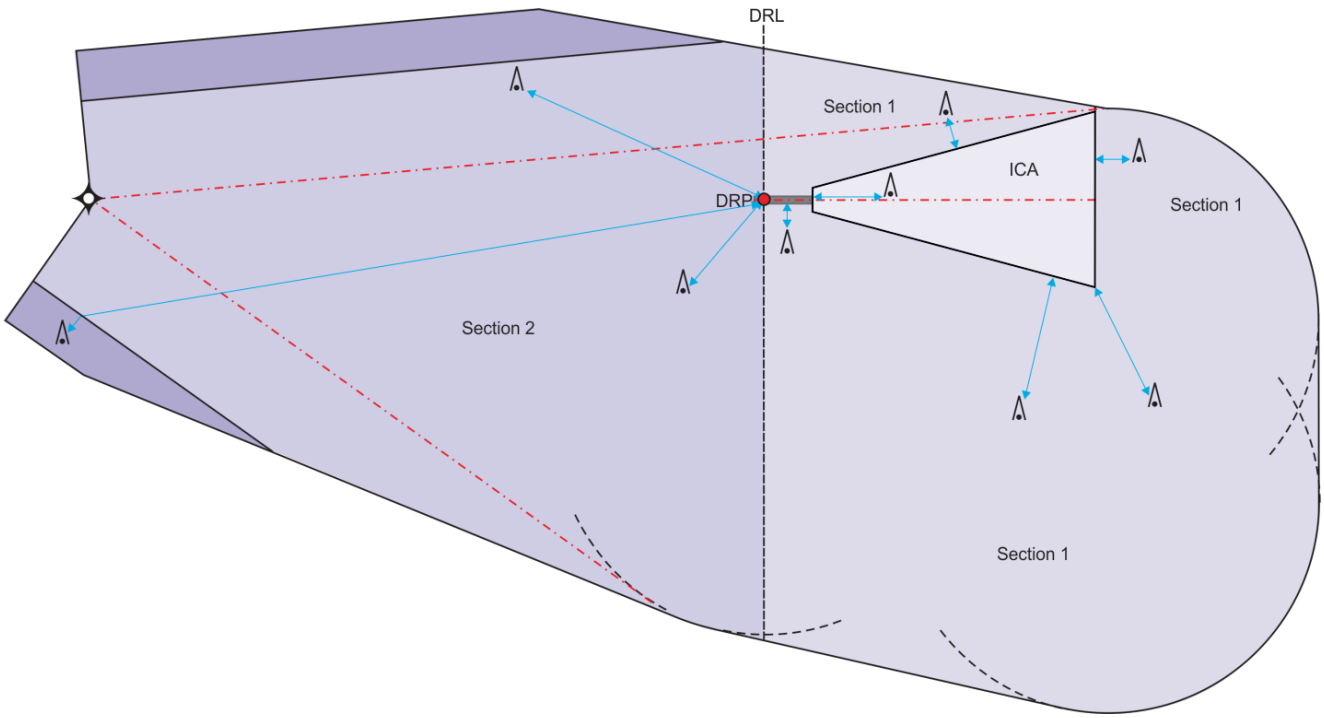


Figure 5-4-2. Obstacle Distance Measurements, Turn at Altitude, small turn

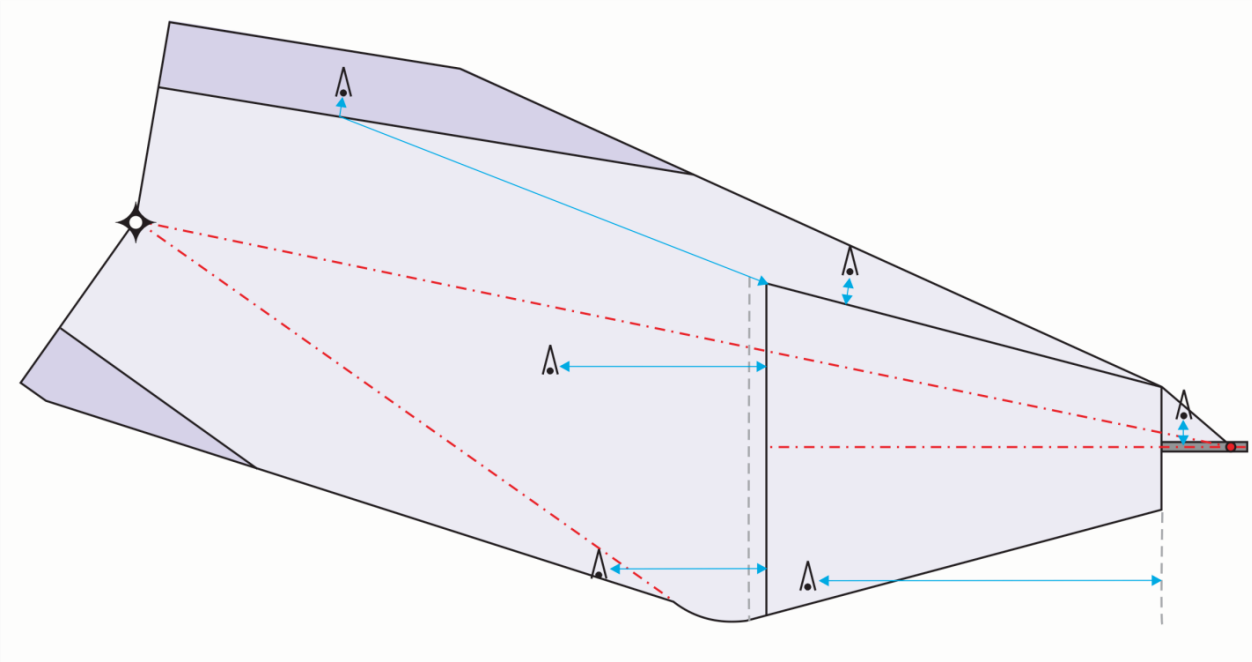


Figure 5-4-3. Obstacle Distance Measurements, Turn at Altitude, multiple legs

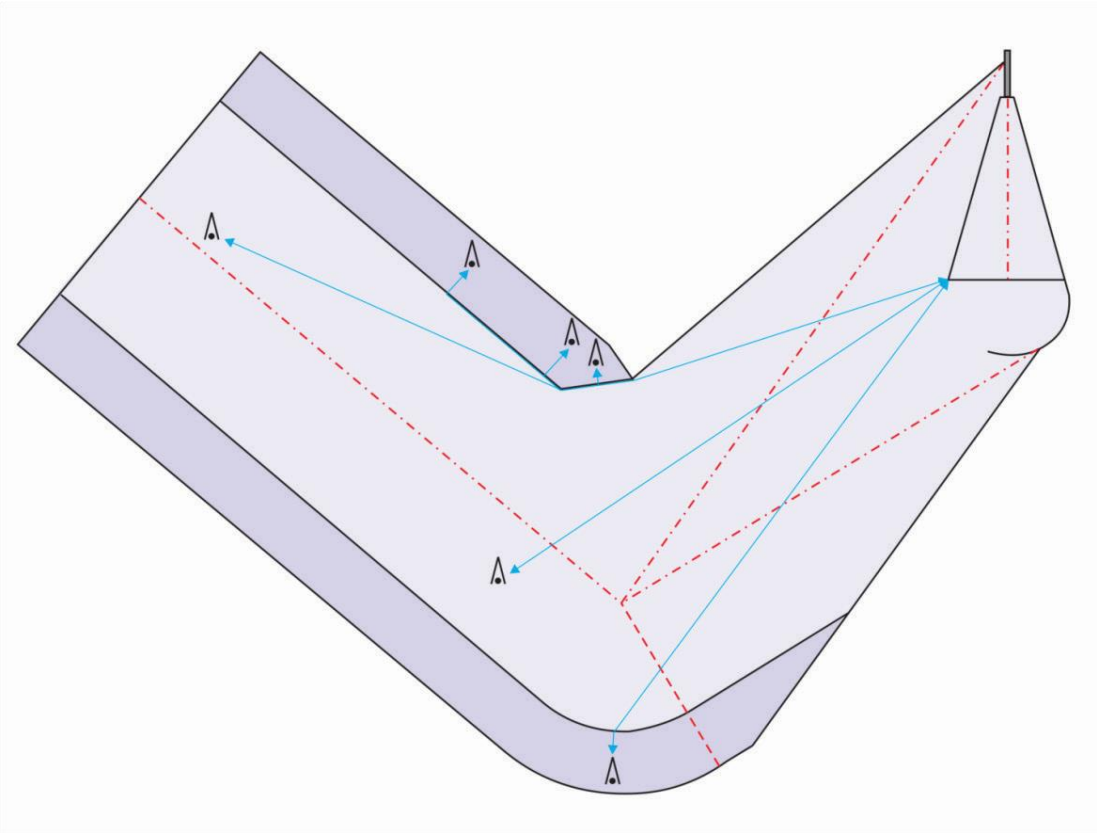


Figure 5-4-4. Obstacle Distance Measurements, Turn at FB Fix

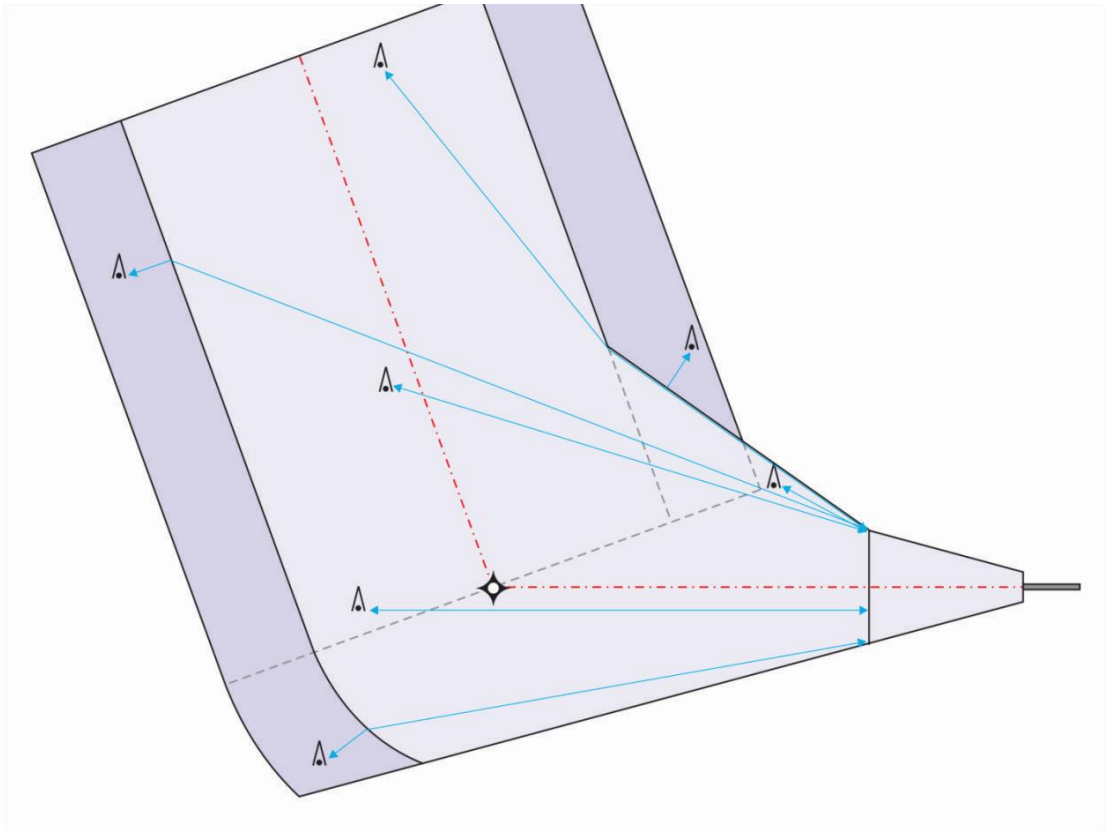


Figure 5-4-5. DF-DF Obstacle Distance Measurements, Turn at FO Fix

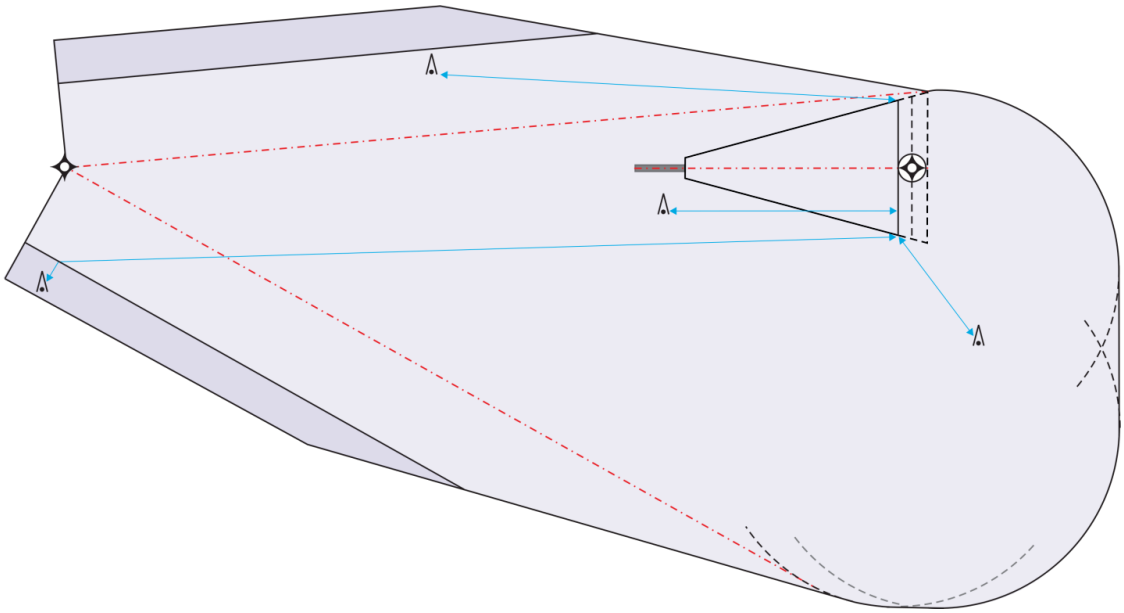


Figure 5-4-6. VI-CF Obstacle Distance Measurements

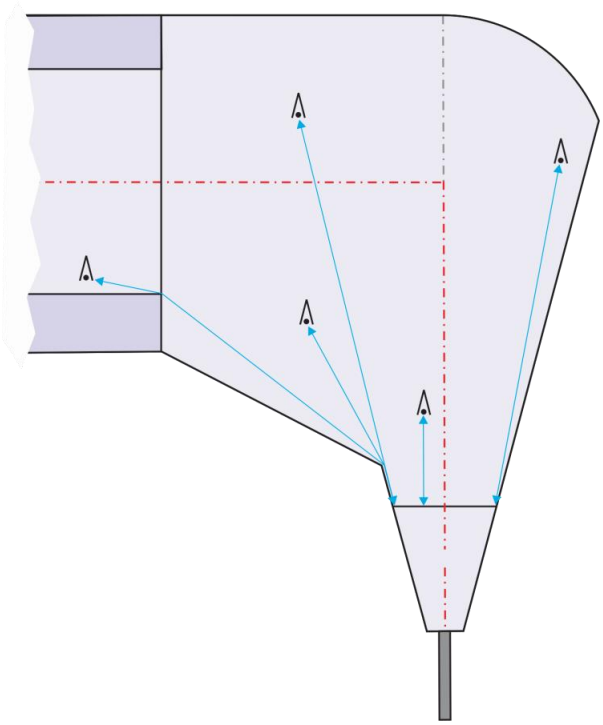
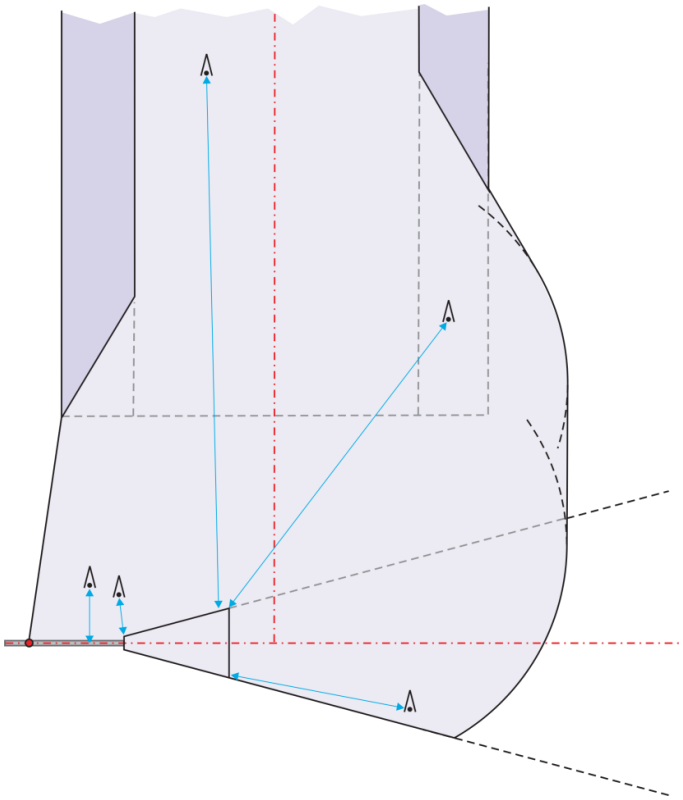
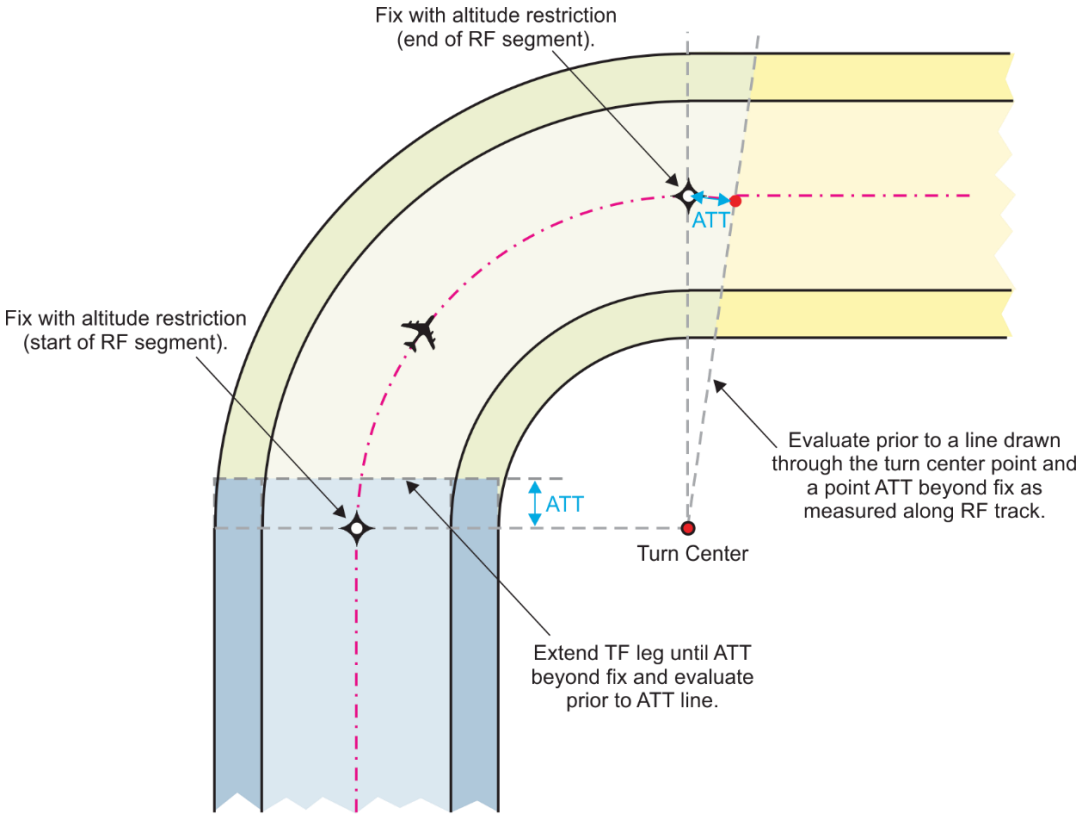


Figure 5-4-7. Minimum VI-CF with turn greater than 30 Degrees Obstacle Distance



Measurements

Figure 5-4-8. Maximum Altitude Restriction Evaluation



SECTION 5-5. CLIMB GRADIENT

5.5. Climb gradient.

5.5.1. General. Where the default OCS slope is penetrated, a greater than standard CG may be required to clear the penetrating obstruction (See Vol 1, paragraph 12.1.4. for maximum CG).

a. When climb gradients are used for obstacle clearance, compute the climb gradient per paragraph 1-3-1.g and formula 1-3-7 using the CG termination altitude from formula 5-5-1.

Formula 5-5-1. CG Termination Altitude

$$\mathrm{CG_{term}} = \frac{\mathrm{O_{MSL}} - \frac{\mathrm{d_{primary}}}{12} - \mathrm{DER_{elev}}}{0.76} + \mathrm{DER_{elev}}$$

Where:
$\mathrm{DER_{elev}}$ = departure end of runway elevation (feet)
$\mathrm{d_{primary}}$ = dist. (feet) from edge of primary to obstacle (zero if not in secondary)

Example:

$$\mathrm{CG_{term}} = \frac{2147.41 - \frac{390.12}{12} - 1104.3}{0.76} + 1104.3$$

$$\mathrm{CG_{term}} \approx 2434.04 \text{ feet}$$

b. Mitigating obstacle penetrations. The preferred method of obstacle mitigation is to use a less onerous route. The next choice is a climb gradient, using paragraph 1.3.1.g(2). Also see Vol 1, chapter 12.

c. Climb in a holding pattern. Where required, apply climb-in-hold criteria contained in Vol 1, section 18-7.

SECTION 5-6. VECTOR SID

5.6. Vector SID

5.6.1. General. When operationally advantageous, a SID may be developed starting with or including a vector leg followed by an RNAV route. [See Figure 5-6-1 and see appendix D for implementation considerations.]

5.6.2. SID starting with vector leg. When designing an RNAV route following vectors, establish the first waypoint as an Initial Fix leg (IF). No OEA construction or DME/DME screening is required prior to the IF of the RNAV route being joined.

a. The IF beginning an RNAV route must fall within an area and be at an altitude protected by an MVA/MIA. The IF altitude may not be less than 500 feet above airport elevation (rounded to the nearest foot). ATC must be consulted and consideration must be given to the time/distance required for RADAR identification and normal vectoring when designing the IF.

b. A single RNAV course must be defined from the IF.

c. The IF must be a FB fix. A TF leg must follow the IF. General OEA construction applies [see paragraph 1.2.5].

d. The length of the first leg must be sufficient to accommodate a 90-degree turn at the IF. Use standard turn parameters. Where a shorter leg is needed, reduce airspeed in increments of not less than five KIAS until the desired length is achieved [see table 1-2-2]. An alternative method to allow design of a shorter first leg is to limit the amount of intercept to 45 degrees, this must be approved and applied by ATC.

e. Each SID is limited to one common route and must start with a single IF.

f. OCS slope and origin. A flat surface evaluation is conducted from the IF early ATT to late ATT. A sloping OCS [see formula 1-3-5] originates at IF late ATT. The OCS starting elevation is the MVA/MIA altitude minus ROC. Where multiple MVA/MIA sectors apply, the most demanding surface must be used. Climb gradients are not authorized as mitigation for obstacles that penetrate the flat or sloping OCS, the surface must be raised by increasing fix altitudes or redesigning the route.

5.6.3. SID including vector legs. A SID may start with an RNAV route that has a manual termination followed by vectors to join an RNAV route (Open SID). Construct and evaluate the route off the runway using the applicable straight or turning criteria. No OEA construction or DME/DME screening is required between the fix beginning a manual termination leg and the IF of the RNAV route being joined.

a. The RNAV route off the runway must terminate with either an FM or VM.

b. An FM beginning with a FB fix is preferred. This combination encompasses the most operators.

c. An FM that results in a turn must start with a FB fix.

d. An FM that doesn't require a turn may be either a FB or FO fix.

e. A VM must start with a FO.

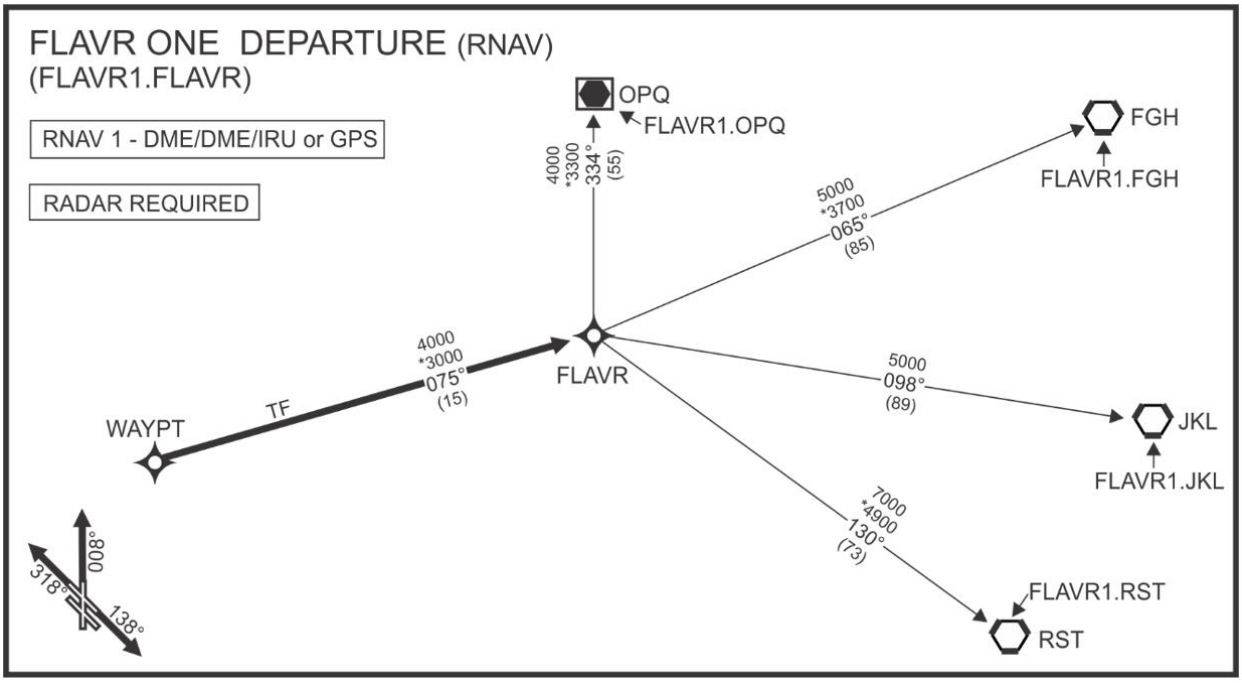
f. The fix beginning a manual termination leg must fall within an area and at an altitude protected by either an MVA/MIA or DVA.

(1) When a sectored DVA is used, the heading/course of the manual termination leg must comply with the heading limitations of that DVA sector.

(2) If the manual termination leg starts with a FO fix and a sectored DVA is used, the turn to the heading/course must be contained within that DVA sector.

g. For an RNAV route following a vector segment, comply with paragraphs 5.6.2.a thru 5.6.2.f.

Figure 5-6-1. RNAV SID Using Vectors



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VOLUME 2: PERFORMANCE BASED NAVIGATION (PBN)

CHAPTER 8: STANDARD FOR HELICOPTER AREA NAVIGATION (RNAV)

SECTION 1: GENERAL INFORMATION

8.1. General Information

8.1.1. Purpose

This Performance Based Navigation (PBN) chapter contains criteria for the formulation, review, approval and publication of area navigation (RNAV) instrument procedures based on Global Navigation Satellite System (GNSS) navigation for helicopter. The criteria were developed by United States Federal Aviation Administration's (FAA).

8.1.2. General

a. This criteria assumes the use of Global Navigation Satellite System (GNSS) receivers approved for approach operations in accordance with the applicable Technical Standard Order (TSO) or equivalent criteria.

b. Unless otherwise specified, TP308/GPH209 procedures applies. Heliport design must meet the requirements contained in Canadian Aviation Regulations Heliport Standards 325. Obstacle clearance area dimensions are based on 90 knots indicated airspeed (KIAS) maximum in both the initial and intermediate segments and 90 KIAS or 70 KIAS maximum in both the final and the missed approach segments.

Note: The missed approach airspeed limitation applies until the aircraft is established on the inbound course to the missed approach clearance limit. Speed must be depicted if 70 KIAS used for final or MA segment.

c. Apply the hold construction methods and obstacle clearance requirements of Volume 1, Chapter 18. Use pattern 4 for all helicopter holding (including climb-in-hold) up to and including 10 000 ft.

8.1.3. **Background**. The analysis of Global Positioning System/Wide Area Augmentation System (GPS/WAAS) navigation flight test data provides the basis for these criteria. A significant difference exists between approach procedures to runways and approach procedures to heliports. Approaches to runways terminate in relatively obstacle-free environments. Approaches to heliports commonly terminate in areas of dense population and large buildings. Speed limitations incorporated in these criteria provide the smallest obstacle clearance areas, the shortest segment lengths, and the lowest ceiling and visibility minimums. The graphic illustrations in this document are not to scale.

8.1.4. Definitions. See Annex B.

8.1.5. Approach Procedure Types using RNAV (GNSS).

a. IFR to an IFR Heliport. An IFR approach to a heliport that meets the applicable regulations and helicopter standard detailed in CARs 305 and 325.

b. Point-in-Space (PinS) Approach (Proceed VFR). An IFR PinS Approach to one or more heliports or a geographical area associated with a specific heliport. The phrase “Proceed VFR” is charted on the procedure for the VFR segment following the MAP.

c. IFR to a Runway. An IFR helicopter approach procedure to a runway.

SECTION 2: BASIC CRITERIA INFORMATION

8.2. Basic Criteria Information.

8.2.1. Data Resolution

See Annex D.

8.2.2. Documentation Accuracy

See Vol 2, paragraph 1.2.2.

8.2.3. Mathematics Convention

See Annex D.

8.2.4. Conversions

See Annex D.

8.2.5. Definition of Mathematical Constants

See Annex D.

8.2.6. Operation Precedence (Order of Operations).

See Annex D.

8.2.7. Geospatial Standards

See Vol 2, paragraph 1.2.3.

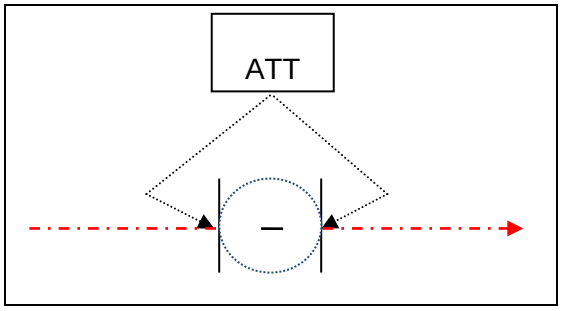
8.2.8. OEA Construction and Obstacle Evaluation Methodology

See Vol 2, Paragraph 1.2.5.

8.2.9. Along Track Tolerance (ATT) Values

Along Track Tolerance (ATT) is the value used (for segment construction purposes) to quantify position uncertainty of an RNAV fix. The application of ATT can; therefore, be considered “circular;” i.e., the ATT value assigned describes a radius around the plotted position RNAV fix (See Figure 8-2-1 and Table 8-2-1). In order to account for ATT in procedure design, OEAs are constructed and evaluated from the ATT value prior to a segment’s initial fix to the ATT value past the segment termination fix. ATT values are not included in minimum segment length calculations.

Figure 8-2-1: Along Track Tolerance (ATT)



Note: Cross-track tolerance (XTT) values were considered in determining minimum segment widths and are not considered further in the segment construction.

Table 8-2-1: ATT Values

RNAV Procedure	Segment	ATT
GNSS	**Enroute** Feeder, initial, Intermediate, Missed Approach (> 30 NM)	**2.0 NM**
	Terminal Feeder, initial, Intermediate, Missed Approach (≤ 30 NM)	**1.0 NM**
	Approach (final)	**0.3 NM**
WAAS* (LP)	**Approach** (final)	**40 meters**

Note: * Applies to the final segment only. Apply GNSS values to all other segment of the approach procedure. Localizer Performance (LP).

8.2.10. **Procedure Identification.** GPS and WAAS are considered to be RNAV systems. TP308/GPH209, Volume 1, Chapter 11, Para 1105, applies, except:

a. For approaches to a heliport, NAVAID type is considered GNSS (e.g., COPTER RNAV (GNSS) 160°).

b. IFR Approach to an IFR Runway within 30 degrees alignment. Use the abbreviation “RWY” following by the runway number. Example: COPTER RNAV (GNSS) RWY 22).

c. Point-In-Space (PinS) Approach procedures. Use the magnetic bearing of the final approach course. (e.g., COPTER RNAV (GNSS) 270°.

d. Multiple Procedures to the Same Runway. Use TP 308/GPH209 Volume 1, Chapter 1, paragraph 161b.

8.2.11. **Segment Width (General).** Table 8-2-2 lists primary and secondary width values for all segments of an RNAV approach procedure. Where segments cross* a point 30 NM from aerodrome reference point (ARP) or heliport reference point (HRP), segment primary area width increases (expansion) or decreases (taper) at a rate of 30 degrees relative to course to the appropriate width. Secondary area expansion/taper is a straight-line connection from the point the primary area begins expansion/taper to the point the primary area expansion/taper ends. Reference to route width values is often specified as NM values measured from secondary area edge across the primary area to the secondary edge at the other side. For example, route width for segments more than 30 NM from ARP/HRP is “1-3-3-1.” See figures 8-2-2b and 8-2-2c. For distances ≤ 30 NM, the width is “0.5-1.5-1.5-0.5.” See table 8-2-2 and figure 8-2-2a.

Table 8-2-2: RNAV Linear Segment Width (NM) Values

<table>
<tr><th colspan="2">Segment</th><th>Primary Area Half-Width (p)</th><th>Secondary Area (s)</th></tr>
<tr><td rowspan="2">En Route, Feeder, Initial & Missed Approach</td><td rowspan="2">> 30 NM from HGC</td><td>± 3.00</td><td>1.00</td></tr>
<tr><td colspan="2">1-3-3-1</td></tr>
<tr><td rowspan="2">Feeder, Initial, Missed Approach</td><td rowspan="2">≤ 30 NM from HGC</td><td>± 1.50</td><td>0.5</td></tr>
<tr><td colspan="2">0.5-1.5-1.5-0.5</td></tr>
<tr><td colspan="2">Intermediate</td><td>Continues initial segment width until 2 NM prior to PFAF. Then tapers uniformly to final segment width.</td><td>Continues initial segment width until 2 NM prior to PFAF. Then tapers to final segment width.</td></tr>
</table>

***Note:** Feeder segment width is 1-3-3-1 at all distances greater than 30 NM from ARP/HRP. A segment designed to cross within 30 NM of the ARP/HRP more than once does not taper in width until the 30 NM limit is crossed for approach and landing; i.e., crosses the limit for the last time before landing. A missed approach segment designed to cross a point 30 NM of the ARP/HRP more than once expands when it crosses the boundary the first time and remains expanded.

Figure 8-2-2a: Segment Width Variables

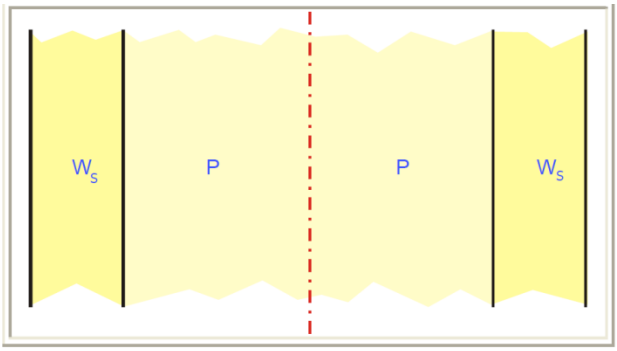


Figure 8-2-2b: Enroute/Feeder/Initial Segment Cross Section (> 30 NM)

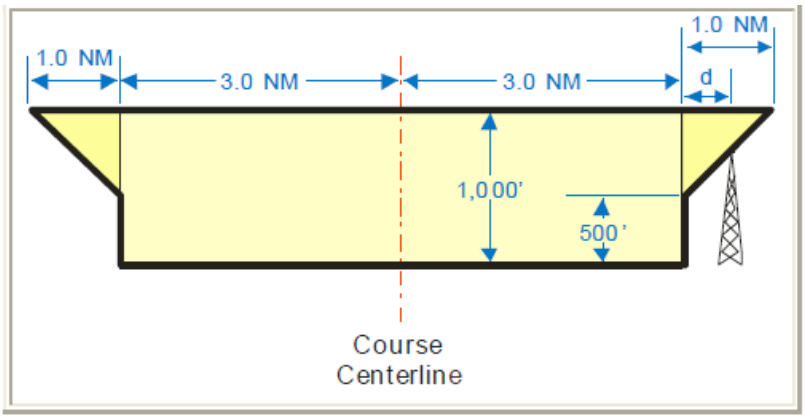
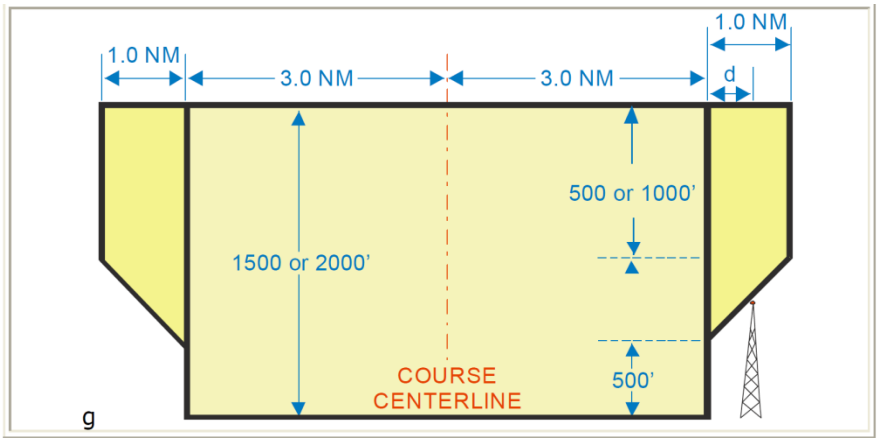


Figure 8-2-2c: Enroute/Feeder/Initial Segment Cross Section Mountainous (> 30 NM)

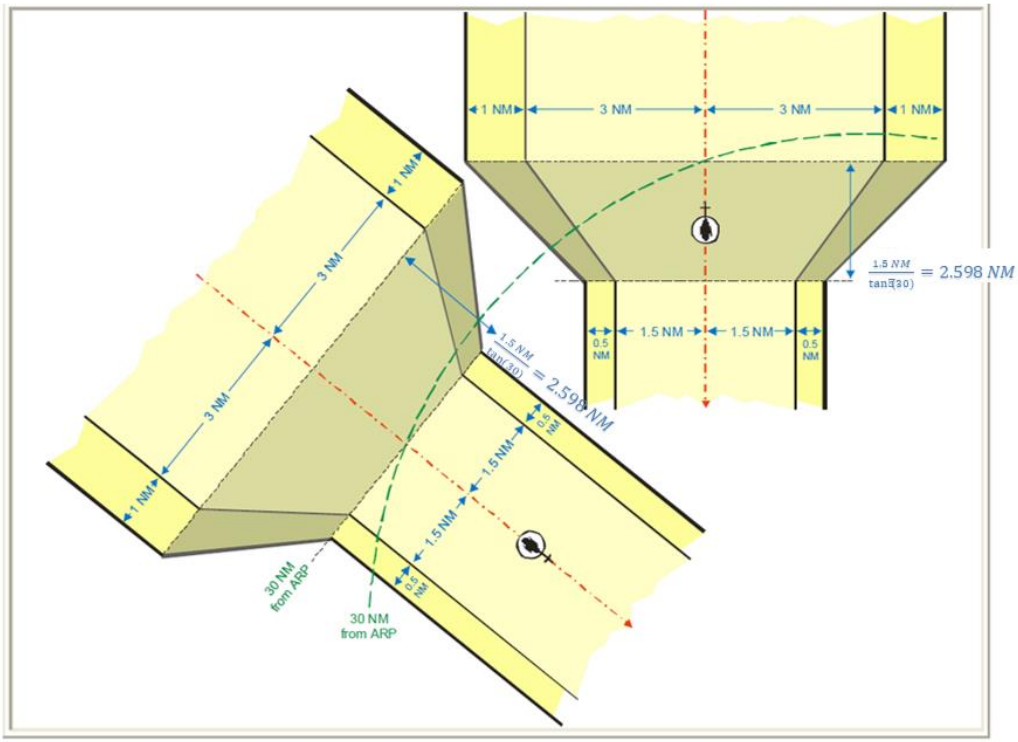


a. Width Changes at 30 NM from ARP/HRP

1. Width Changes at 30 NM from ARP/HRP (non-RF). Receiver sensitivity changes at 30 NM from ARP/HRP. From the point the

designed course crosses 30 NM from ARP/HRP, the primary OEA can taper inward at a rate of 30 degrees relative to course from ± 3 NM to ± 1.5 NM. The secondary area tapers from a 1 NM width when the 30 NM point is crossed to a 0.5 NM width abeam the point the primary area reaches the ± 1.5 NM width. The total along-track distance required to complete the taper is approximately 2.598 NM (15,786.211 ft). Segment width tapers regardless of fix location within the tapering section unless a turn is associated with the fix. Delay OEA taper until the turn is complete and normal OEA turn construction is possible (see figure 8-2-3a).

Figure 8-2-3a: Segment Width Changes at 30 NM



2. Width Changes at 30 NM from ARP/HRP (RF). When the approach segment crosses the point 30 NM from aerodrome reference point in an RF leg, construct the leg beginning at a width of 1-3-3-1 prior to the 30 NM point and taper to 0.5-1.5-1.5-0.5 NM width inside the 30 NM point. Calculate the perpendicular distance ($B_{primary}$, $B_{secondary}$) from the RF segment track centerline to primary and secondary boundaries at any along-track distance (specified as degrees of RF arc "α") from the point the track crosses the 30 NM point using formula 2-1 (see figure 8-2-3b, apply formula 2-3c to find the RF arc radius).

Formula 2-1: RF Segment Taper Width

$$D = \frac{P_{HW > 30} - P_{HW \leq 30}}{\tan(30°)}$$

$$D = \frac{3 - 1.5}{\tan(30°)}$$

$$\alpha = \frac{180 \cdot D}{\pi \cdot R}$$

Calculates degrees of arc (α) to complete taper

$$B_{primary} = P_{HW > 30} - P_{HW \leq 30} \cdot \frac{\phi \cdot \pi \cdot R}{180 \cdot D}$$

$$B_{primary} = 3 - 1.5 \cdot \frac{\phi \cdot \pi \cdot R}{180 \cdot D}$$

$$B_{secondary} = S_{HW > 30} - S_{HW \leq 30} \cdot \frac{\phi \cdot \pi \cdot R}{180 \cdot D}$$

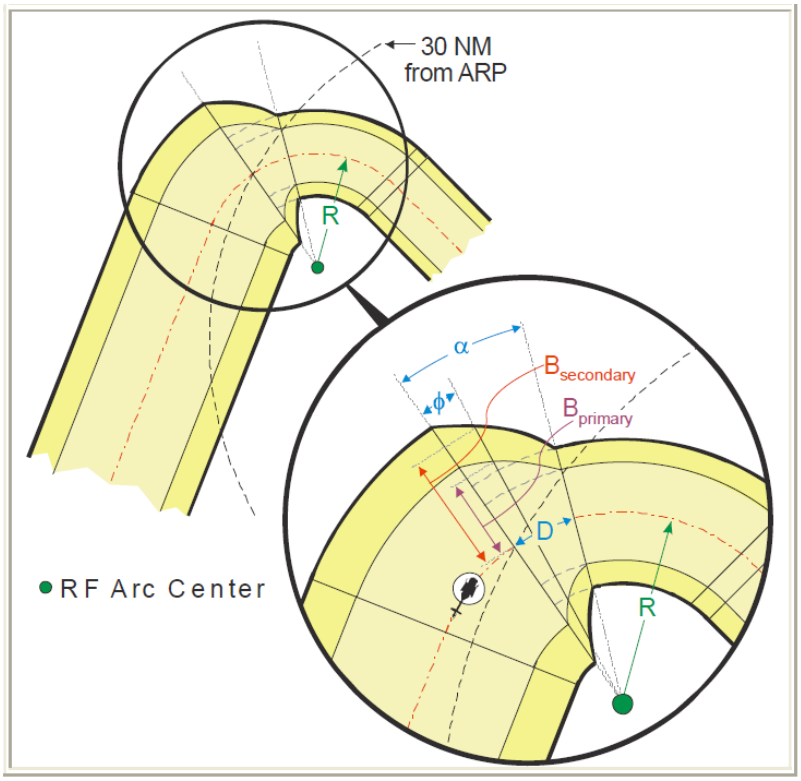
$$B_{secondary} = 4 - 2 \cdot \frac{\phi \cdot \pi \cdot R}{180 \cdot D}$$

Where:

D = taper distance
R = RF leg radius
ϕ = degrees of arc (RF track)
$P_{HW > 30}$ = Primary Half Width outside 30 NM
$P_{HW \leq 30}$ = Primary Half Width at or inside 30 NM
$S_{HW > 30}$ = Secondary Half Width outside 30 NM
$S_{HW \leq 30}$ = Secondary Half Width at or inside 30 NM
B = taper width from centerline

Note: "D & R" units will be in NM.

Figure 8-2-3b: Segment Width Changes in RF Leg



8.2.12. **Calculating the Turn Radius (R).** The design turn radius value is based on four variables: indicated airspeed, assumed tailwind, altitude, and bank angle. Calculate R using formula 2-3c. Apply the indicated airspeed from table 1-2-2 for the highest speed helicopter category that will be published on the approach procedure. Apply the highest expected turn altitude value. Apply the appropriate bank angle from table 8-2-4 and formula 2-2 to determine the vertical path altitude (VP_{alt}).

Formula 2-2: Vertical Path Altitude (VP_{alt})

$$\mathbf{VP_{alt} = e^{\frac{D_Z \cdot \tan(\theta)}{r}} \cdot (r + PFAF_{alt}) - r}$$

Where:

$PFAF_{alt}$ = Designed PFAF MSL altitude

θ = glidepath angle

D_Z = distance (ft) from PFAF to fix

Note: If D_Z is a NM value, convert to feet by multiplying NM by 1852/0.3048

Note: Determine the highest altitude within a turn by:

- For approach, calculate the vertical path altitude (VP_{alt}) by projecting a 3-degree vertical path from the PFAF along the designed nominal flight track to the turn fix.

- For missed approach highest altitude in a turn, apply (a) or (b), and (c).

  a. Turn-At-A-Fix, project a vertical path along the nominal flight track from the SOC point and altitude to the turn fix, that rises at a rate of 400 ft/NM (Helicopter) or a higher rate if a steeper climb gradient is specified. Compare the vertical path altitude at the fix to the minimum published fix altitude, apply the higher of the two; or

  b. Turn-At-An-Altitude, apply the climb-to-altitude; and

  c. Plus an additive, (Turn-At-A-Fix (FO) and Turn-At-An-Altitude) based on a continuous climb of 400 ft per 12 degrees of turn [ϕ*400/12], where ϕ is degrees of turn). The turn altitude must not be higher than the published missed approach altitude.

- Helicopter example: 900 ft would be added for a turn of 27 degrees, 767 ft would be added for 23 degrees, 333 ft for 10 degrees of turn.

Step 1: Determine the true airspeed **(V_{KTAS})** for the turn using formula 2-3a. Locate and use the appropriate knots indicated airspeed **(V_{KIAS})** from table 1-2-2. Use the highest altitude within the turn.

Formula 2-3a: True Airspeed (V_{KTAS})

$$V_{KTAS} = \frac{V_{KIAS} \cdot 171233 \cdot \sqrt{(288 + 15) - 0.00198 \cdot alt}}{(288 - 0.00198 \cdot alt)^{2.628}}$$

where alt = aircraft MSL elevation
V_{KIAS} = knots indicated airspeed

(VKIAS*171233*((288+15)-0.00198*alt)^0.5)/(288-0.00198*alt)^2.628

Table 8-2-3. Reserved

Step 2: Calculate the appropriate tailwind component (V_{KTW}) using formula 2-3b for the highest altitude within the turn. EXCEPTION: If the MSL altitude is 2,000 ft or less above airport elevation, use 30 knots.

Formula 2-3b: Tailwind (V_{KTW})

$V_{KTW} = 0.00198 \cdot alt + 47$

where alt = highest turn altitude (MSL)

Note: If "alt" is 2,000 or less above airport elevation, then $V_{KTW} = 30$

0.00198*alt+47

Note: Greater tailwind component values may be used where data indicates higher wind conditions are likely to be encountered. Where a higher value is used, it must be recorded in the procedure documentation.

Step 3: Calculate R using formula 2-3c.

Formula 2-3c. Turn Radius (R)

$$R = \frac{(V_{KTAS} + V_{KTW})^2}{tan(bank_{angle}) \cdot 68625.4}$$

where $bank_{angle}$ = assumed bank angle (normally 11° or 14° for Helicopter)

Note: Use formula 2-8 to verify the required bank angle does not exceed the design bank angle (11 or 14 degrees), see table 8-2-4. R is in nautical miles.

Table 8-2-4: Bank Angles

Knots True Airspeed (KTAS)	< 90	≥ 90
Bank Angle (In degrees)	11.0	14.0

8.2.13. **Turn Construction.** If the outbound course from a fix differs by more than 0.03 degrees from the inbound course to the fix (courses measured at the fix), a turn is indicated.

a. Turns at Fly-Over Fixes (see figures 8-2-4 and 8-2-5).

1) Extension for Turn Delay. Turn construction incorporates a delay in start of turn to account for pilot reaction time and roll-in time (rr). Calculate the extension distance in feet using formula 2-4a (terminal) or formula 2-4b (feeder and enroute).

Formula 2-4a: Reaction & Roll Dist (Terminal)

$$rr = 6 \cdot \frac{\frac{1852}{0.3048}}{3600} \cdot V_{KTAS}$$

$6*1852/0.3048/3600*V_{KTAS}$

Note: 6 second delay. “rr” units will be in ft.

Formula 2-4b: Reaction & Roll Dist (Enroute, Feeder)

$$rr=8 \cdot \frac{\frac{1852}{0.3048}}{3600} \cdot (V_{KTAS}+V_{KTW})$$

$8*(1852/0.3048/3600)*(V_{KTW}+V_{KTAS})$

Note: 8 second delay. “rr” units will be in ft.

Step 1: Determine **R.** See formula 2-3c.

Step 2: Determine **rr**. See formula 2-4a or formula 2-4b.

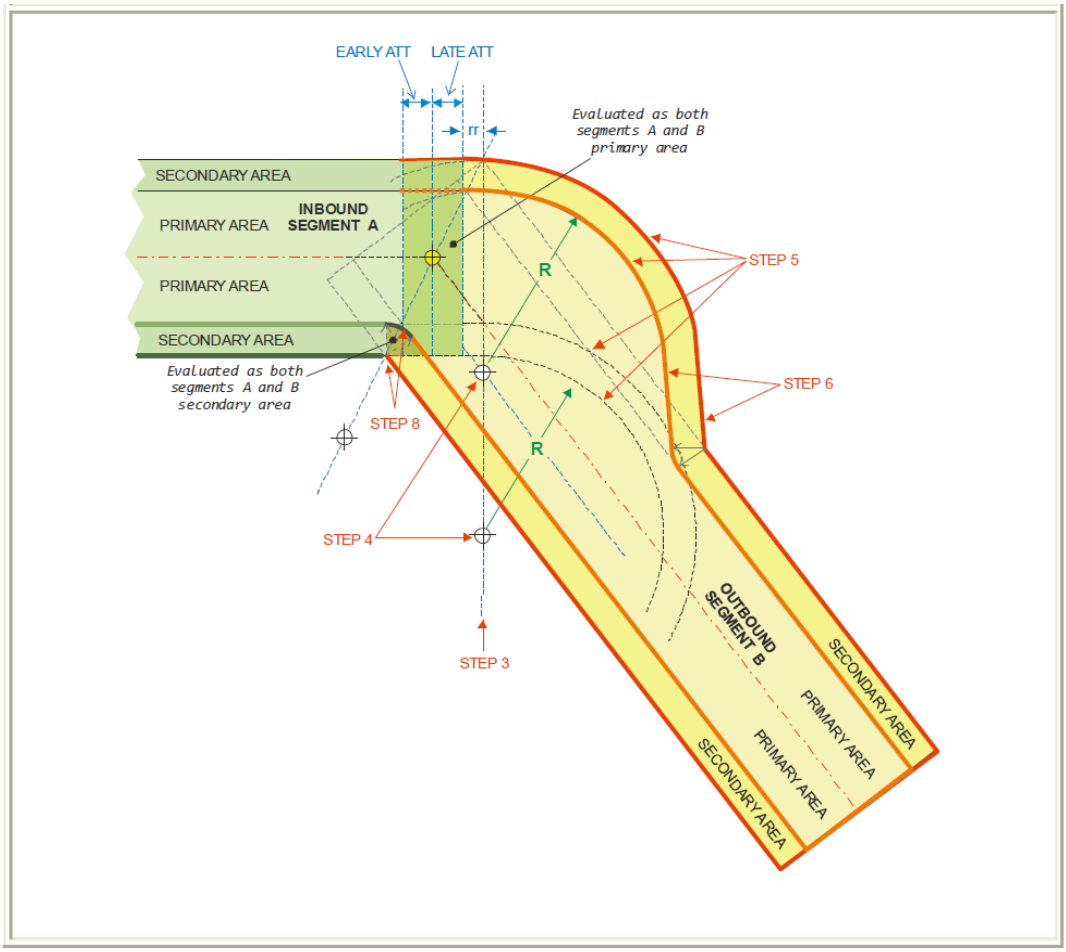
Step 3: Establish the baseline for construction of the turn expansion area as the line
perpendicular to the inbound track at a distance past the turn fix equal to **(ATT+rr).**

Step 4: On the baseline, locate the center points for the primary and secondary turn
boundaries. The first is located at a distance R from the non-turning side primary boundary. The second is located at a distance R from the turning side secondary boundary (see figures 8-2-4 and 8-2-5).

Step 5: From these center points construct arcs for the primary boundary of radius R. Complete the secondary boundary by constructing additional arcs of radius ($R+W_S$) from the same center points. (W_S=width of the secondary). This is shown in figures 8-2-4 and 8-2-5.

Step 6: The arcs constructed in step 5 are tangent to the outer boundary lines of the inbound segment. Construct lines tangent to the arcs based on the first turn point tapering inward at an angle of 30 degrees relative to the outbound track that joins the arc primary and secondary boundaries. If both the inner and outer arcs lie outside subsequent segment boundary lines, but the resulting tapering line tangent points lie inside the subsequent segment boundary lines, consider the expanded boundary connection points to be the intersection of the arc and the subsequent segment boundary lines. If the arcs from the second turn point are inside the tapering lines as shown in figure 8-2-4, then they are disregarded and the expanded area construction is completed. If not, proceed to step 7.

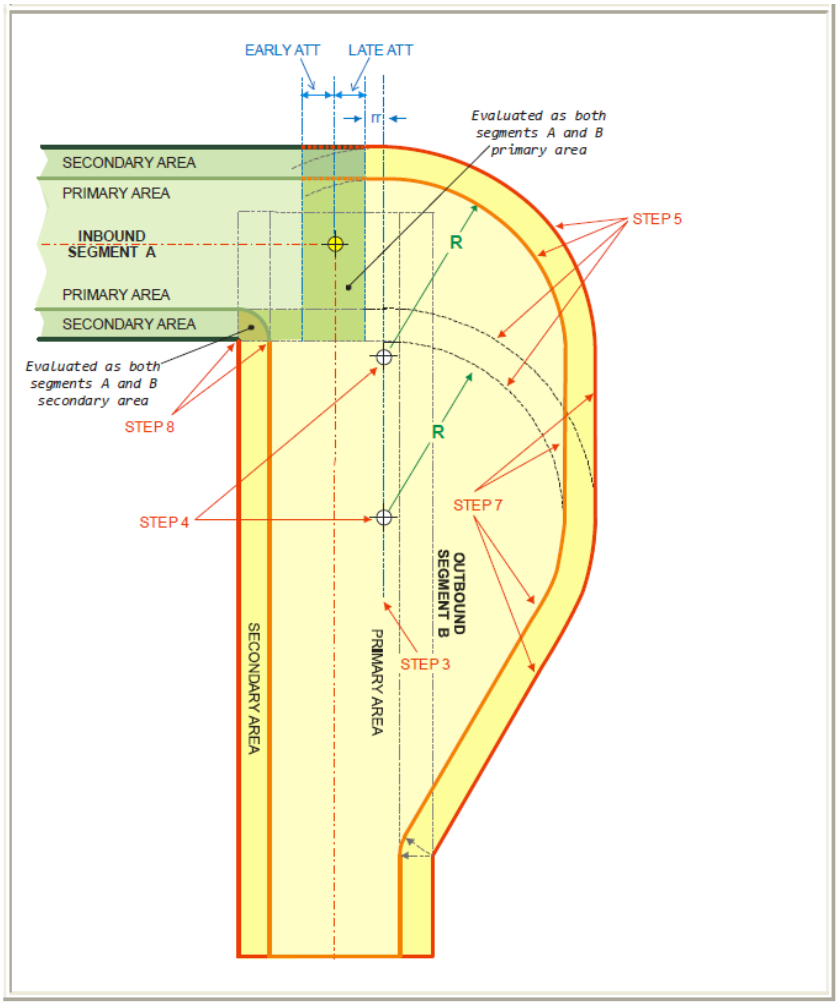
Figure 8-2-4: Fly-Over with No Second Arc Expansion



Step 7: If both the inner and outer arcs lie outside the tapering lines constructed in step 6, connect the respective inner and outer arcs with tangent lines and then construct the tapering lines from the arcs centered on the second center point as shown in figure 8-2-5.

Step 8: The inside turn secondary boundary is the intersection of the preceding and succeeding segment secondary boundaries. The inside turn primary boundary is an arc of secondary-width radius joining the preceding and succeeding segment primary boundaries.

Figure 8-2-5: Fly-Over with Second Arc Expansion



Note: The inbound OEA end (± ATT) is evaluated for both inbound and outbound segments.

2) Minimum length of TF leg following a fly-over turn. The leg length of a TF leg following a fly-over turn must be sufficient to allow the aircraft to return to course centerline. Determine the minimum leg length (L) using Distance of Turn Anticipation **(**DTA) distance from formula 2-5 and formula 2-6.

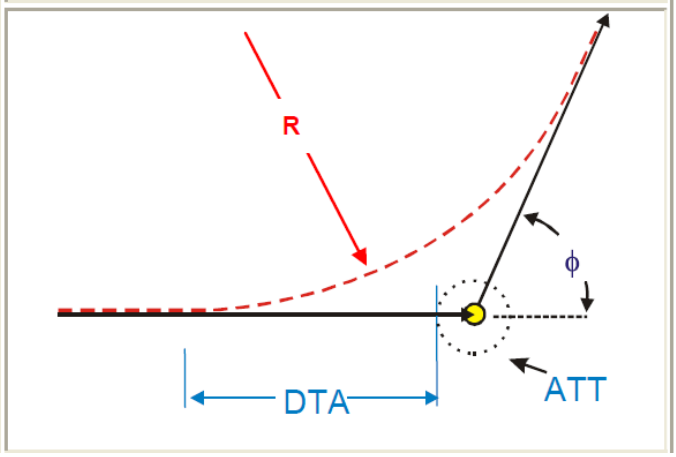
Formula 2-5: Distance of Turn Anticipation (DTA)

$$\mathbf{DTA} = \mathbf{R} \cdot \mathbf{tan}\left(\frac{\Phi}{\mathbf{2}}\right)$$

Where:

R = turn radius from formula 2-3c

ϕ = degrees of heading change



Note: "R" units will be in NM.

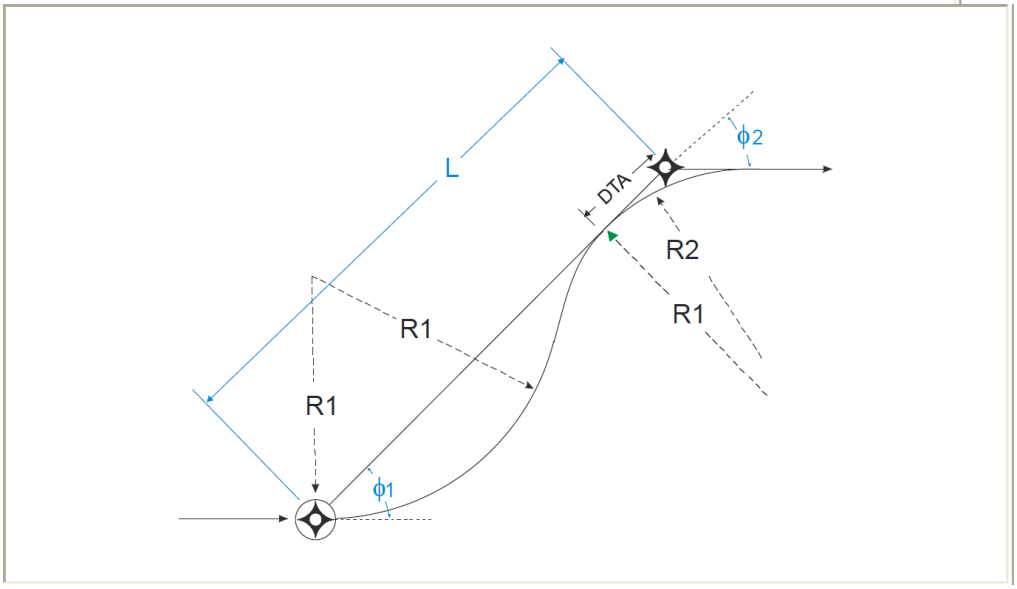
Formula 2-6: TF Leg Minimum Length (L) Following Fly-Over Turn

$$\text{If } \phi_1 < \frac{180}{\pi} \cdot \text{acos}(3^{0.5} - 1), \text{then}$$

$$L = R_1 \cdot \left(\sin(\phi_1) + 2 \cdot \sin\left(\text{acos}\left(\frac{1 + \cos(\phi_1)}{2} \right) \right) \right) + R_2 \cdot \tan\left(\frac{\phi_2}{2} \right), \text{else}$$

$$L = R_1 \cdot \left(sin(\phi_1) + 4 - 3^{0.5} - 3^{0.5} \cdot \cos(\phi_1) \right) + R_2 \cdot \tan\left(\frac{\phi_2}{2} \right)$$

Where:
R1 = turn radius (NM) at the segment initial fix (formula 2-3c)
R2 = turn radius (NM) at the segment termination fix (zero if no fly-by turn)
ϕ1 = turn magnitude at the segment initial fix
ϕ2 = turn magnitude at the segment termination fix



Note: "L" units will be in NM.

b. **Fly-By Turn.** See figure 8-2-6.

Step 1: Establish a line through the turn fix that bisects the turn angle. Determine Turn Radius (R). See formula 2-3c. Scribe an arc (with origin on bisector line) of radius R tangent to inbound and outbound courses. This is the designed turning flight path.

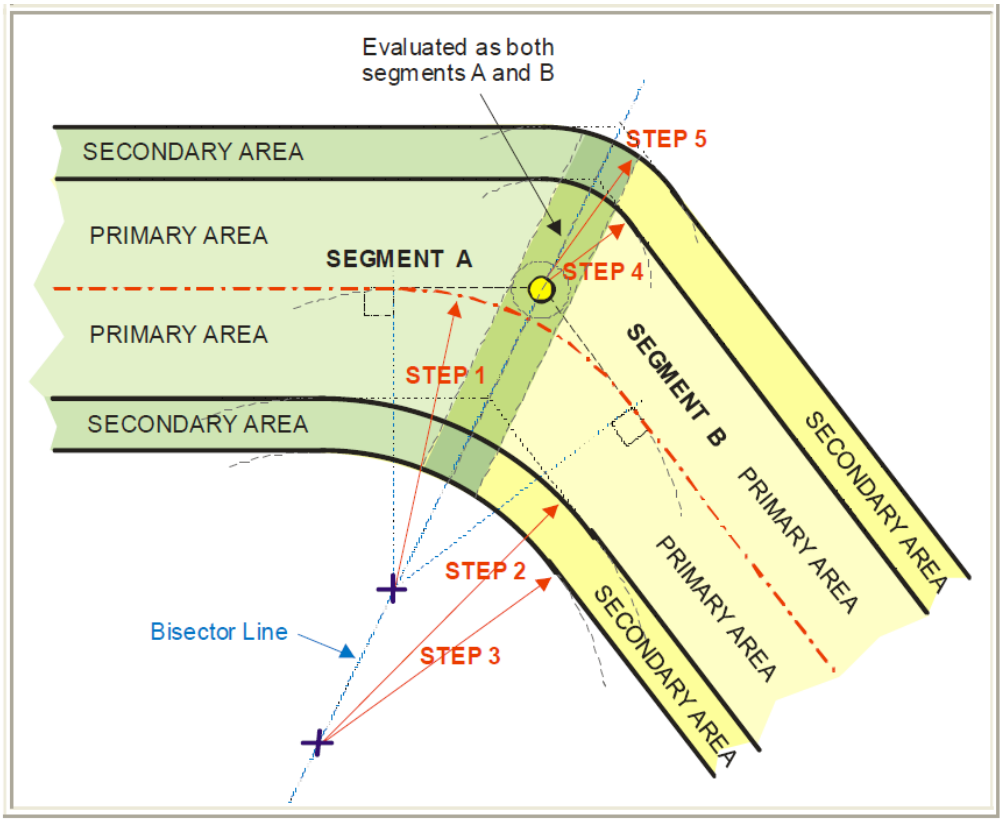
Step 2: Scribe an arc tangent to the inner primary boundaries of the two segment legs with a radius equal to $R + \frac{\text{Primary Area Half-width}}{2}$ (example: half width of 2 NM, the radius would be R+1.0 NM).

Step 3: Scribe an arc that is tangent to the inner secondary boundaries of the two segment legs using the origin and radius from step 2 minus the secondary width.

Step 4: Scribe the primary area outer turning boundary with an arc with a radius equal to the segment half width centered on the turn fix.

Step 5: Scribe the secondary area outer turning boundary with the arc radius from step 4 plus the secondary area width centered on the turn fix.

Figure 8-2-6: Fly-By Turn Construction



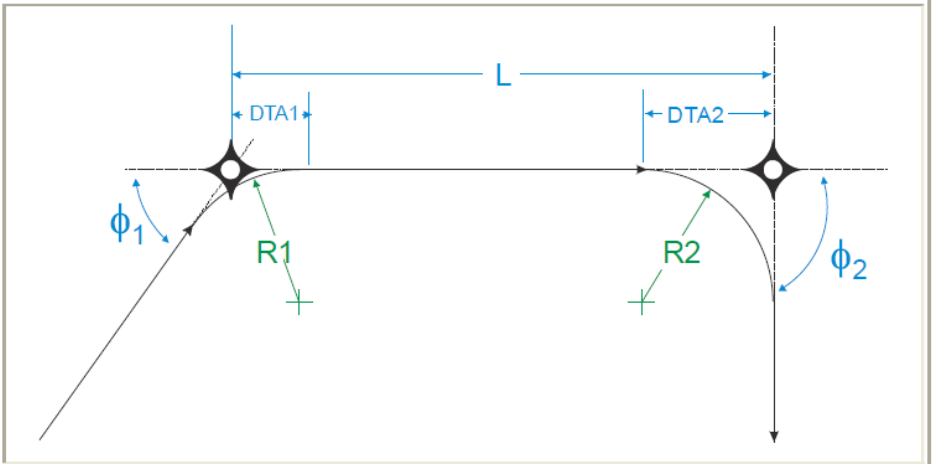
1) Minimum length of track-to-fix (TF) leg following a fly-by turn. Calculate the minimum length for a TF leg following a fly-by turn using formula 2-7.

Formula 2-7: TF Leg Minimum Length (L) Following Fly-by Turn

$$\mathbf{L = R1 \cdot \tan\left(\frac{\phi_1}{2}\right) + R2 \cdot \tan\left(\frac{\phi_2}{2}\right)}$$

Where:

R1 = Turn radius at the segment initial fix (formula 2-3c)
R2 = Turn radius at the segment termination (formula 2-3c)
Note: Zero when no turn
ϕ_1 = turn magnitude at the segment initial fix
ϕ_2 = turn magnitude, if any at the segment termination fix



Note: "L" units will be in NM.

c. **Radius-to-Fix (RF) Turn.** Incorporation of an RF segment may limit the number of aircraft served by the procedure. RF legs are used to control the ground track of a turn where obstructions prevent the design of a fly-by or fly-over turn, or to accommodate other operational requirements.* The curved leg begins tangent to the previous segment course at its terminating fix and ends tangent to the next segment course at its beginning fix (see figure 8-2-7). OEA construction limits turn radius to a minimum value equal-to or greater-than the OEA (primary and secondary) half-width. The RF segment OEA boundaries are parallel arcs.

***Note:** RF legs segments are not applicable to the final segment or section 1 of the missed approach segment. RF legs in the intermediate segment must terminate at least 2 NM prior to the PFAF. Where RF legs are used, annotate the procedure (or segment as appropriate) "RF Required."

Step 1: Determine the segment turn radius (R) that is required to fit the geometry of the terrain/airspace. Enter the required radius value into formula 2-8 to verify the resultant bank angle is ≤ 20 degrees (maximum allowable bank angle). Where a bank angle other than standard is used, annotate the value in the remarks section of the appropriate form.

Formula 2-8: Radius-to-Fix (RF) Bank Angle

$$bank_{angle} = atan\left(\frac{(V_{KTAS} + V_{KTW})^2}{R \cdot 68625.4}\right)$$

Where:

V_{KTAS} = value from formula 2-3a

V_{KTW} = value from Order 8260.58, table 1-3

R = required radius

Calculate RF segment length using formula 2-9a.

Formula 2-9a: Radius-to-Fix (RF) Segment Length

$$Segment_{length} = \frac{\pi \cdot R \cdot \phi}{180}$$

Where:

R = RF segment radius
(answer will be in the units entered)

ϕ = # of degrees of ARC
(heading change)

$\pi*R*\phi/180$

Step 2: Turn Center. Locate the turn center at a perpendicular distance R from the preceding and following segments.

Step 3: Flight path. Construct an arc of radius R from the tangent point on the preceding course to the tangent point on the following course.

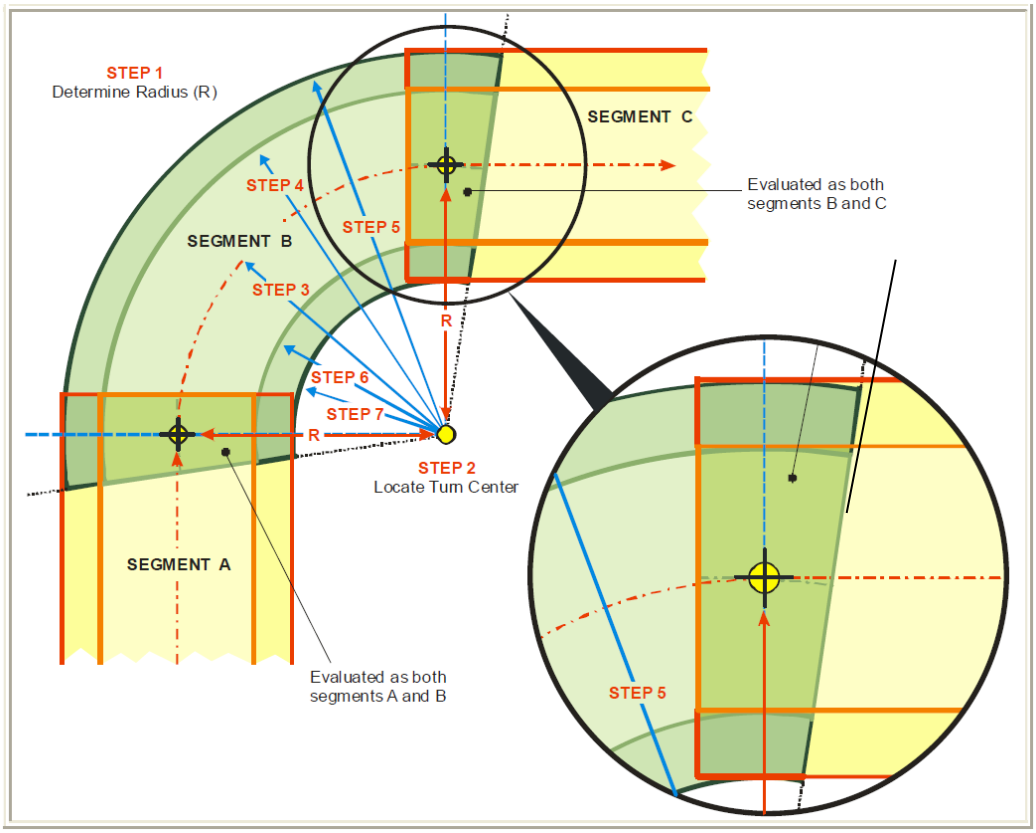
Step 4: Primary area outer boundary. Construct an arc of radius R+Primary area halfwidth from the tangent point on the preceding segment primary area outer boundary to the tangent point on the following course primary area outer boundary.

Step 5: Secondary area outer boundary. Construct an arc of radius R+Primary area halfwidth+ secondary area width from the tangent point on the preceding segment secondary area outer boundary to the tangent point on the following course secondary area outer boundary.

Step 6: Primary area inner boundary. Construct an arc of radius R-Primary area halfwidth from the tangent point on the preceding segment inner primary area boundary to the tangent point on the following course inner primary area boundary.

Step 7: Secondary area inner boundary. Construct an arc of radius R-(Primary area halfwidth + secondary area width) from the tangent point on the preceding segment inner secondary area boundary to the tangent point on the following course inner secondary area boundary.

Figure 8-2-7: Radius-to-Fix (RF) Turn Construction



d. **RNAV TF/VA/VI/CF leg followed by a DF Leg.** Calculate minimum DF segment length using formula 2-9b.

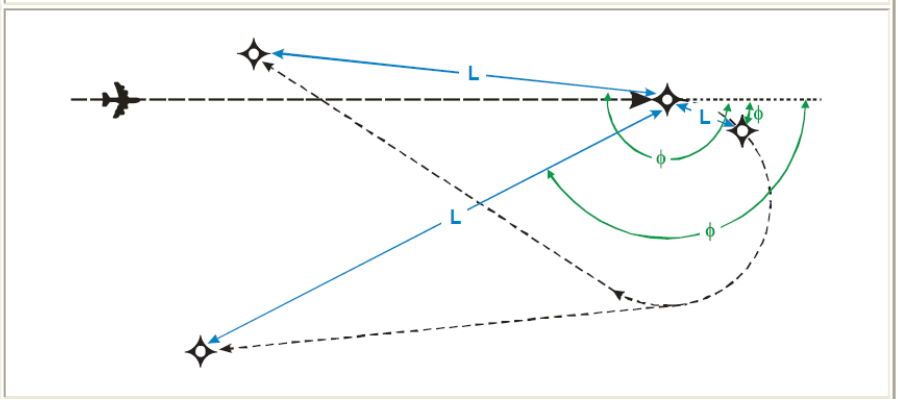
Formula 2-9b: RNAV DF Leg Minimum Length following TF/VA/VI/CF Legs (L)

If $\phi > 30$ then

$$L = 4 \cdot R \cdot \left(\sin\left(\frac{\phi + 30}{2} \right) \right)^2 \text{, else}$$

$$L = 2 \cdot R \cdot \sin(\phi)$$

Where:
R = turn radius (NM) at the segment initial fix (formula 2-3c)
ϕ = turn magnitude at the segment initial fix

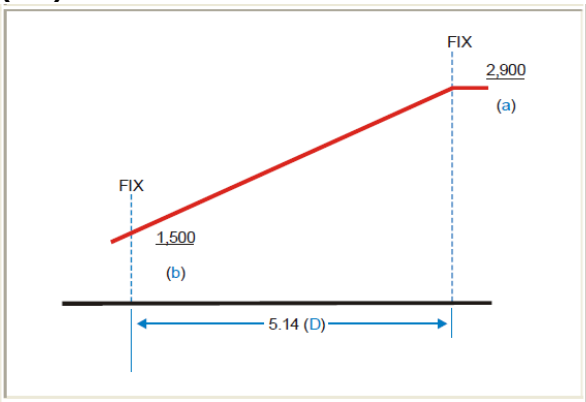


Note: "ϕ" units will be in degrees.

8.2.14. **Helicopter Initial and Intermediate Descent Gradient.** The optimum descent gradient in the initial and intermediate segment is 400 ft/NM (6.58%, 3.77°); maximum is 600 ft/NM (9.87%, 5.64°).

a. **Calculating Descent Gradient (DG).** Determine total altitude lost between the plotted positions of the fixes. Determine the distance (D) in NM. Divide the total altitude lost by D to determine the segment descent gradient using formula 2-10 (see figure 8-2-8).

Figure 8-2-8: Calculating Descent Gradient (DG)



Formula 2-10: Descent Gradient

$$DG = \frac{r \cdot \ln\left(\frac{r + a}{r + b} \right)}{D}$$

Where:
a = beginning altitude
b = ending altitude
D = distance (NM) between fixes

r*ln((r+a)/(r+b))/D

8.2.15. **Feeder Segment.** When the initial approach fix (IAF) is not part of the enroute structure, it may be necessary to designate feeder routes from the enroute structure to the IAF. The feeder segment may contain a sequence of TF segments (and/or RF segments). The maximum course change between TF segments is 90 degrees (70 degrees preferred). Formula 2-3c note applies. Section 2, paragraph 8.2.13 turn construction applies. The feeder segment terminates at the IAF (see section 2, figures 8-2-4, 8-2-5, 8-2-6 and 8-2-7 for construction).

a. **Length.** The **minimum** length of a sub-segment is determined under section 2, paragraph 8.2.13.a(2) or 8.2.13.b(1) as appropriate. The **maximum** length of a sub-segment is 50 miles. The total length of the feeder segment should be as short as operationally possible.

b. **Width.** Primary area width is ± 3.0 NM from course centerline; secondary area width is 1.0 NM (1-3-3-1). These widths apply from the feeder segment initial fix to the approach IAF/termination fix.

c. **Obstacle Clearance.** The feeder segment OEA begins at the beginning fix early ATT and ends at the ending fix late ATT. The minimum ROC over areas is 1,000 ft (2,000 ft or 1500 ft as required for mountainous). TP308/GPH209, Volume 1, paragraph 1720 and 1721 applies. The published minimum feeder route altitude must provide at least the minimum ROC value and must not be less than the altitude established at the IAF. (Refer to figures 8-2-2a, 8-2-2b and apply formula 2-12a for standard secondary ROC.) Apply formula 2-12b for designated mountainous area calculations (formulas are applicable for enroute, feeder, and initial).

d. **Descent Gradient, Helicopter (feeder, initial, intermediate segments).** The optimum descent gradient in feeder, initial, and intermediate segments is 400 ft/NM (6.58%, 3.77°); maximum is 600 ft/NM (9.87%, 5.64°). Where higher descent gradients are required, TP308/GPH209, Volume 1, paragraph 1110 applies.

e. **Minimum Crossing Altitude (MCA).** Establish an MCA when an obstacle prevents a normal climb to a higher minimum enroute altitude (MEA). The normal climb gradient is shown in table 8-2-5. When a MCA is required, chart the required climb gradient and rate of climb on the procedure.

Table 8-2-5: Normal Helicopter Enroute Climb Gradient

Gradient Level (MSL)	Gradient	OCS Slope
at or below 5,000 ft	300 ft per NM	20.25:1
5,001 ft through 10,000 ft	240 ft per NM	25.3:1

Note: The MCA computation is based on the distance from the nearest fix displacement tolerance line to the obstacle. The computation is rounded to the next higher 100-ft increment (see figure 8-2-9 for an example MCA computation).

f. **Determine MCA.** Apply formula 2-11a, or 2-11b to determine MCA.

Formula 2-11a: MCA Sea Level to 5,000 ft MSL

$$MCA = A - 300 \cdot L$$

Where:

A = "Climb to" MSL Altitude

L = Length of segment (NM)

A-300*L

Formula 2-11b: MCA 5,001 - 10,000 ft MSL

$$MCA = 5000 - 300\left(L - \frac{A-5000}{240}\right)$$

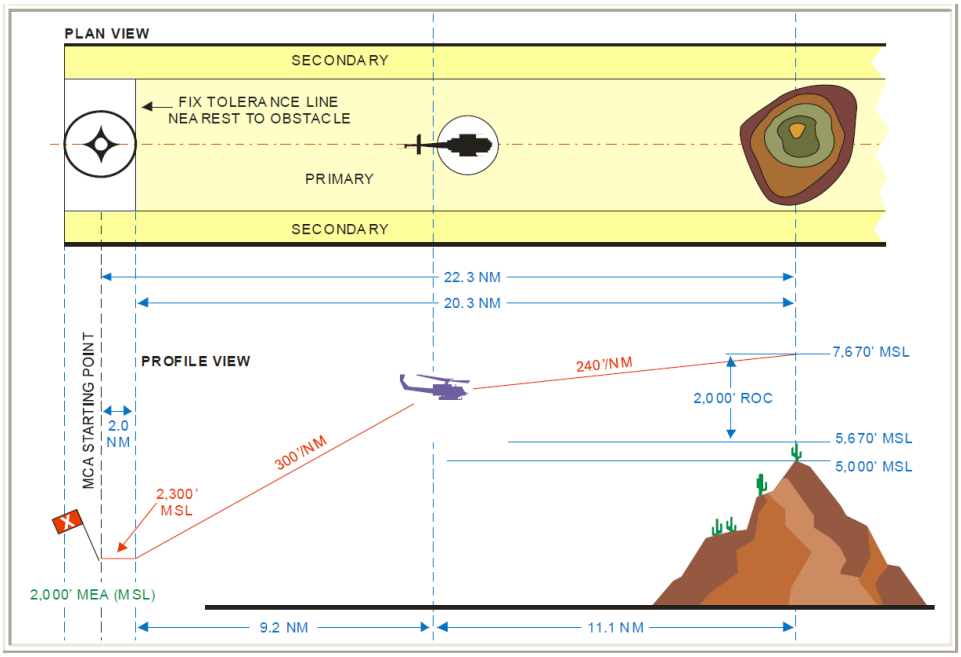
Where:

A = "Climb to" MSL Altitude

L = Length of segment (NM)

5000-300*(L-(A-5000)/240)

Figure 8-2-9: Minimum Crossing Altitude (MCA)



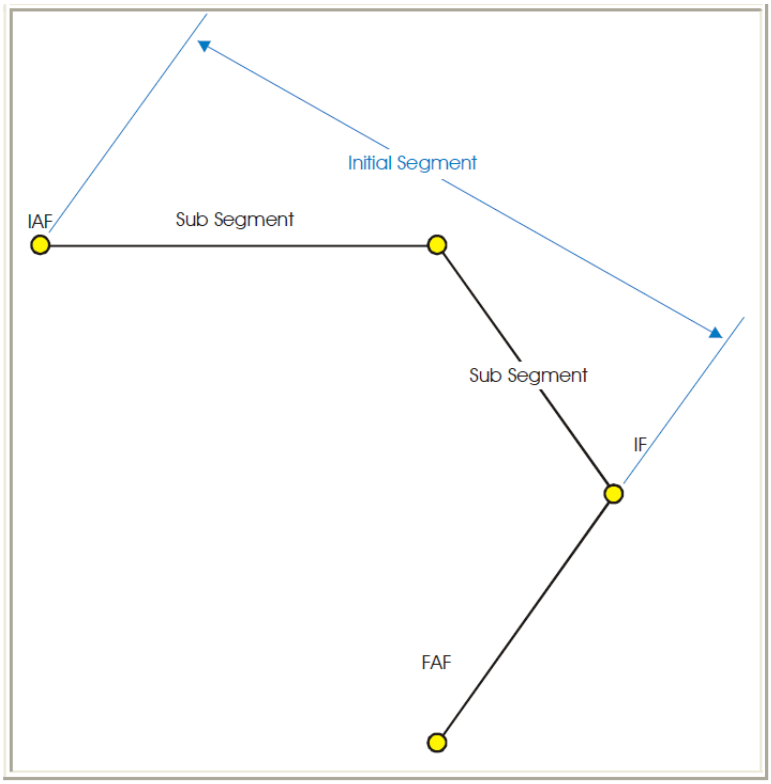
Step 1: Add 1,000 ft ROC (or 2,000/1500 ft as required for mountainous) to MSL height of obstacle.

Step 2: Apply formula 2-11a or 2-11b to determine the MCA.

Terminal Segments

8.2.16. **Initial Segment.** The initial segment begins at the IAF and ends at the intermediate fix (IF). The initial segment may contain sequences of straight sub segments (see figure 8-2-10). Section 2, paragraphs 8.2.16.b, 8.2.16.c, 8.2.16.d, and 8.2.16.e apply to all sub segments individually. The total length of all sub segments must not exceed 50 NM. For descent gradient limits, see Volume 1, paragraph 1110.

Figure 8-2-10: Initial Sub Segments



a. **Course Reversal.** The optimum design incorporates either the basic Y or T configuration. This design eliminates the need for a specific course reversal pattern. Where the optimum design cannot be used and a course reversal is required, establish a holding pattern at the initial, or intermediate approach fix. See section 2, paragraph 8.2.16.f(2). The maximum course change at the fix (IAF/IF) is to 90 degrees (70 degrees above FL 190).

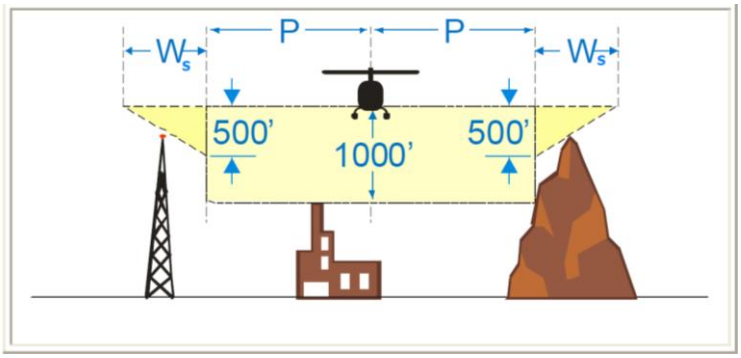
b. **Alignment.** Design initial/initial and initial/intermediate TF segment intersections with the smallest amount of course change that is necessary for the procedure. No course change is optimum. Where a course change is necessary, it should normally be limited to 70 degrees or less; 30 degrees or less is preferred. The maximum allowable course change between TF segments is 90 degrees.

c. **Area – <u>Length</u>.** The maximum segment length (total of sub segments) is 50 NM. Minimum length of sub segments is determined as described in section 2, paragraphs 8.2.13.a(2) and 8.2.13.b(1).

d. **Area – <u>Width</u>** (see table 8-2-2).

e. **Obstacle Clearance.** The initial OEA begins at the segment beginning fix early ATT and ends at the segment ending fix late ATT. Apply 1,000 ft of ROC over the highest obstacle in the primary OEA. The ROC in the secondary area is 500 ft at the primary boundary tapering uniformly to zero at the outer edge (see figure 8-2-11).

Figure 8-2-11: Enroute/Feeder/Initial Segment ROC



Note: Allowance for precipitous terrain should be made as specified in TP308/GPH209, Volume 1, paragraph 3.2.2.b.

Calculate the secondary ROC values using formula 2-12a.

Formula 2-12a: Enroute/Feeder/Initial Secondary ROC (Standard)

$$ROC_{secondary} = 500 \cdot \left(1 - \frac{d}{W_s}\right)$$

Where:

W_s = width (ft) of secondary

d = distance (ft) from edge of primary area measured perpendicular to boundary

500*(1-d/Ws)

Calculate the secondary ROC values for designated mountainous areas using formula 2-12b. Consult TP308/GPH209, Volume 1, para 1720 for possible adjustments to formula output.

Formula 2-12b: Enroute/Feeder/Initial Secondary ROC (Mountainous)

$$ROC_{secondary} = 500 \cdot \left(1 - \frac{d}{D}\right) + (500 \text{ or } 1000)^*$$

Where:

D = width (ft) of secondary

d = distance (ft) from edge of primary area measured perpendicular to boundary

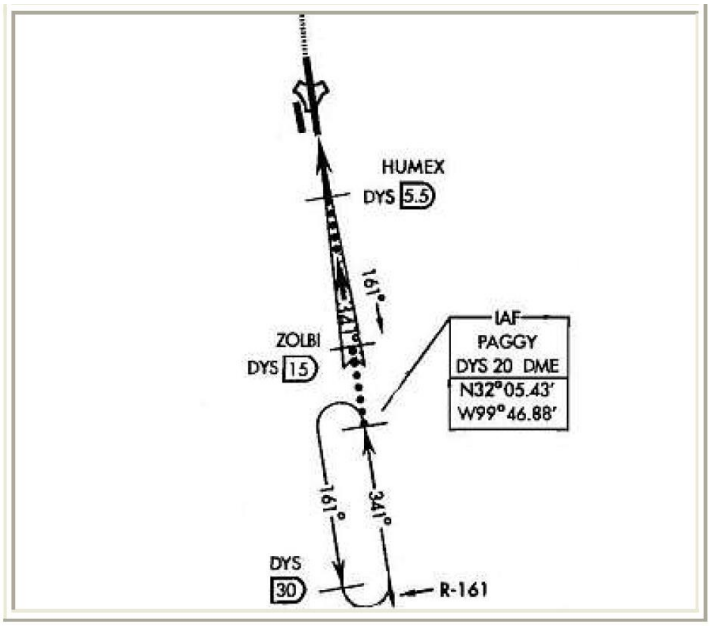
500*(1-d/D)+(500 or 1000)*

***NOTE:** For mountainous regions requiring obstacle clearance of 1500' add 500' and add 1000' for the regions requiring 2000' obstacle clearance.

f. **Holding Pattern Initial Segment.** A holding pattern may be incorporated into the initial segment procedure design where an operational benefit can be derived; e.g., arrival holding at an IAF, course reversal pattern at the IF, etc. See TP308/GPH209 Volume 1, Chapter 18, Holding Pattern Criteria, for RNAV holding pattern construction guidance.

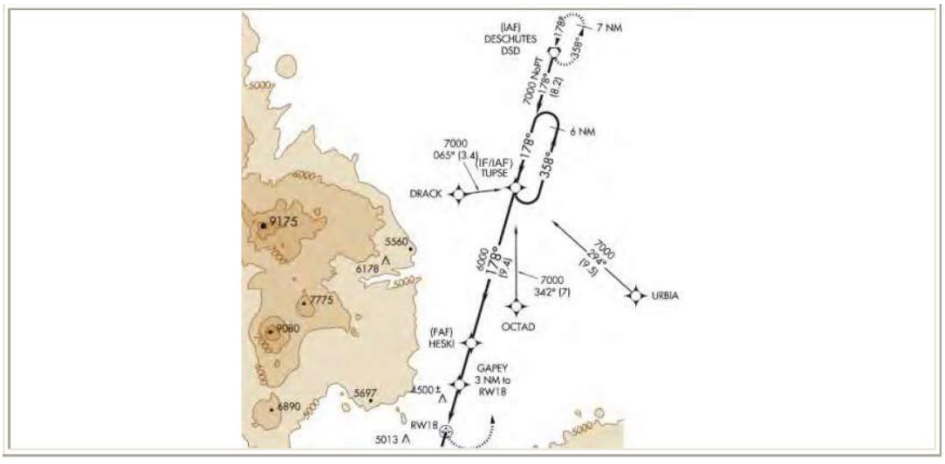
1) Arrival Holding. Ideally, the holding pattern inbound course should be aligned with the subsequent TF leg segment (tangent to course at the initial fix of the subsequent RF segment). See figure 8-2-12a. If the pattern is offset from the subsequent TF segment course, the subsequent segment length must accommodate the resulting DTA requirement. Establish the minimum holding altitude at or above the IAF/IF (as appropriate) minimum altitude. MEA minimum altitude may be lower than the minimum holding altitude.

Figure 8-2-12a: Arrival Holding Example



2) Course Reversal. Ideally, establish the minimum holding altitude as the minimum IF fix altitude (see figure 8-2-12b). In any case, the published holding altitude must result in a suitable descent gradient in the intermediate segment: optimum descent gradient in the initial and intermediate segment is 400 ft/NM (6.58%, 3.77°); maximum is 600 ft/NM (9.87%, 5.64°). If the pattern is offset from the subsequent TF segment course, the subsequent segment length must accommodate the resulting DTA requirement. Maximum offset is 90 degrees.

Figure 8-2-12b: Course Reversal Example



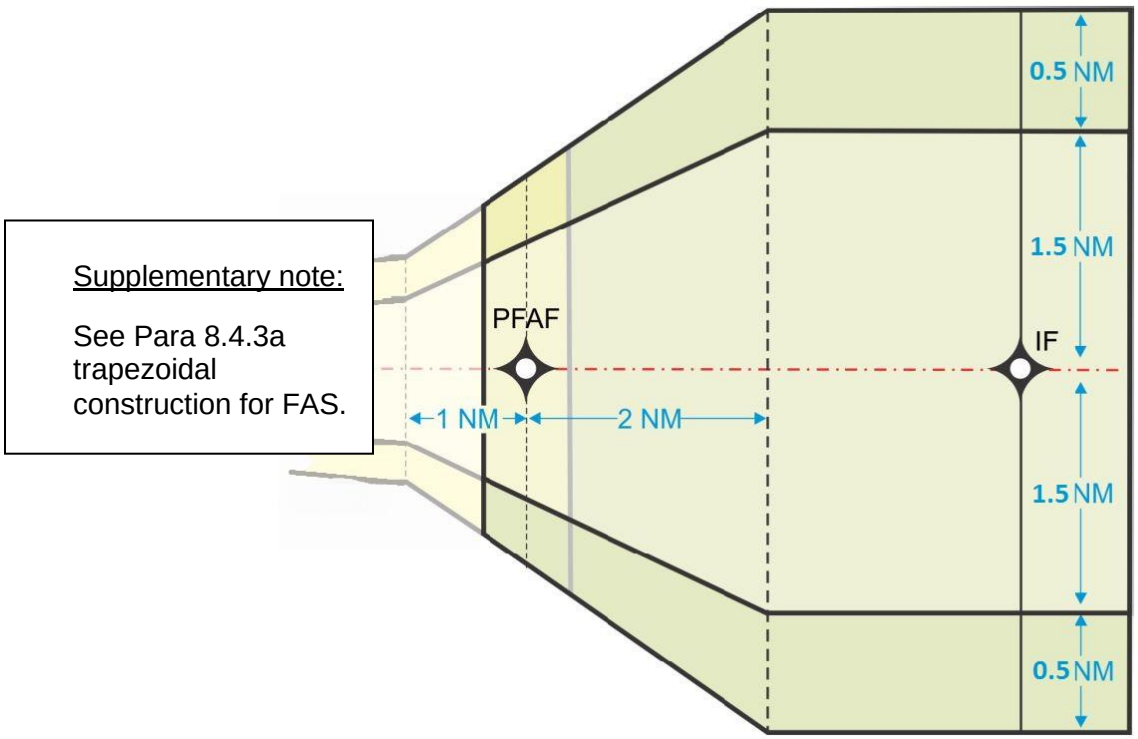
8.2.17. **Intermediate Segment.** The intermediate segment primary and secondary boundary lines connect abeam the plotted position of the PFAF at the appropriate primary and secondary final segment beginning widths.

a. **Alignment** (Maximum Course Change at the PFAF). LNAV & LP. Align the intermediate course within 30 degrees of the final approach course (30 degrees maximum course change).

b. **Length (Fix to Fix).** The minimum Helicopter category segment length is 2 NM. Where turns over 30 degrees at the IF are required, the minimum is 3 NM. Where turns to and from the intermediate segment are necessary, determine minimum segment length using formula 2-6 or formula 2-7, as appropriate.

c. **Width.** The intermediate segment primary area tapers uniformly from ±1.5 NM at a point 2 NM prior to the PFAF to the outer boundary of the X OCS abeam the PFAF (1 NM past the PFAF for LNAV). The secondary boundary tapers uniformly from 1 NM on each side of the primary area at a point 2 NM prior to the PFAF to the outer boundary of the Y OCS abeam the PFAF (1 NM past the PFAF for LNAV). See figure 8-2-13a.

Figure 8-2-13a: RNAV Intermediate Segment (LNAV Final)

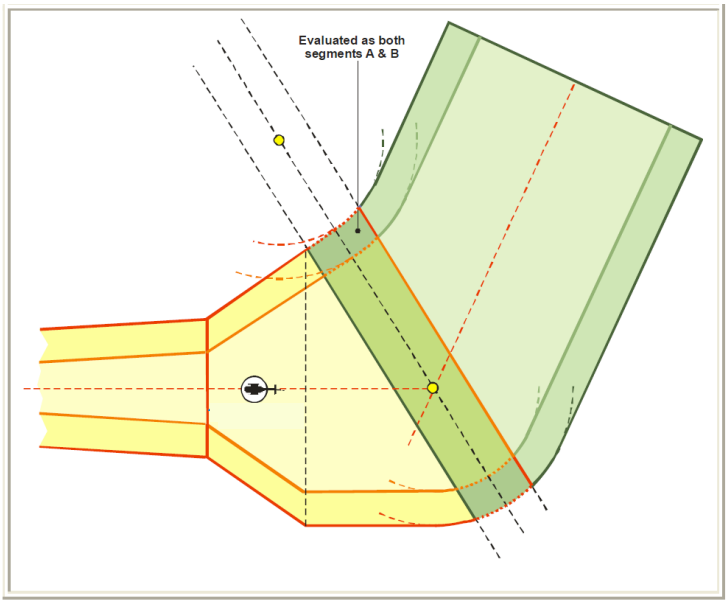


Supplementary note:

See Para 8.4.3a trapezoidal construction for FAS.

If a turn is designed at the IF, it is possible for the inside turn construction to generate boundaries outside the normal segment width at the taper beginning point 2 miles prior to the PFAF. Where these cases occur, the inside (turn side) boundaries are a simple straight line connections as illustrated in figure 8-2-13b.

Figure 8-2-13b: RNAV Turn at IF (LNAV Final)



Maximum turn at the PFAF is 30 degrees. When a PFAF turn is constructed, minimum FAS length is 3 NM for turns greater than 15 degrees. Where the RNAV or LP intermediate course is not an extension of the FAC, use the following construction (see figure 8-2-13c).

1) LNAV Offset Construction. Where LNAV intermediate course is not an extension of the final course, use the following construction (see figure 8-2-13c, upper graphic).

Step 1: Construct line A perpendicular to the intermediate course 2 NM prior the PFAF.

Step 2: Construct line B perpendicular to the intermediate course extended 1 NM past the PFAF.

Step 3: Construct the inside turn boundaries by connecting the points of intersection of line A with the turn side intermediate segment boundaries with the intersection of line B with the turn side final segment boundaries.

Step 4: Construct arcs centered on the PFAF of 1 NM and 1.5 NM radius on the non-turn-side of the fix.

Step 5: Connect lines from the point of intersection of line A and the outside primary and secondary intermediate segment boundaries to tangent points on the arcs constructed in step 4.

Step 6: Connect lines tangent to the arcs created in step 4 that taper inward at 30 degrees relative to the FAC to intersect the primary and

secondary final segment boundaries as appropriate. The final segment evaluation extends to a point ATT prior to the angle bisector. The intermediate segment evaluation extends ATT past the angle bisector. Therefore, the area within ATT of the angle bisector is evaluated for both the final and intermediate segments.

2) LP Offset Construction. Where LP intermediate course is not an extension of the final course, use the following construction (see figure 8-2-13c, lower graphic).

Step 1: Construct line A perpendicular to the intermediate course 2 NM prior the PFAF.

Step 2: Construct line B perpendicular to the intermediate course extended 1 NM past the PFAF.

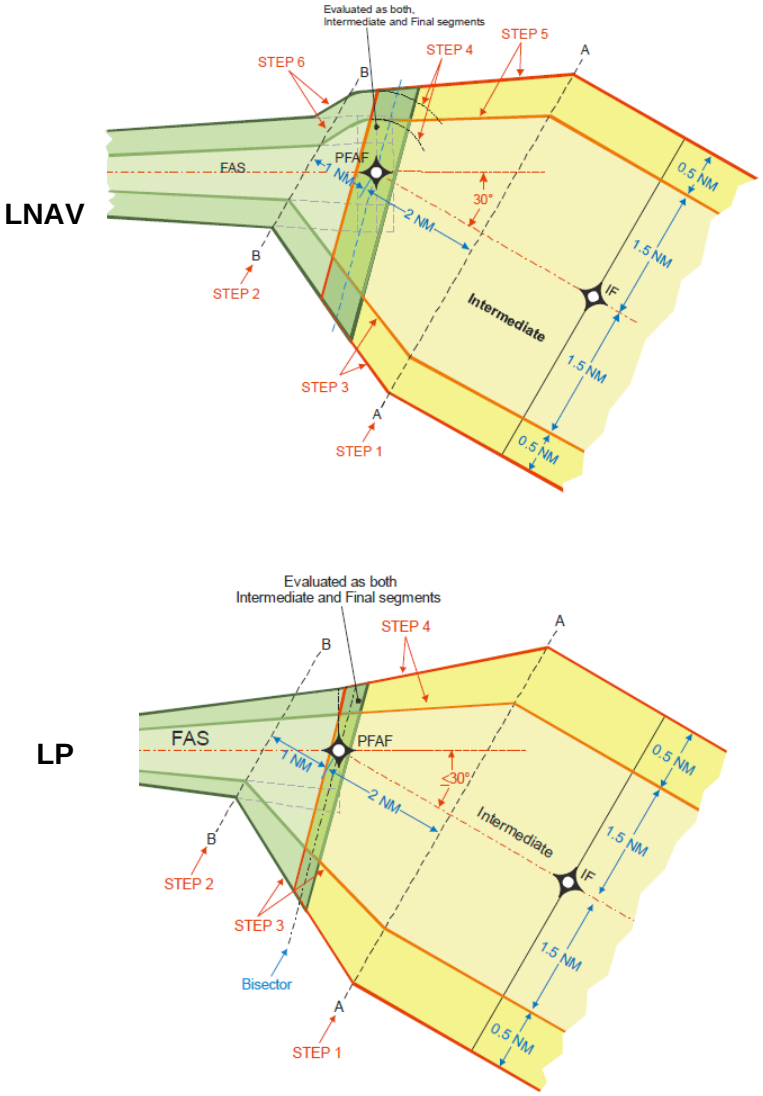
Step 3: Construct the inside turn boundaries by connecting the points of intersection of line A with the turn side intermediate segment boundaries with the intersection of line B with the turn side final segment boundaries.

Step 4: Connect lines from the point of intersection of line A and the outside primary and secondary intermediate segment boundaries to the final segment primary and secondary final segment lines at a point perpendicular to the final course at the PFAF.

Note: MDA must not occur at a greater distance from ARP/HRP than the turn-side point of intersection of the expanded outer boundary line with the final segment secondary boundary (intersection of line “B” with secondary boundary in figure 8-2-13c lower graphic). If a higher MDA is required, then the degree of offset must be less.

The final segment evaluation extends to a point ATT prior to the angle bisector. The intermediate segment evaluation extends ATT past the angle bisector. Therefore, the area within ATT of the angle bisector is evaluated for both the final and intermediate segments.

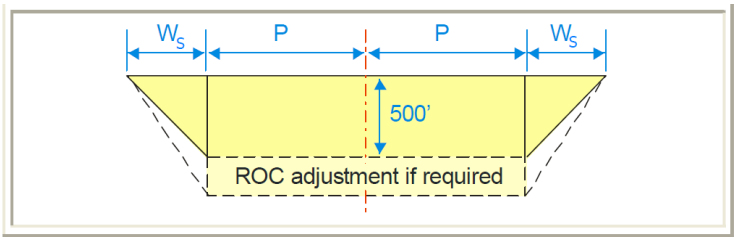
Figure 8-2-13c: Offset LNAV/LP Turn at PFAF Construction



3) RF intermediate segments. Reserved.

d. **Obstacle Clearance.** The intermediate OEA begins at the segment beginning fix early ATT and ends at the segment ending fix late ATT. Apply 500 ft of ROC over the highest obstacle in the primary OEA. The ROC in the secondary area is 500 ft at the primary boundary tapering uniformly to zero at the outer edge (see figure 8-2-14).

Figure 8-2-14: Intermediate Segment ROC



Calculate intermediate secondary ROC values using formula 2-13.

Formula 2-13: Intermediate Secondary ROC ($ROC_{SECONDARY}$)

$$ROC_{secondary} = (500 + adj) \cdot \left(1 - \frac{d_{primary}}{W_s}\right)$$

Where:

$d_{primary}$ = perpendicular distance (ft) from edge of primary area

W_S = Width (ft) of the secondary area

adj = TP308, Vol 1, Para 323 adjustments

(500+adj)*(1-$d_{primary}$/W_S)

e. **Minimum IF to FHP Distance** (applicable for LP procedures with no turn at PFAF). Locate the IF <u>at least</u> d_{IF} (NM) from the FHP (see formula 2-14).

Formula 2-14: Minimum IF Distance (d_{IF})

$$d_{IF} = 0.3 \cdot \frac{d}{a} - d \cdot \frac{0.3048}{1852}$$

Where:

d = distance (ft) from FPAP to FHP

a = width (ft) of azimuth signal at FHP

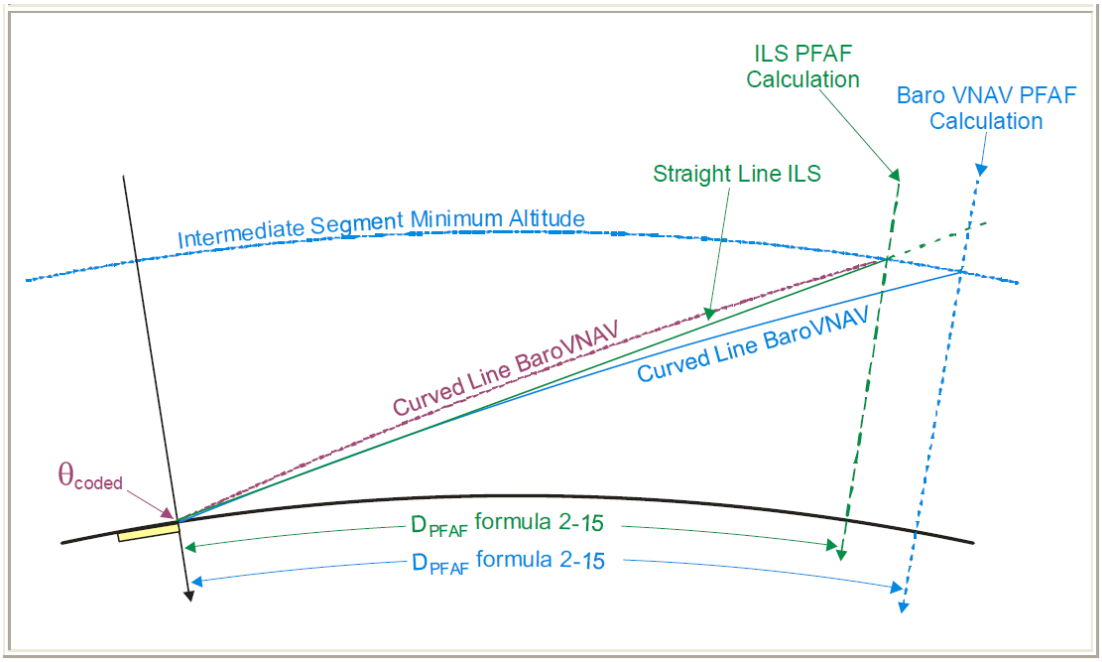
Note: See Section 4, table 8-4-1, column 3

0.3*d/a-d*0.3048/1852

Basic Vertically Guided Final Segment General Criteria

8.2.18. Determining Precise Final Approach Fix/Final Approach Fix (PFAF/FAF) Coordinates (see figure 8-2-15 fixed-wing example).

Figure 8-2-15: Determining PFAF Distance to LTP (Example)



Geodetically calculate the latitude and longitude of the PFAF using the true bearing from the ARP/HRP to the PFAF and the horizontal distance ($\mathbf{D_{PFAF}}$) from the ARP/HRP to the point the glidepath intercepts the intermediate segment altitude. The LNAV (BaroVNAV) glidepath is a curved line (logarithmic spiral) in space. Calculation the PFAF distance from the ARP/HRP using formula 2-15 (calculates the LNAV PFAF distance from ARP/HRP; i.e., the point the curved line BaroVNAV based vertical path intersects the minimum intermediate segment altitude (see TP308/GPH209 Volume 2 for additional information).

Formula 2-15: LNAV PFAF

$$D_{PFAF} = \frac{\ln\left(\frac{r + alt}{r + HRP_{elev} + HCH}\right) \cdot r}{\tan(\theta)}$$

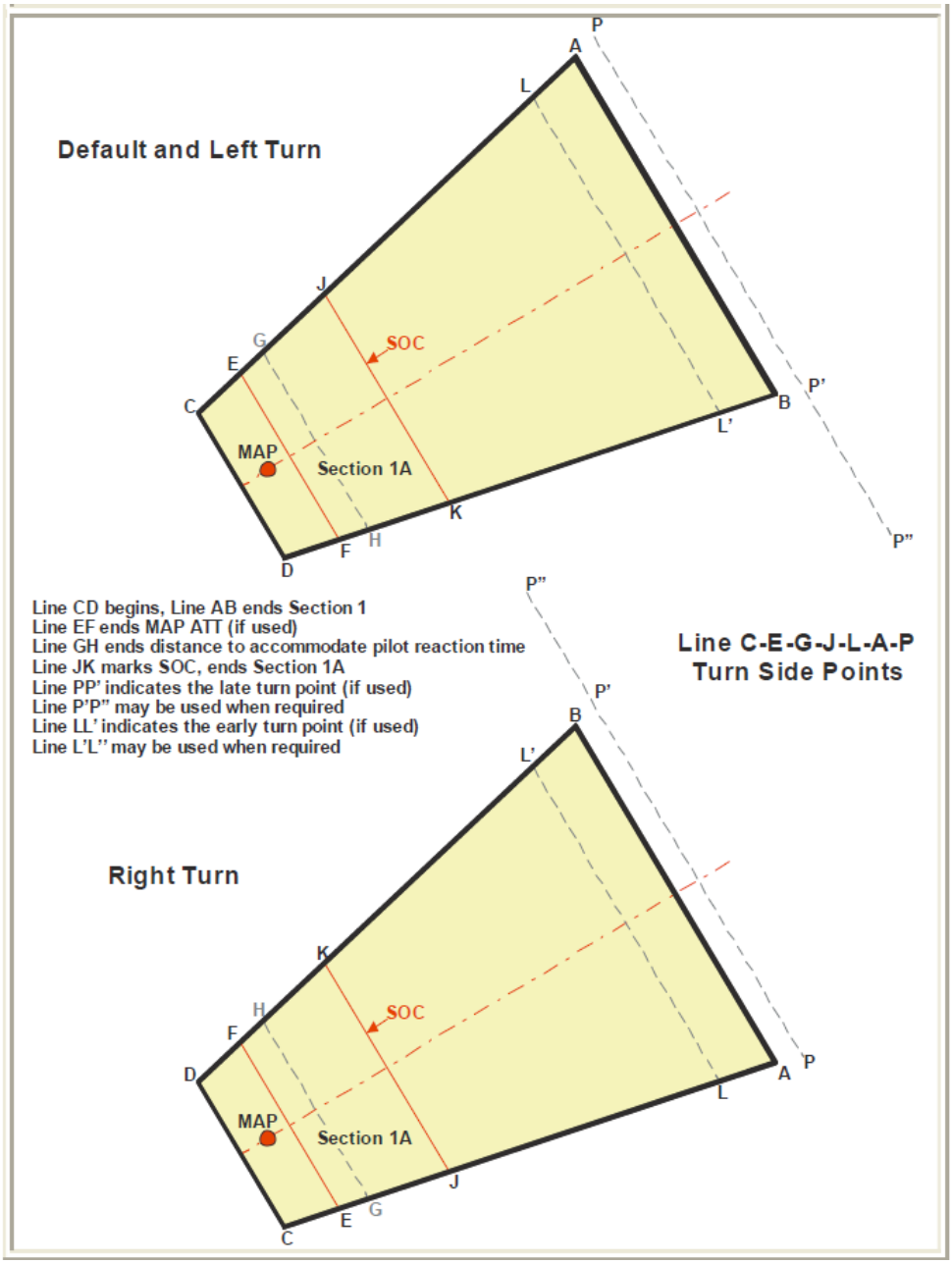
where alt = minimum intermediate segment altitude
HRP_{elev} = HRP MSL elevation
HCH = Heliport Crossing Height value
r = 20890537
θ = glidepath angle

Note: D_{PFAF} is the distance from ARP/HRP.

8.2.19. **Common Fixes.** Design all procedures published on the same chart to use the same sequence of charted fixes.

8.2.20. **Missed Approach Segment (MAS) Conventions.** Figure 8-2-16 defines the MAP point OEA construction line terminology and convention for section 1.

Figure 8-2-16: MAS Point/Line Identification



The missed approach obstacle clearance standard is based on a minimum helicopter climb gradient of 400 ft/NM, protected by a ROC surface that rises at 304 ft/NM. The MA ROC value is based on a requirement for a 96 ft/NM (400-304 = 96) increase in ROC value from the start of- climb (SOC) point located at JK. The actual slope of the MA surface is (1 NM in feet)/304≈19.987. In manual application of TP 308/GPH 209, the rounded value of 20:1 has traditionally been applied. However, this order is written for automated application; therefore, the full value (to 15 significant digits) is used in calculations. The nominal OCS slope ($MA_{OCSslope}$) associated with any given missed approach climb gradient is calculated using formula 2-16.

Formula 2-16: Helicopter Missed Approach OCS Slope

$$MA_{OCSslope} = r \bullet \ln\left(\frac{\frac{1852}{0.3048 \cdot (CG - 96)} + r}{r}\right)$$

Where:

CG = Climb Gradient (nominally 400 ft/NM)

```
r*ln((1852/(.3048*(CG-96))+r)/r)
```

a. **Charted Missed Approach Altitude.** Apply TP308/GPH209 Volume 1, paragraphs 2.7.7d and 2.7.7f to establish the preliminary and charted missed approach altitudes.

b. **Climb-In-Holding.** Apply TP308/GPH209 Volume 1, paragraph 2.7.7e for climb-inholding guidance.

SECTION 3: TERMINAL OPERATIONS

8.3. Terminal Operations.

8.3.1. Approach Configuration. The BASIC “Y” or “T” approach configuration should be the basis of procedure design. Segment length is affected by altitude to be lost, fix tolerances, and turn magnitude at the fixes. The **optimum** design incorporates a basic **Y** or **T** configuration. This design eliminates the need for a specific course reversal pattern. Where the **optimum** design cannot be used and a course reversal is required, establish a holding pattern at the initial or intermediate approach fix. General (70 KIAS) procedures should not deviate from these shape and dimension configurations unless there is an operational advantage. Construct IAFs within 25 NM of the aerodrome reference point/heliport reference point (ARP/HRP). See section 2, paragraph 8.2.16 for construction methods.

Note 1: Allowance for precipitous terrain should be made as specified in TP308/GPH209 Volume 1, paragraph 3.2.2.b.

Table 8-3-1. Helicopter GPS MINIMUM

Initial/Intermediate/Final Segment Lengths

Course Intercept Angle (Degrees)	Minimum Leg Length (NM)
00 – 30	2.0
> 30 - 90 *	3.0

* Final segment 30-degree MAXIMUM intercept angle for Global Positioning System (GPS) and Wide Area Augmentation System (WAAS) procedures.

a. **Initial Approach Segment.** The initial approach segment begins at the IAF and ends at the IF. The initial segment/subsegment obstacle evaluation area (OEA) begins at the early ATT of the segment beginning fix and ends at the late ATT of the segment/subsegment ending fix. Course change at the IF must not exceed 90 degrees. Construct the inbound leg of course reversal holding patterns within 30 degrees of the intermediate course (IF/IAF). Apply section 2, paragraph 8.2.16 for course reversal using holding pattern criteria. Do not establish a holding pattern in lieu of procedure turn at the PFAF. See section 2 for construction methods.

(1) Length. The initial segment begins at IAF and ends at the IF. The length should not exceed 10 NM unless operational requirements mandate a longer segment. Determine the **minimum** length using the greater distance from formulas 2-6, 2-7, and table 8-3-1.

(2) Width.

(a) Primary Area. 1.5 NM each side of the course centerline.

(b) Secondary Area. 0.5 NM on each side of the primary area.

Obstacle Clearance. Provide a **minimum** of 1,000 ft of required obstacle clearance (ROC) in the primary area. In the secondary area, provide 500 ft of ROC at the inner edge, tapering uniformly to zero at the outer edge (see section 2, figure 8-2-12). Calculate the secondary ROC using section 2, formula 2-12a or formula 2-12b. Establish initial segment altitudes in 100-ft increments that meet or exceed minimum ROC.

(3) Descent Gradient for Initial Segments (see section 2, paragraph 8.2.14).

b. **Intermediate Segment.** The intermediate segment begins at the IF and ends at the PFAF. The intermediate segment OEA begins at the early ATT of the segment beginning fix and ends at the late ATT of the segment ending fix. The intermediate segment is used to prepare the helicopter speed and configuration for final approach segment entry; therefore, the gradient should be as flat as possible. At a point beginning 2.0 NM from the PFAF, construct a taper to join the final approach segment (FAS).

(1) Alignment. The maximum course change at the PFAF is 30 degrees.

(2) Area.

(a) Length. The intermediate segment begins at the IF and ends at the PFAF. The length should not exceed 5.0 NM (optimum length is 3.0 NM). Determine the minimum length using the greater distance from formulas 2-7, 2-8, and table 8-3-1.

(b) Width.

1 Primary Area. 1.5 NM each side of the segment centerline, beginning at the earliest IF position. The segment taper begins 2.0 NM prior to the plotted position of the PFAF to reach a 0.55 NM width at the PFAF plotted position (see section 2, figures 8-2-13a, 8-2-13b, and 8-2-13c).

Note: For 90 KIAS speed, change 0.55 NM to 0.70 NM.

2 Secondary Area. 0.50 NM on each side of the primary area.

(3) Obstacle Clearance. Provide a MINIMUM of 500 ft of ROC in the primary area. In the secondary area, provide 500 ft of ROC at the inner edge tapering to zero feet at the outer edge. Establish altitudes for each intermediate segment in 100-ft increments, and round to the

next higher 100-ft increment. Calculate the secondary ROC using section 2, formula 2-13 (see section 2, figure 8-2-14).

(4) Descent Gradient for Intermediate Segments (see section 2, paragraph 8.2.14).

SECTION 4: IFR FINAL AND VISUAL SEGMENTS

8.4. IFR Final and Visual Segments.

8.4.1. **General.** The approach procedure type is determined by the visual segment. The instrument flight rule (IFR) final approach segment (FAS) applies to all three types of procedures. Use the criteria in section 3 for the construction of the initial and intermediate segments up to the precise final approach fix (PFAF), and section 5 criteria for the missed approach segment construction. Apply section 4, paragraph 8.4.3 criteria to LNAV IFR final segments, and section 4, paragraph 8.4.9 to WAAS LP IFR final segments.

Note: Section 4 graphics are not drawn to scale.

a. **Final Segment Stepdown Fix (SDF).** An SDF may be applied where the MDA can be lowered 60 ft, or a visibility reduction can be achieved. TP308/GPH209, Volume 1, paragraph 2.8.10 applies, with the following exceptions:

(1) Establish step-down fix locations in 0.10 NM increments.

(2) The minimum distance between stepdown fixes is 1 NM.

(3) Establish stepdown fix altitudes using 20-ft increments, rounded to the next **higher** 20-ft increment. For example, 2104 becomes 2120.

(4) Where a Remote Altimeter Setting Source (RASS) adjustment is in use, the published stepdown fix altitude must be established no lower than the altitude required for the greatest amount of adjustment (i.e., the published minimum altitude must incorporate the greatest amount of RASS adjustment required).

(5) Descent gradient: Section 4, paragraphs 8.4.3.a(3), 8.4.3.a(4), and 8.4.3.a(5) apply.

(6) Obstacles eliminated from consideration (3.5:1 area) under this paragraph must be noted in the procedure documentation.

(7) Use formula 4-4 in section 4, paragraph 8.4.3.a(6) concerning TP308/GPH209, Volume 1, paragraph 2.8.10 to determine the OIS elevation at an obstacle and minimum fix altitude based on an obstacle height.

(8) To mitigate surface penetrations:

- Remove obstruction, or
- Reduce obstruction height, or
- Adjust the MDA, or
- Combination of options.

8.4.2. **Missed Approach.** Construct the missed approach for all procedures using section 5 criteria.

8.4.3. The three procedure types are:

- IFR to an IFR Heliport.
- Point-in-Space (PinS) Approach (Proceed VFR).
- IFR to an IFR Runway.

a. **LNAV IFR Final Approach Segment (FAS).** The IFR FAS begins at the PFAF and ends at the missed approach point (MAP) (see figure 8-4-1). This FAS construction is unique to helicopters. It applies trapezoidal rather than the linear construction used for fixed-wing applications. Locate LNAV PFAF using section 2, formula 2-15. MAP location should provide the best compromise of lowest visibility and visual segment descent angle (VSDA). For general (70 KIAS) procedures, the preferred approach paths should be aligned with the prevailing wind direction to avoid downwind and minimize crosswind operations. Other approach/departure paths should be based on the assessment of the prevailing winds or when this information is not available, the separation between such flight paths and the preferred flight path should be at least 135 degrees.

(1) Alignment. The IFR final segment connects the PFAF to the MAP. The course change at the PFAF from the intermediate course to the final approach course (FAC) must not exceed 30 degrees. The MAP is located on the FAC between the PFAF and a point no closer to the helipoint than 0.3 NM from the visual segment reference line (VSRL). For a straight-in approach, the course change at the MAP must not exceed 30 degrees to an IFR heliport helipoint **or** 30 degrees from a runway centerline (RCL) extended to an IFR runway threshold (RWT). Optimum alignment is coincident with the RCL. When the alignment exceeds 5 degrees the optimum alignment point is 1,500 ft from the RWT on RCL.

(2) Area. The obstacle evaluation area (OEA) begins at the earliest PFAF along-track tolerance (ATT) and ends at the latest MAP ATT (see figure 8-4-1).

(a) Length. The IFR final approach segment begins at the PFAF and ends at the MAP. The length should not exceed 10 NM (**optimum** length is 3 NM). Determine the **minimum** length using the greater of descent distance, formula 2-7 or 2-8, and table 8-3-1.

(b) Width.

1 Primary Area. The primary area boundary begins 0.55 NM***** each side of the final segment centerline at the earliest PFAF

ATT. The width remains constant until the latest PFAF ATT. It then tapers to 0.40 NM* at the latest MAP ATT.

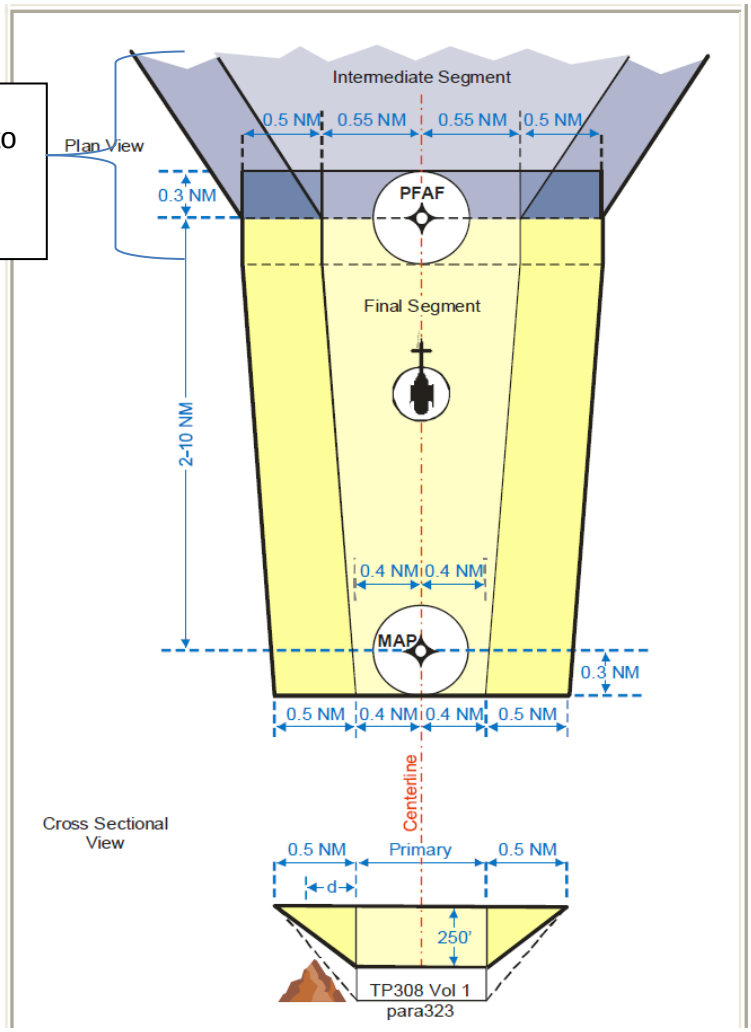
***Note:** For 90 KIAS speed, change 0.55 NM to 0.70 NM and 0.40 NM to 0.50 NM (primary area).

2 Secondary Area. The secondary area boundary is constant, 0.50 NM each side of the primary area. Calculate the primary half-width at any distance from latest MAP ATT using formula 4-1a.

(c) Required Obstacle Clearance. Primary area required obstacle clearance (ROC) is 250 ft. Secondary ROC is 250 ft at the edge of the primary area, tapering uniformly to zero at the outer edge. Calculate secondary ROC using formula 4-1b.

Figure 8-4-1: LNAV Final Segment Construction

Note: For correct intermediate to final segment construction, see figure 8-2-13a.



Formula 4-1a: Final Area Half-Width (W_P)

$$W_P = P_{W2} + \left(\frac{P_{W1} - P_{W2}}{D_1}\right) \cdot D_2$$

Where P_{W1} = Primary Width, PFAF, (0.55 or 0.7) NM
P_{W2} = Primary Width, latest MAP ATT, (0.4 or 0.5) NM
D_1 = PFAF to MAP distance (NM)
D_2 = Latest MAP ATT to desired point (NM)
W_T = Final Total Width (ft) (Wp+0.5NM)

$P_{W2}+((P_{W1}- P_{W2})/D_1)*D_2$

Formula 4-1b: Secondary Area ROC ($ROC_{secondary}$)

$$ROC_{secondary} = (250 + adj) \cdot \left(1 - \frac{d_{primary}}{W_S}\right)$$

Where adj = TP308 Vol1 para 323 adjustments (ft)
$d_{primary}$ = distance (perpendicular to C/L from edge primary area (ft))
W_S = Secondary area width (ft)

$(250+adj)*(1-d_{primary}/W_S)$

(3) Descent Gradient/Angle [PinS Approach]. The descent gradient/angle is measured from the plotted positions of the PFAF at PFAF altitude to the MAP at MDA. Calculate the final segment descent angle using formula 4-2. (Where required, calculate descent gradient using section 2, formula 2-10).

Formula 4-2: Final Approach Angle to MAP (DescentAngle)

$$\mathbf{DescentAngle} = \mathbf{atan}\left(\frac{\mathbf{r}}{\mathbf{c}} \cdot \mathbf{In}\left(\frac{\mathbf{r}+\mathbf{a}}{\mathbf{r}+\mathbf{b}}\right)\right)$$

Where:
c = PFAF to MAP distance (ft)
a = PFAF altitude MSL
b = MDA at MAP MSL

Note 1: For 90 KIAS speed, normal descent gradient/angle is up to 478 ft/NM (4.5 degrees). Descent gradient/angle up to 800 ft/NM (7.5 degrees) may be granted by Transport Canada for inclusion in the Restricted CAP.

Note 2: The visual segment descent gradient is considered separately in approaches to VFR heliports or VFR runways.

(4) Descent Gradient/Angle to an IFR Runway or an IFR Heliport. Apply the same descent gradient/angle in section 4, paragraph 8.4.3.a(3) for an IFR approach to an IFR runway, but the distance/elevation

calculations begin at the PFAF and end at Runway Threshold (RWT)/Threshold Crossing Height (TCH) elevation (see figure 8-4-2b). For an IFR approach to an IFR Heliport, the distance/elevation calculations begin at the PFAF and end at Helipoint Crossing Height (HCH) (see figure 8-4-2c). Apply formula 4-3 for descent angle, and section 2, formula 2-10 for descent gradient:

Formula 4-3: Descent Angle to Runway or Helipoint Crossing Height (HCH)

$$\mathbf{DescentAngle} = \mathbf{atan}\left(\frac{\mathbf{r}}{\mathbf{c}} \cdot \mathbf{In}\left(\frac{\mathbf{r}+\mathbf{a}}{\mathbf{r}+\mathbf{b}}\right)\right)$$

Where:

c = PFAF to RWT/helipoint distance (ft)
a = PFAF Altitude MSL
b = TCH/HCH elevation at RWT or HCH

Figure 8-4-2a: Descent Angle, PFAF to MAP for PinS Approach Procedures

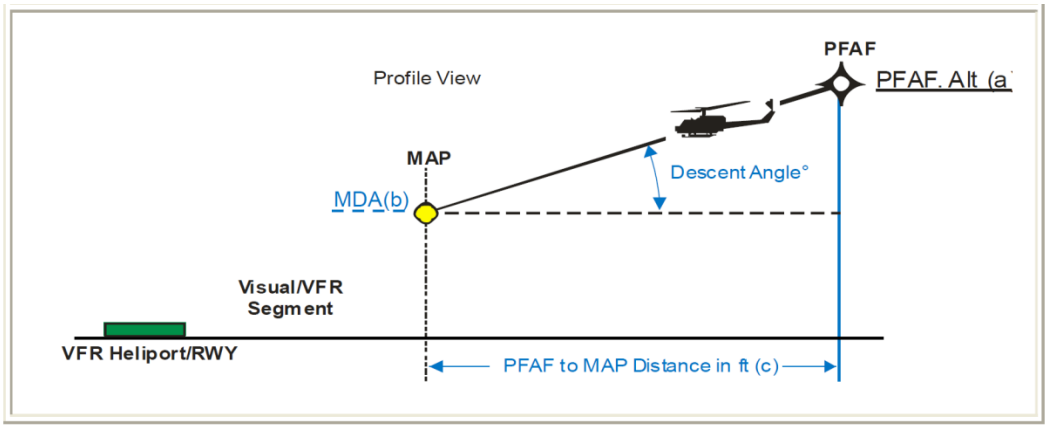


Figure 8-4-2b: Descent Angle, PFAF to TCH for IFR Approach to IFR Runway

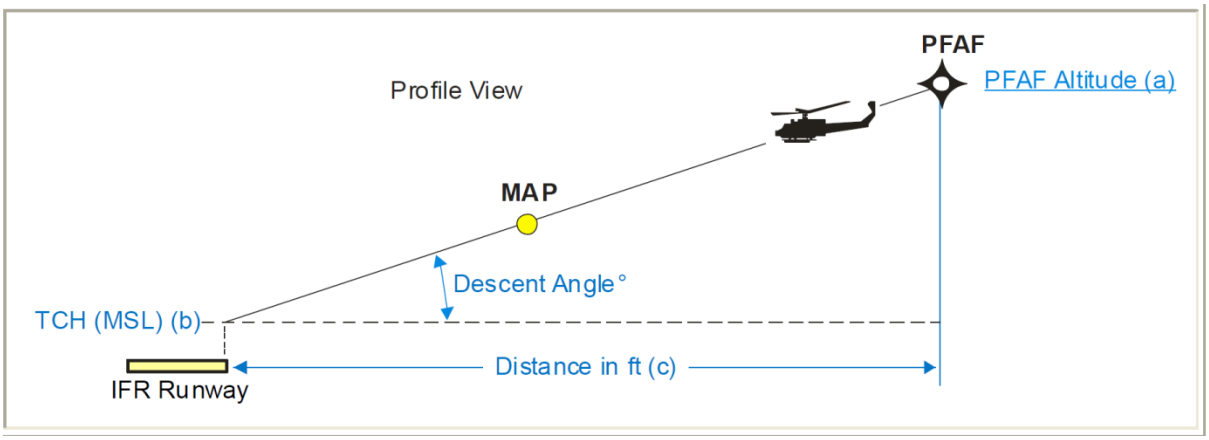
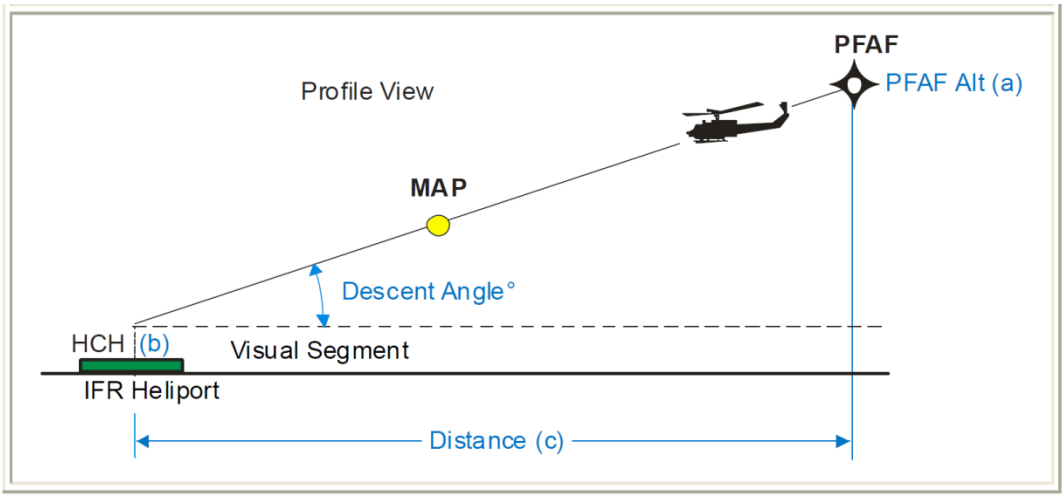


Figure 8-4-2c: Descent Angle, PFAF to HCH for IFR Approach to IFR Heliport



(5) Stepdown Descent Gradient/Angle. When a stepdown fix is used, measure the descent gradient/angle from the PFAF at the PFAF altitude to the stepdown fix at the minimum fix altitude, then to the MAP at the MDA. For a stabilized approach, provide a constant gradient/angle from the PFAF to the MAP, (may require raising the PFAF altitude). A stepdown fix must be located no closer than 0.6 NM to the PFAF or MAP.

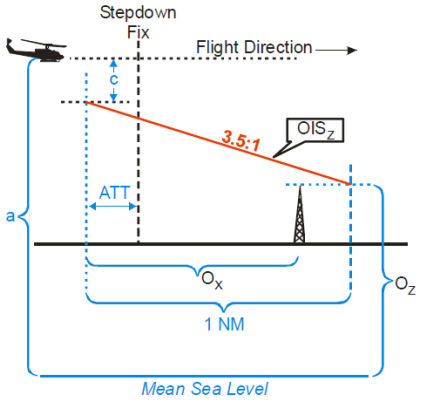
(6) Existing Obstacles Close to the PFAF or Stepdown Fix. If the segment descent gradient/angle is less than 800 ft/NM (7.5 degrees), TP308/GPH209 Volume 1, paragraph 2.8.10 may be applied substituting an OIS slope of 3.5:1 vice 7:1. Calculate the OIS Elevation and Minimum fix altitude using formula 4-4.

Formula 4-4: OIS Elevation & Minimum Fix Altitude (OIS_z & MFa)

$$OIS_z = (r + a - c) \cdot e^{\frac{-O_x}{3.5 \cdot r}} - r$$

$$MFa = (r + O_z + c) \cdot e^{\frac{O_x}{3.5 \cdot r}} - r$$

Where:
a = MSL fix altitude (ft)
c = ROC plus adjustments (TP308 Volume 1, para 323)
O_X = Obstacle along-track distance (ft) from ATT prior to fix (1 NM max)
O_Z = MSL obstacle elevation (ft)
MFa = Minimum Fix Altitude (rounded to next higher 100-ft increments)



OISZ=(r+a-c)*e^(-O_X/(3.5*r))-r
MFa=(r+O_Z+c)*e^(O_X/(3.5*r))-r

8.4.4. **IFR Heliport Visual Segment.** The IFR Heliport visual segment connects the MAP to the helipoint. The visual segment OCS starts at the VSRL and extends to the later of a point 250 ft below the MDA or the latest MAP ATT (see figures 8-4-3 and 8-4-4).

a. **Alignment.** The IFR Heliport visual segment connects the MAP to the helipoint. The course change at the MAP from the FAC must not exceed 30 degrees.

b. **Area.** The obstacle evaluation area (OEA) begins at the Visual Segment Reference Line (VSRL) and extends toward the MAP as defined below:

(1) Length. The IFR Heliport Visual segment begins at the MAP and ends at the Heliport (see profile figures 8-4-3 and 8-4-4).

(2) Width. The visual segment splay begins at the Visual Segment Reference Line (VSRL). It splays from the VSRL endpoints relative to the FAC to the latest FAS primary area width at the latest MAP ATT (see plan view figure 8-4-6 (right)). Where the OCS surface extends to a point 250 ft below the MDA, the boundary follows the primary area to its end point (see plan view figures 8-4-4 and 8-4-6 (left)).

c. **Obstacle Clearance Surface.** The OCS begins at the VSRL and extends 1.0 degree below the VSDA (see figures 8-4-3, 8-4-4 and formula 4-6). The VSDA is a developer-specified angle extending from a point 5 to 20 ft

directly above the helipoint to the MDA. The VSDA must cross the MDA between the helipoint and the MAP. The maximum VSDA is 7.5 degrees and the optimum VSDA is 6.0 degrees.

Formula 4-6: OCS Elevation (OCS_{elev})

$$OCS_{elev} = (r + HE) \cdot e^{\frac{D \times Tan(\beta)}{r}} - r$$

Where:

HE = Helipoint elevation MSL
D = Distance obstacle to VSRL (ft)
β = OCS Angle

Figure 8-4-3: IFR Heliport Visual Segment OCS Terminating at Latest MAP Position

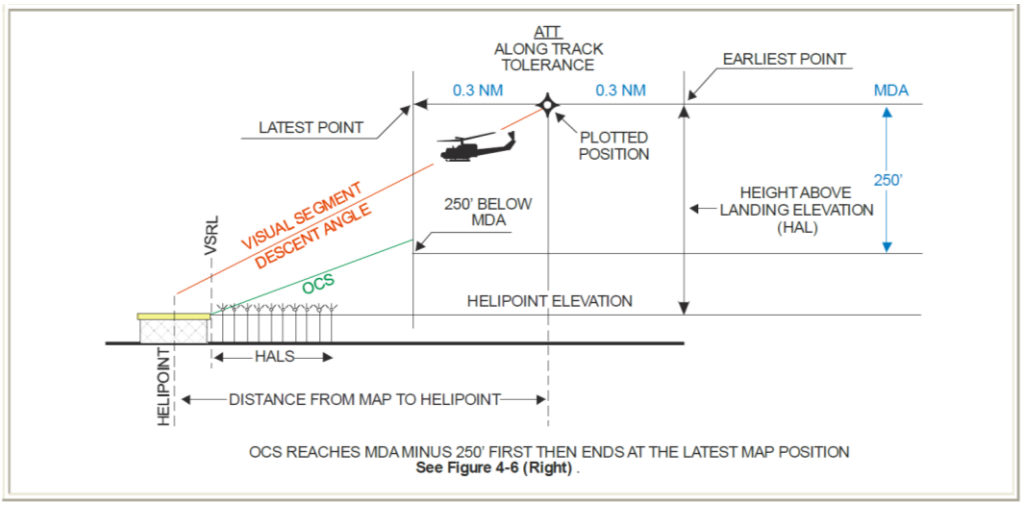
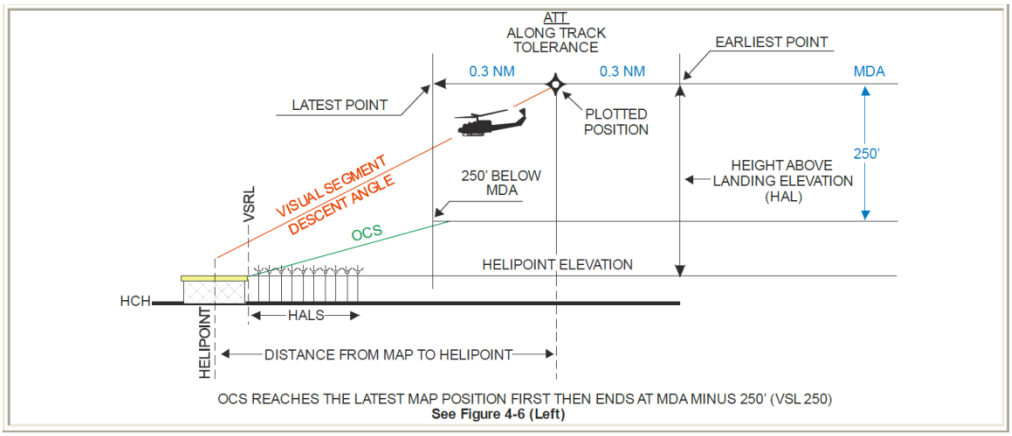


Figure 8-4-4: IFR Heliport Visual Segment OCS Terminating at an Altitude 250 ft Below MDA



Supplementary note: IFR Heliport HAL, VSDA-based Visual Segment Length (VSL_{250}), and Visual Segment Descent Angle (VSDA) Computations. Calculate HAL, VSRL to a point 250 ft below MDA (VSL_{250}), and VSDA using the following steps (see figure 8-4-5).

(a) Calculate HAL using formula 4-7:

Formula 4-7: Height Above Landing Area Elevation (HAL)

HAL = MDA-Helipoint Elevation (HE)

MDA-HE

(b) Calculate VSDA using formula 4-8:

Formula 4-8: Visual Segment Descent Angle (VSDA)

$$\mathbf{VSDA} = \mathbf{atan}\left(\frac{\mathbf{r}}{\mathbf{c}} \cdot \mathbf{In}\left(\frac{\mathbf{r} + \mathbf{HAL} + \mathbf{HCH}}{\mathbf{r} + \mathbf{HCH}}\right)\right)$$

Where:

c = MAP to Helipoint Distance (ft)
HAL = Formula 4-7 output
HCH = Heliport Crossing Height

(c) Calculate visual segment length from the VSRL to a point 250 ft below MDA (VSL_{250}) using formula 4-9.

Formula 4-9: Visual Segment Length ($\mathbf{VSL_{250}}$)

$$\mathbf{VSL_{250}} = \frac{\left(\mathbf{r} \cdot \mathbf{In}\left(\frac{\mathbf{r} + \mathbf{a}}{\mathbf{r} + \mathbf{HE}}\right)\right)}{\mathbf{tan}(\mathbf{VSDA} - \mathbf{1})}$$

Where:
HAL = Formula 4-7 output
a = HAL-250 (MSL)
HE = Heliport elevation
VSDA = Formula 4-8 output

Figure 8-4-5: IFR Heliport Visual Segment Area

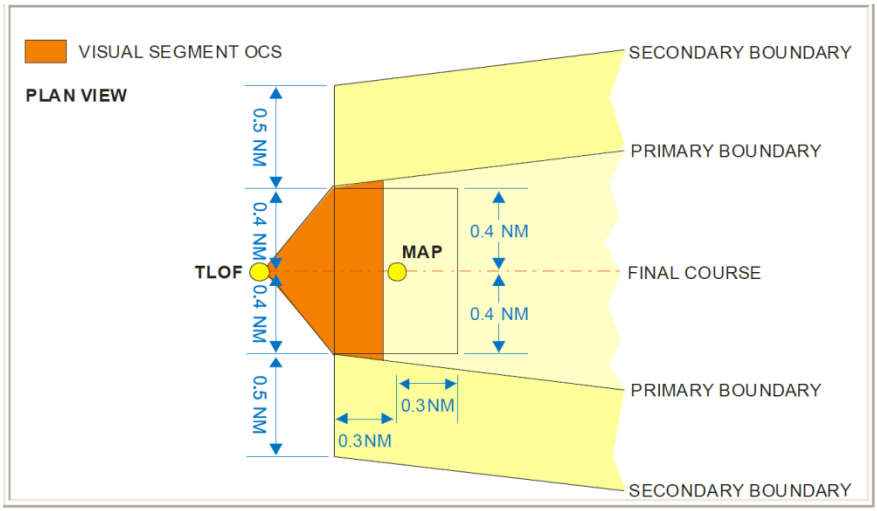
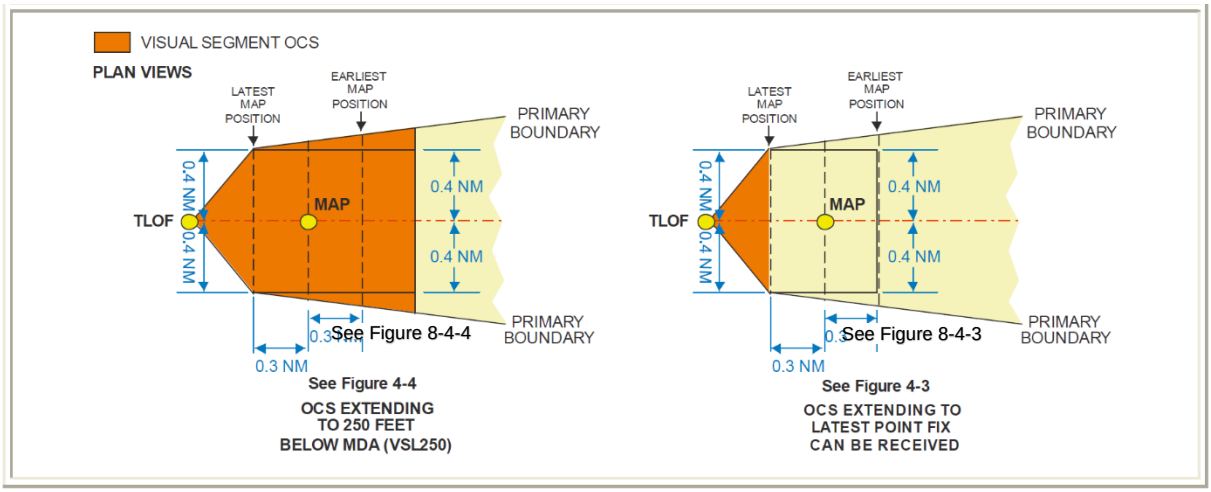


Figure 8-4-6: IFR Heliport Visual Segment Area Splays



d. RESERVED

e. RESERVED

8.4.5. **RESERVED**

8.4.6. **RESERVED**

8.4.7. **PinS Approach (Proceed VFR).** The VFR segment on a PinS Approach (Proceed VFR) approach procedure provides a measure of obstacle

protection/identification to allow a safe transition from IFR to VFR flight. The area is not intended to support IFR descent.

Apply TP308/GPH209 Volume 1, Chapter 11 pertaining to PinS Approach criteria, except no requirement exists for a MAP to be located beyond 2,600 ft of the helipoint. A PinS Approach (Proceed VFR) procedure may be developed to a heliport, multiple heliports, or a geographical area associated with a specific heliport. Compute the distance for the Remote Altimeter Setting Source (RASS) adjustment for the MDA and stepdown altitudes for the PinS Approach procedures from the source to the MAP.

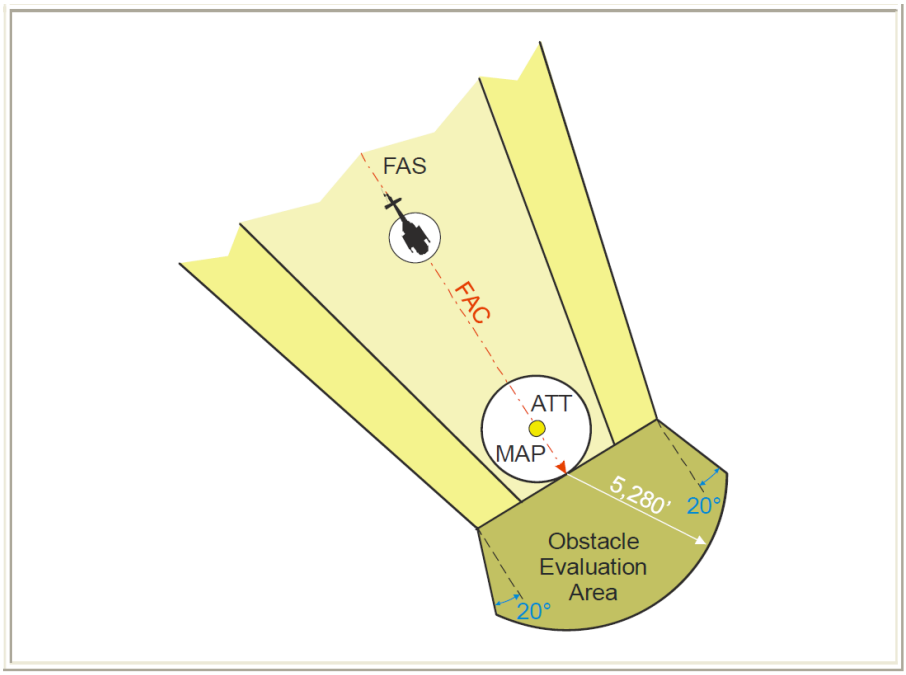
a. **Alignment.** The PinS Approach visual segment is a 5,280 ft-radius arc segment centered at the FAC and the latest MAP ATT intersection.

b. **Area.** The PinS Approach OEA is a 5,280 ft-radius arc segment centered at the FAC and the latest MAP ATT intersection. The arc segment is laterally bounded by 20 degree splay lines (relative the FAC-extended), originating at the FAS secondary boundaries and the latest MAP ATT (see figure 8-4-13).

c. **Length.** A 5,280 ft radius as described above.

d. **PinS Approach visual segment OIS** (see section 4, paragraph 8.4.7.e). This surface **must not** be penetrated.

Figure 8-4-13: PinS Approach (Proceed VFR) VFR Transition Area Obstacle Evaluation (OEA)



e. **Obstacle Clearance in the PinS Approach VFR Segment.** Add 250 ft of ROC (without adjustments) to the highest obstacle/terrain within the VFR area and round to the next higher 20-ft increment. The final MDA is the higher of the MDAs calculated for the final and VFR segments.

f. **Visibility.** The **minimum** final segment visibility is 1 SM.

8.4.8. **IFR to an IFR Runway.**

a. **Configuration and Alignment.** The MAP location should provide the best compromise of lowest visibility and VSDA. Except where the alignment is to the RWT, the mandatory MAP location is at the FAC and RCL intersection. Where the alignment is to the RCL, the optimum MAP location is at the RWT, with optional MAP location along the FAC between the PFAF and the RWT.

b. **Area.** The final OEA begins at the earliest PFAF ATT and ends at the latest MAP ATT, RWT, or a point abeam the RWT, whichever is farthest. Apply section 4, paragraph 8.4.3.a criteria for the IFR segment OEA and ROC (see figure 8-4-1).

c. **Descent Gradient/Angle.** Calculate the FAS descent angle from the PFAF altitude at the plotted position of the PFAF to the TCH at RWT. Apply section 4, paragraph 8.4.3.a(4).

d. **Visual Segment.** Establish a 40 ± 5 ft TCH for runways where no VGSI is installed. Where a VGSI is installed, a final descent gradient and VSDA may be established to coincide with the gradients/angles for angles of 3.0 degrees or more. If the descent gradient/angle cannot be published coincident (within ± 0.20 degrees) and TCH values within 3 ft of the published VGSI glide slope angle, publish a note on the chart.

e. **Minimum.** See TP308/GPH209, Volume 1, Chapter 11, Section 3.

8.4.9. **WAAS LP Criteria.** The WAAS LP criteria apply to the final approach only. For all other segments apply GPS criteria except where noted for a turn at the PFAF, and missed approach constructions that are different. This implementation of WAAS does not include a glidepath function for these procedures. Criteria in this section provide a narrower OEA in the IFR FAS and OIS in the visual segment. The segment lengths and descent rate/gradients are the same as section 4, paragraph 8.4.3. The intermediate segment begins with the same width at the GPS intermediate fix (IF), reference section 3, paragraph 8.3.1.b, tailored to the beginning WAAS FAS width, reference section 4, paragraph 8.4.9.d at the PFAF. Apply section 4, paragraph 8.4.7 to design approaches in the visual/visual flight rule (VFR) segments, and apply section 4, paragraphs 8.4.8 and 8.4.9 for the IFR FAS OEA and ROC. Apply an OIS, reference section 4, paragraph 8.4.8.d. Apply section 4, paragraph 8.4.7 for the analysis of the VFR area of a Point-in-Space (PinS) Approach (Proceed VFR) approach.

Figure 8-4-14 depicts the basic configuration for determining the Flight Path Alignment Point (FPAP) and fictitious helipoint (FHP) coordinates. Locate the FHP 2,600 ft from the MAP. The FPAP is a point defined by the World Geodetic System 1984 (WGS-84) latitude, longitude, and is located 9,023 ft from the FHP.

a. **Minimums.** See TP308/GPH209, Volume1, Chapter 11, Section 3.

b. Use The Following Steps for WAAS LP Procedure Construction:
Step 1: Determine the FAS course alignment, MAP, FHP, and FPAP coordinates.

Step 2: Calculate the distance (ft) from the FHP to the PFAF (D_{PFAF}) using formula 4-11. Calculate the primary and secondary area widths at any distance from FHP to the earliest point the PFAF can be received using formulas 4-11 and 4-13 (see figure 8-4-14).

Formula 4-11. LP PFAF (D_{PFAF})

$$D_{PFAF} = \frac{\ln\left(\frac{r + alt}{r + FPH_{elev} + HCH}\right) \cdot r}{\tan(\theta)}$$

Where:
alt = minimum intermediate segment altitude
FHP_{elev} = FHP MSL elevation
HCH = HCH value
θ = glidepath angle

Step 3: After constructing the IFR final trapezoid area, analyze the FAS by determining the controlling obstacle within the IFR final segment by applying the ROC in section 4, paragraph 8.4.9.d and determining the minimum descent altitude (MDA).

Step 4: When constructing a PinS Approach (Proceed VFR) approach, apply section 4 criteria for the VFR segment and adjust the MDA of the IFR segment after an analysis of the VFR segment if required.

Step 5: Construct the missed approach using section 5.

c. **Determine FAS Course Alignment, FPAP and FHP Coordinates.** The FAS course determines the positional relationship between the FPAP and the FHP. Calculate the FPAP latitude and longitude coordinates using the MAP as a starting point after determining the procedure final approach course (FAC). Use the direct program and extend the FAS course as an azimuth at a distance of 2,600 ft from the MAP to determine the FHP coordinates. Extend this course 9,023 ft beyond the FHP to calculate the FPAP coordinates (see figure 8-4-14 and table 8-4-1).

Figure 8-4-14: FPAP and FHP Coordinates

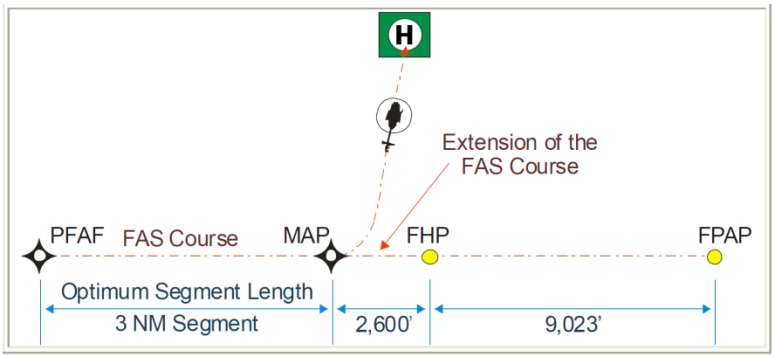


Table 8-4-1: FPAP Information

FPAP Distance from FHP	± Splay	± Width	Length Offset
9,023 ft	2.0°	350 ft (106.75 m)*	0

*Round result to the nearest 0.25 m.

d. **Area.** The FAS OEA begins at the earliest PFAF position and ends at the MAP latest ATT (see figure 8-4-16). The PFAF and MAP ATT is ±40 m. Apply 250 ft of ROC in the primary area (plus adjustments). The secondary area ROC is 250 ft at the primary boundary tapering uniformly to zero at the outer edge. The beginning primary area width nearest the FHP is 867.79 ft, and the secondary areas are 468.60 ft (see figures 8-4-15b and 8-4-16). Calculate the primary and secondary widths at any point between FHP and PFAF using formulas 4-12 (primary) and 4-13 (secondary).

(1) Length. The **standard** IFR final segment length PFAF to MAP is 3 NM but is also determined by descent gradient. The **minimum** length is 2 NM and the **maximum** length is 50,000 ft. (see figure 8-4-15a).

Figure 8-4-15a: WAAS LP Final Segment

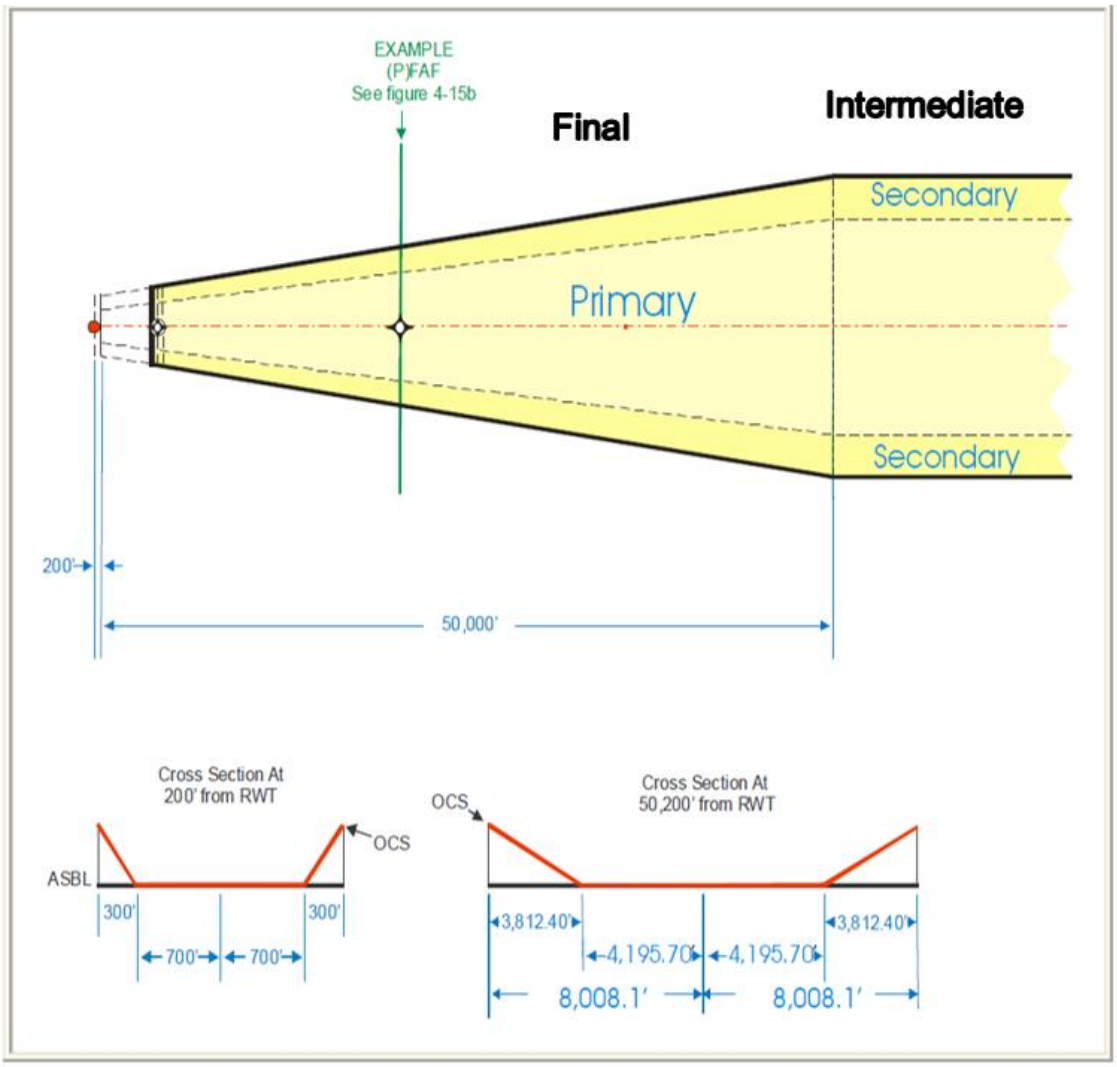


Figure 8-4-15b: WAAS LP Final Segment Construction

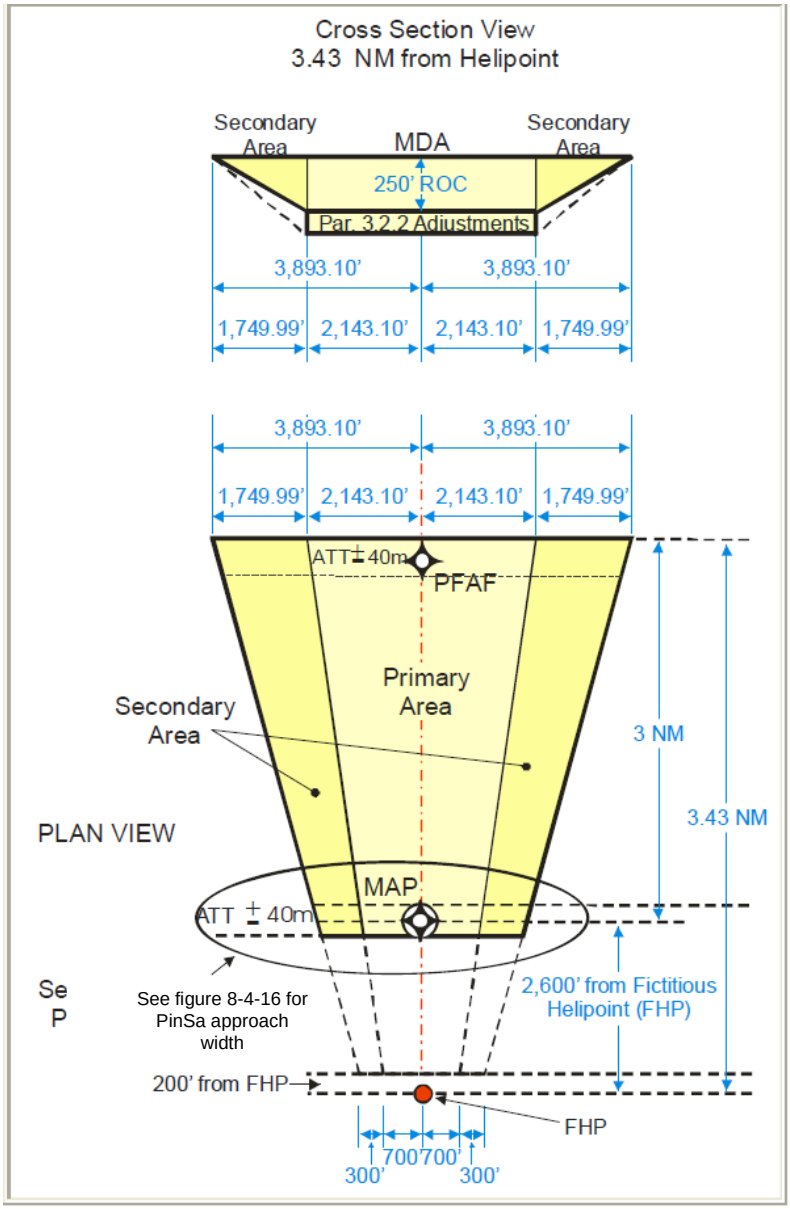
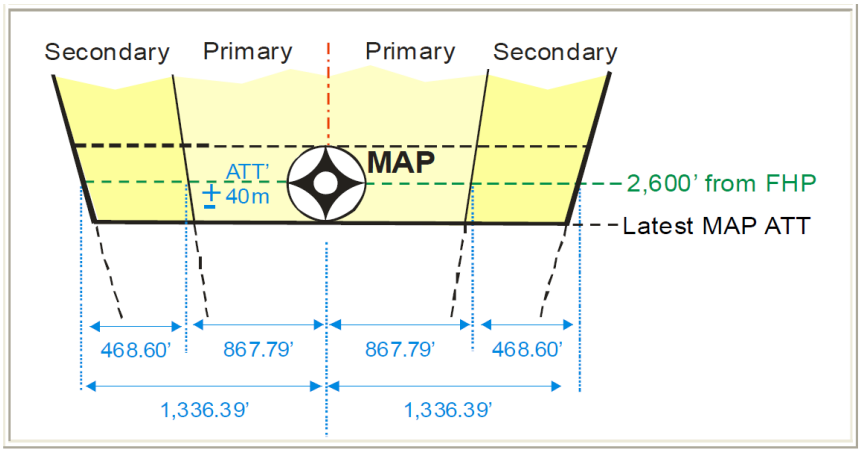


Figure 8-4-16: OCS Beginning Width, IFR to VFR Heliport and Copter PinS Approach FAS at 2,600 ft from FHP



(2) The primary area half-width (D_P) each side of FAC at its origin (2,600 ft from FHP) is 867.79 ft. The primary area expands uniformly to 3,495.70 ft from FAC at a point 50,200 ft from FHP. From 50,200 ft outward, the OEA is linear (boundaries parallel the centerline). The OEA begins at the earliest PFAF ATT and ends 2,600 ft from the FHP (MAP latest ATT). Calculate primary area half-width at any point in final using formula 4-12 (see figures 8-4-15a, 8-4-15b, and 8-4-16).

Calculate the perpendicular distance (ft) D_p from FAC to the primary area boundary at any distance (d_{FHP}) using formula 4-12:

Formula 4-12: Half-Width of Primary Area (D_p)

$$D_P = 1/2 \text{ Primary Area Width (ft)} = 0.0699139\ (d_{FHP} - 200) + 700$$

d_{FHP} = Distance (ft) from FHP, along course

$$0.0699139*(d_{FHP}-200)+700$$

(3) The perpendicular distance from FAC to outer secondary boundary (D_S) is 1,336.39 ft at the origin, and expands uniformly to 7,008.1 ft at 50,200 ft from the FHP (see figures 8-4-15a, 8-4-15b, and 8-4-16). Calculate D_S (ft) using formula 4-13.

Formula 4-13: Distance Secondary (D_s)

$$D_S = \text{Secondary Boundary Dist. (ft)} = 0.140162\ (d_{FHP} - 200) + 1000$$

Where:

D_S = Course to Outer Secondary Distance (ft)

d_{FHP} = Distance from FHP (ft), along course

$$0.140162*(d_{FHP} - 200) + 1000$$

e. **Required Obstacle Clearance (ROC).** Primary ROC is 250 ft. The MDA can be no lower than the controlling obstacle height adjusted for obstacle accuracy tolerance (see TP308/ GPH209 Annex E, paragraphs 2.11.3 and 2.11.4) plus the ROC value plus adjustments rounded to the next higher 20 ft-increment. Calculate secondary area ROC using formula 4-14.

Formula 4-14: Secondary Area ROC ($ROC_{secondary}$)

$$ROC_{secondary} = (250+adj) \cdot \left(1 - \frac{d_{primary}}{W_s}\right)$$

Where: adj = *TP308, Volume 1 para 323*
$d_{primary}$ = perpendicular distance (ft) from primary area edge
W_S = Secondary Area Width (ft)

(250+adj)*(1-$d_{primary}$/W_s)

f. **FAS Descent Angle/Gradient.** Apply section 4, paragraphs 8.4.3.a(4) and 8.4.3.a(5).

g. **PinS Approach.** Apply section 4, paragraph 8.4.9 to determine a preliminary MDA based on the FAS OEA. Apply section 4, paragraphs 8.4.7 and 8.4.7.e for the VFR segment analysis.

SECTION 5: MISSED APPROACH

8.5. Missed Approach.

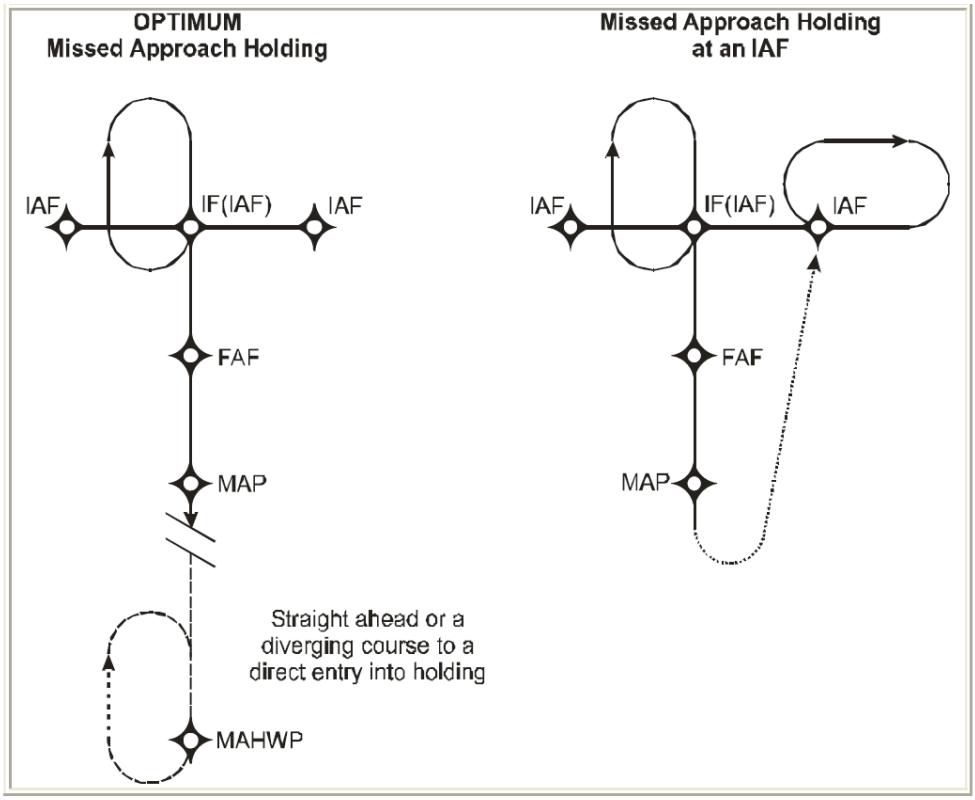
8.5.1. General.

a. Missed Approach (MA) Construction.

(1) Speed. Apply 70 KIAS or 90 KIAS procedures (see section 1, paragraph 8.1.2) as applicable. Apply wind values (see section 2, formula 2-3b) and bank angles (see section 2, table 8-2-4).

(2) Optimum Flight Path. The missed approach segment ends at a holding point designated by a missed approach holding fix (MAHF). Optimum routing is straight ahead to a direct entry into holding at the MAHF. If the MA routing terminates at a "T" IAF, optimum MA holding pattern alignment is with the initial inbound course, with either a teardrop or direct entry into holding (see figure 8-5-1a).

Figure 8-5-1a: Missed Approach Optimum Flight Paths



Note: Figures are NOT drawn to scale.

b. **Obstacle Clearance Standard.** Calculate the nominal OCS slope ($MA_{OCSSLOPE}$) associated with a given missed approach climb gradient using section 2, formula 2-16. See section 2, paragraph 8.2.19 for Missed Approach Conventions.

c. Missed Approach Section 1 (MAS-1). Section 1 begins at earliest MAP along-track tolerance (ATT) and extends to the start-of-climb (SOC), or the point where the aircraft is projected to cross 400 ft above airport/heliport elevation, whichever is the greatest distance from MAP. See figure 8-5-1b for MA segment point and line designations. Figure 8-5-2 depicts the Section 1/Section 2 (partial), OCS plan and profile view beginning at an altitude of MDA minus 100 ft plus adjustments (see section 4 for greater final segment detail).

Figure 8-5-1b: MAS Point/Line Identification

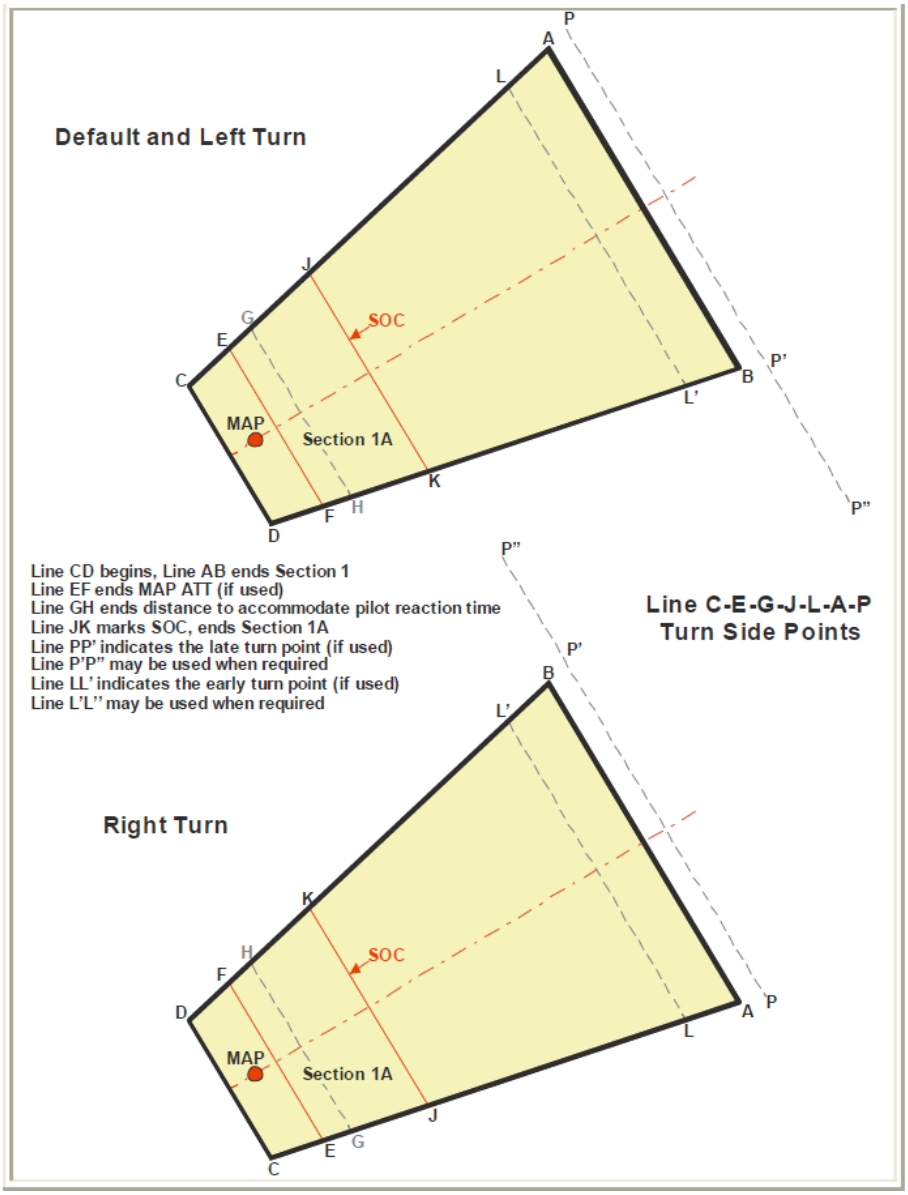
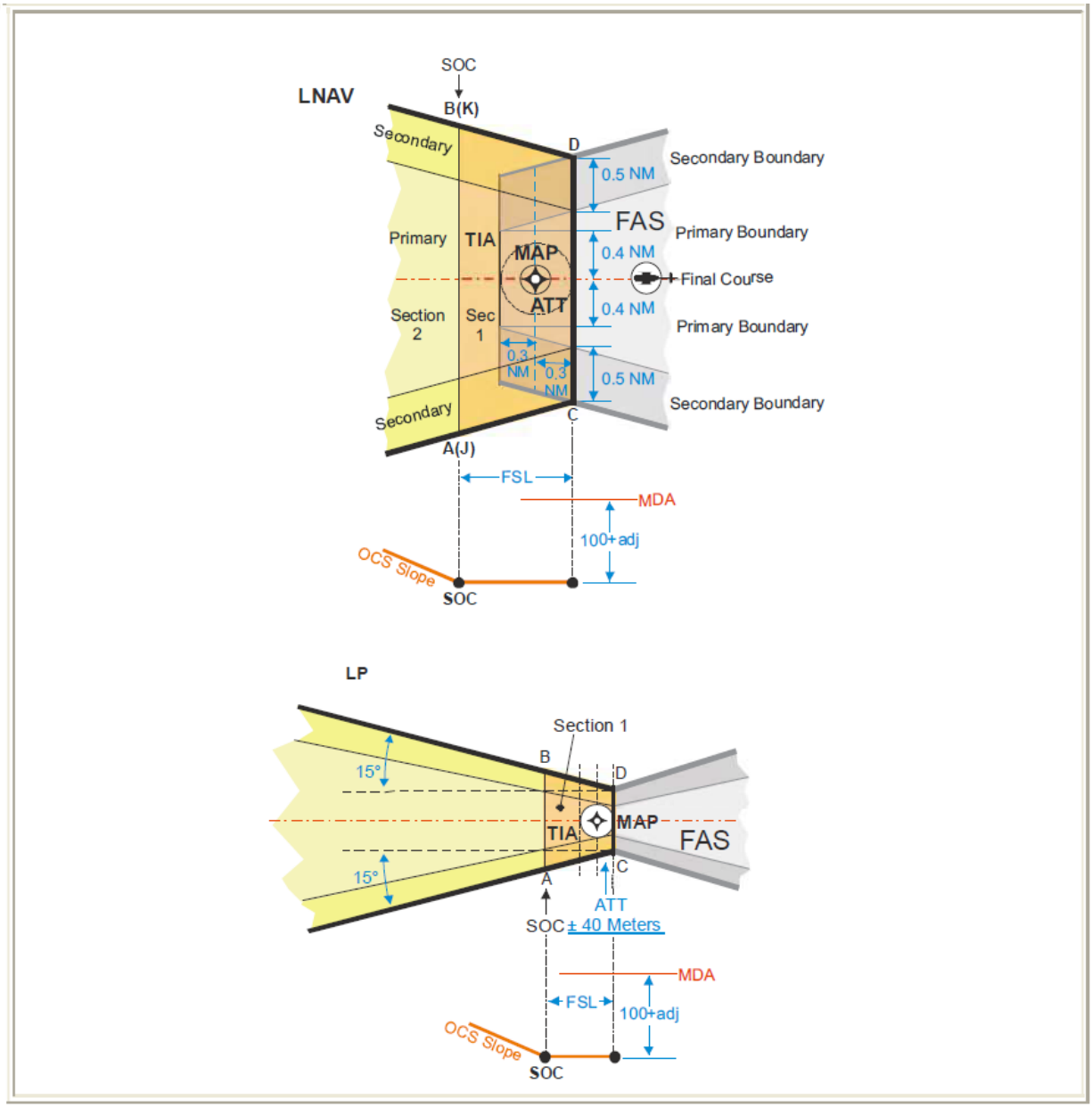


Figure 8-5-2: Missed Approach Section 1



(1) Length.

(a) Flat Surface Length (FSL).

1 LNAV. Section 1 flat surface begins at CD (0.3 NM prior to the MAP) and extends (distance FSL feet) to JK.

2 LP. Section 1 flat surface begins at CD [40 meters prior to the MAP] and extends (distance FSL feet) to JK.

Step 1: Calculate the FSL value using formula 5-1. Use section 4, final segment formulas 4-1a, (LNAV primary and total), and 4-12 (LP primary), and 4-13 (LP Secondary distance) to determine MAS starting widths.

Formula 5-1: Flat Surface Length (FSL)

$$FSL = 8 \bullet \frac{\frac{1852}{0.3048}}{3600} \cdot \left(\left(V_{KIAS} \cdot \frac{171233 \cdot \sqrt{(288+15) - 0.00198 \cdot MDA}}{(288 - 0.00198 \cdot MDA)^{2.628}} \right) + 10 \right) + 2 \cdot ATT$$

8*(1852/0.3048/3600)*((V_KIAS*(171233*((288+15)-0.00198*MDA)^0.5)/ (288-0.00198*MDA)^2.628)+10)+2*ATT

Note: FSL time is 3 seconds reaction, and 5 seconds delay. "ATT" units will be in ft.

(2) Section 1 end location (AB).

(a) MDA ≥ 400 ft above airport/heliport elevation. Locate AB coincident with JK.

(b) MDA < 400 ft above airport/heliport elevation. Locate AB at $\frac{1852}{0.3048\ CG}$ feet beyond JK for each foot of altitude needed to reach 400 ft above airport/heliport/surface elevation. The surface between JK and AB is a rising slope commensurate with the standard rate of climb (400 ft/NM). Find the appropriate CG-related slope using section 2, formula 2-16.

(c) Required/assigned turning altitude > 400 ft above airport/heliport elevation. Locate AB and apply the surface described in section 5, paragraph 8.5.1.c(2)(b) until reaching the assigned turning altitude.

(3) Width. LNAV and LP.

(a) LNAV. Splay each secondary area outer boundary line outward 15 degrees relative to the missed approach course (MAC) from the secondary area outer edge at CD (0.3 NM prior to MAP) until it reaches a point 2 NM from MAC. Splay the primary area boundary uniformly outward from the primary area edge at CD to reach 1.5 NM from MAC at the same

distance the secondary reaches full width. Calculate the distance from MAC to the MAS-1 OEA primary and outer secondary boundary at any distance from CD using formula 5-1a. Calculate final primary and secondary widths at CD using section 4, final formula 4-1a.

(b) LP. Splay each secondary area outer boundary line outward 15 degrees relative to the MAC from the secondary area outer edge at CD (40 meters prior to MAP) until it reaches a point 2 NM from MAC. Splay the primary area boundary uniformly outward from the primary area edge at CD to reach 1.5 NM from MAC at the same distance the secondary reaches full width. Calculate the distance (ft) from MAC to the MAS-1 OEA primary and outer secondary boundary at any distance from CD using formula 5-1a. Calculate final primary and secondary widths at CD using section 4, final segment formulas 4-12 and 4-13.

Formula 5-1a: LNAV/LP Section 1 Primary & Secondary Width

$$\mathbf{MAS_{Yprimary}} = \mathbf{d} \cdot \frac{\tan(15°) \cdot \left(1.5 \cdot \frac{1852}{0.3048} - \mathbf{W_p}\right)}{2 \cdot \frac{1852}{0.3048} - \mathbf{W_s}} + W_p$$

$$\mathbf{MAS_{Ysecondary}} = \mathbf{d} \cdot \tan(15°) + \mathbf{W_s}$$

Where:

d = along-track distance (ft) from the CD line

W_p = Primary Start Half Width (ft) (final formula)

W_s = Secondary Start Width (ft) (final formula)

(4) Obstacle Clearance Section 1.

(a) The nominal MAS-1 OCS is a flat surface. The MSL surface height (HMAS) is equal to the MDA minus 100 ft plus adjustments (see formula 5-1b). No obstacle may penetrate this surface.

(b) Where Section 1 extends beyond SOC (JK), no obstacle may penetrate the CG-associated OCS slope between SOC and AB. Find helicopter altitude at AB using formula 5-1c.

Formula 5-1b: HMAS

$$HMAS = MDA - (100 + adj)$$

Where:

adj = precipitous terrain, remote altimeter (only if full time), and excessive length of final adjustments

MDA-(100+adj)

Formula 5-1c: Section 1 End Helicopter Altitude ($Copter_{AB}$)

$$Copter_{AB} = (r+MDA\ or\ DA) \cdot e^{\frac{AB_{NM} \cdot CG}{r}} - r$$

Where:

AB_{NM} = SOC to AB distance (NM)

CG = applied climb gradient (ft/NM)

(r+(MDA or DA))*e^((AB$_{NM}$*CG)/r)-r

d. These criteria cover two basic MA constructions:

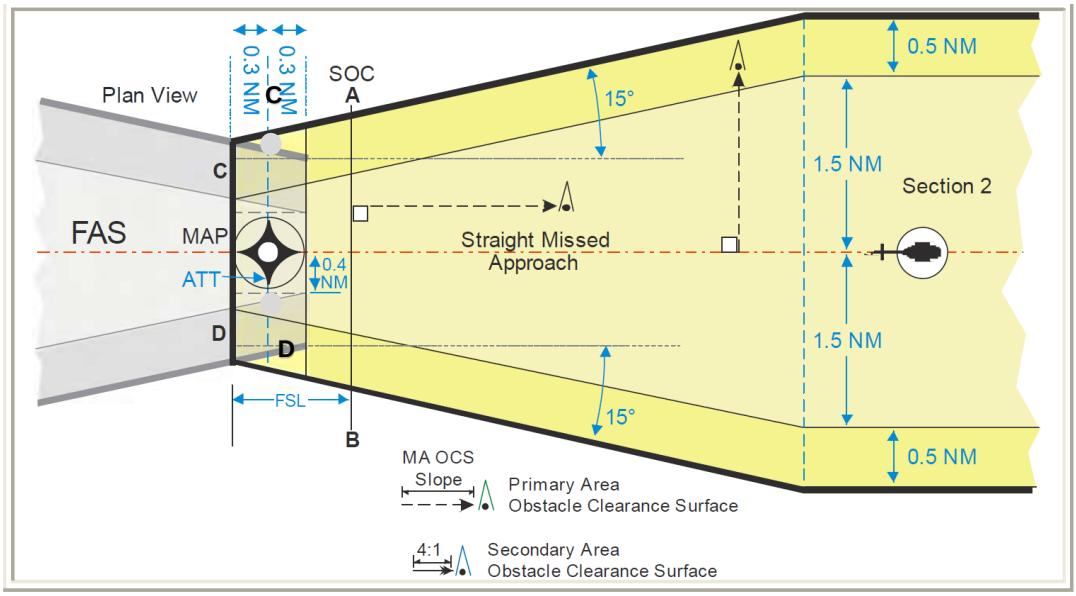
- Straight missed approach; and
- Turning missed approach.

Note: These construction methods accommodate traditional combination straight and turning missed approaches.

(1) The section 2 obstacle evaluation area (OEA) splays 15 degrees relative to the nominal track to reach full width (see figure 8-5-3). The OEA ends at the MA Holding Fix (MAHF) latest ATT. Apply the Section 2 standard MA OCS slope beginning from AB (SOC). Calculate MA OCS slope values using section 2, formula 2-16.

Note: All references to 'standard MA OCS slope' and/or use of '20:1' refer to section 2, formula 2-16 output, with an input climb gradient (CG) of 400 ft/NM.

Figure 8-5-3: Straight Missed Approach



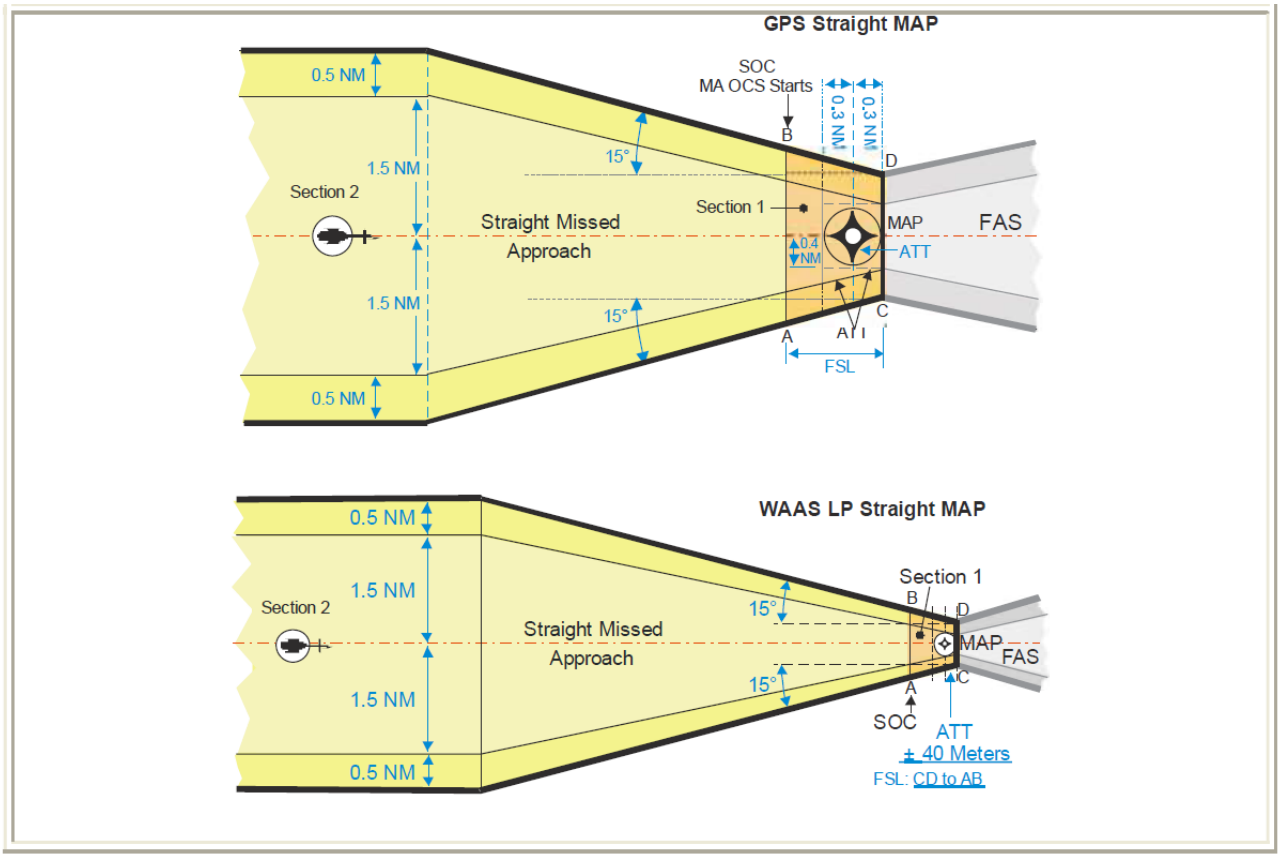
(2) Where a higher than standard CG (400 ft/NM) is required, apply the CG and the CG-related OCS from the SOC. Apply secondary areas as specified in this section. Measure the 4:1 secondary OCS perpendicular to the nominal track, measured from the primary boundary, or perpendicular to the primary boundary when considering arcs, diagonal corner-cutters, etc.

(3) Locate the MAHF within 25 NM of the ARP/ HRP. Determine minimum leg length for course changes following the first fix after the MAP using the greater distance from section 2, formulas 2-6, 2-7, and 2-9a, climb distance required, and section 3, table 8-3-1.

(4) Design MA holding for 90 KIAS, or the appropriate restricted speed.

8.5.2. **Straight Missed Approach.** The straight missed approach course (MAC) is a continuation of the final approach course (FAC). The straight MA section 2 OEA begins at section 1 end (AB) and splays at 15 degrees relative to the nominal track until reaching full primary and secondary width (0.5-1.5-1.5-0.5). Apply the section 2 standard OCS, or the OCS associated with a higher CG, beginning at AB from the section 1 end OCS elevation. (When the increased CG is no longer required, revert to the section 2 standard OCS). Determine primary OCS elevation at an obstacle by measuring the along-track distance from AB to a point at/abeam the obstacle. Where the obstacle is located in the secondary area, apply the primary OCS slope to a point abeam the obstacle, then apply the 4:1 secondary slope (perpendicular to the track) from the primary boundary to the obstacle (see section 5, figures 8-5-3, 8-5-4).

Figure 8-5-4: Straight Missed Approach (GPS/LNAV / LP)



8.5.3. **Turning Missed Approach.** Apply turning criteria when requiring a turn at or beyond SOC. Where secondary areas exist in section 1, they continue to full width in section 2. Terminate turn-at-fix turn-side secondary areas not later than the early turn point. Do not apply turn-side secondary areas for turn-at-altitude construction. The terms ‘inside turn’ and ‘outside turn’ are used to reduce verbiage in describing turn associated construction and relationships. Where required, alternate construction steps (indicated by Step #ALT) are provided to supplement or replace the primary step.

There are two types of turn construction for the first MA turn:

- Turn at an altitude (see section 5, paragraph 8.5.3.a):
  - Always followed by a DF leg ending with a DF/TF connection

- Turn at a fix (see section 5, paragraph 8.5.3.b):
  - Always followed by a TF leg ending with a TF/TF connection.
  - May be followed by an RF leg (which requires advanced avionics) when the initial straight leg has reached full width, ending with an RF/TF or RF/RF connection. RF turn initial fix must be located where the aircraft is at least 500 ft above airport elevation.

Following a turn, the minimum segment length must be the greater of:

- The minimum length calculated using section 2, formulas 2-6, 2-7 and 2-9a.
- The distance from previous fix to the intersection of the 30-degree converging outer boundary line extension and the nominal track, (plus segment end fix DTA).

Minimum DF leg length must accommodate 6 seconds (minimum) of flight time based on either 70 KIAS or 90 KIAS, as appropriate, applied between the wind spiral (WS)/direct-to-fix-line tangent point, and the earliest manoeuvring point of the DF/TF fix. Convert to TAS using section 2, formula 2-3a and the MAHF altitude.

a. **Turn at an Altitude.** Apply turn-at-an-altitude construction unless the first MA turn is at a fix. Since pilots may commence the MA at altitudes higher than the MDA and helicopter climb rates differ, turn-at-an-altitude construction protects the large area where turn initiation is expected. This construction also provides protection for 'turn as soon as practicable' and combination straight and turning operations. When a required turning altitude exceeds the minimum turning altitude (400 ft above the airport, heliport, or height above surface), specify the turning altitude in a 100-ft increment. Where operationally required, 20-ft increments may be applied.

   Note: 'Turn as soon as practicable' includes, but is not limited to operational suitability, flight characteristics/capability, appropriate altitude, positioned at or beyond the MA early ATT, as well as the feasibility, workability, and viability of the intended maneuver.

Track guidance is assumed throughout the operation; therefore, dead reckoning (DR) segments are not considered. Apply turning MA criteria whenever the MAC differs from the FAC. The following applies:

- Section 1/Section 2 connection is depicted in section 5, figure 8-5-5 for a minimum altitude turn-at-altitude MA. The CD is the earliest the MAP can be received. AB is the SOC (section 5, figure 8-5-6 depicts higher than minimum altitude turns).

Figure 8-5-5: Turn at Altitude Missed Approach, ≤ 75°
(Minimum Turning Altitude)

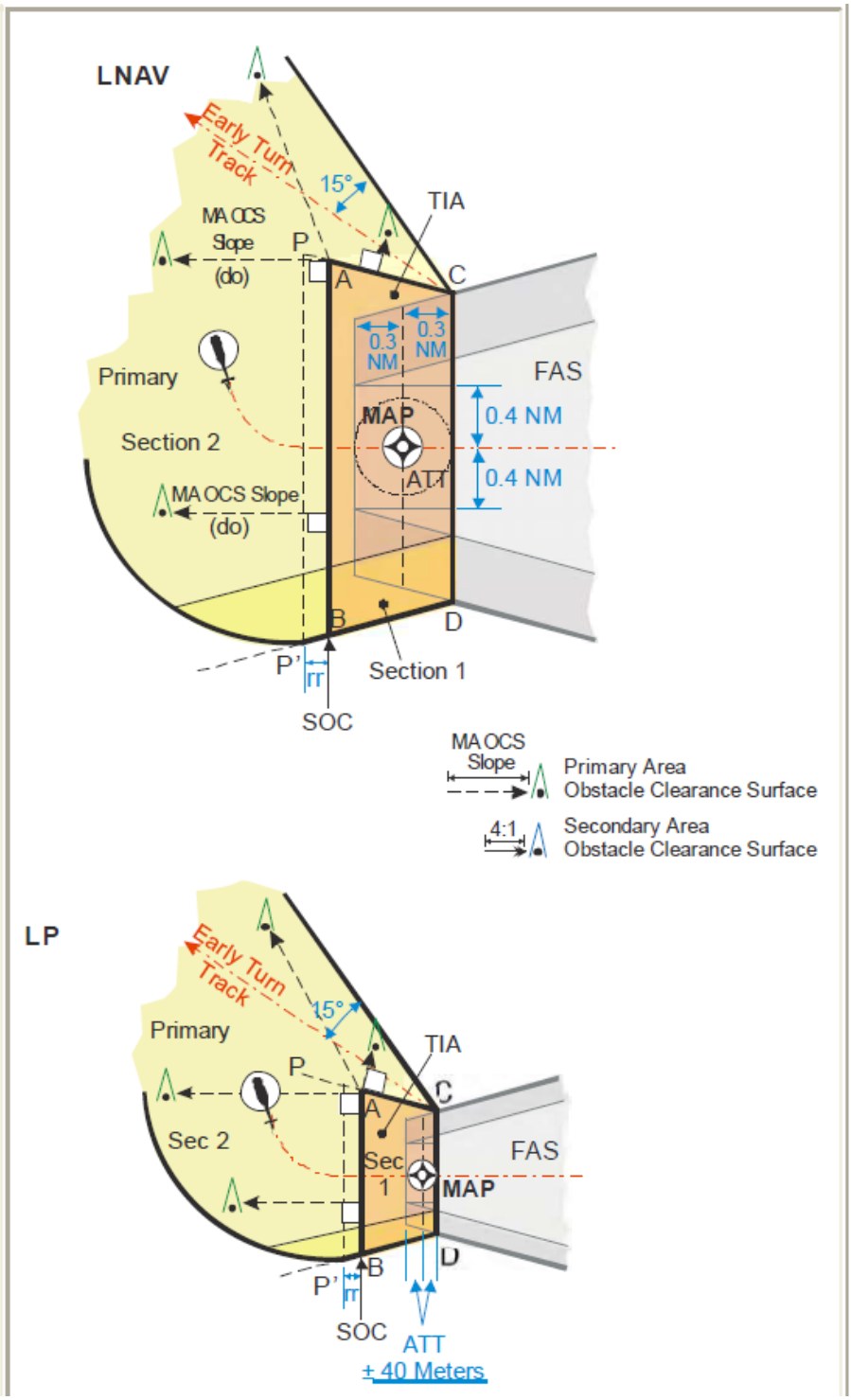
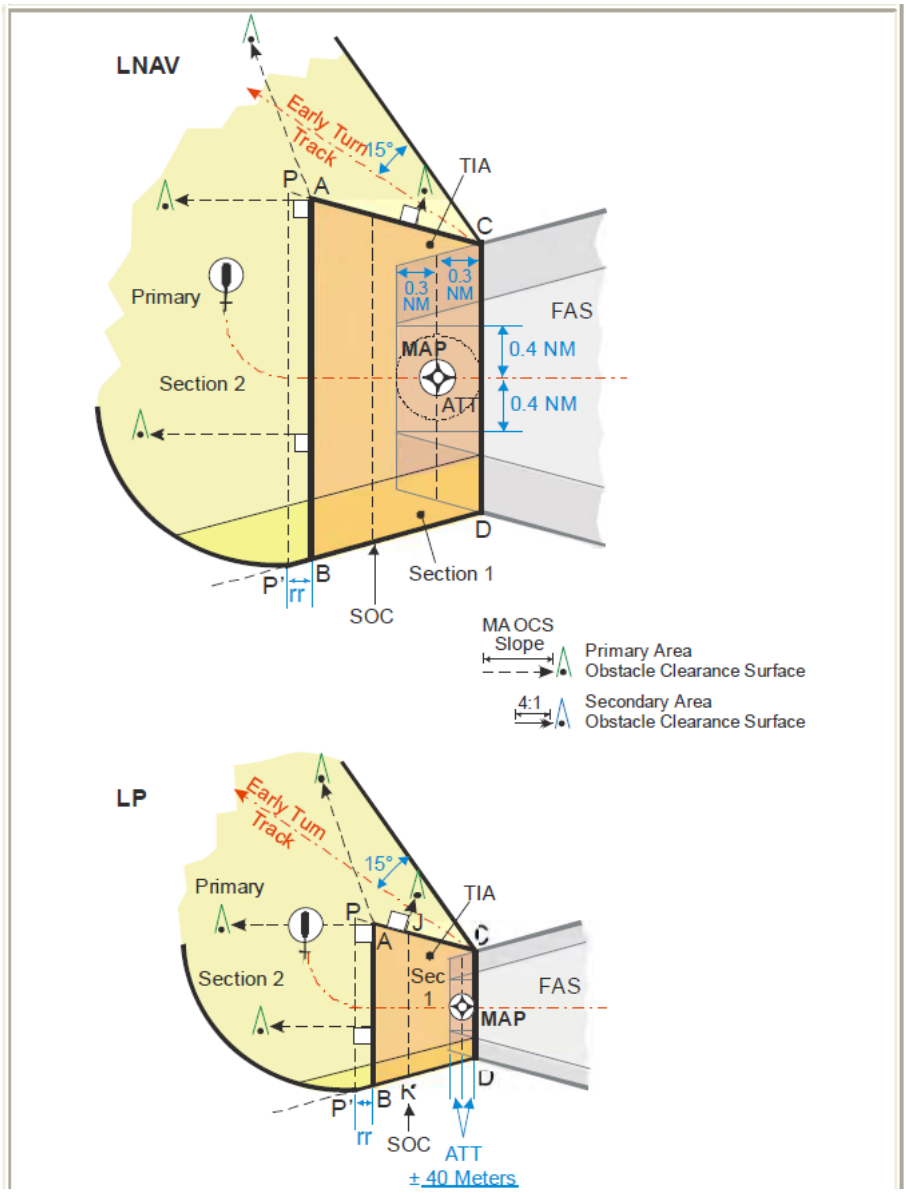


Figure 8-5-6: Turn at Altitude Missed Approach, ≤ 75° (> Minimum Turning Altitude)



- Section 2 and section 1 connect at AB.
- Construct section 2 outside-turn boundaries using WS vice specified radii. Construct outside boundaries in relation to these WS and late turn track (see section 5, figures 8-5-9, 8-5-13, 8-5-15).
- Construct inside-turn boundaries in relation to the early turn track (see section 5, figures 8-5-5, 8-5-6).

- Apply the standard OCS slope (or the assigned CG-associated slope) beginning at AB at AB OCS height. The secondary 4:1 surface rises from the primary OCS.

(1) Turn Initiation Area (TIA). Construct the TIA, a portion of a straight MA, beginning from the earliest MA turn point (CD), and ending where the specified minimum turning altitude is reached, (AB or LL'). Base the TIA length on the climb distance required to reach the turning altitude. The TIA minimum length must place the aircraft at an altitude from which obstacle clearance is provided in section 2 outside the TIA. The TIA boundary varies with length, the shortest B-A-C-D, where AB overlies JK. Where the TIA is contained within section 1, B-A-J-C-D-K defines the boundary. Where the required turn altitude exceeds that supported by section 1, the TIA extends into section 2, (see figure 8-5-8 and TP308 Volume 2 publication for construction examples) and points L'-L-A-J-C-D-K-B define its boundary. In this case, L-L' is the early turn point based on the helicopter climbing at the prescribed CG. Calculate TIA length using section 5, formula 5-2a. A 4:1 secondary is depicted on the non-turning side of the primary (see section 5, figures 8-5-6, 8-5-8, and 8-5-9).

Figure 8-5-7: Turn at Altitude Missed Approach, > 75˚ (Minimum Turn Altitude)

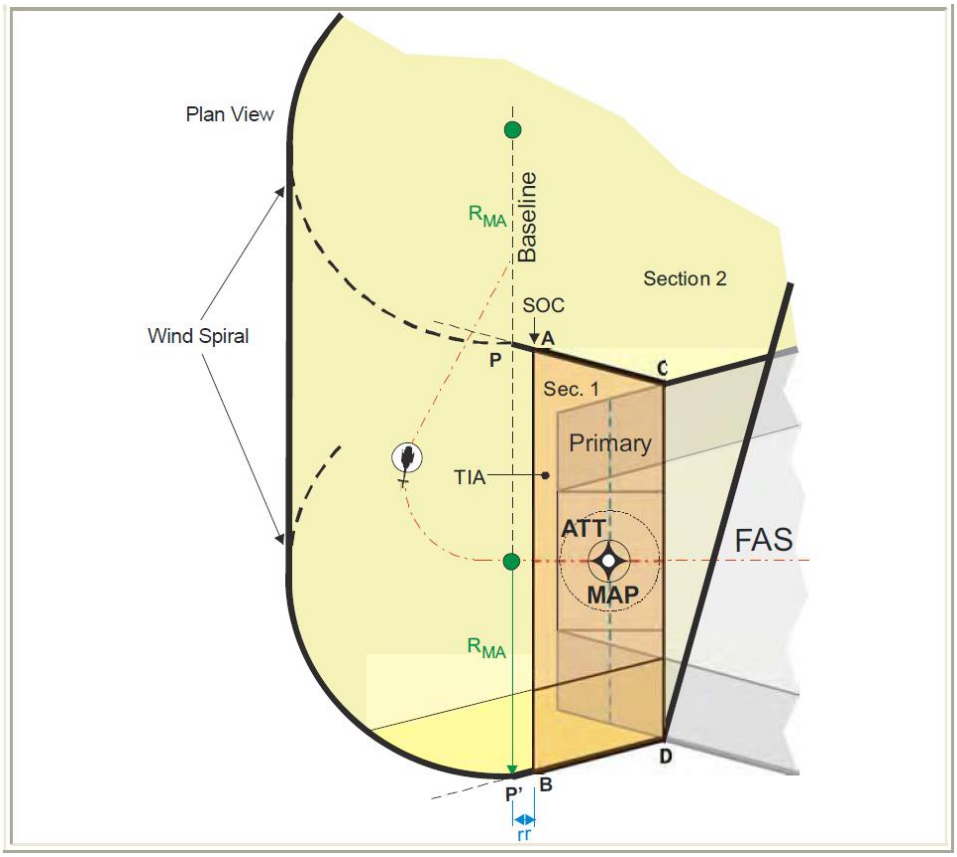
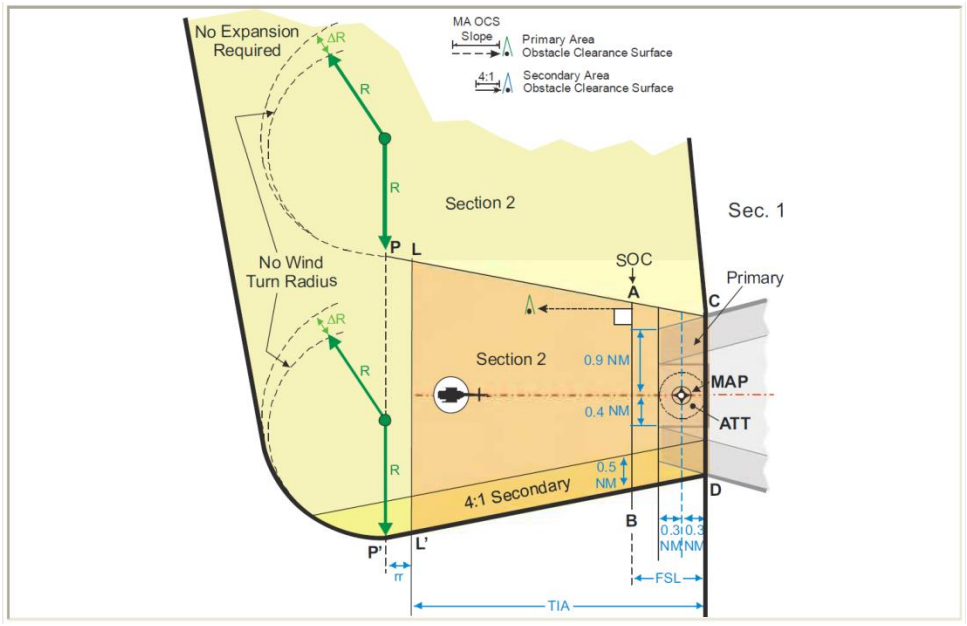


Figure 8-5-8: Turn at Altitude Missed Approach, 75˚ (Greater than Minimum Turn Altitude)



Step 1: Turn altitude. The turn altitude is either operationally specified (must be at or above altitude required by obstacles) or determined by obstacle evaluation. Evaluate the nominal OCS. If the OCS is penetrated, mitigate the penetration with one or a combination of the following:

- Raise MDA.
- Establish a climb gradient that clears the obstacle.
- Move MAP.
- If the penetration is outside the TIA, consider raising the climb-to altitude.

(a) Determine the helicopter required minimum turning altitude:

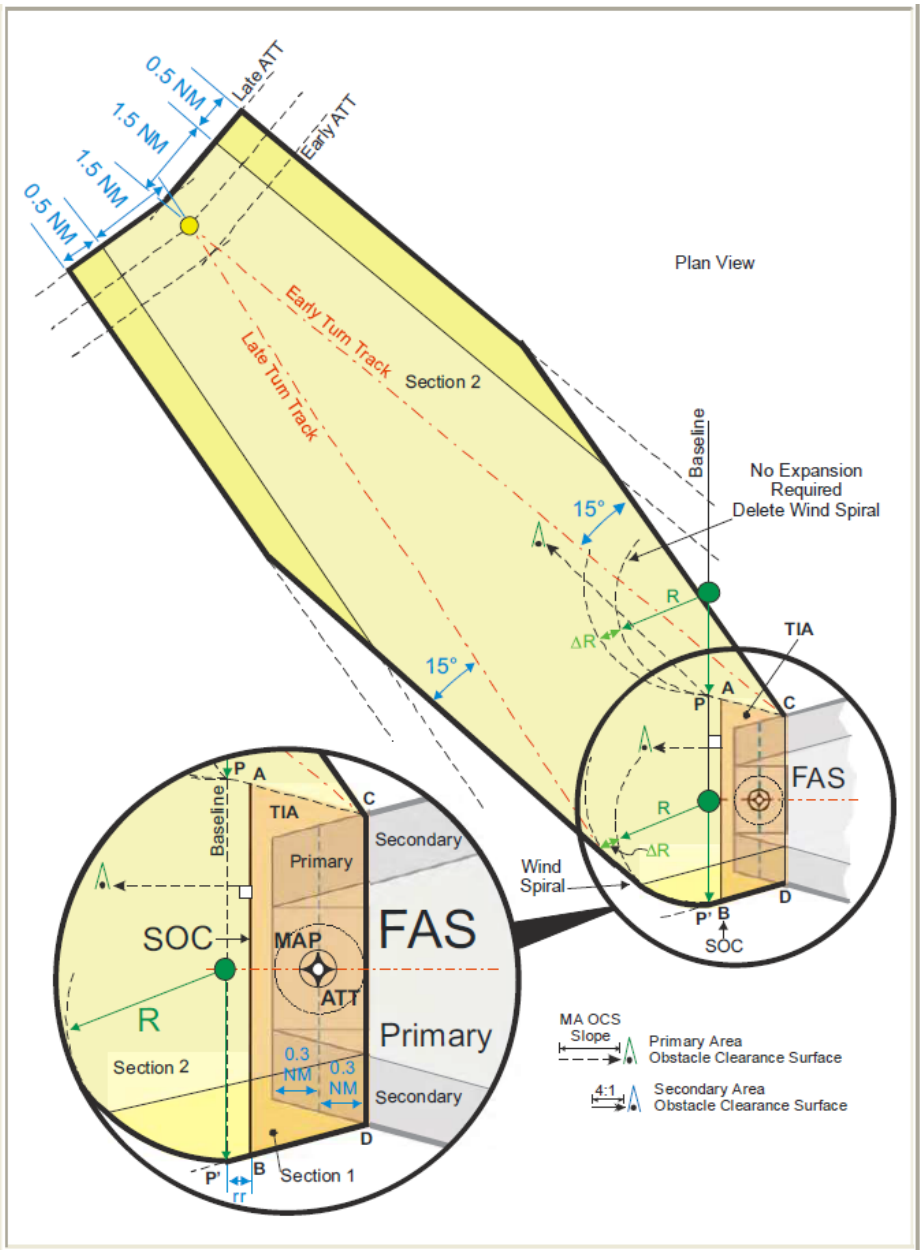
- Identify the controlling obstacle in section 2 (straight MA).
  - For straight OCS/CG/length options.
- Identify the controlling obstacle in section 2, (typically turn-side).
- Find the shortest distance from the TIA lateral boundary to the obstacle.
- Apply this distance and the MA OCS slope to find the TIA-to-obstacle OCS rise.
- The minimum TIA boundary, (and OCS end elevation) equals the obstacle elevation minus OCS rise.
- The minimum turn altitude is the sum of (TIA OCS boundary elevation) and (final ROC), rounded to the next higher 100 ft-increment (where operationally required, 20-ft increments may be applied).

Note 1: TIA lateral boundary is the straight segment (portion) lateral boundary until the required minimum turn altitude and TIA length are established.

Note 2: Repeat Step 1 until acceptable results are obtained.

The specified altitude must equal or exceed the section 1 end altitude. Find section 1 end altitude using section 5, formula 5-1c or formula 5-2a for $\mathrm{TIA}_{\mathrm{length}}$.

Figure 8-5-9: Turn at Altitude Missed Approach, ≤ 75 Degrees (Minimum Turn Altitude)



Step 2: Calculate TIA length (ft) using section 5, formula 5-2a (see section 5, figures 8-5-6 and 8-5-8).

Formula 5-2a: $\mathrm{TIA_{length}}$

$$\mathrm{TIA_{length}} = \mathrm{FSL} \cdot \frac{r}{(r + \mathrm{MDA})} + \frac{r}{CG} \cdot \frac{1852}{0.3048} \cdot \ln\left(\frac{r + \mathrm{turn_{alt}}}{r + \mathrm{MDA}}\right)$$

Where MDA = Final MDA
CG = Climb Gradient (Standard 400 ft/NM)
$\mathrm{turn_{alt}}$ = required turn altitude

FSL*r/(r+MDA)+r/CG*1852/0.3048*ln((r+$\mathrm{turn_{alt}}$)/(r+MDA))

Step 3: Locate the TIA end at a distance $\mathrm{TIA_{length}}$ beyond CD (from Step 2) (LL') where the applied OCS reaches the required TIA end surface elevation (from Step 1).

Step 4: Locate the latest turn point, (PP') at distance rr (from section 2, formula 2-4a) beyond the TIA end (AB/LL'). See example section 5, figures 8-5-6 and 8-5-8.

(2) OEA Construction after TIA. The OEA includes areas to protect the earliest and latest direct tracks from the TIA to the fix. Construct the obstacle areas about each of the tracks as described below. See section 5, figures 8-5-9 through 8-5-15 for various turn geometry construction illustrations.

(a) Early Turn Track and OEA Construction. Where the early turn track from the FAC/CD intersection defines a turn less than or equal to 75 degrees relative to the FAC, the tie-back point is C (see section 5, figure 8-5-5); if the early track defines a turn greater than 75 degrees relative to the FAC, tie-back to point D (see section 5, figure 8-5-7). Where the early track represents a turn greater than 165 degrees (see section 5, figures 8-5-12 and 8-5-15), begin the early turn track and the 15-degree splay from the non-turn side TIA end + rr (section 2, formula 2-4a) (PP').

Step 1: Construct a line (defines the earliest-turn flight track), from the tieback point to the fix. See section 5, figures 8-5-9, 8-5-10, 8-5-14, and 8-5-15.

Step 2: Construct the outer primary and secondary OEA boundary lines parallel to this line (0.5-1.5-1.5-0.5 segment width). See section 5, figures 8-5-9 and 8-5-10.

Step 3: From the tie-back point, construct a line splaying at 15 degrees to intersect the parallel boundary lines or segment end, whichever occurs earlier (see section 5, figures 8-5-9 and 8-5-10).

Note: Apply secondary areas only after the 15-degree splay line intersects the primary boundary line (see section 5, figures 8-5-9, 8-5-10, 8-5-13, etc).

Step 3Alt: Where Step 3 construction provides less than full-width protection at the DF fix, construct the OEA inner boundary with a line splaying from the tieback point at 15 degrees relative the direct-to-fix line, (or greater where required to provide full-width protection at the DF fix), until it intersects the parallel boundary lines (not later than tangent/tangent-extension to the full-width-arc about the fix), and provides full-width protection at or before the DF fix. DF secondary areas begin/exist only where full width primary exists. See section 5, figures 8-5-10, 8-5-14, and 8-5-15.

Note: Where excessive splay results (dependent upon various conditions but generally in the 20-25 degree range), consider modifying the segment to avoid protection and/or construction difficulties.

Figure 8-5-10: Turn at Altitude Missed Approach, > 75 degrees (Minimum Turn Altitude)

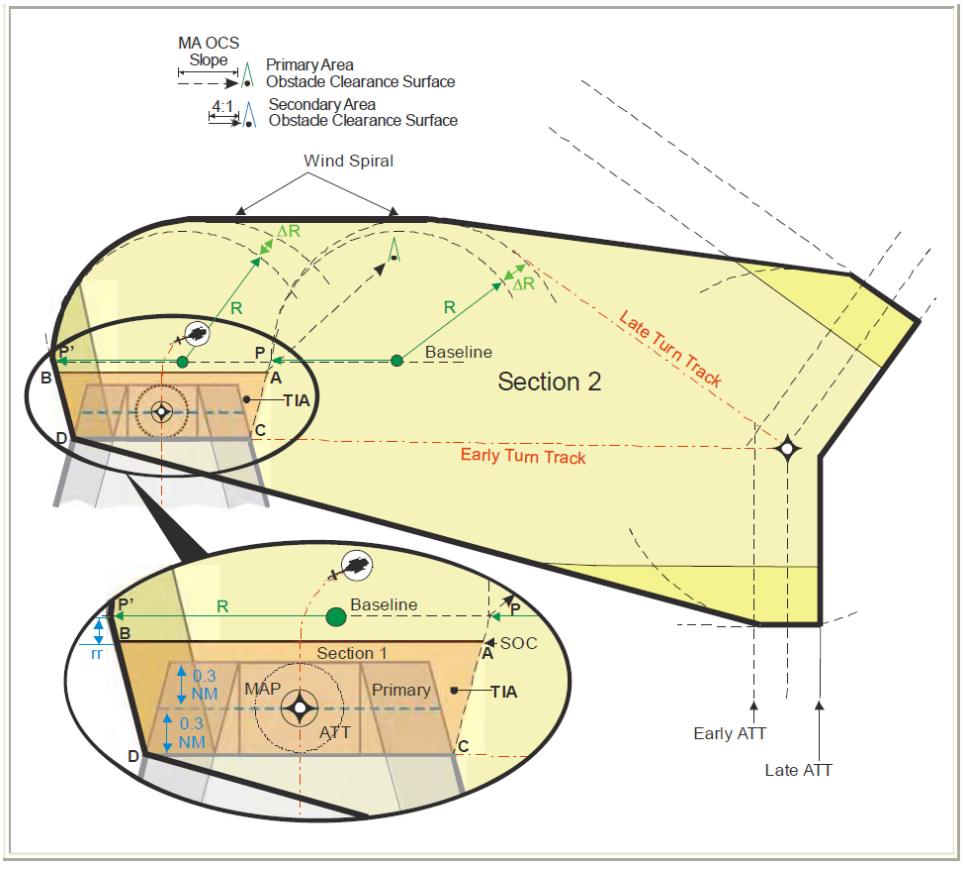


Figure 8-5-11: 70 KIAS Missed Approach Segment, > 75 degrees, ≤ 165 degrees (Minimum Turn Altitude) 2 WS

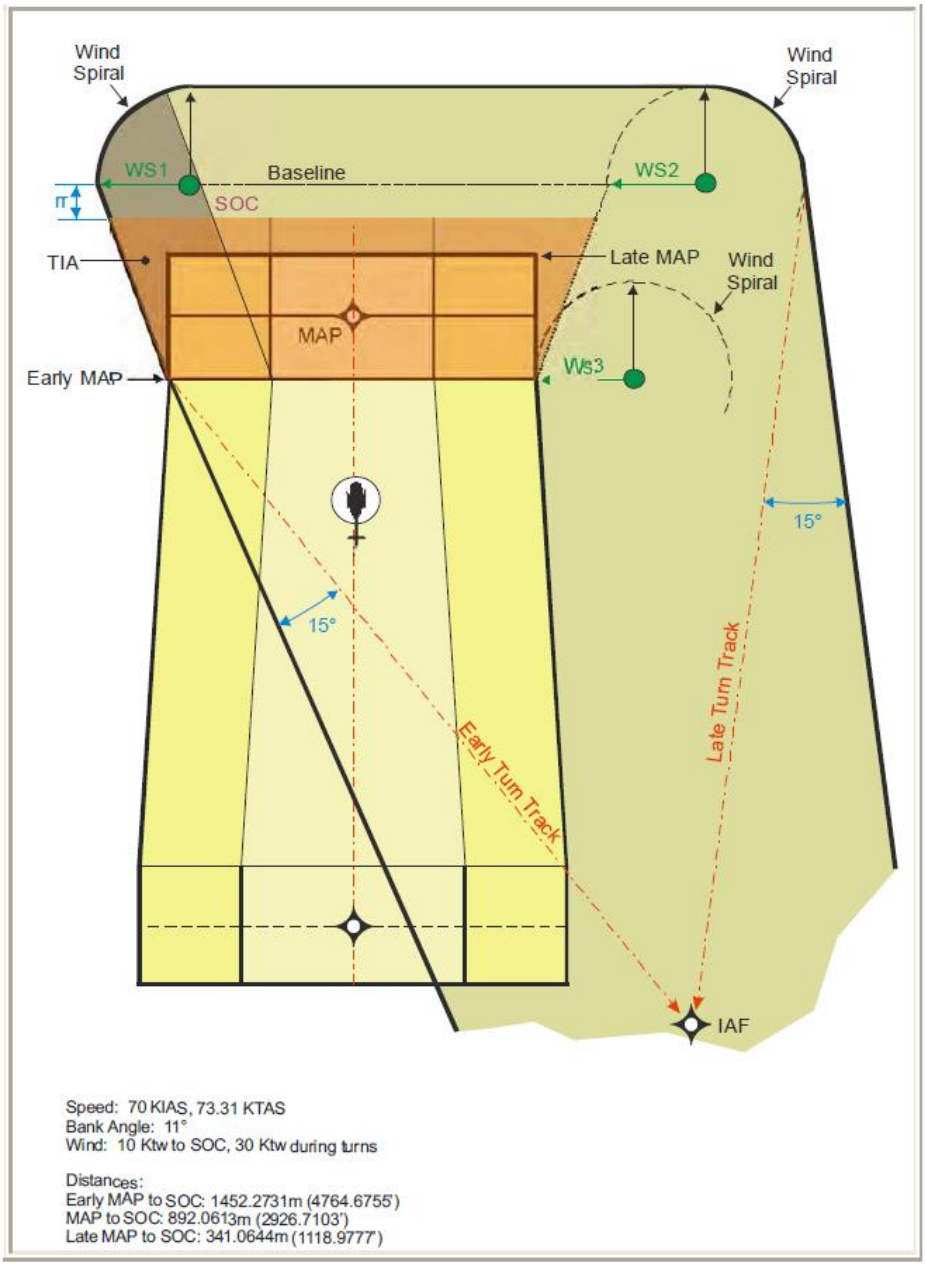


Figure 8-5-12: 90 KIAS Missed Approach Segment, > 165 degrees (Minimum Turn Altitude) 3 WS

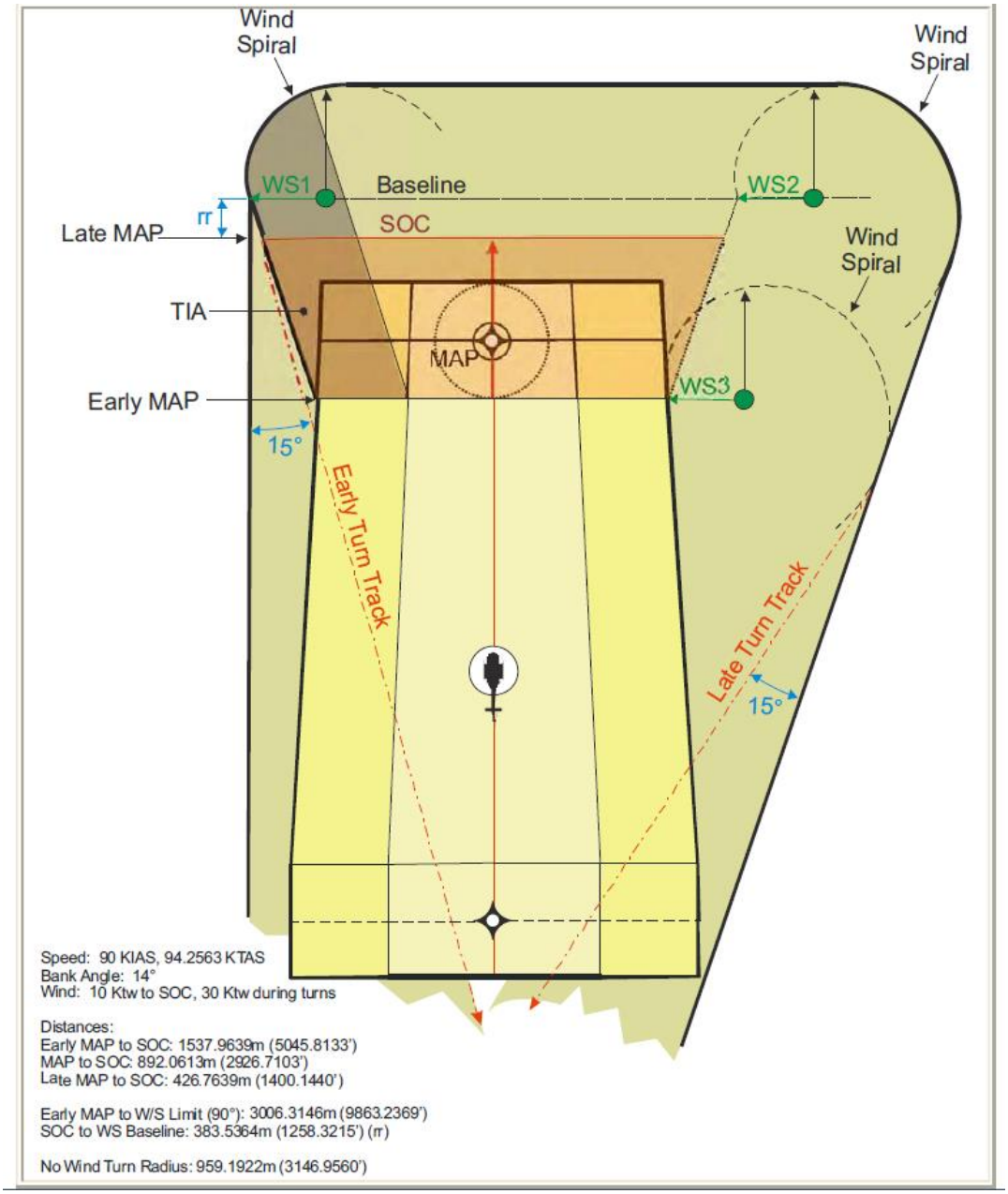


Figure 8-5-13: Direct to Fix Segment Following a TIA completion ≤ 75 Degrees (One WS)

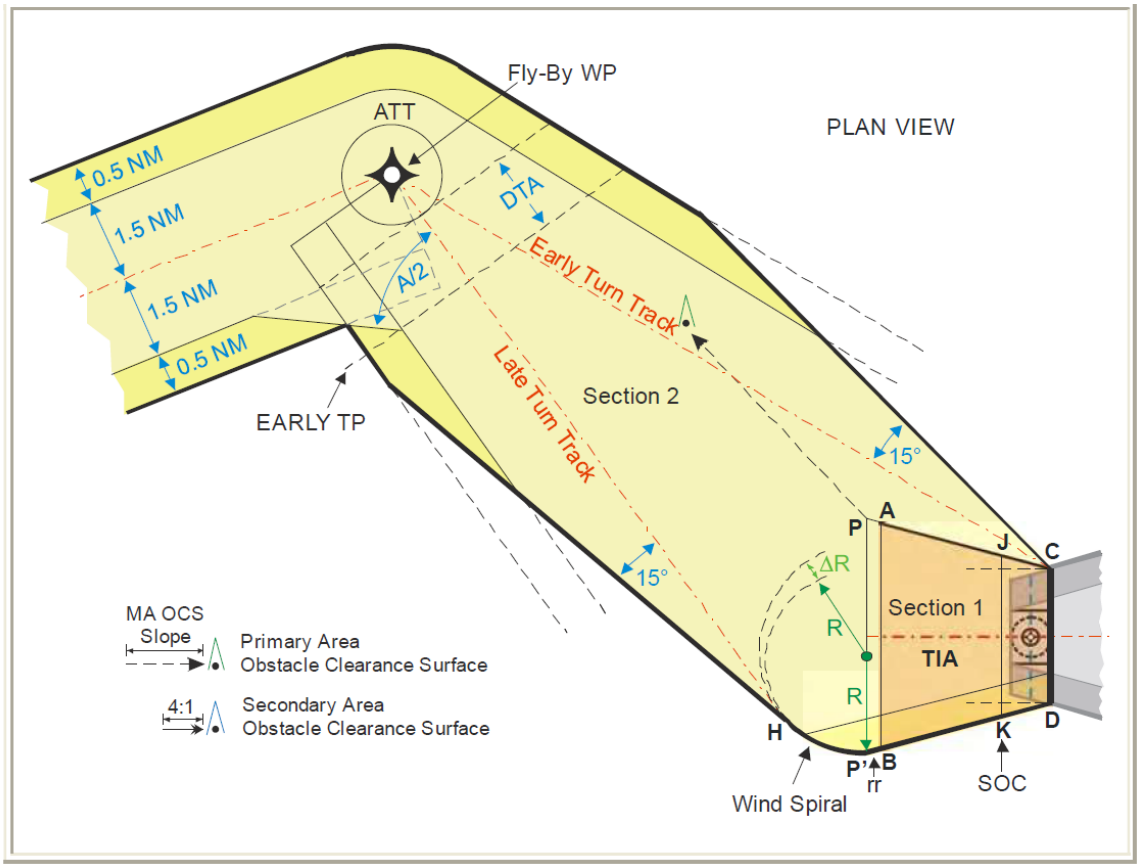


Figure 8-5-14: Direct to Fix Segment Following a TIA completion >75 degrees (Two WS)

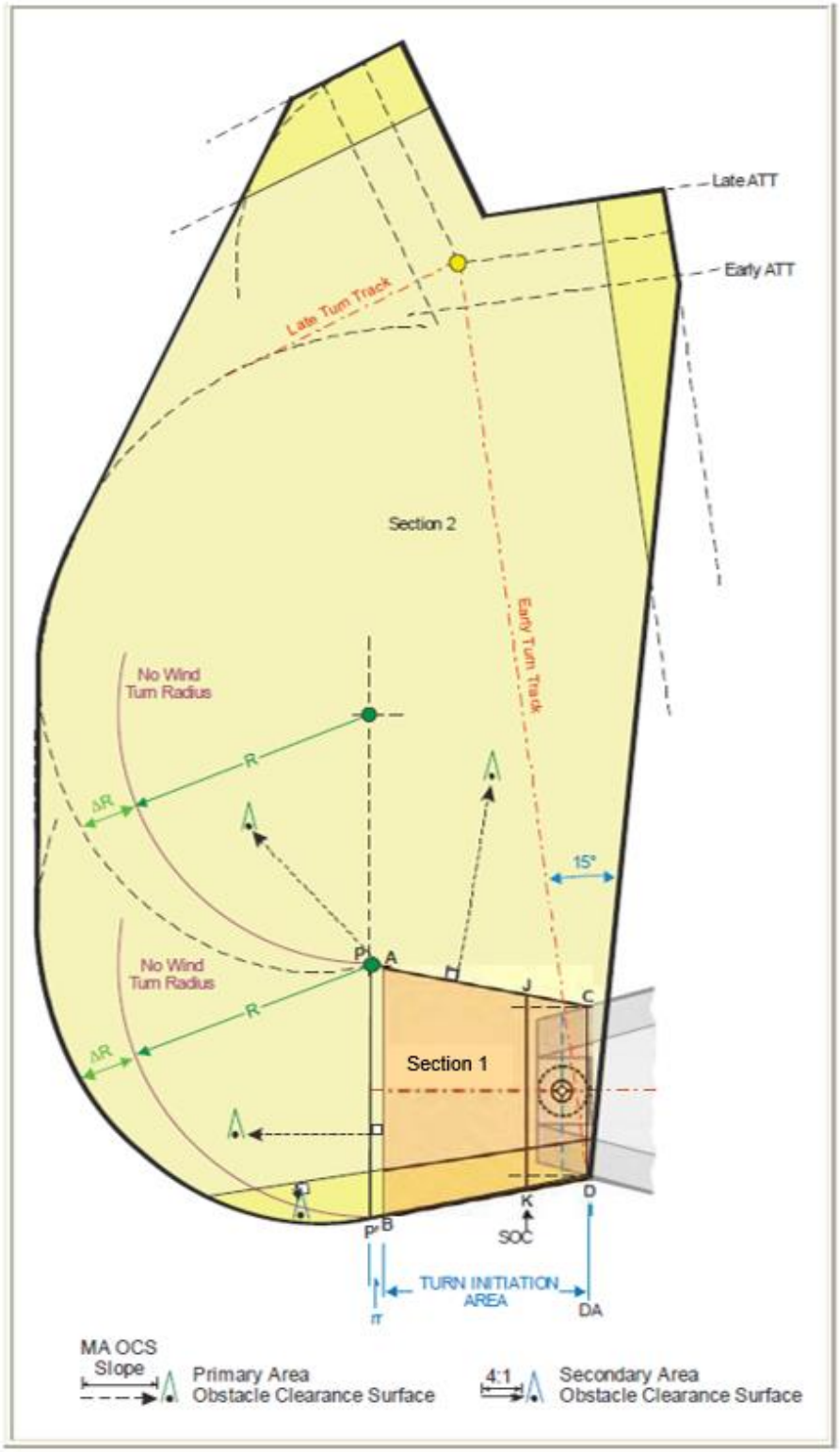
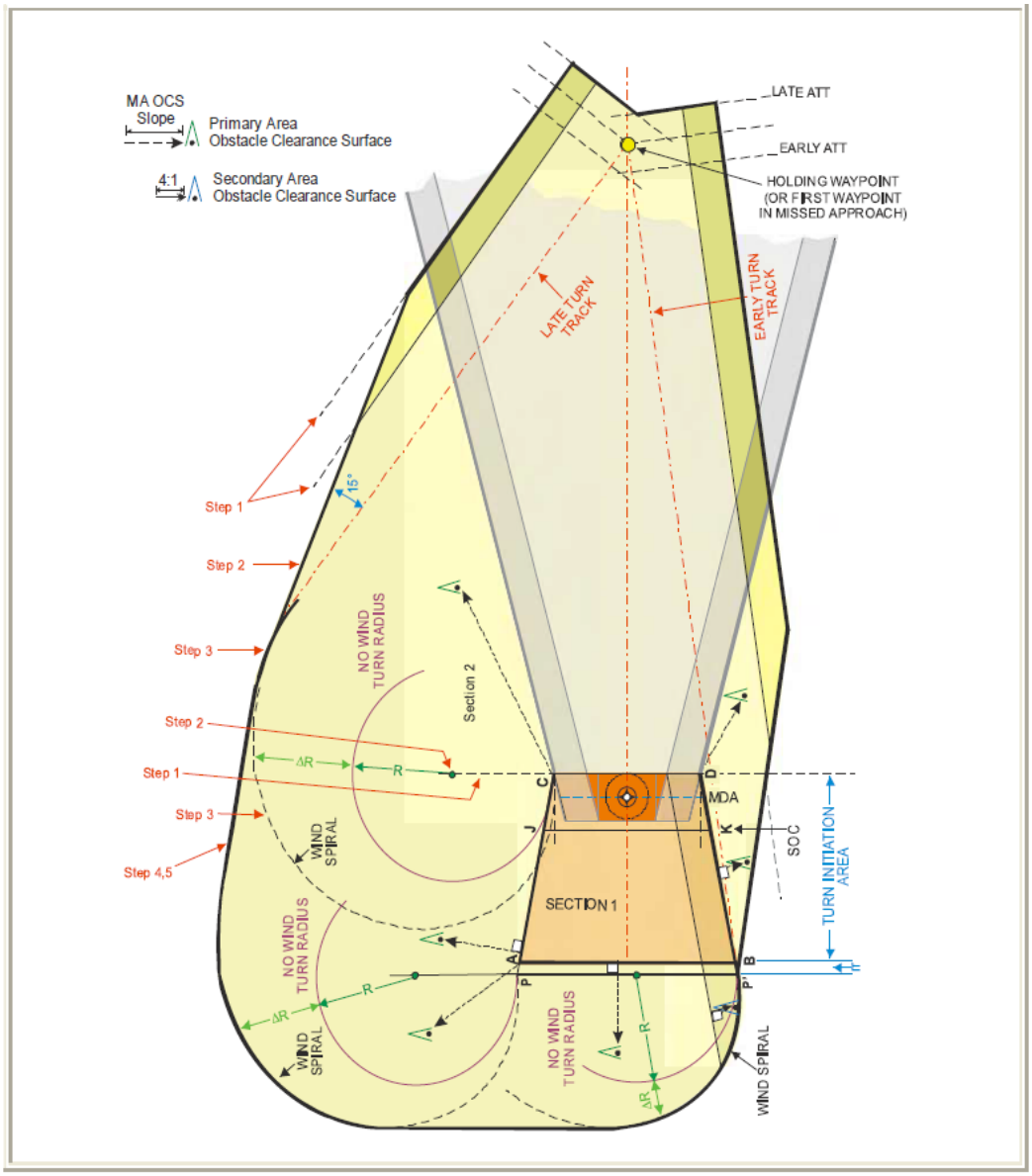


Figure 8-5-15: Direct to Fix Segment Following a TIA completion > 165 degrees 3 WS



(b) Late Turn Track and OEA Construction. Apply WSs for late-turn outer boundary construction using the following calculations, construction techniques, and bank angles of 11 degrees or 14 degrees, as appropriate.

Step 1: Find the no-wind turn radius (R) using section 5, formula 5-2b.

Formula 5-2b: No-Wind Turn Radius (R)

$$\mathbf{R} = \frac{(\mathbf{V_{KTAS}} + \mathbf{0})^2}{\tan(\mathbf{Bank_{angle}}) \cdot \mathbf{68625.4}}$$

Where:

V_{KTAS} = True Airspeed, formula 2-3a

$Bank_{ANGLE}$ = Table 2-4 value

Note: Apply the appropriate indicated airspeed and minimum assigned turn altitude when converting to true airspeed for this application.

Step 2: Calculate the Turn Rate (TR) using section 5, formula 5-2c. Maximum TR is 3 degrees per second.

Formula 5-2c: Turn Rate (TR)

$$\mathbf{TR} = \frac{\mathbf{3431} \cdot \tan(\mathbf{Bank_{angle}})}{\pi \cdot \mathbf{V_{KTAS}}}$$

Where:

$Bank_{ANGLE}$ = Table 2-4

V_{KTAS} = Formula 2-3a

Step 2a: Calculate the Turn Magnitude ($\mathrm{Turn_{Magnitude}}$) using the appropriate nowind turn radius and the arc distance (degrees) from turn start (at PP') to the point of tangency with a line direct to the fix.

Step 2b: Calculate the highest altitude in the turn using section 5, formula 5-2d (MAHF altitude may be used). Determine subsequent fix altitudes using fix-to-fix direct measurement and 400 ft/NM, (or higher assigned) climb rate.

Formula 5-2d: Highest Altitude Gained ($\mathbf{Total_{ALT}}$)

$$\mathrm{HighestTurn} = \mathrm{MDA_{ALT}} + \left(2R \cdot \pi \cdot \frac{\mathrm{Turn_{Magnitude}}}{360} \cdot CG\right)$$

Where:

MDA_{ALT} = Procedure MDA

R = No-wind turn radius (NM), Formula 5-2b

$Turn_{Magnitude}$ = Turn start to rollout (deg)

CG = Standard 400 ft/NM

$MDA_{ALT}+(2*R*\pi*Turn_{Magnitude}/360*CG)$

Step 3: Find the omni-directional wind component (V_{KTW}) for the highest altitude in the turn applying section 2, paragraph 8.2.11.

Step 4: Apply this common wind value (**Step 3**) to all first-turn wind spirals.

Note: Apply 30 knots for turn altitudes ≤ 2,000 ft above heliport/airport elevation.

Step 5: Calculate the wind spiral radius increase (△R) (relative R), for a given turn magnitude (ϕ) using section 5, formulas 5-2c and 5-2e.

Formula 5-2e: Wind Spiral (WS) Radius Increase (△R)

$$\Delta R = \frac{V_{KTW} \cdot \phi}{3600 \cdot TR}$$

Where:

V_{KTW} = Windspeed, formula 2-3b

ϕ = Degrees of turn

TR = Turn Rate, formula 5-2c

$(V_{KTW} * \phi)/(3600 * TR)$

8.5.3. b. **Turn-At-A-Fix.** The first MA turn-at-a-fix may be a fly-by or fly-over fix. Use fly-by unless a fly-over is required for obstacle avoidance or where mandated by specific operational requirements. The turn fix early-turn-point must be at or beyond section 1 end.

(1) Early/Late Turn Points.

(a) The fly-by fix early-turn-point is located at (FIX-ATT-DTA) prior to the fix.

(b) The fly-by fix late-turn-point is located at a distance (FIX + ATT – DTA + rr) from the fix.

Fly-by fixes (see section 5, figure 8-5-16).

$Early_{TP}$ = Fix - ATT - DTA

$Late_{TP}$ = Fix + ATT - DTA + rr

(c) The fly-over early-turn-point is located at a distance (FIX - ATT) prior to the fix.

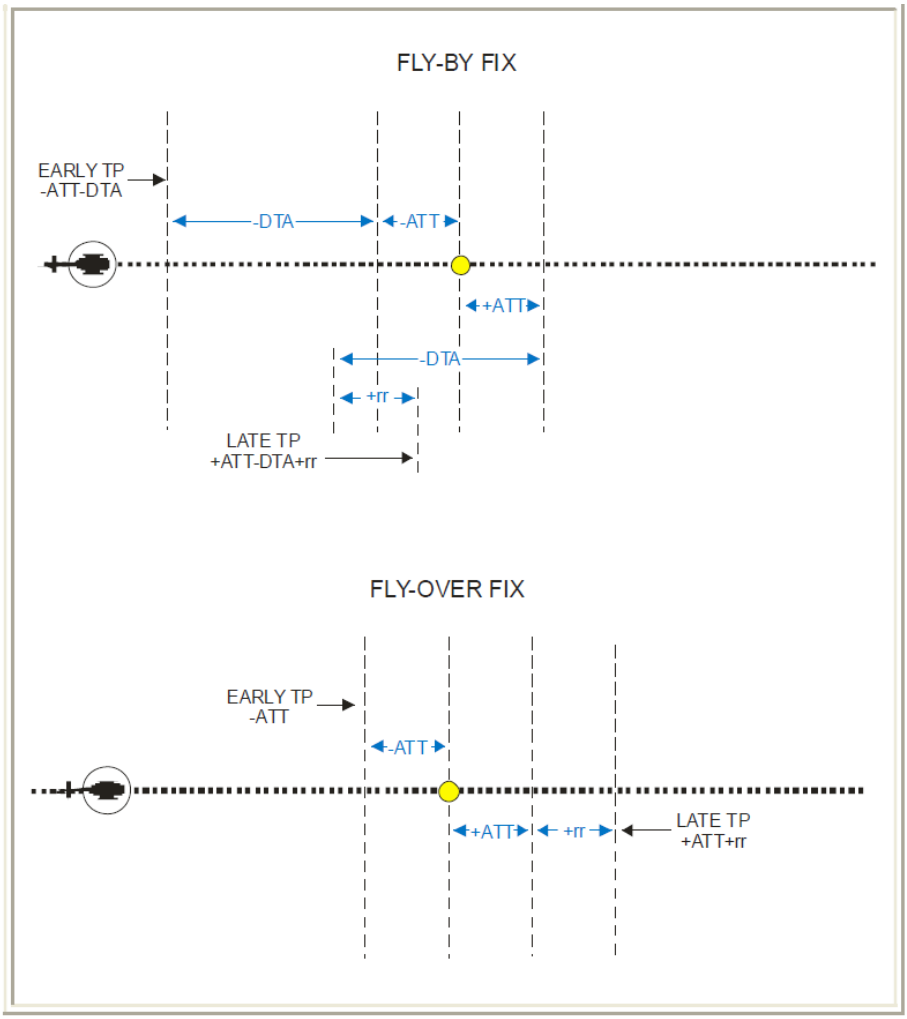
(d) The fly-over late-turn-point is located at a distance (FIX + ATT + rr) beyond the fix.

Fly-over fixes (see section 5, figure 8-5-16).

$Early_{TP}$ = Fix - ATT

$Late_{TP}$ = Fix + ATT + rr

Figure 8-5-16: Fly-Over/Fly-By Diagrams



(2) Turn-at-a-fix. (First MA turn) Construction. The recommended maximum turn is 70 degrees; the absolute maximum is 90 degrees. The first turn fix must be located on the final approach track extended.

Step 1: Calculate aircraft altitude at AB using section 5, formula 5-1c.

Step 2: Calculate fix distance based on minimum fix altitude. Where the first fix must be located at the point the helicopter reaches or exceeds a specific altitude, apply section 5, formula 5-2f (using the

assigned/applied CG), to calculate fix distance (D_{fix}) (NM) from SOC (AB/JK) (see section 5, figures 8-5-17 through 8-5-20).

Formula 5-2f. Fix Distance (D_{fix})

$$D_{fix} = \ln\left(\frac{Minalt_{fix} + r}{Copter_{SOC} + r}\right) \cdot \frac{r}{CG}$$

Where:

$Minalt_{fix}$ = Minimum altitude required at fix

$Copter_{SOC}$ = Copter AB (SOC) altitude

CG = Climb Gradient (Standard 400 ft/NM)

ln((Minaltfix+r)/(Copter$_{soc}$+r))*r/CG

Figure 8-5-17: Turn at a Waypoint (fly-by)

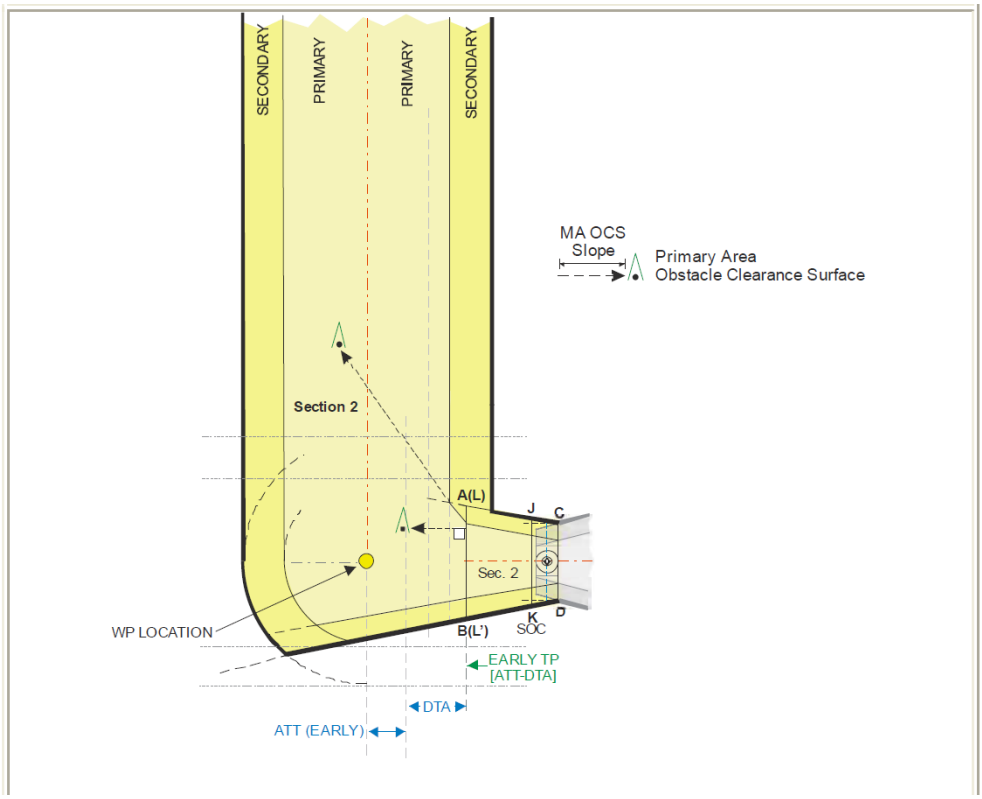


Figure 8-5-18a: Turn at a Waypoint (fly-by)

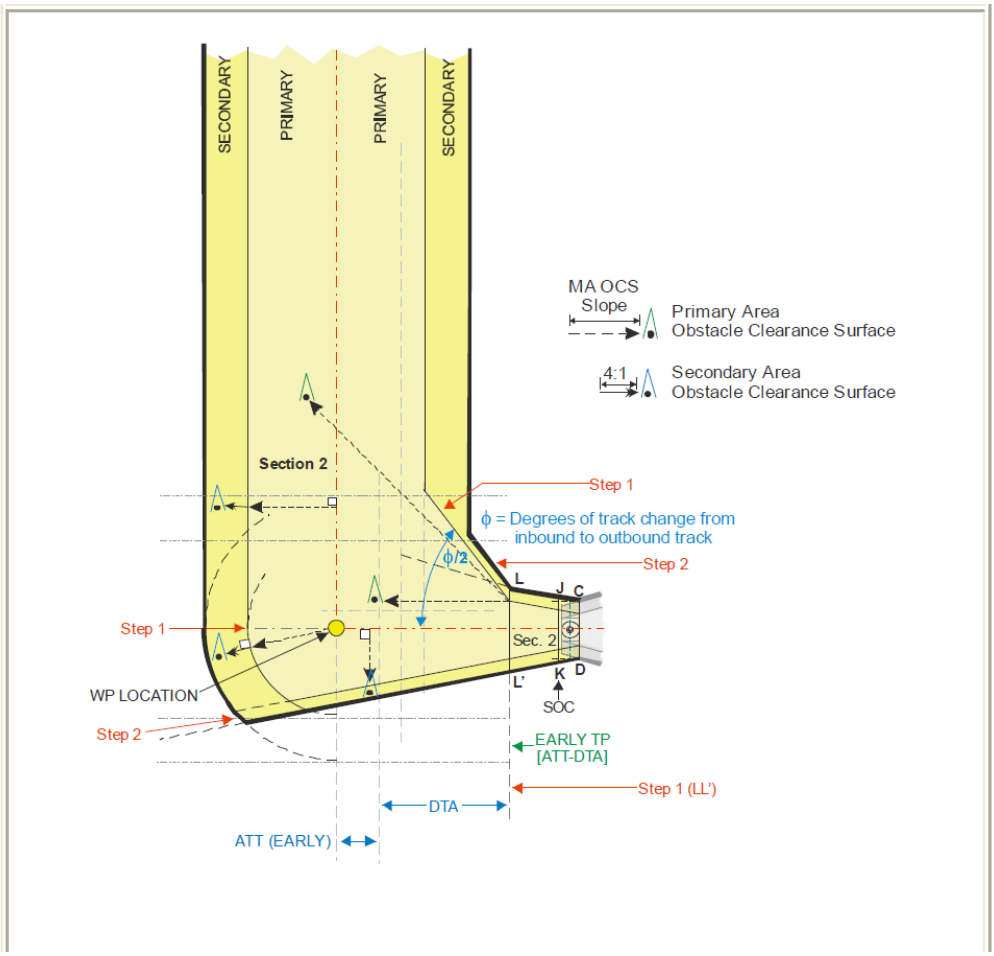


Figure 8-5-18b: Turn at a Waypoint (fly-by)

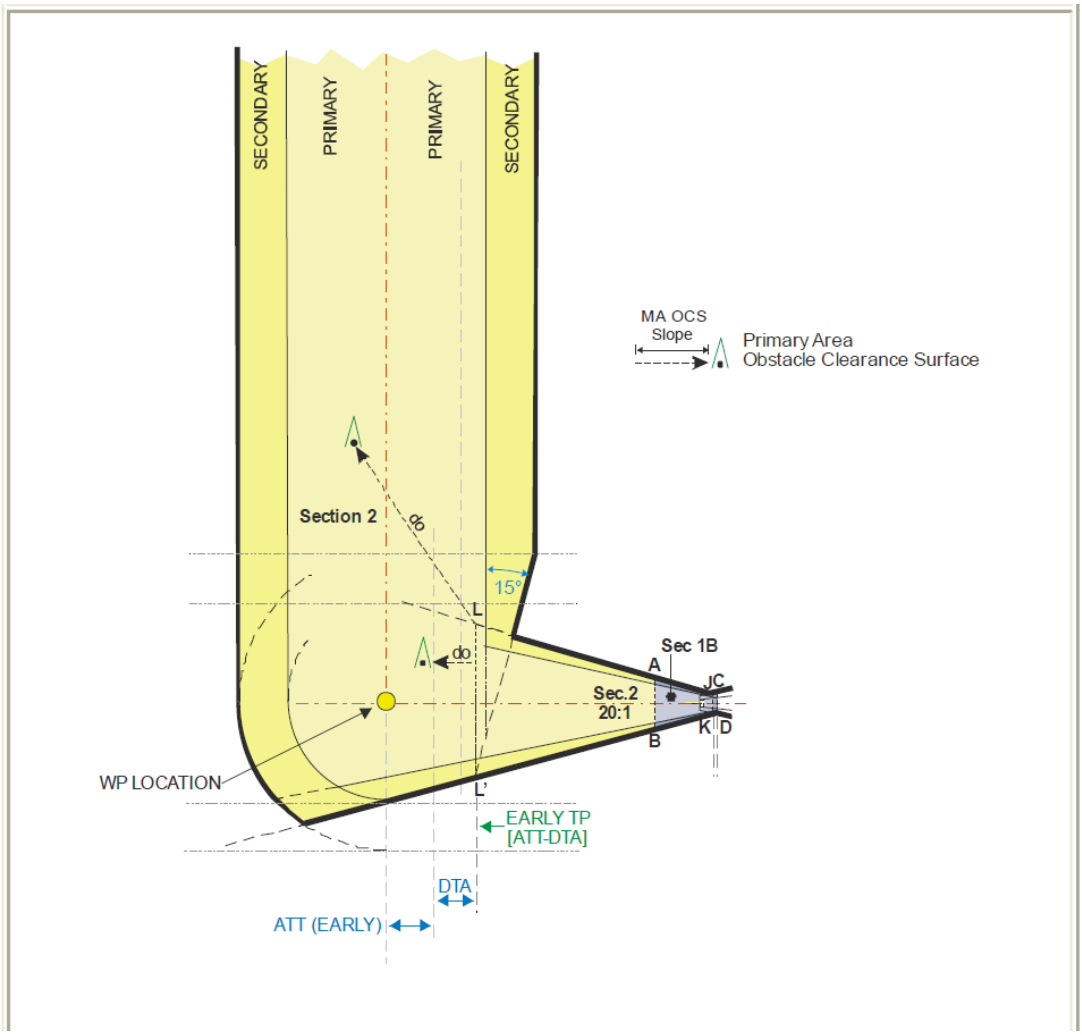


Figure 8-5-19: Turn at a Waypoint (fly-over) ≤ 75 Degrees

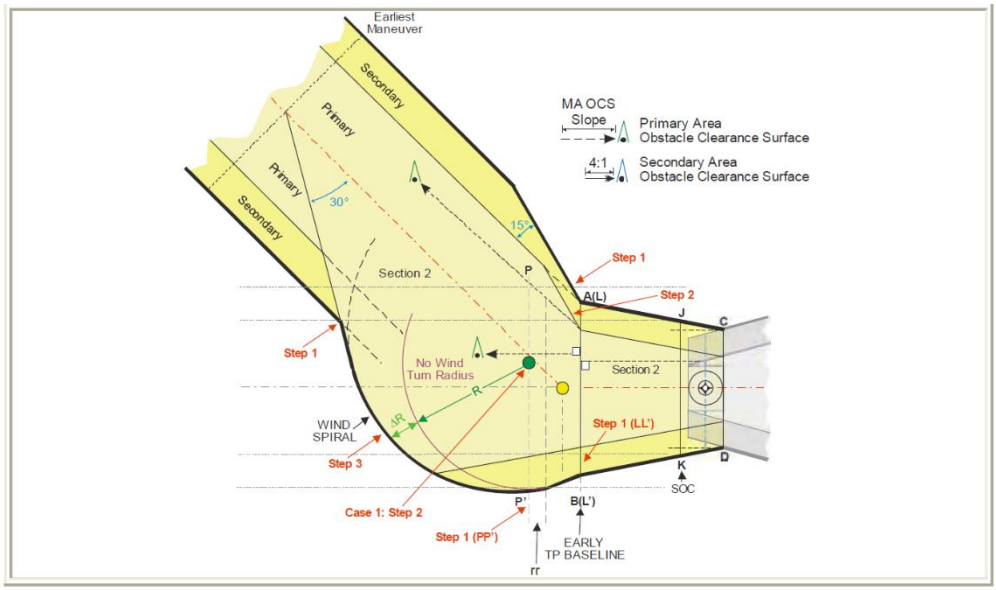
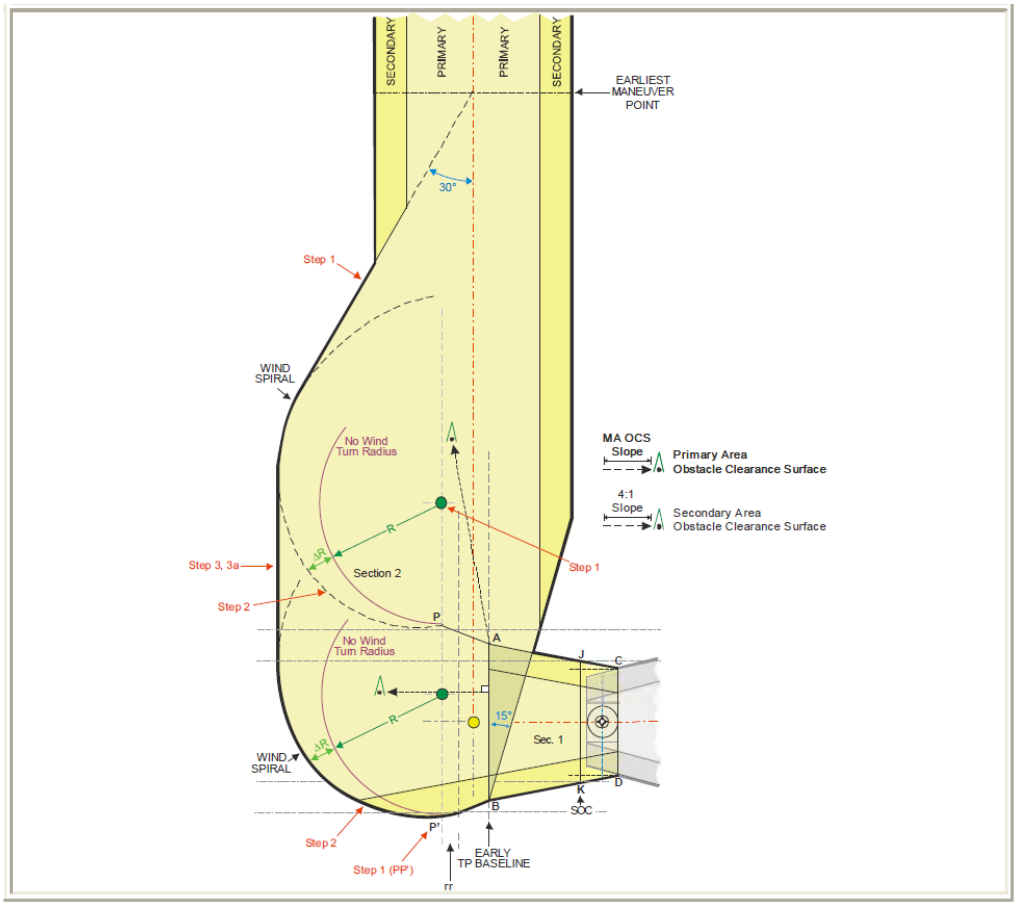


Figure 8-5-20: Turn at a Waypoint (fly-over) > 75 Degrees



Step 3: Calculate the altitude a helicopter climbing at the assigned CG would achieve over an established fix using section 5, formula 5-2g.

Formula 5-2g: Altitude Achieved at Fix ($\mathbf{Alt_{fix}}$)

$$\mathrm{Alt_{fix}} = (\mathrm{r} + \mathrm{Copter_{soc}}) \times \mathrm{e}^{\left(\frac{\mathrm{CG} \times \mathrm{D_{fix}}}{\mathrm{r}}\right)} - \mathrm{r}$$

Where:

$\mathrm{Copter_{soc}}$ = Copter JK (SOC) Altitude

CG = Climb Gradient (Standard 400 ft/NM)

$\mathrm{D_{fix}}$ = Distance (NM) from JK to fix

(3) Fly-By Turn Calculations and Construction. Consider direction-of-flight-distance positive, opposite-flight-direction distance negative.

(a) Fly-By Turn Calculations.

Step 1: Apply section 5, formula 5-2h for distance turn anticipation (DTA).

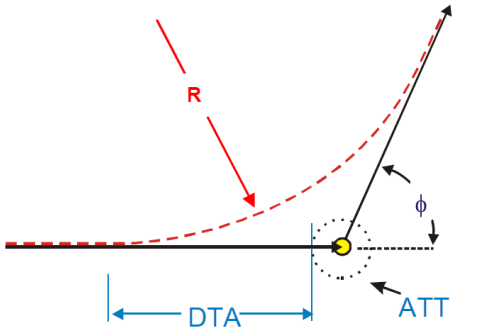
Formula 5-2h: Distance Turn Anticipation

$$\mathrm{DTA} = \mathrm{R} \cdot \tan\left(\frac{\phi}{2}\right)$$

Where:

ϕ = Turn/Heading Change (Degrees)

R = No-Wind Turn Radius, formula 5-2b



Calculate the fix to early-turn distance ($\mathrm{D_{early\ TP}}$) using section 5, formula 5-2i.

Formula 5-2i: Early Turn Distance ($\mathbf{Dearly_{TP}}$)

$$\mathrm{D_{earlyTP}} = \mathrm{ATT} + \mathrm{DTA}$$

Where:

ATT = along-track tolerance (NM)

DTA = Turn anticipation distance (NM), formula 5-2h

ATT+DTA

(b) Early Turn Point (ETP) and Area construction.

Table 8-5-1: Inside Turn Expansion Guide

Outbound Segment Boundary Relative ETP Connections	Expansion Line Required
Secondary & Primary **PRIOR** ETP	15-Degree Line
Secondary **Prior** ETP	15-Degree Line
Primary **Beyond** ETP	$\phi/2$
Secondary & Primary **Beyond** ETP	$\phi/2$

Note: ETP = LL' early turn point connection, 15-degree line relative the outbound segment, $\phi/2$ = half turn-angle

(c) Inside turn (Fly-By) Construction is predicated on the location of LL' and primary/secondary boundary intersections (early turn connections), relative the outbound segment, see section 5, table 8-5-1. (See section 5, figures 8-5-17 and 8-5-18).

Where no inside turn secondary area exists in section 1, apply secondary areas only after the turn expansion line/s intersect the outbound segment boundaries.

Apply the same technique to primary and secondary area connections when both inbound segment connection points fall either outside the outbound segment, or inside the outbound segment primary area. When both inbound connection points are within the outbound segment secondary area or its extension, table 8-5-1 provides a connection method for each point.

Note: Where half-turn-angle construction is indicated, apply a line splaying at the larger of, half-turn-angle, or 15 degrees, relative the outbound track. Where a small angle turn exists and standard construction is suitable for one, but not both splays; connect the uncommon splay, normally primary, to the outbound primary boundary at the same along-track distance as the secondary connection. Maintain or increase primary area as required.

Step 1: Construct a baseline (LL') perpendicular to the inbound track at distance $D_{earlyTP}$ (section 5, formula 5-2i) prior to the fix (see section 5, figures 8-5-17 and 8-5-18).

CASE 1: The outbound segment boundary, or its extension, is beyond the baseline (early-turn connection points are prior to the outbound segment boundary).

Step 1: Construct the inside turn expansion area with a line, drawn at one-half the turn angle from the inbound segment primary early turn connection point, to intercept the outbound segment primary boundary (see section 5, figure 8-5-18).

Step 2 (if required): Construct the inside turn expansion area with a line, drawn at one-half the turn angle, from the inbound segment secondary early turn connection point, to intercept the outbound segment secondary boundary (see section 5, figure 8-5-18).

CASE 2: The outbound segment secondary boundary or its extension is prior to the LL' baseline and outbound segment primary boundary or its extension is beyond the LL' baseline, (early-turn connection points are both **within** the outbound segment secondary area or its extension).

Step 1: Construct the inside-turn expansion area with a line splaying at 15-degree, (relative the outbound track) from the inbound segment secondary early turn connection point to intersect the outbound segment boundary.

Step 1Alt: Where the turn angle exceeds 75 degrees, begin the splay from L'.

Step 2: Construct the primary boundary with a line, drawn at one-half the turn angle, from the inbound segment primary early turn connection point to intercept the outbound segment primary boundary (see section 5, figure 8-5-17).

CASE 3: The outbound segment secondary and primary boundaries, or their extensions, are **prior** to the LL' baseline (primary early-turn connection point, or **both** connection points are **inside** the outbound segment primary area).

Step 1: Construct the inside turn expansion area with a line, splaying at 15-degree (relative the outbound track) from the more conservative point, (L') or (the intersection of LL' and the inbound segment inner primary boundary), to intersect the outbound segment boundaries.

Step 1Alt: Where the turn angle exceeds 75 degrees, begin the splay from L'. In this case, terminate the inside turn secondary area at the outbound segment primary boundary, since it falls before the early turn points, LL' (see section 5, figure 8-5-18a).

(d) Outside Turn (Fly-By) Construction.

Step 1: Construct the outer primary boundary using a radius of 1/2 primary width (1.5 NM), centered on the plotted fix position, drawn from the inbound segment extended primary boundary until tangent to the outbound segment primary boundary. See section 5, figure 8-5-17.

Step 2: Construct the secondary boundary using a radius of one-half segment width (2 NM), centered on the plotted fix position, drawn from the inbound segment extended outer boundary until tangent to the outbound

segment outer boundary (see section 5, figures 8-5-17, 8-5-18, and 8-5-18a). Where no inbound secondary exists, use an arc of radius one-half segment width from tangent to the outbound segment secondary boundary to terminate at the inbound segment boundary.

(4) Fly-Over Turn Construction.

(a) Inside Turn (Fly-Over) Construction.

Step 1: Construct the early-turn baseline (LL') at distance ATT prior to the fix, perpendicular to the inbound nominal track.

Step 2: Refer to section 5, paragraph 8.5.3.b(3)(c), (skip **Step 1**).

(b) Outside Turn (Fly-Over) Construction.

Step 1: Construct the late-turn baseline (PP') at distance (ATT + rr) beyond the fix, perpendicular to the inbound nominal track. Calculate late turn distance using section 5, formula 5-2j (see section 5, figure 8-5-19).

Formula 5-2j: Late Turn Point Distance (D_{lateTP})

$$D_{lateTP} = ATT + \left(rr \bullet \frac{0.3048}{1852}\right)$$

Where:

ATT = along-track tolerance (NM)

rr = delay/roll-in formula 2-4a

ATT+(rr*0.3048/1852)

Step 2: Apply wind spiral outer boundary construction for the first MA fly-over turn. See section 5, paragraph 8.5.3.a(2)(b) for necessary data, using the higher of section 5, formula 5-2g output, or the assigned fix crossing altitude for TAS and turn radius calculations and section 5, paragraph 8.5.5 for wind spiral construction. A non-turn side secondary area may extend into the WS1 area.

(c) Obstacle Evaluations. See section 5, paragraph 8.5.3.b(4)

(5) Section 2 Obstacle Evaluations.

(a) Turn at an Altitude Section 2. Apply the standard MA OCS slope, (or the assigned CG slope) to section 2 obstacles based on the shortest primary area distance (do) from the TIA boundary to the obstacle. Shortest primary area distance is the length of the shortest line kept within primary segments that passes through the early turn baseline of all preceding segments.

Step 1: Measure and apply the OCS along the shortest primary area distance (do) from the TIA boundary to the obstacle (single and multiple

segments). See various obstacle measurement examples in section 5, figures 8-5-19 through 8-5-22.

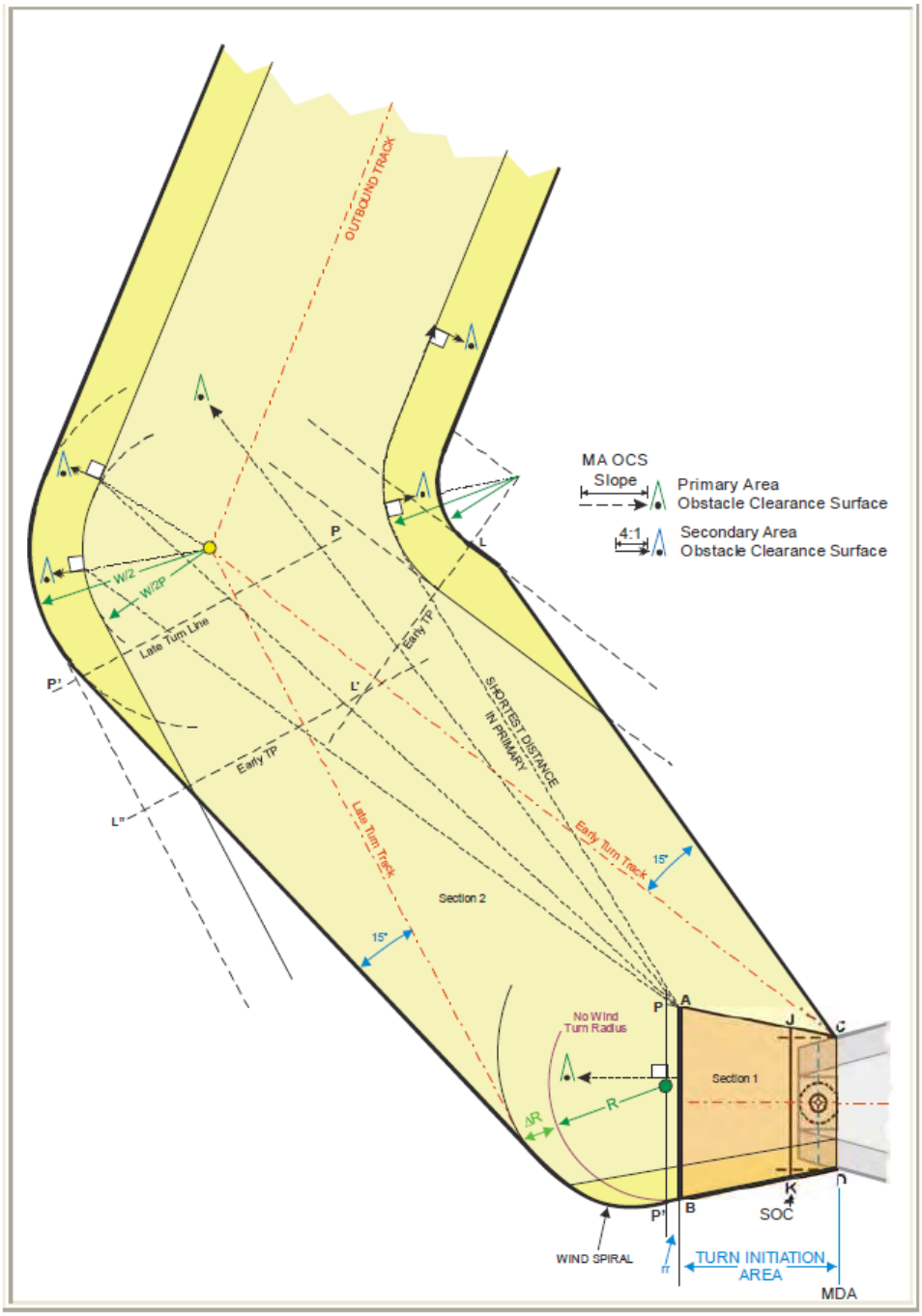
Step 2: For obstacles located in secondary areas, measure and apply the OCS along the shortest primary area distance (do) from the TIA boundary to the primary boundary abeam the obstacle, then the 4:1 slope along the shortest distance to the obstacle, (taken perpendicular to the nominal track or in expansion areas, to the primary arc, the primary corner-cutter, corner apex, or other appropriate primary boundary). Where an obstacle requires multiple measurements (an obstacle is equidistant from multiple primary boundary points, or lies along perpendiculars from multiple primary boundary points, etc.), apply the more adverse result from each of the combined primary/secondary measurements. See section 5, figures 5-19 through 5-22.

(b) Turn at Fix Section 2. Apply an inclined OCS (MA OCS) slope, beginning at SOC at the inbound-segment end OCS height.

Step 1: Measure and apply the OCS along the shortest distance (do) from AB (parallel to track) to LL', the shortest primary distance to the obstacle (single and multiple segments). See section 5, figures 8-5-19 and 8-5-20, for various obstacle measurement examples.

Step 2: For obstacles located in secondary areas, measure and apply the OCS along the shortest primary area distance (do) from the TIA boundary to the primary boundary abeam the obstacle, then the 4:1 slope along the shortest distance to the obstacle, (taken perpendicular to the nominal track or in expansion areas, to the primary arc, the primary corner-cutter, corner apex, or other appropriate primary boundary). Where an obstacle requires multiple measurements (where an obstacle is equidistant from multiple primary boundary points, or lies along perpendiculars from multiple primary boundary points, etc.), apply the more adverse result from each of the combined primary/secondary measurements (see section 5, figure 8-5-21).

Figure 8-5-21: Second Turn Fly-By Construction



8.5.4. Turning Missed Approach (Second Turn)

a. **DF/TF Turn (Second Turn, following turn-at-altitude).** Turns at the DF path terminator fix will be fly-by or fly-over to a TF leg. In either case, the outer boundary provides fly-over protection, and the inner boundary provides fly-by protection. Maximum turn angle is 90 degrees (applicable to both

tracks within the DF segment). This application provides that construction under Chapter 8 ection 2, or this section will apply, including cases where the inside and outside turn construction differs.

(1) DF/TF (Fly-By) Turn.

(a) Inside DF/TF (Fly-By) construction.

CASE 1: Full width inside secondary exists at the early turn point (LL').

Step 1: Construct a baseline (LL') perpendicular to the inbound track nearer the turn side boundary at distance $D_{earlyTP}$ (section 5, formula 5-2i) prior to the fix.

Step 2: Apply Section 2 criteria.

CASE 2: Less than full width inside secondary exists at (LL').

Step 1: Apply Section 5, paragraph 8.5.3.b(3)(c) criteria.

(b) Outside DF/TF (Fly-By) construction.

CASE 1: Full width outside secondary exists at the early turn point (L'L'').

Step 1: Construct a baseline (L'L'') perpendicular to the inbound track nearer the non-turn side boundary at distance $D_{earlyTP}$ (section 5, formula 5-2h) prior to the fix.

Step 2: Apply Section 2 criteria. See Section 5, figures 8-5-21 through 8-5-22.

CASE 2: Less than full width outside secondary exists at (L'L'').

Step 1: Apply Section 5, paragraph 8.5.3.b(3)(d) criteria.

(2) DF/TF (Fly-Over) Turn.

(a) Inside DF/TF (Fly-Over) Turn Construction.

Step 1: Construct a baseline (LL') perpendicular to the inbound track nearer the turn side boundary at distance ATT prior to the fix (see Section 5, figure 8-5-22).

Note: Where half-turn-angle construction is specified, apply a line splaying at the larger of half-turn-angle or 15 degrees relative the outbound track.

CASE 1: No inside secondary area exists at LL'.

Step 1: Create the OEA early-turn protection by constructing a line, splaying at the larger of one-half (1/2) the turn angle, or 15 degrees relative the outbound track, from the intersection of LL' and the inbound segment inner primary boundary to connect with the outbound TF segment boundaries. The TF secondary area begins at the intersection of this diagonal line and the outbound segment boundary.

CASE 2: Partial width inside secondary area exists at LL'.

Step 1: Create the OEA early-turn primary area protection by constructing a line, splaying at the larger of one-half (1/2) the turn angle, or 15 degrees relative the outbound track, from the intersection of LL' and the inbound segment inner primary boundary to connect with the TF segment primary boundary.

Step 2: Create the OEA early-turn secondary protection by constructing a line, splaying at the larger of one-half (1/2) the turn angle, or 15 degrees relative the outbound track, from the intersection of LL' and the inbound segment inner boundary to connect with the TF segment boundary.

CASE 3: Full width inside secondary area exists at LL'.

Step 1: Apply Section 2 criteria. See Section 5, figure 8-5-21.

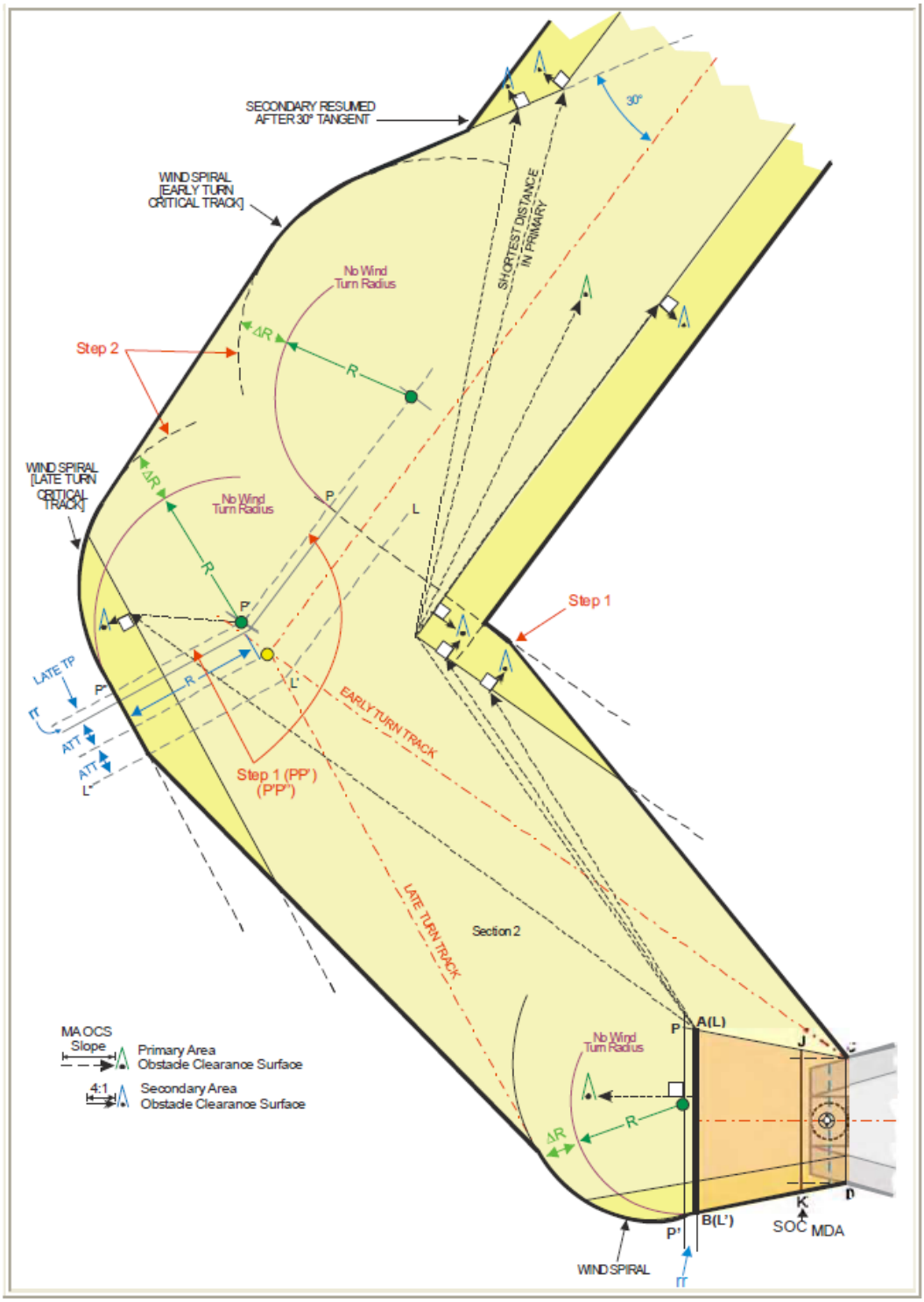
(b) Outside DF/TF (Fly-Over) Turn Construction.

Step 1: Construct the late-turn baseline for each inbound track, (PP') for the track nearer the inside turn boundary, and (P'P'') for the outer track at distance (ATT + rr) beyond the fix, perpendicular to the appropriate inbound track. See Section 5, figure 8-5-22.

Note: A DF/TF Fly-Over turn is limited to 90 degrees (both inbound tracks) and should require no more than one WS per baseline. Construct the outside track WS (WS1) on base line **P'P''**, then construct WS2 on baseline **PP'**.

Step 2: Apply wind spiral construction, see Section 5, paragraph 8.5.3.a(2)(b) for necessary data, and Section 5, paragraph 8.5.5 for wind spiral construction See Section 5, figure 8-5-22.

Figure 8-5-22: Second Turn Fly-Over Construction



b. TF/TF Turn (Second Turn, following turn-at-fix). Turns at the TF path terminator fix will be fly-by or fly-over to a TF leg. In either case, the outer boundary provides fly-over protection, and the inner boundary provides fly-

by protection. Maximum turn angle is 90 degrees. This application provides that construction under Section 2, or this Section will apply, including cases where the inside and outside turn construction differs.

(1) TF/TF (Fly-By) Turn.

(a) Inside TF/TF (Fly-By) construction.

Step 1: Apply Section 2 criteria.

(b) Outside TF/TF (Fly-By) construction.

Step 1: Apply Section 2 criteria.

(2) TF/TF (Fly-Over) Turn.

(a) Inside TF/TF (Fly-Over) Turn Construction.

Step 1: Apply Section 2 criteria.

(b) Outside TF/TF (Fly-Over) Turn Construction.

Step 1: Apply Section 2 criteria.

8.5.5. **Wind Spiral Cases.** Wind Spiral (WS) construction applies to turn-at-an-altitude, turn-at-a fix (Fly-Over) for the first MA turn, and DF/TF (Fly-Over) for the second turn. The late-turn line P' designator is typically placed where the baselines cross. Where baseline extension is required, mark each baseline inner end with P'.

Each WS has several connection options along its boundary. The chosen connection(s) must provide the more conservative reasonable track and protection areas (see section 5, figures 8-5-23 through 8-5-25 for examples).

- A 15-degree, (or greater*) splay line to join outbound segment outer boundaries, from:
  - WS/direct-to-fix tangent point.
  - WS to WS tangent line origin.
  - WS to WS tangent line end.
  - WS/outbound segment parallel point (DF segment NA).

- A tangent line to join the next WS (see section 5, figure 8-5-25).
- A tangent line direct to the next fix (DF segment) (see section 5, figure 8-5-24).
- A tangent line, converging at 30 degrees to the segment track (TF segment) (see section 5, figure 8-5-20).

***Note:** See section 5, paragraphs 8.5.5.b(1) and 8.5.5.b(2) for alternate connection details.

Note: Where multiple WSs exist, a line from the earlier WS splaying at 15 degrees relative the tangent line between WSs may produce the more conservative construction.

Outbound segment type and turn magnitude are primary factors in WS application. Refer to section 5, table 8-5-2 for basic application differences. Calculate rr using section 2, formula 2-4a.

Table 8-5-2: MA First Turn Wind Spiral Application Comparison

	Turn At Fix (FO)	Turn At Altitude
WS1 Baseline (PP')	Fix + ATT + rr	TIA + rr
WS2 Baseline (PP')	Fix + ATT + rr	TIA + rr
WS3 Baseline (CD Ext)	NA	TIA + rr
WS Number	1 or 2	1, 2, or 3 *
Final WS Connection (Tangent line)	30° to outbound track	Direct to Fix

***Note:** Where a required turn exceeds that served by three wind spirals, consider adding fixes to avoid prohibitively large protection areas resulting from further wind spiral application.

a. **Turn-at-Fix (FO) and Turn-at-Altitude WS Comparison.** Three cases for outer-boundary wind spirals commonly exist:

- (Case 1), Small angle turns use one wind spiral (WS1);
- (Case 2), Turns near/exceeding 90° ~ use a second wind spiral (WS2); and
- (Case 3), turns near/exceeding 180° ~ use a third wind spiral (WS3).

(1) Turn-at-Altitude WS application concludes with a line tangent to the final WS direct to the next fix.

(2) Turn-at-Fix (FO) WS application concludes with a line tangent to the final WS converging at a 30-degree angle to the outbound segment nominal track. The intersection of this line with the nominal track establishes the earliest maneuvering point for the next fix. The minimum segment length is the greater of:

- The minimum length calculated using the section 2 formulas or,
- The distance from previous fix to the intersection of the 30-degree converging outer boundary line extension and the nominal track, (plus DTA). See section 5, paragraph 8.5.4.a.

(3) Second MA Turn DF/TF Turn-at-Fix (FO) WS application concludes with a line tangent to the final WS converging at a 30-degree angle to the outbound segment nominal track. This construction requires two WS

baselines, one for each inbound track. Each late turn baseline is located (ATT + rr) beyond the fix, oriented perpendicular to the specific track. The baseline for the inbound track nearer the inside turn boundary is designated PP', the baseline associated with the outside turn track is designated P'P''. For convenience P' is often placed at the intersection of the two baselines, but a copy properly goes with each baseline inner end if baseline extensions are required (see section 5, figure 8-5-22).

Figure 8-5-23: WS Connection (Inside Outbound Segment Primary Boundary)

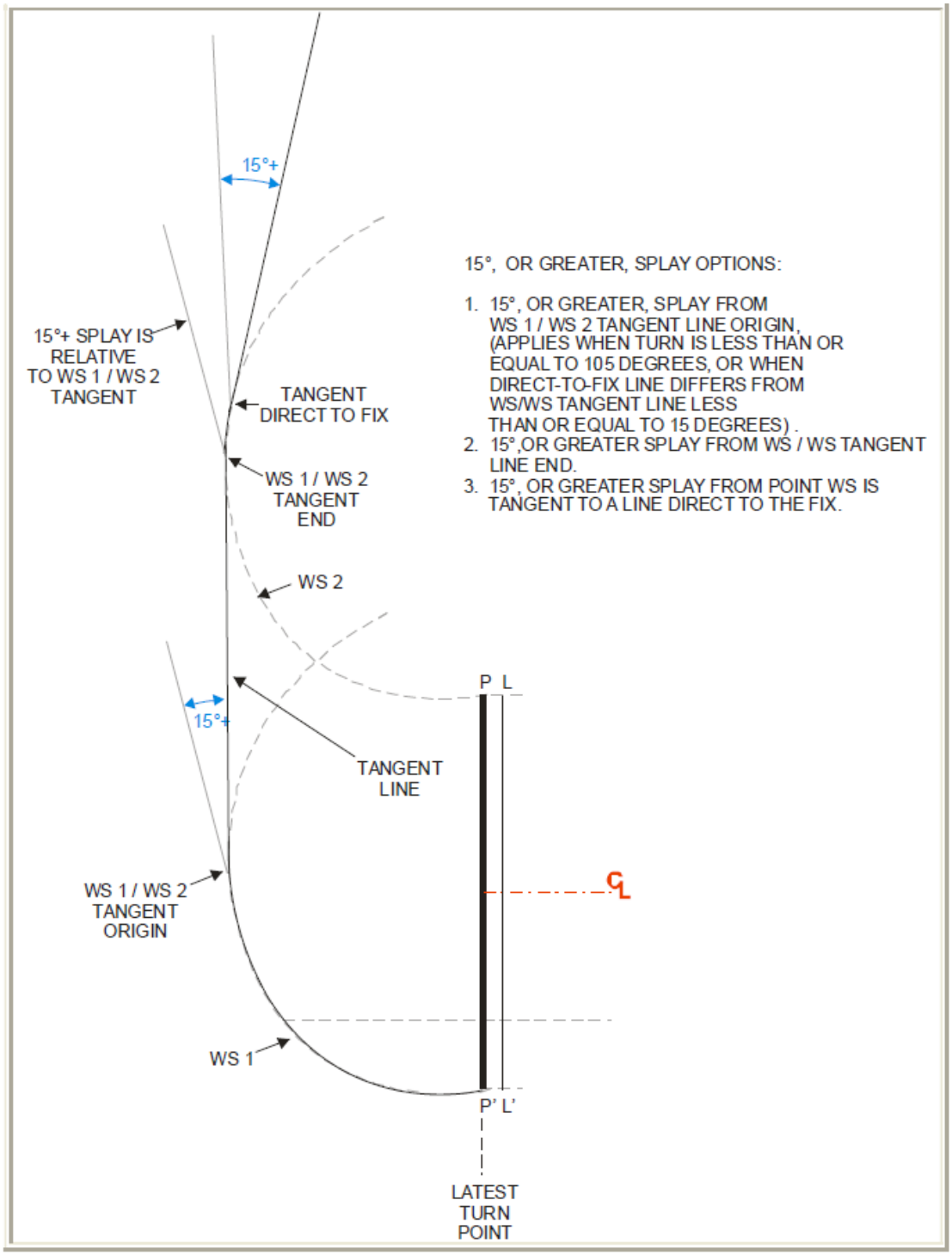


Figure 8-5-24: WS Connection (Inside Outbound Segment Primary Boundary)

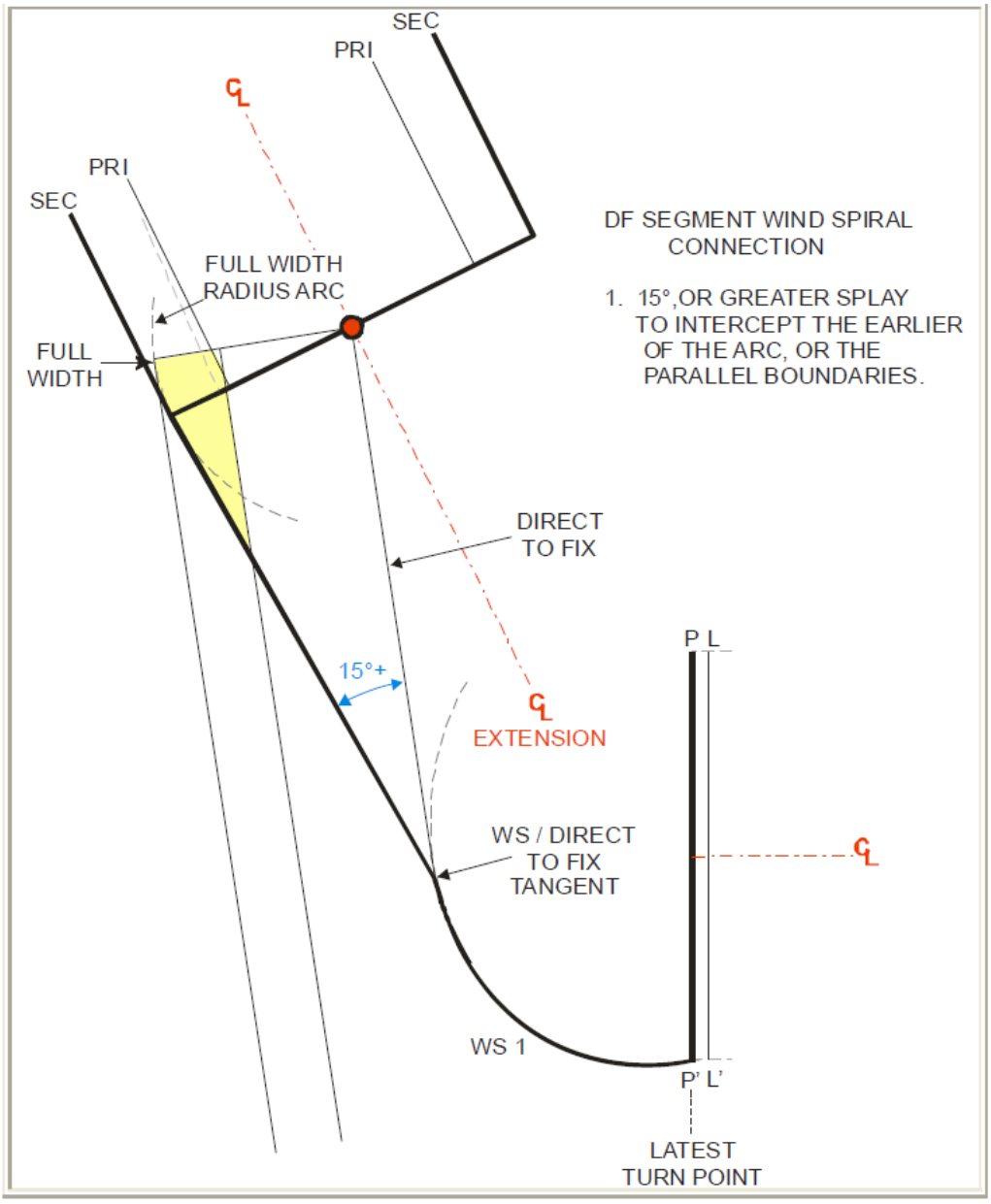
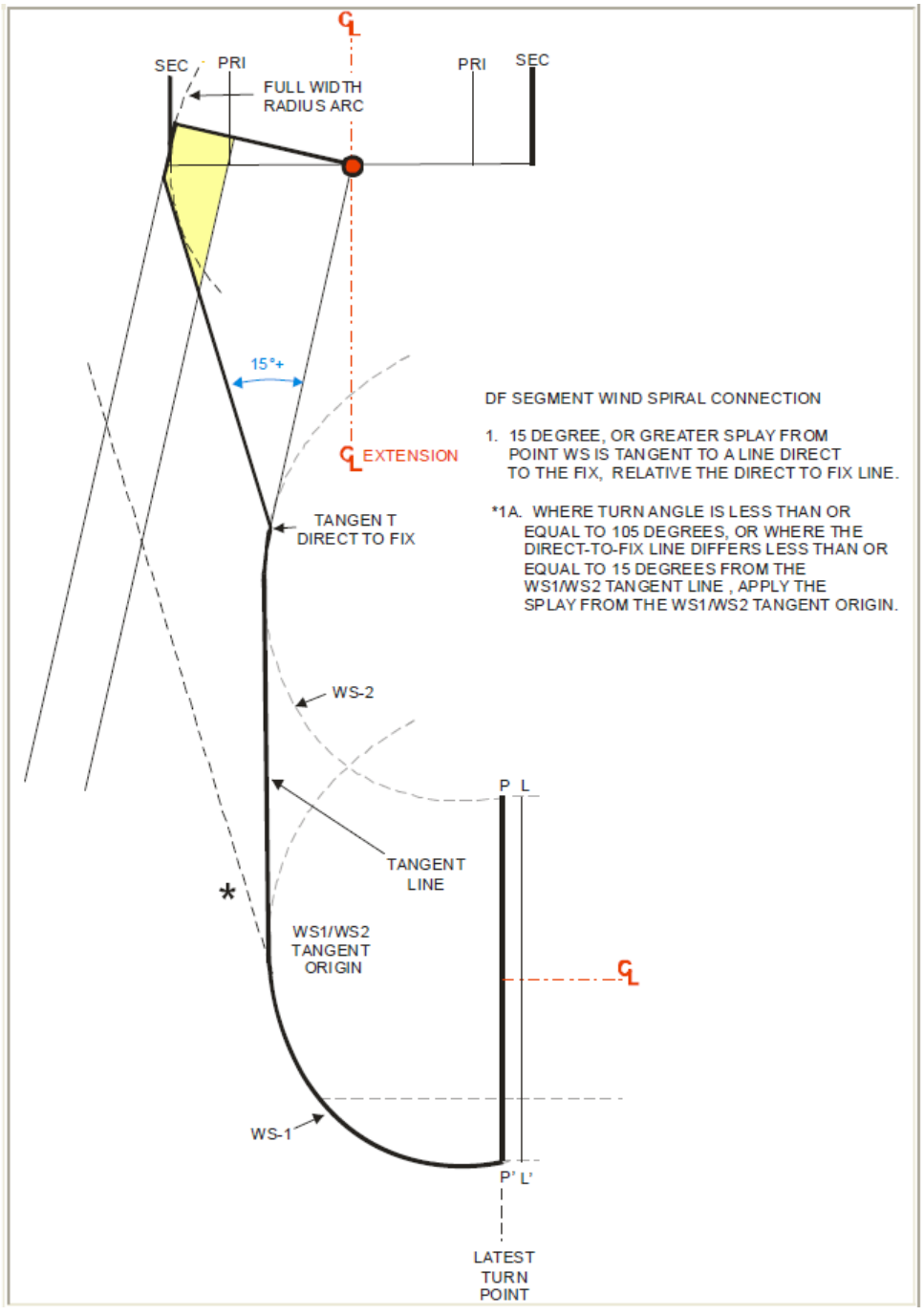


Figure 8-5-25: WS Connection Inside Outbound Segment Secondary Boundary)



b. **First MA Turn WS Construction.** Find late turn point distance ($D_{late\ TP}$) using section 5, formula 5-2j.

(1) CASE 1: Small angle turn using 1 WS.

Step 1: Construct the WS1 baseline, (PP') perpendicular to the straight MA track at the late-turn-point (see section 5, table 8-5-2 for line PP' location). See section 5, figures 8-5-5 and 8-5-8.

Step 2: Locate the wind spiral center on PP' at distance R (no-wind turn radius, using section 5, formula 5-2b; see section 5, figure 8-5-8) from the intersection of PP' and the inbound-segment outer-boundary extension (see section 5, figures 8-5-8 and 8-5-9).

Step 3: Construct WS1 from this outer boundary point in the direction of turn until tangent to the WS/Segment connecting line from section 5, table 8-5-2 (see section 5, figure 8-5-9).

CASE 1-1: Turn-at-Altitude (WS1 ends when tangent to a line direct to fix).

Step 1: Construct the OEA outer primary and secondary boundary lines parallel to this track (0.5-1.5-1.5-.0.5 segment width). See section 5, figure 8-5-9.

Step 2: Construct a line from the WS1 tangent point, splaying at 15 degrees from the WS1-to-fix track until it intersects the parallel boundary lines or reaches the segment end (see section 5, figure 8-5-9).

Note: Consider 'full-width protection at the fix' to exist where the splay line is tangent to a full-width- radius- circle about the fix.

Step 2Alt: Where **Step 2** construction provides less than full-width protection at the DF fix, construct the OEA outer boundary with a line splaying from the WS1/direct-to-fix tangent point at 15 degrees relative the direct-to-fix line, (or greater where required to provide full-width protection at the DF fix), until it intersects the parallel boundary lines (not later than tangent/tangent-extension to the full width-arc about the fix), and provides full-width protection at or before the DF fix. DF secondary areas begin/exist only where full width primary exists (see section 5, figure 8-5-9).

Note: Where excessive splay (dependent upon various conditions generally in the 35-40 degree range), consider lengthening the segment, restricting the speed, category, etc. to avoid protection and/or construction difficulties.

CASE 1-2: Turn-at-Fix (FO) (WS1 ends when tangent to a 30-degree line converging to nominal track).

Step 1: Construct the OEA outer boundary line using WS1 and the tangent 30-degree converging line until it crosses the outbound segment boundaries (see section 5, figure 8-5-19).

Step 1a: Where WS1 lies within the outbound segment primary boundary, construct the OEA boundary using WS1 and a line (from the point WS1 is parallel to the outbound segment nominal track), splaying

at 15 degrees relative the outbound segment nominal track until it intersects the outbound segment boundary lines.

Step 1b: Where WS1 lies within the outbound segment secondary boundary, construct the OEA boundary using WS1 and a line (from the point WS1 is parallel to the outbound segment nominal track), splaying at 15 degrees relative the outbound segment nominal track until it intersects the outbound segment boundary line. Continue WS1 and the tangent 30-degree converging line to establish the inner primary/secondary boundary (see section 5, similar figure 8-5-24).

(2) CASE 2: Larger turn using more than 1 WS. For turns nearing or greater than 90 degrees, WS2 may be necessary. See section 5, figure 8-5-20.

Step 1: To determine WS2 necessity, locate its center on baseline PP', at distance R from the inbound-segment inner-boundary extension.

Step 2: Construct WS2 from this inner boundary point in the direction of turn until tangent to the WS/WS, or WS/Segment connecting line from section 5, table 8-5-2. See section 5, figure 8-5-20.

Step 3: Where WS2 intersects, or is outside WS1 construction, (including the connecting and expansion lines where appropriate), include WS2 in the OEA construction. Otherwise revert to the single WS construction.

Step 3a: Connect WS1 and WS2 with a line tangent to both (see section 5, figure 8-5-20).

Note: The WS1/ WS2 tangent line should parallel a line between the WS center points.

CASE 2-1: Turn-at-Altitude (WS2 ends when tangent to a line direct to fix).

Step 1: Construct the OEA outer primary and secondary boundary lines parallel to this track (0.5-1.5-1.5.0.5 segment width).

Step 2: Construct a line from the WS2 tangent point, splaying at 15 degrees from the WS2-to-fix track until it intersects the parallel boundary lines or reaches the segment end (see section 5, figure 8-5-9).

Note: Consider 'full-width protection at the fix' exists where the splay line is tangent to a full-width- radius- circle about the fix.

Step 2Alt: Where **Step 2** construction provides less than full-width protection at the DF fix, construct the OEA outer boundary with a line splaying from the WS2/direct-to-fix tangent point at 15 degrees relative the direct-to-fix line, (or greater where required to provide full-width protection at the DF fix), until it intersects the parallel boundary lines (not later than tangent/tangent-extension to the full-width-arc about the fix), and provides full-width protection at or before the DF fix. Where the turn angle is ≤ 105 degrees, or the divergence angle between the WS/WS

tangent line and the direct-to-fix line is ≤ 15 degrees, apply the splay line form the WS1/WS2 tangent line origin. DF secondary areas begin/exist only where full width primary exists (see section 5, figure 8-5-9).

Note: Where excessive splay exists (dependent upon various conditions but generally greater than 30 degrees), consider using an earlier splay origin point, lengthening the segment, restricting the speed, category, etc. to avoid protection or construction difficulties (see section 5, paragraph 8.5 for origin points).

CASE 2-2: Turn-at-Fix (FO): (WS2 ends when tangent to a 30-degree line converging to nominal track).

Step 1: Construct the OEA outer boundary line using WS2 and the 30-degree converging line until it crosses the outbound segment boundaries (see section 5, figure 8-5-20).

Step 1a: Where WS2 lies within the outbound segment primary boundary, construct the OEA boundary using WS1, WS2, and a line (from the point WS1 or WS2 is parallel to the outbound segment nominal track, the more conservative), splaying at 15 degrees relative the outbound segment nominal track until it intersects the outbound segment boundary lines.

Step 1b: Where WS2 lies within the outbound segment secondary boundary, construct the OEA boundary using WS1, WS2, and a line (from the point WS2 is parallel to the outbound segment nominal track), splaying at 15 degrees relative the outbound segment nominal track until it intersects the outbound segment boundary line. Continue WS2 and the tangent 30-degree converging line to establish the inner primary/secondary boundary.

(3) CASE 3: Larger turn using more than 2 WSs. (Not applicable to Turn-at-Fix due to 90 degree turn limit). For turns nearing or greater than 180 degrees (such as a missed approach to a holding fix at the IF).

Step 1: Construct the WS3 baseline perpendicular to the straight MA track along CD-extended toward the turn side. See section 5, figure 8-5-15.

Step 2: To determine WS3 necessity, locate its center on the WS3 baseline at distance R from point C. See section 5, figure 8-5-15.

Step 3: Construct WS3 from point C in the direction of turn until tangent to the WS/WS, or WS/Segment connecting line from section 5, table 8-5-2. See section 5, figure 8-5-15.

Step 4: Where WS3 intersects, or is outside WS2 construction, include WS3 in the OEA construction. Otherwise revert to the dual WS construction. See section 5, figure 8-5-15.

Step 5: Connect WS2 and WS3 with a line tangent to both. See section 5, figure 8-5-15.

Note: The WS2 & WS3 tangent line should parallel a line between the WS center points.

CASE 3-1: Turn-at-Altitude: (WS3 ends when tangent to a line direct to fix)

Step 1: Construct the OEA outer primary and secondary boundary lines parallel to this track (0.5-1.5-1.5-0.5 segment width). See section 5, figure 8-5-15.

Step 2: Construct a line from the WS3 tangent point, splaying at 15 degrees from the WS3-to-fix track until it intersects the parallel boundary lines or reaches the segment end. See section 5, figure 8-5-15.

(4) Outside Turn Secondary Area. Outbound segment secondary areas following wind spirals begin where either the 30-degree converging line crosses the secondary and primary boundaries from outside the segment, or the 15-degree splay line crosses the primary boundary from inside the segment.

c. **Second MA Turn WS Construction (DF/TF FO).** To accommodate the two inbound tracks in the DF leg, the second MA turn DF/TF (fly-over) construction uses two WS baselines, PP' and P'P''.

Note: Apply section 5, table 8-5-2 PP' location information for each baseline (formula is identical).

(1) CASE 1: Small angle turn using 1 WS for each inbound DF track.

Step 1: Construct the WS1 baseline, (P'P'') perpendicular to the DF track nearer the outside of the DF/TF turn, at the late-turn-point. See section 5, table 8-5-2 for line PP' location.

Step 1a: Construct the WS2 baseline, (PP') perpendicular to the DF track nearer the inside of the DF/TF turn, at the late-turn-point. See section 5, table 8-5-2 for line PP' location.

Step 2: Locate the WS1 center on P'P'' at distance R (no-wind turn radius, using section 5, formula 5-2b; see section 5, figure 8-5-5) from the intersection of P'P'' and the inbound-segment outer-boundary extension.

Step 2a: Locate the WS2 center on PP' at distance R (no-wind turn radius, using section 5, formula 5-2b; see section 5, figure 8-5-5) from the intersection of PP' and the inbound-segment inner-boundary extension.

Step 3: Construct WS1 from this outer boundary point in the direction of turn until tangent to the WS/Segment connecting line from section 5, table 8-5-2.

Step 3a: Construct WS2 from this inner boundary point in the direction of turn until tangent to the WS/Segment connecting line from section 5, table 8-5-2.

Step 4: Where WS2 intersects WS1 construction, include WS2 in the OEA construction, and connect WS1 to WS2 with a tangent line. Otherwise revert to the single WS construction.

CASE 1-1: WS1 and/or WS2 lie outside the outbound segment boundary.

Step 1: Construct the OEA outer boundary using WS1 and/or WS2 and the tangent 30-degree converging line until it crosses the outbound segment boundaries . See section 5, figure 8-5-22.

CASE 1-2: WS1 and WS2 lie inside the outbound segment boundary.

Step 1: Where WS1 and/or WS2 lie inside the outbound segment primary boundary, construct the OEA outer boundary using WS1 and/or WS2 and a line (from the point WS1 or WS2 is parallel to the outbound segment nominal track), splaying at 15 degrees relative the outbound segment nominal track until it intersects the outbound segment boundary lines.

Step 1a: Where WS1 and/or WS2 lie inside the outbound segment secondary boundary, construct the OEA outer boundary using WS1 and/or WS2 and a line (from the point WS1 or WS2 is parallel to the outbound segment nominal track), splaying at 15 degrees relative the outbound segment nominal track until it intersects the outbound segment boundary line. Continue the final WS and 30 degrees converging line to establish the primary/secondary boundary.

8.5.6. **Missed Approach Climb Gradient.** Where the MA standard OCS is penetrated and a CG is required, specify a missed approach CG to clear the penetrating obstruction. MA starting ROC is 100 ft (plus adjustments). ROC increases at 96 ft/NM, measured parallel to the MA track to TIA end (Turn-at-Altitude), or early-turn point (Turn-at-Fix), then shortest primary distance to the next fix. Apply fix-to-fix distance for subsequent segments. Where a part-time altimeter is in use, consider the helicopter SOC altitude to be the MDA associated with the local altimeter (ensures adequate CG is applied).

Step 1: Calculate the ROC, the altitude at which the ROC for the obstacle is achieved, and the required CG (ft/NM) using section 5, formula 5-3.

Step 2: Apply the CG to:

- The altitude which provides appropriate ROC, or
- The point/altitude where the subsequent MA OCS clears all obstacles.

Step 2a: Where a RASS adjustment is applicable for climb-to-altitude operations (prior to turn, terminate CG, etc.), apply the CG associated with the lower MDA (section 5, formula 5-3). Where there is a local altimeter, to establish the RASS-based climb-to-altitude, add the difference between the local altimeter-based MDA and the RASS-based MDA to the climb-to-altitude and round to the next higher 100-ft increment (see TP308/GPH209, Volume 1, chapter 3 for further details).

Formula 5-3: ROC/CG/Minimum Altitude/OCS

STEP 1

$$ROC_{obs} = ROC_{start} + 96 \cdot d$$

Where:

ROC_{start} = SOC ROC (100 ft for NVGP)

d = distance (NM) CG origin (SOC) to obstacle

$ROC_{start}+96*d$

STEP 2

$$Alt_{min} = O_{elev} + ROC_{obs}$$

Where:

ROC_{obs} = Step 1 result

O_{elev} = Obstacle Elevation (MSL)

$O_{elev}+ROC_{obs}$

STEP 3

$$CG = \frac{r}{d} \cdot \ln\left(\frac{(r + Alt_{min})}{(r + Copter_{SOC})}\right)$$

Where:

Alt_{min} = Step 2 result

$Copter_{SOC}$ = Helicopter altitude (MSL) at CG origin

d = distance (NM), CG origin (SOC) to obstacle

$r/d*\ln((r+ALT_{min})/(r+Copter_{SOC}))$

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SECTION 6: HELICOPTER INSTRUMENT DEPARTURE DESIGN CRITERIA

8.6. Helicopter Instrument Departure Design Criteria.

8.6.1. General. See section 1, paragraphs 8.1.1 to 8.1.5.

8.6.2. Terms. See Annex D.

8.6.3. Reserved.

8.6.4. PinS Departures.

a. **Background operational information for procedure designers.** The PinS Departure Procedures (DPs) described in this criteria allow a pilot to depart a heliport and visually navigate and avoid obstacles to the Initial Departure Fix (IDF) where IFR obstruction clearance begins. The IDF is a Fly-by (FB) Waypoint (WP). IFR helicopter departure procedures will consist of a defined route in graphic form, published/charted as a Instrument Departure and comply with design and documentation guidelines as specified in this section and NAV CANADA charting instructions.

b. Procedure Design. Establish the IDF at a distance from 1.5 NM to 5.0 NM from ARP/HRP. Positive Course Guidance (PCG) and obstruction clearance must be provided from the earliest ATT at the IDF to the latest ATT at the last DP WP (DP termination fix) where the DP joins the enroute structure and an altitude that permits enroute flight.

(1) DP Construction. Optimum leg length is 3.0 NM. If the magnitude ($\boldsymbol{\beta}$) of the first turn is ≤ 70 degrees, the minimum leg length allowed is 3.0 NM. If $\boldsymbol{\beta}$ of the first turn is > 70 degrees the minimum leg length is 3.5 NM. Maximum turn magnitude is 90 degrees and leg length is 10.0 NM.

(2) Reserved

(3) After the first turn fix, and expanding to full width, apply standard RNAV initial segment OEA construction for Category “A” aircraft. Minimum leg length is the greater of the current RNAV minimum leg length criteria or as construction requires after the first turn fix.

(4) Use Formula 6-1 to determine turn radius (R) and DTA appropriate for $\boldsymbol{\beta}$. For a general DP, use a design climb airspeed of 80 KIAS and a 13-degree bank angle until the climb trajectory reaches the target departure altitude. After the target departure altitude is reached, design for 140 KIAS and 15-degree bank angle.

(5) If lower or higher airspeeds are required because of design helicopter performance or equipment operating limitations, publish a speed restriction.

Formula 6-1: Turn Radius/Distance of Turn Anticipation (DTA)

(1) $input\ V_{KIAS},\ bank_{angle},\ turn_{alt},\ \beta,\ HRP_{elev}$

(2) $\text{case}(\text{turn}_{\text{alt}} - \text{HRP}_{\text{elev}} > 2000)$: $V_{KTW} = round(0.00198 \cdot turn_{alt} + 47, 0)$

$\text{case}(\text{turn}_{\text{alt}} - \text{HRP}_{\text{elev}} \leq 2000)$: $V_{KTW} = 30$

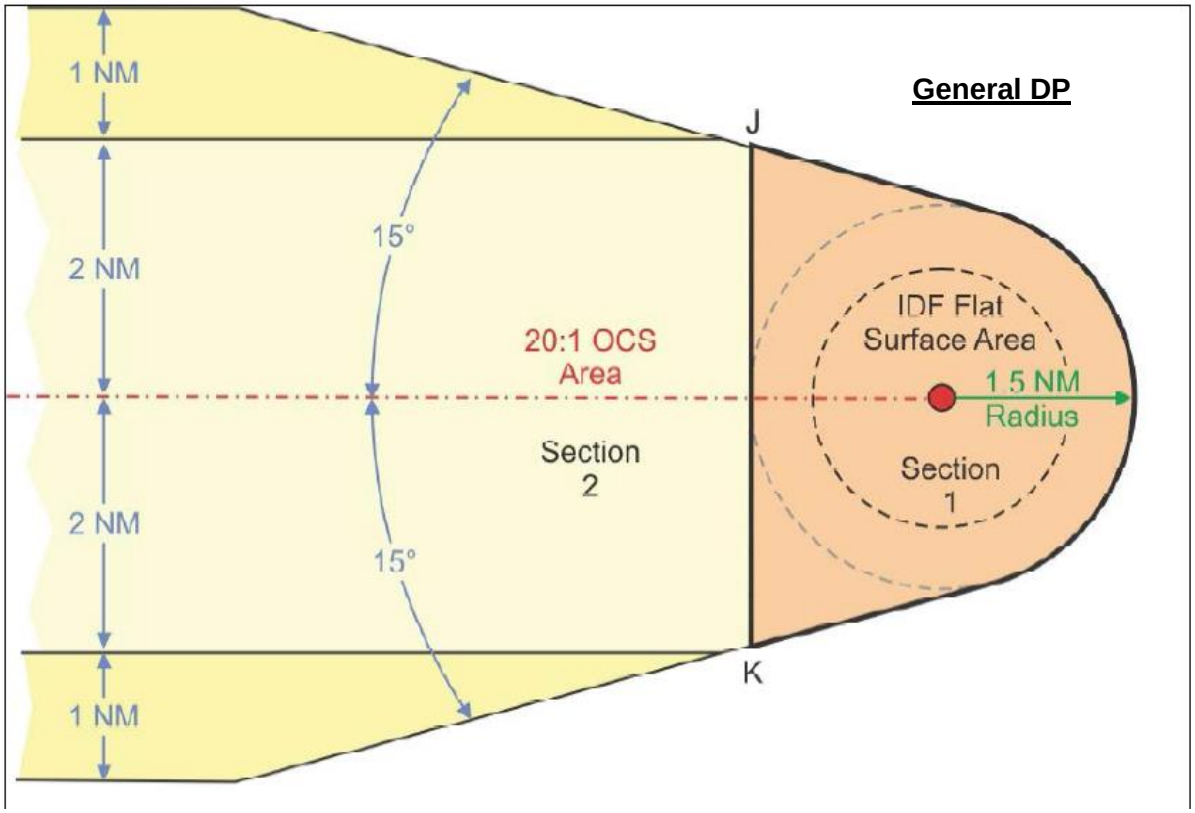
(3) $V_{KTAS} = \text{round}\left[\frac{V_{KIAS} \cdot 171233 \cdot \sqrt{303 - 0.00198 \times turn_{alt}}}{(288 - 0.00198 \cdot turn_{alt})^{2.628}}, 0\right]$

(4) $R = \text{round}\left[\frac{(V_{KTAS} + V_{KTW})^2}{\tan(bank_{angle}) \cdot 68625.4}, 2\right]$

(5) $DTA_{NM} = \text{round}\left[R \cdot \tan\left(\frac{\beta}{2}\right), 2\right]$

8.6.5. **Obstacle Evaluation Area.** The OEA consists of Section 1 (the IDF flat surface area), and Section 2 (the 20:1 sloping OCS), as shown in Figure 8-6-1. The JK line (end of section 1/ beginning of section 2) is a line perpendicular to the initial departure course that is at a distance of 1.5 NM from the IDF (1 NM ATT + 0.5 NM FTE) . The construction radius around the IDF is 1.5 NM (1 NM ATT + 0.5 NM FTE). A 15-degree splay defines the Section 1 and Section 2 outer boundaries as shown in Figure 8-6-1 below. The OEA entry is centered on the IDF and the route is constructed as a series of TF legs to the DP termination fix.

Figure 8-6-1: Section 1 Flat Surface, Section 2 OCS Areas



8.6.6. General PinS Departure Construction. For general DP construction, OEA configuration is dependent on the course change angle at the first turn fix, and the length of the first segment. Some examples are illustrated in Figure 8-6-2 thru Figure 8-6-4. Instructions on how to define these cases (creating the specific OEAs and turn boundaries) are located in steps below:

Figure 8-6-2: General OEA Area Plan View (90-Degree Turn)

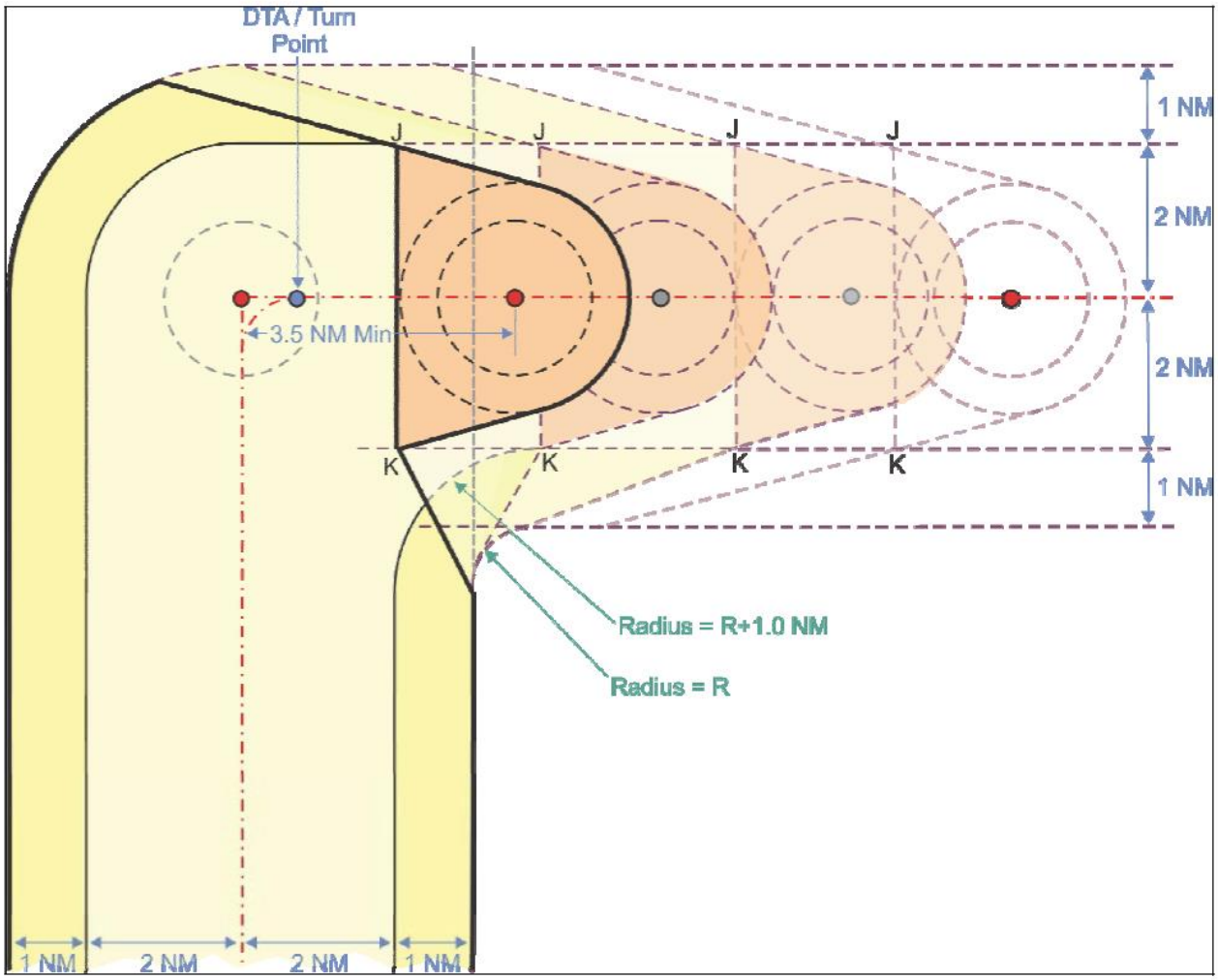


Figure 8-6-3: General OEA Area Plan View (15- and 30-Degree Turns)

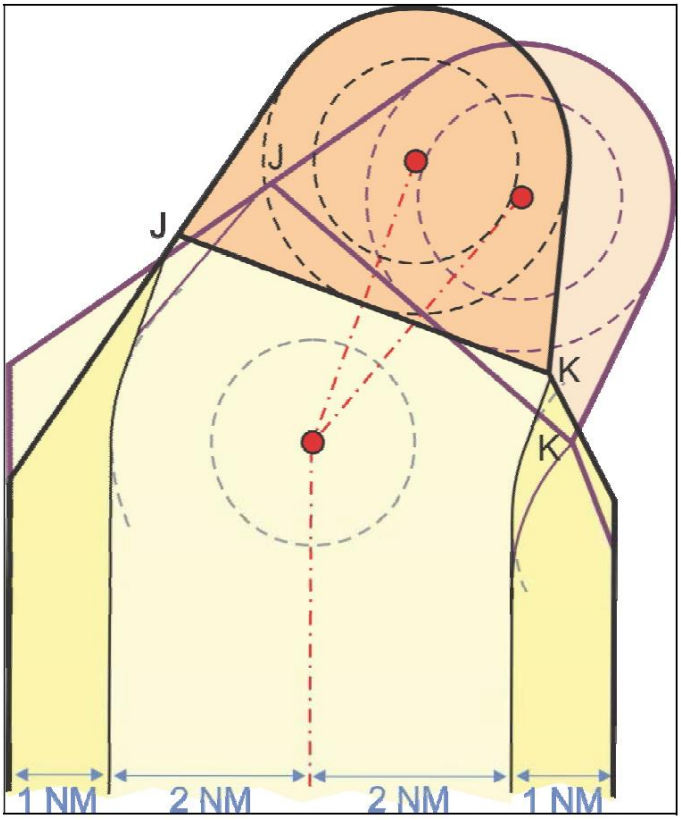
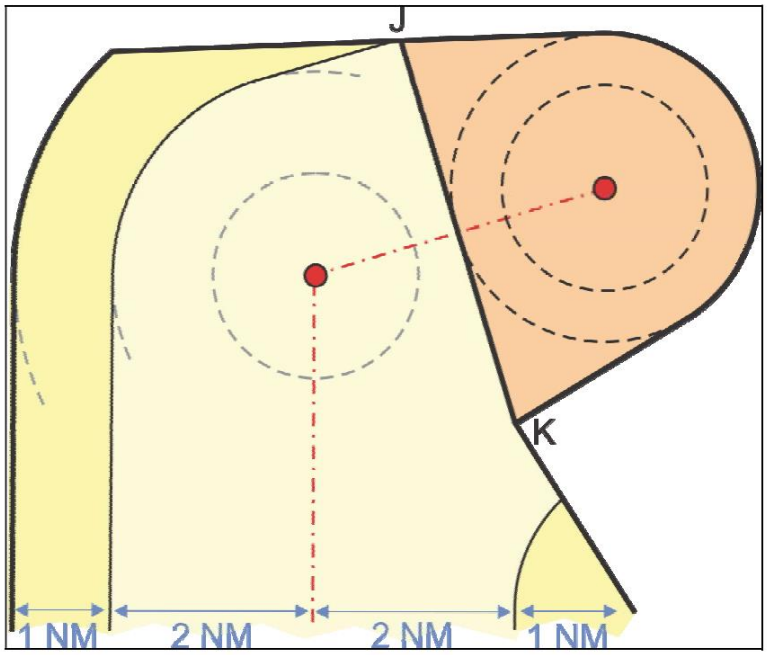


Figure 8-6-4: General OEA Area Plan View (70-Degree Turn)



Step 1: Position the Initial Departure Fix (IDF) as a Fly-By (FB) fix. Use a fix-to-fix distance that is in accordance with paragraph 8.6.4b(1).

Step 2: Construct the IDF Circle as an arc with a 1.5 NM radius centered at the IDF fix.

Step 3: Construct the Designed Turning Flight Path.

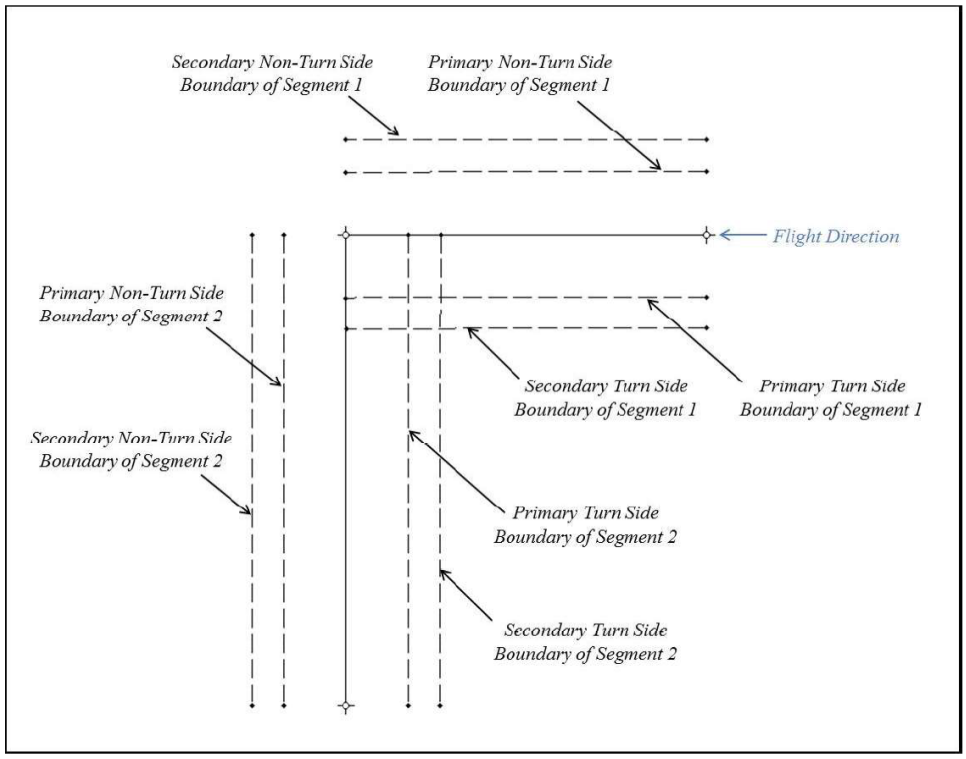
Step 3a: Determine the turn radius (R) utilizing Formula 6-1.

Step 3b: Construct an arc of radius R that lays tangent to Segments 1 and 2.

Step 4: Construct Segment 1 Boundaries. Construct Boundaries of half-widths 1-2-2-1 in reference to Segment 1. They will hereby be referred to as the Secondary Turn Side Boundary of Segment 1, the Primary Turn Side Boundary of Segment 1, the Primary Non-Turn Side Boundary of Segment 1, and the Secondary Non-Turn Side Boundary of Segment 1. These boundaries are depicted in Figure 8-6-5.

Step 5: Construct Segment 2 Boundaries. Construct Boundaries of half-widths 1-2-2-1 in reference to Segment 2. They will hereby be referred to as the Secondary Turn Side Boundary of Segment 2, the Primary Turn Side Boundary of Segment 2, the Primary Non-Turn Side Boundary of Segment 2, and the Secondary Non-Turn Side Boundary of Segment 2. These boundaries are depicted in Figure 8-6-5.

Figure 8-6-5: Construction of the Segment 1 and Segment 2 Boundaries



Step 6: Construct the Turn Side Splay Line (see Figure 8-6-6).

Step 6a: Locate the Splay End Reference Point a distance of 1.5/tan(15°) NM from the IDF along the Segment 1 Course Line.

Step 6b: Locate the Turn Side Splay Line End Point as the Splay End Reference Point projected onto the Secondary Turn Side Boundary of Segment 1.

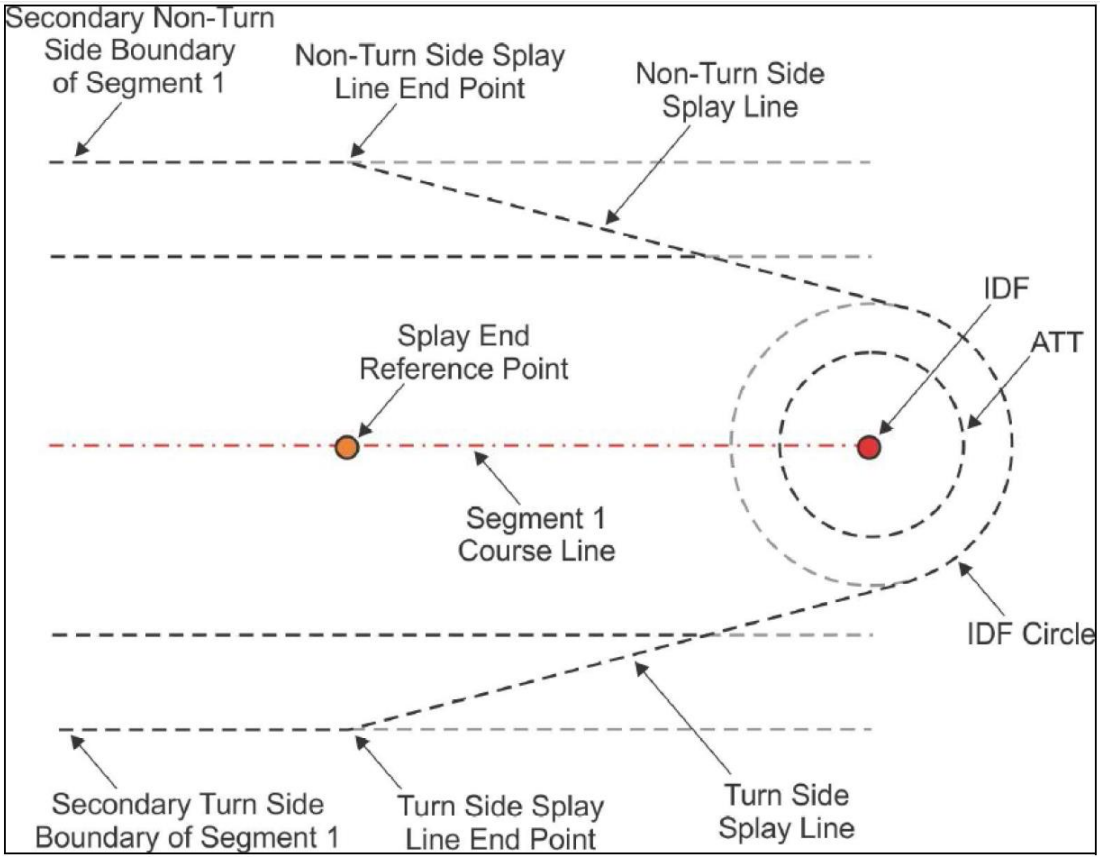
Step 6c: Construct the Turn Side Splay Line as a line that is tangent to the IDF Circle passing through the Turn Side Splay Line End Point.

Step 7: Construct the Non-Turn Side Splay Line (see Figure 8-6-6).

Step 7a: Locate the Non-Turn Side Splay Line End Point as the Splay End Reference Point projected onto the Secondary Non-Turn Side Boundary of Segment 1.

Step 7b: Construct the Non-Turn Side Splay Line as a line that is tangent to the IDF Circle passing through the Non-Turn Side Splay Line End Point.

Figure 8-6-6: Construction of the Splay Lines



Step 8: Construct the IDF Flat Surface Area (see Figure 8-6-7).

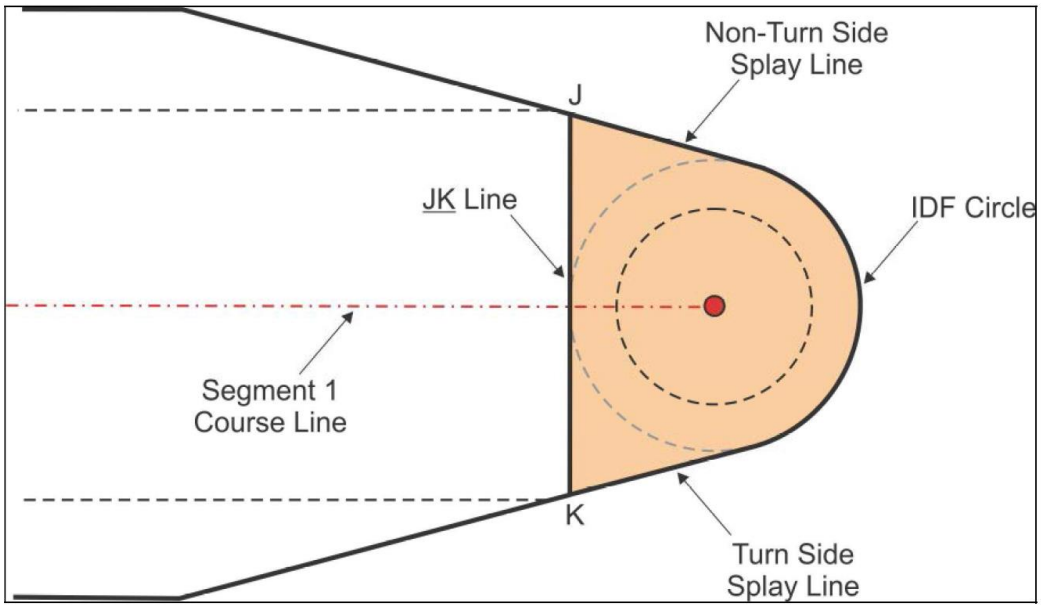
Step 8a: Construct the JK line as a line that lays tangent to the IDF Circle at a point intersecting the Segment 1 Course Line.

Step 8b: Truncate the JK line where it intersects the Turn Side Splay Line and the Non-Turn Side Splay Line.

Step 8c: The IDF Flat Surface Area is the area bounded by the IDF Circle, the Turn Side and Non-Turn Side Splay Lines, and the JK line.

Step 8d: The Turn Side end of the JK line will hereby be referred to as Point K and the Non-Turn Side end of the JK line will hereby be referred to as Point J.

Figure 8-6-7: Construction of the IDF Flat Surface Area

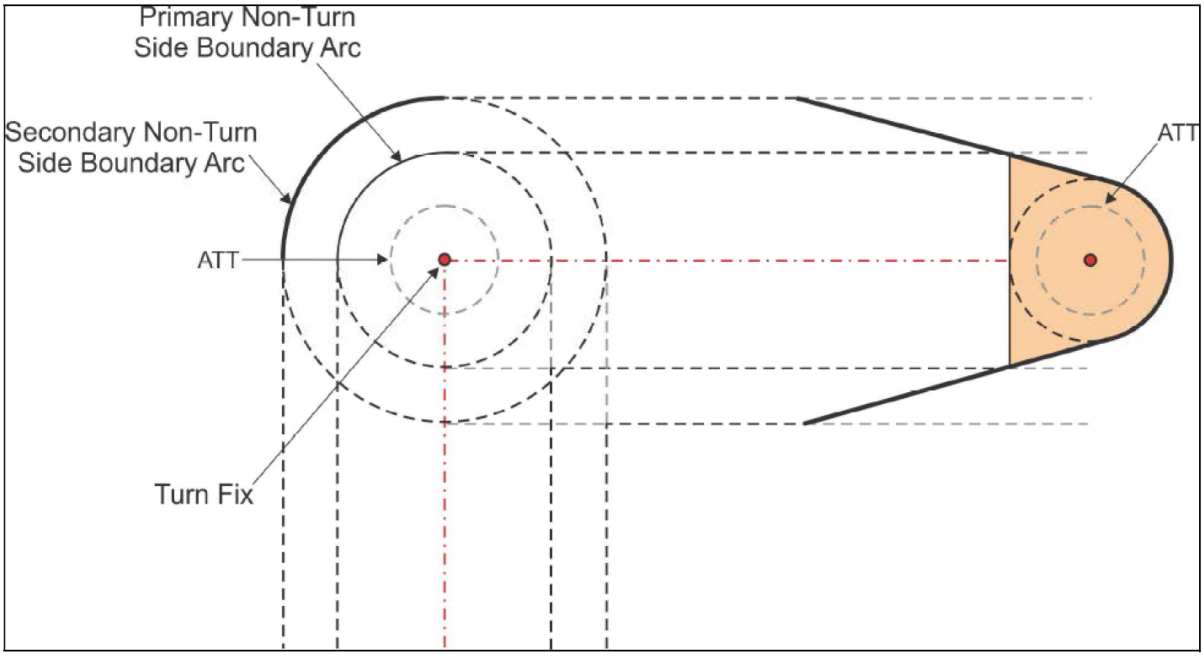


Step 9: Construct Non-Turn Side Boundary Arcs (see Figure 8-6-8).

Step 9a: Construct the Primary Non-Turn Side Boundary Arc centered on the turn fix with a radius equal to the Segment 1 primary half-width.

Step 9b: Construct the Secondary Non-Turn Side Boundary Arc centered on the turn fix with a radius equal to the Segment 1 primary half-width plus the segment secondary width.

Figure 8-6-8: Construction of the Non-Turn Side Boundary Arcs

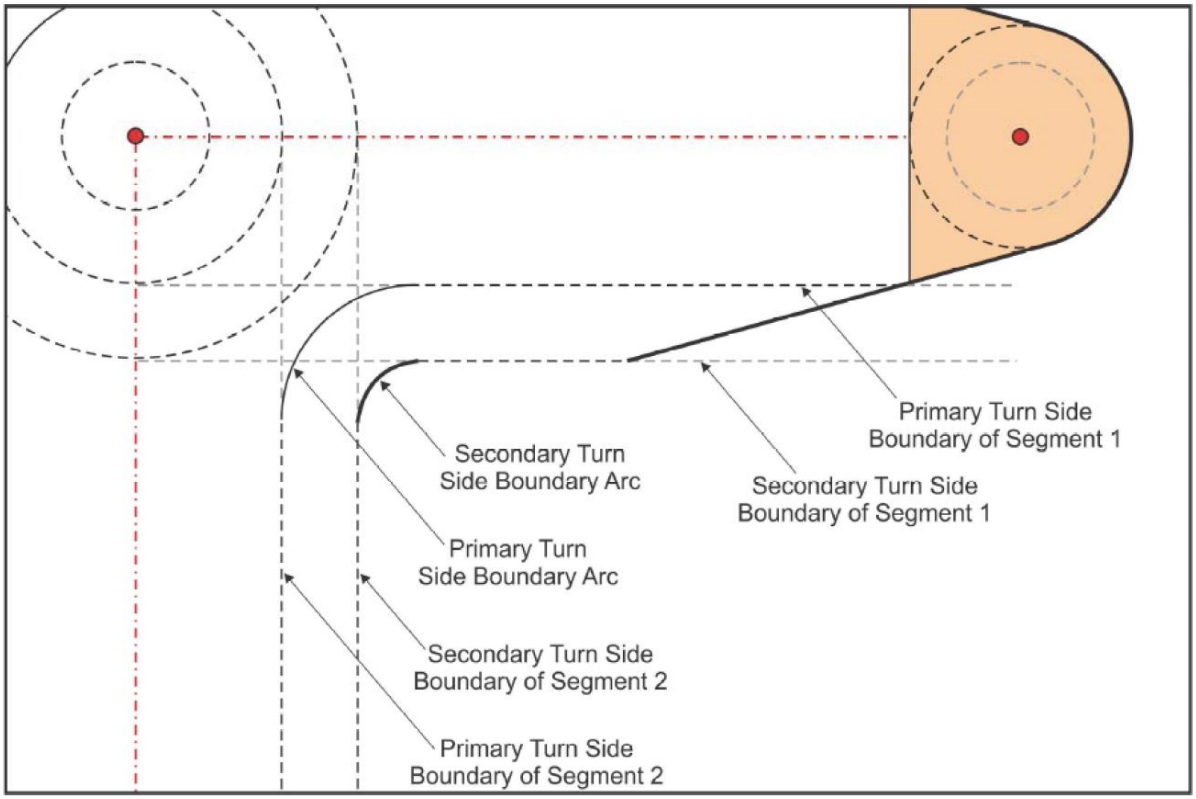


Step 10: Construct Turn Side Boundary Arcs (see Figure 8-6-9).

Step 10a: Construct the Primary Turn Side Boundary Arc tangent to the Primary Turn Side Boundaries of Segments 1 and 2 with a radius equal to R + 1 NM.

Step 10b: Construct the Secondary Turn Side Boundary Arc tangent to the Secondary Turn Side Boundaries of Segments 1 and 2 with a radius equal to R.

Figure 8-6-9: Construction of the Turn Side Boundary Arcs



Step 11: Define and Construct the Non-Turn Side Boundary.

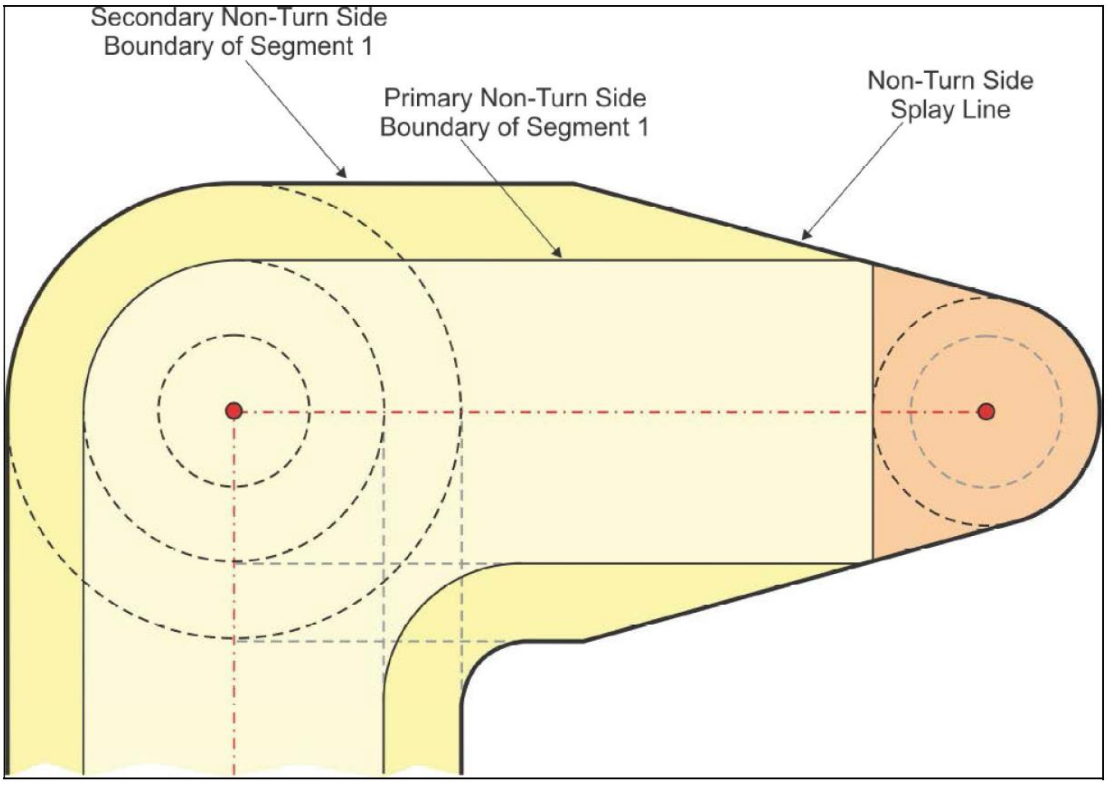
Step 11a: Depending on the course change at the second waypoint and the length of Segment 1, the Non-Turn Side Splay Line will either intersect the Secondary Non-Turn Side Boundary of Segment 1, the Secondary Non-Turn Side Boundary Arc, or the Secondary Non-Turn Side Boundary of Segment 2.

Step 11b: If the Non-Turn Side Splay Line intersects the Secondary Non-Turn Side Boundary of Segment 1 (see Figure 8-6-10), then:

Step 11b (1): Truncate the Secondary Non-Turn Side Boundary of Segment 1 at the intersection, and,

Step 11b (2): Truncate the Primary Non-Turn Side Boundary of Segment 1 where it intersects the Non-Turn Side Splay Line.

Figure 8-6-10: Construction of the Non-Turn Side Boundary, Case 1



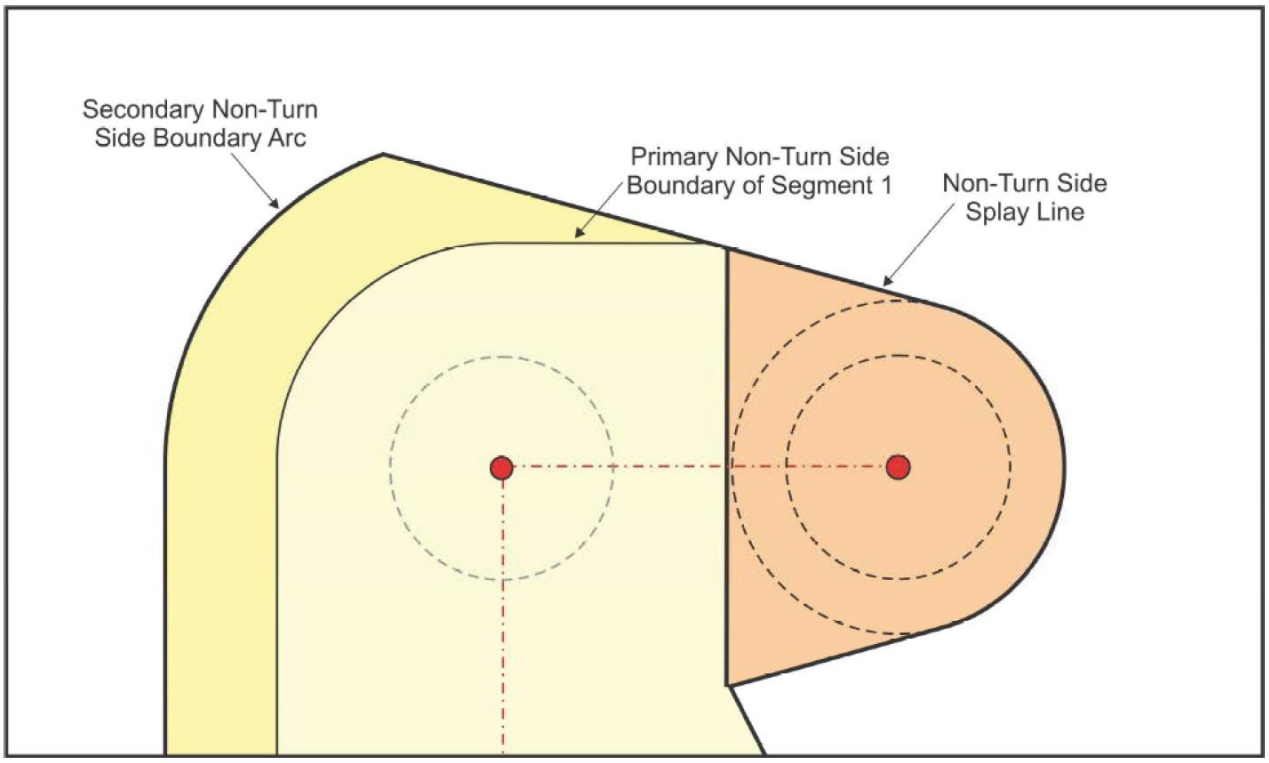
Step 11c: If the Non-Turn Side Splay Line intersects the Secondary Non-Turn Side Boundary Arc (see Figure 8-6-11) then,

Step 11c (1): Remove the Secondary Non-Turn Side Boundary of Segment 1,

Step 11c (2): Truncate the Secondary Non-Turn Side Boundary Arc at the intersection and,

Step 11c (3): Truncate the Primary Non-Turn Side Boundary of Segment 1 where it intersects the Non-Turn Side Splay Line.

Figure 8-6-11: Construction of the Non-Turn Side Boundary, Case 2



Step 11d: If the Non-Turn Side Splay Line intersects the Secondary Non-Turn Side Boundary of Segment 2 (see Figure 8-6-12) then,

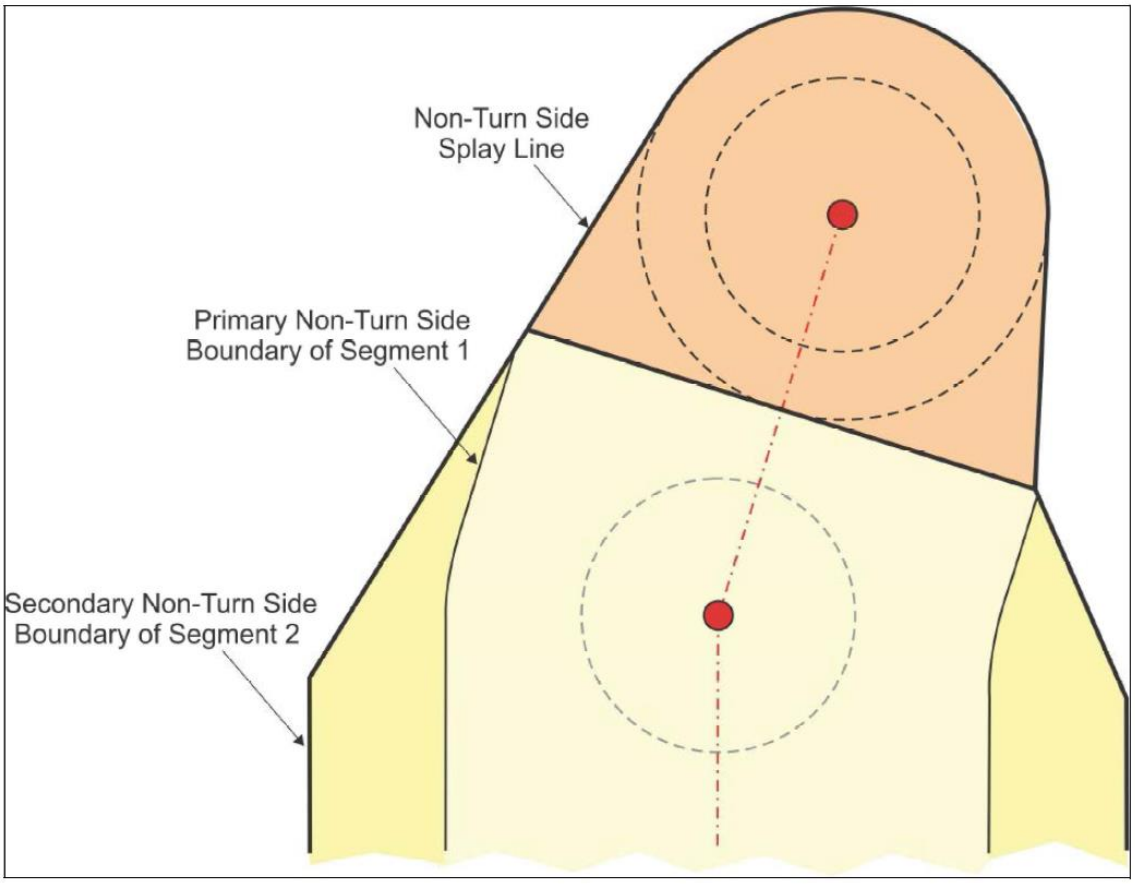
Step 11d (1): Remove the Secondary Non-Turn Side Boundary of Segment 1,

Step 11d (2): Remove the Secondary Non-Turn Side Boundary Arc,

Step 11d (3): Truncate the Secondary Non-Turn Side Boundary of Segment 2 at the intersection and,

Step 11d (4): Truncate the Primary Non-Turn Side Boundary of Segment 1 where it intersects the Non-Turn Side Splay Line.

Figure 8-6-12: Construction of the Non-Turn Side Boundary, Case 3



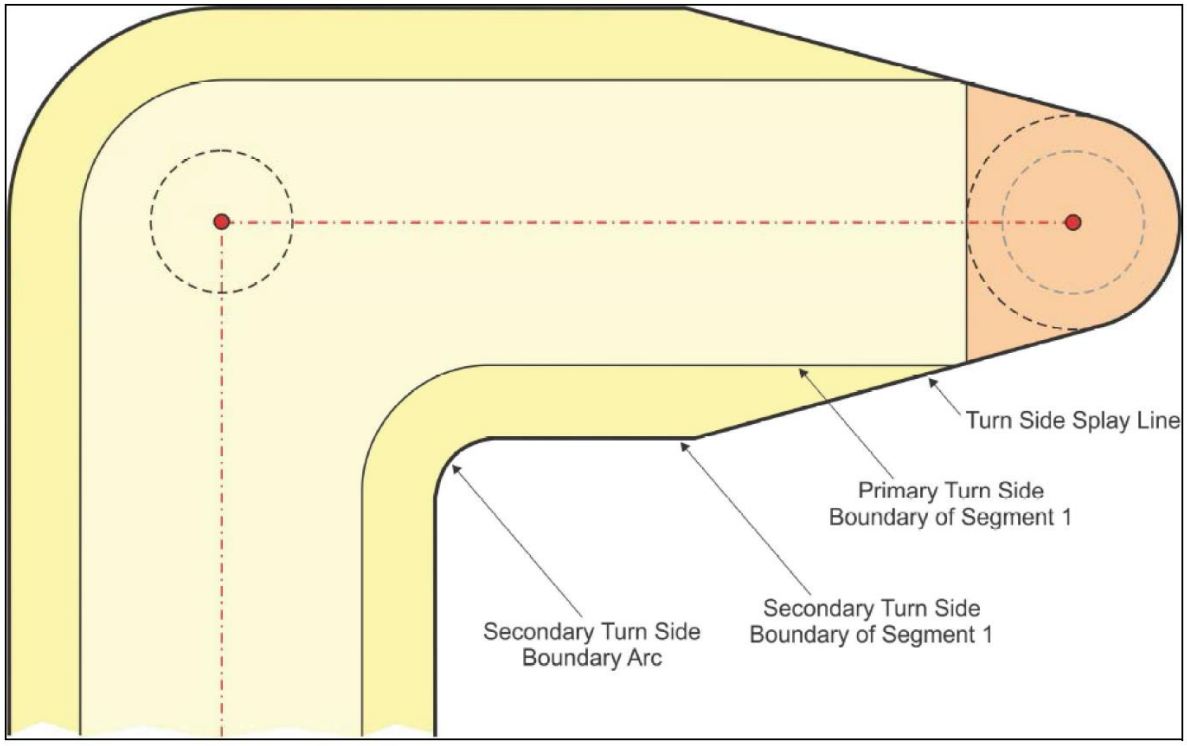
Step 12: Define and Construct the Turn Side Boundary.

Step 12a: If the Turn Side Splay Line intersects the Secondary Turn Side Boundary of Segment 1 before the start of the Secondary Turn Side Boundary Arc (see Figure 8-6-13) then,

Step 12a (1): Truncate the Primary Turn Side Boundary of Segment 1 at its intersection with the Turn Side Splay Line and,

Step 12a (2): Truncate the Secondary Turn Side Boundary of Segment 1 at its intersection with the Turn Side Splay Line.

Figure 8-6-13: Construction of the Turn Side Boundary, Case 1

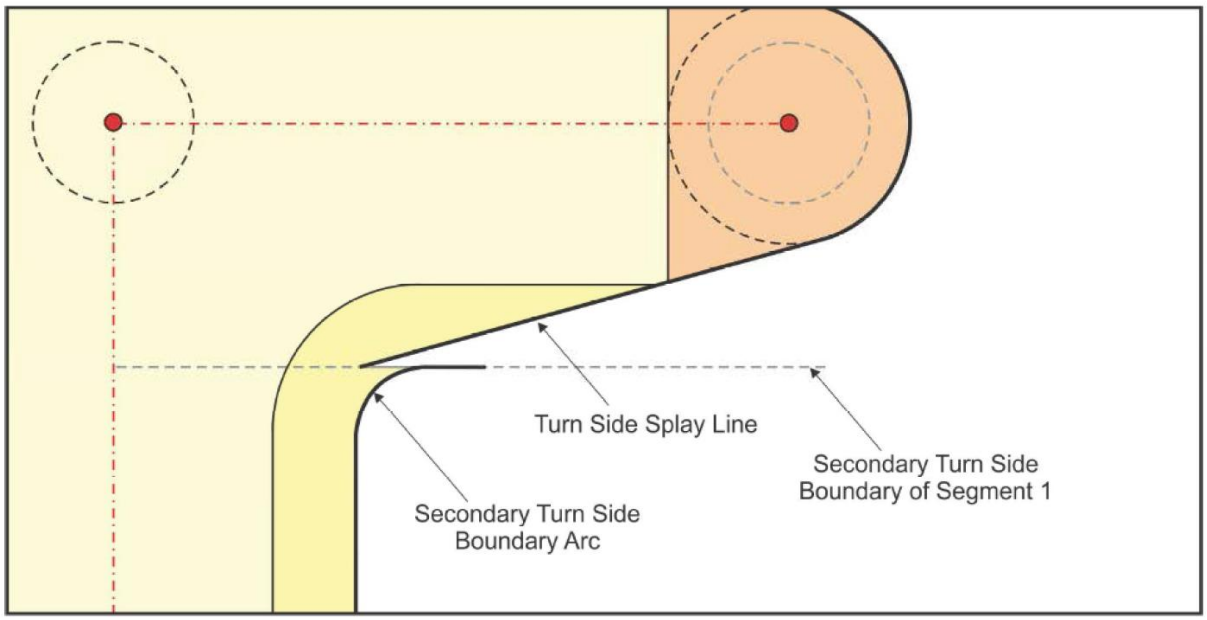


Step 12b: If the Turn Side Splay Line intersects the Secondary Turn Side Boundary of Segment 1 after the start of the Secondary Turn Side Boundary Arc (see Figure 8-6-14) then,

Step 12b (1): Construct the Turn Side Boundary Line as a line that lays tangent to the Secondary Turn Side Boundary Arc and passes through Point K.

Step 12b (1)(a): If the configuration of the procedure is such that this step cannot be performed, forego this step and proceed to Step 12c.

Figure 8-6-14. Construction of the Turn Side Boundary, Case 2 Determination



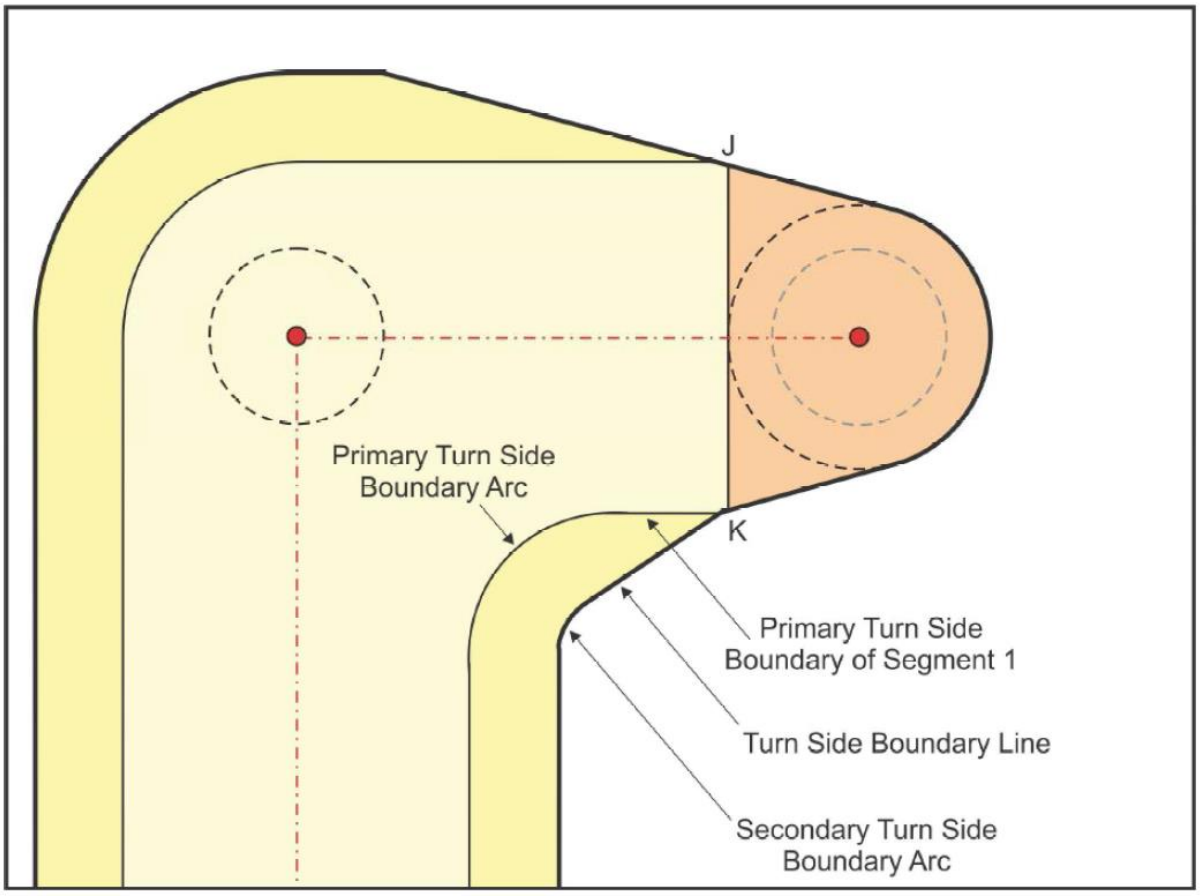
Step 12b (2): If the Turn Side Boundary Line intersects the Primary Turn Side Boundary of Segment 1 (see Figure 8-6-15) then,

Step 12b (2)(a): Truncate the Primary Turn Side Boundary of Segment 1 at its intersection with the Turn Side Boundary Line,

Step 12b (2)(b): Remove the Secondary Turn Side Boundary of Segment 1, and

Step 12b (2)(c): Truncate the Secondary Turn Side Boundary Arc at its point of tangency with the Turn Side Boundary Line.

Figure 8-6-15: Construction of the Turn Side Boundary, Case 2a



Step 12b (3): If the Turn Side Boundary Line intersects the Primary Turn Side Boundary Arc (see Figure 8-6-16) then,

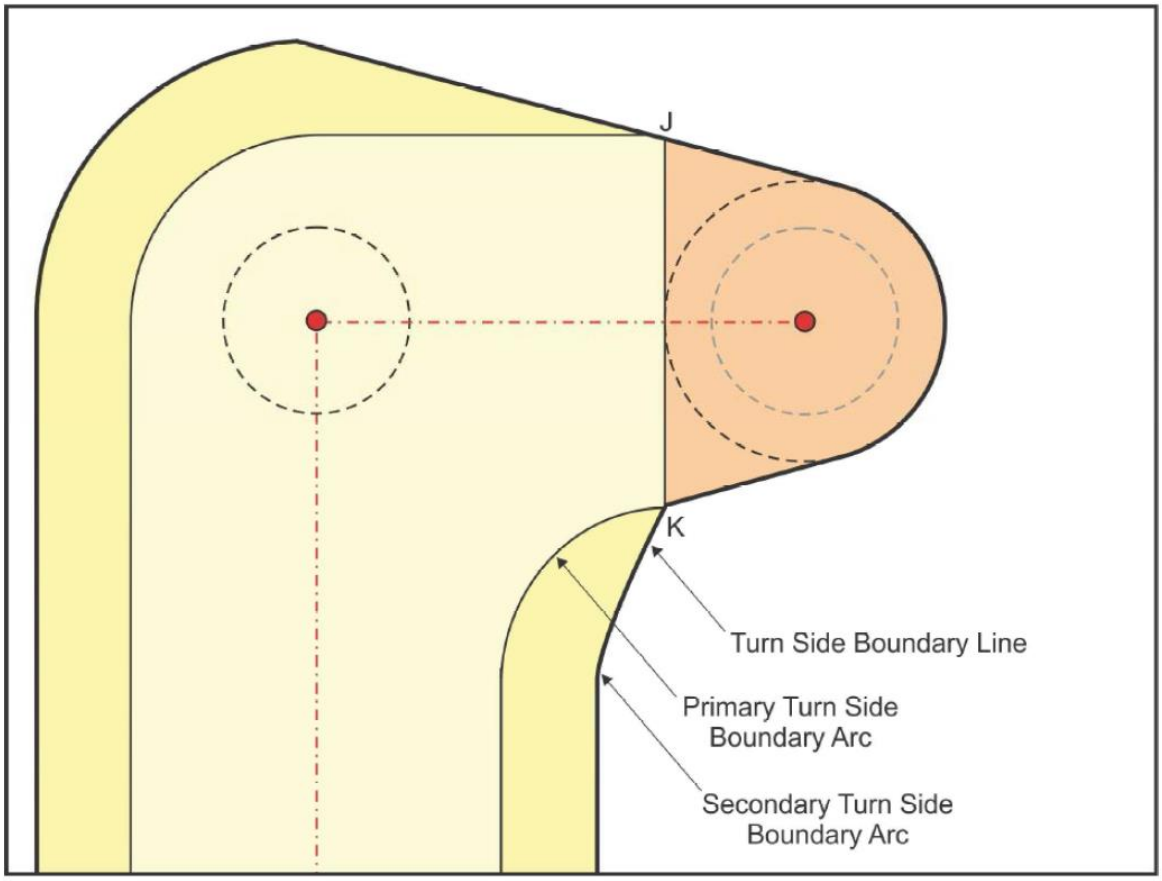
Step 12b (3)(a): Truncate the Primary Turn Side Boundary Arc at its intersection with the Turn Side Boundary Line,

Step 12b (3)(b): Truncate the Secondary Turn Side Boundary Arc at its point of tangency with the Turn Side Boundary Line,

Step 12b (3)(c): Remove the Primary Turn Side Boundary of Segment 1, and

Step 12b (3)(d): Remove the Secondary Turn Side Boundary of Segment 1.

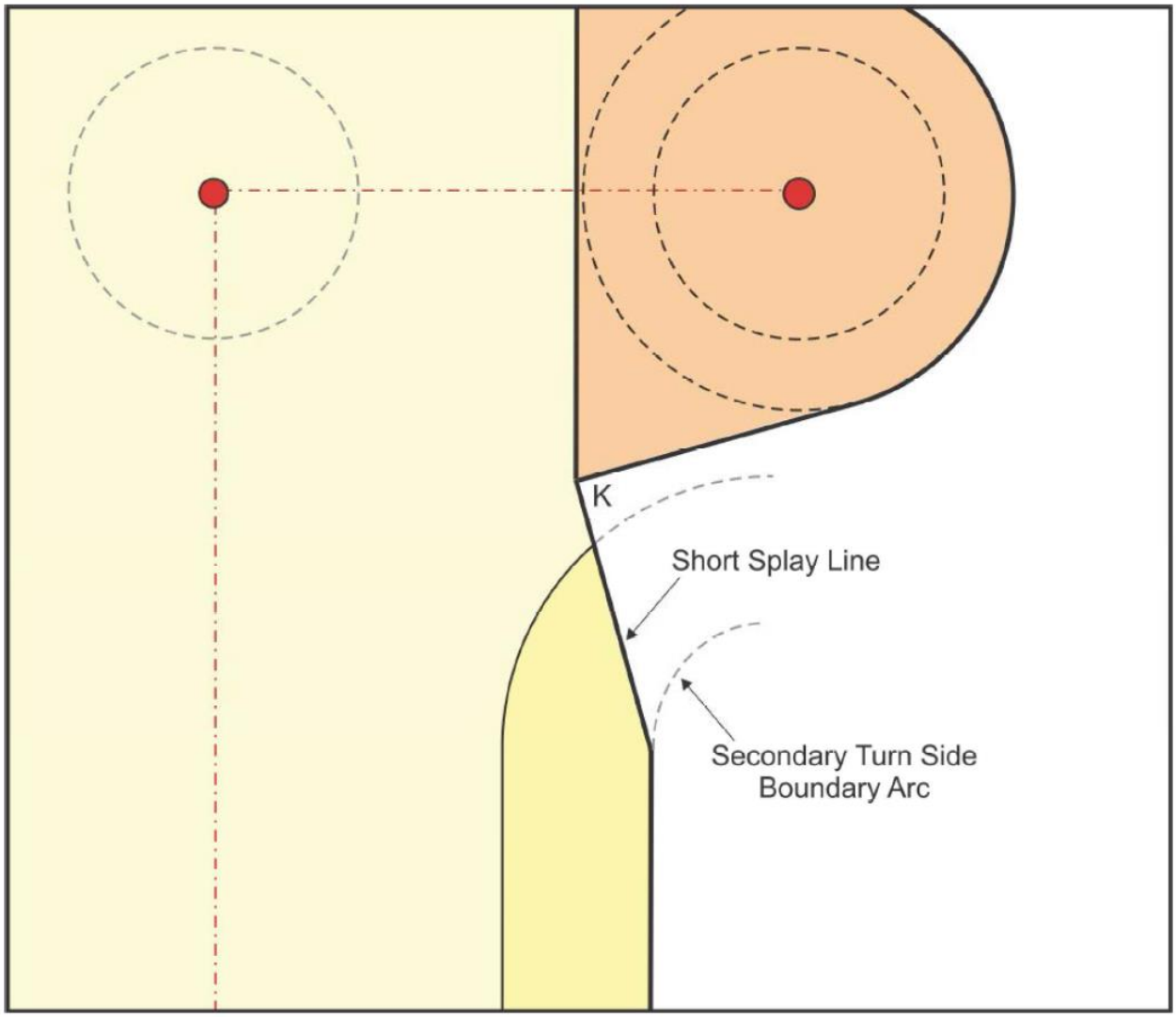
Figure 8-6-16: Construction of the Turn Side Boundary, Case 2b



Step 12c: If full width cannot be achieved in the initial segment [as described in Step 12a], and a tangent line cannot be drawn between Point K and the Secondary Turn Side Boundary Arc [as described in Step 12b(1)(a)],

Step 12c (1): Construct the Short Splay Line as a line that starts at Point K and ends at the end of the Secondary Turn Side Boundary Arc (see Figure 8-6-9).

Figure 8-6-17: Construction of the Turn Side Boundary, Case 3 Determination



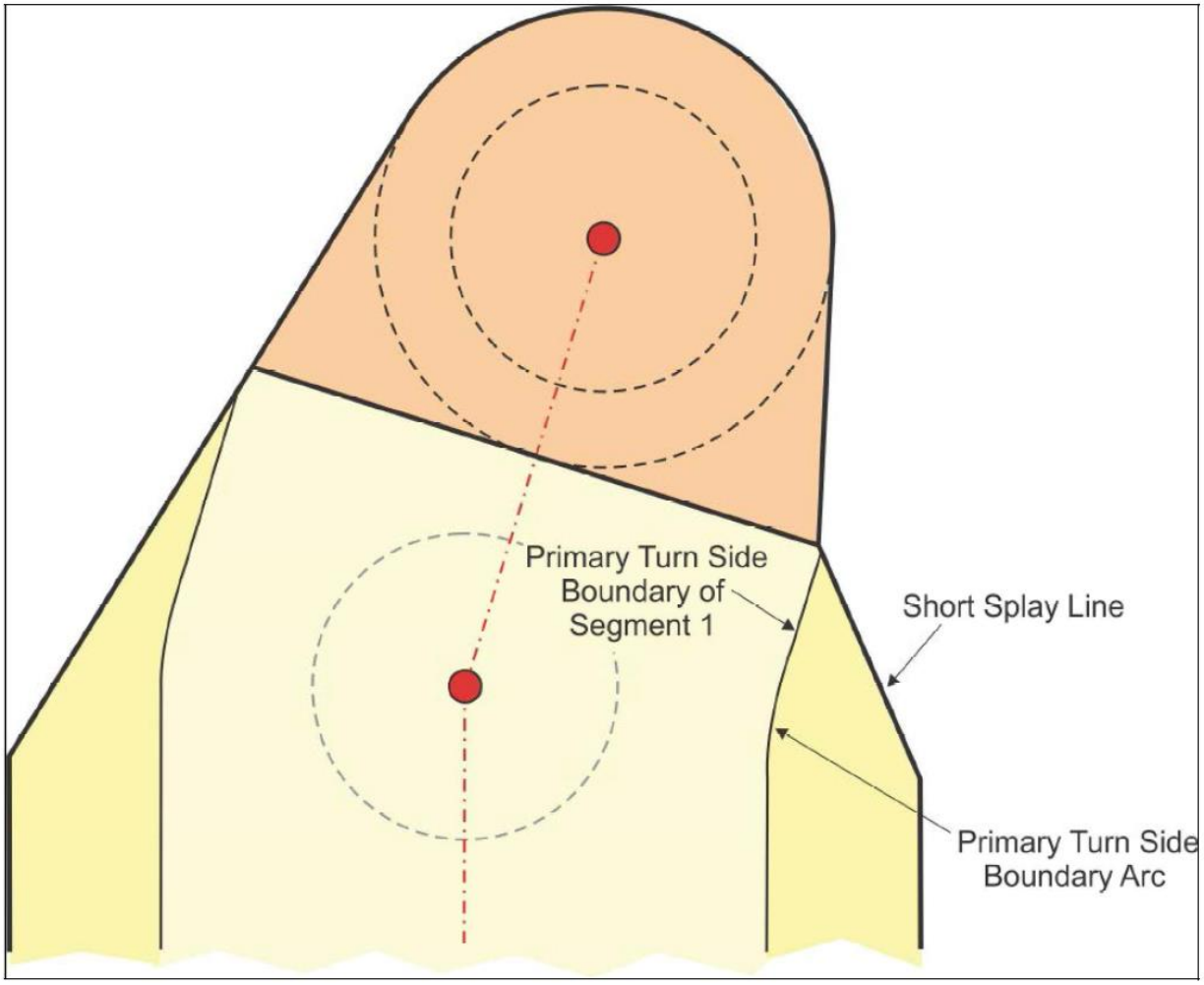
Step 12c (2): If the Short Splay Line intersects the Primary Turn Side Boundary of Segment 1 (see Figure 8-6-18) then,

Step 12c (2)(a): Remove the Secondary Turn Side Boundary of Segment 1,

Step 12c (2)(b): Remove the Secondary Turn Side Boundary Arc, and

Step 12c (2)(c): Truncate the Primary Turn Side Boundary of Segment 1 at its intersection with the Short Splay Line.

Figure 8-6-18: Construction of the Turn Side Boundary, Case 3a



Step 12c (3): If the Short Splay Line intersects the Primary Turn Side Boundary Arc (see Figure 8-6-19) then,

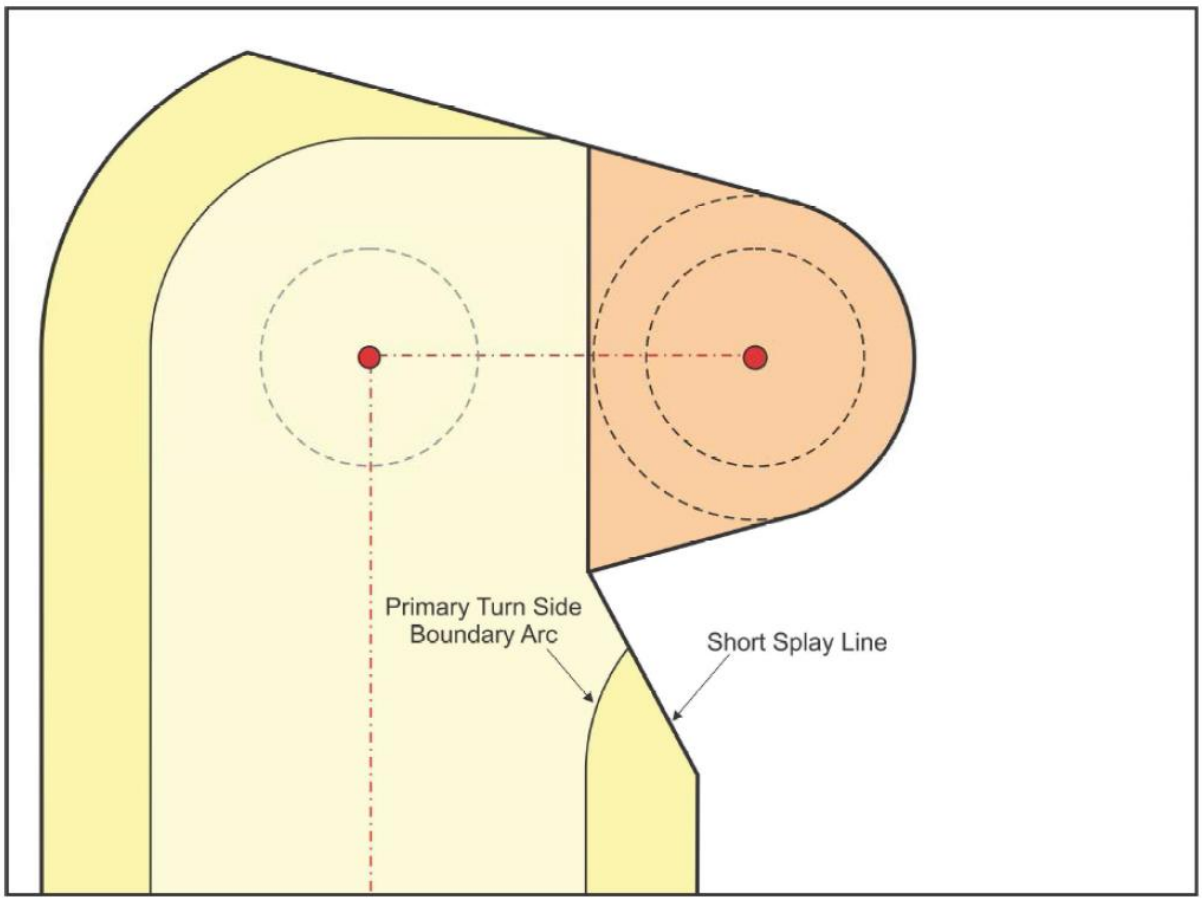
Step 12c (3)(a): Remove the Primary Turn Side Boundary of Segment 1,

Step 12c (3)(b): Remove the Secondary Turn Side Boundary of Segment 1,

Step 12c (3)(c): Remove the Secondary Turn Side Boundary Arc, and

Step 12c (3)(d): Truncate the Primary Turn Side Boundary Arc at its point of intersection with the Short Splay Line.

Figure 8-6-19: Construction of the Turn Side Boundary, Case 3b



8.6.7. **Reserved**.

Figure 8-6-20 to Figure 8-6-33 : Reserved

8.6.8. Obstacle Evaluation (OE). Starting at the JK line, apply a 20:1 OCS in the primary OEA, and a 6:1 OCS in the secondary OEA rising perpendicular from the edge of the primary area. Where an obstacle penetrates the primary OCS, or the *secondary OCS throughout the DP, calculate a minimum CG to clear the penetration(s) for all departure segments (legs) or raise the IDF crossing altitude. The highest required CG of all the departure legs is maintained until penetration(s) are cleared, and then the CG may be relaxed. See Figure 8-6-34 for a Climb Area Profile View and Figure 8-6-35/Figure 8-6-36 for a Climb Area Plan View. See paragraph 8.6.9 for assessing ROC, minimum altitude and CG.

***Note:** The elevation of obstacles in the secondary is reduced.

Figure 8-6-34: Climb Area Profile View

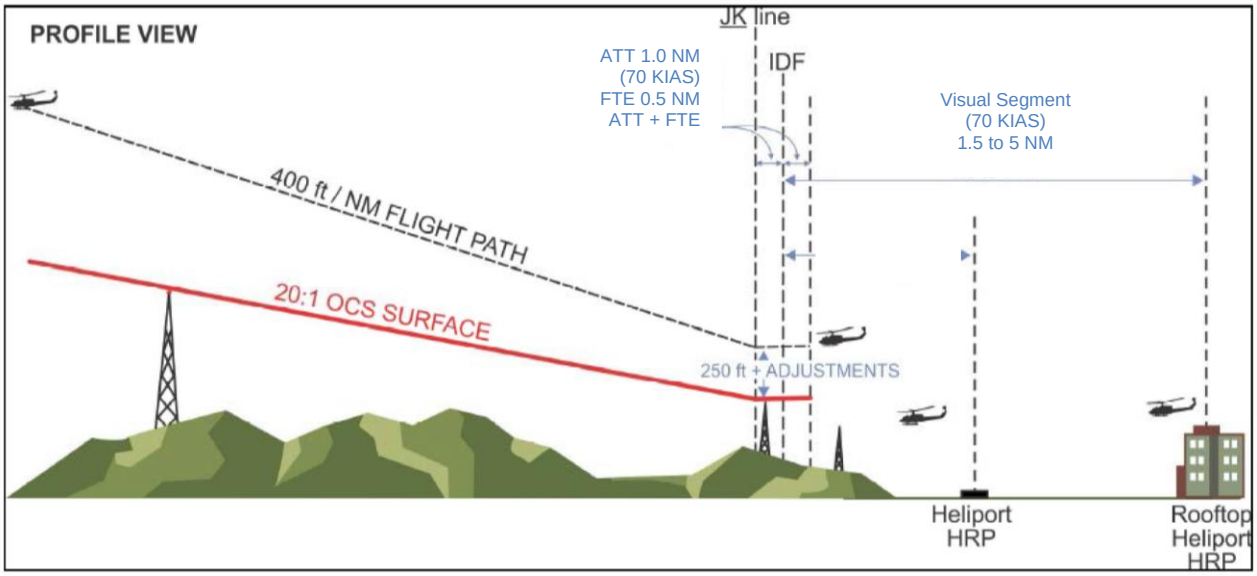


Figure 8-6-35: Departure Climb Area Plan View (General)

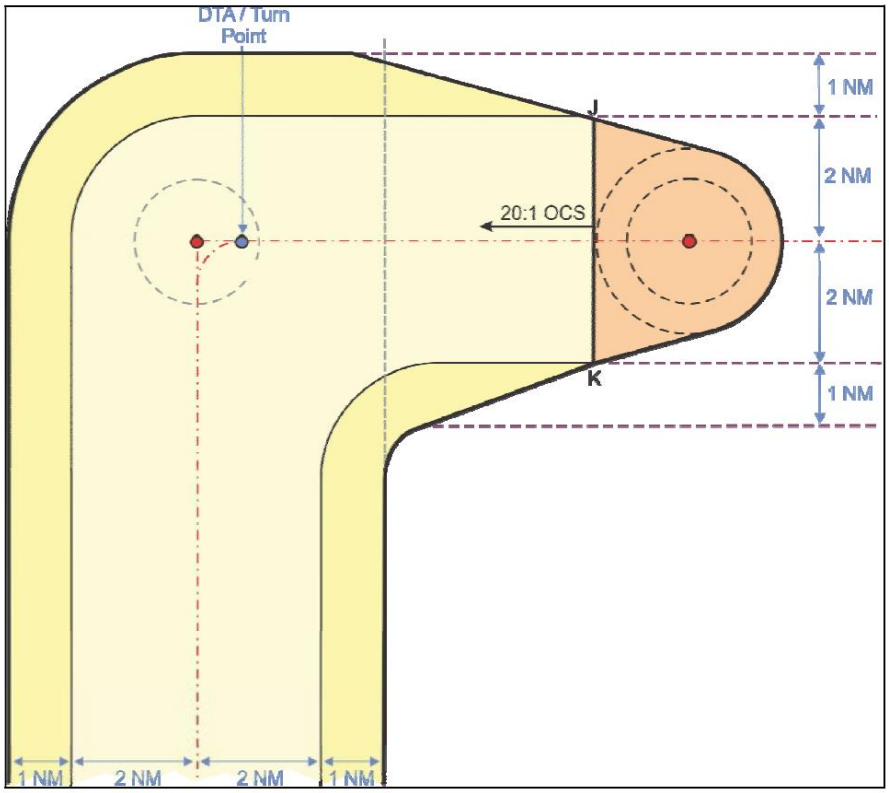


Figure 8-6-36: Reserved

8.6.9. Required Obstacle Clearance (ROC)

a. Section 1 Obstacle Clearance

(1) The PinS DP minimum ROC at the IDF is 250 ft, plus any adjustments for RASS (when altimeter source greater than 5 NM from the IDF), precipitous terrain, and obstacle accuracy standard.

Note 1: Precipitous terrain apply Section 1 only.
Note 2: IDF altitude must not be lower than the heliport elevation.

(2) ROC is applied within the IDF flat surface area (Section 1), and then rounded to the next higher 100-ft increment. For example, 500 ft remains 500 ft and 501 ft becomes 600 ft. The rounded altitude is the IDF crossing altitude.

(3) Accuracy Standard. Obstacle accuracy standard is 50 ft horizontal/20 ft vertical (Ref: Annex E, 2.11.3 b (2)) in the IDF flat surface area.

b. Section 2 Obstacle Clearance

(1) Sloping OCS. ROC increases at 96 ft/NM for all climb gradients.

(2) Primary OEA. Apply a 20:1 OCS originating at the JK line in the direction of departure. The OCS origin elevation is equal to the IDF crossing altitude subtracting ROC and any adjustments.

(3) Secondary OEA. Apply a 6:1 OCS from the edge of the primary OEA. The OCS origin elevation is equal to the height of the primary OEA boundary directly abeam the obstacle and perpendicular to the segment track. For obstacles located within a turn OEA (see Figure 8-6-37).

(4) Obstacle evaluation. If the OCS is clear, then the standard CG (400 ft/NM) applies. If the OCS is not clear, then take the following actions:

(a) Publish a CG to clear the penetration(s). If CGs exceeds 600 ft/NM, raise the IDF to an altitude where a CG of 600 ft/NM will clear the penetration.

(b) Alternatively, raise the IDF altitude to clear the penetration(s) to accommodate helicopters that cannot meet the climb gradient.

Note: This option will increase the ceiling value at the IDF.

(c) Lastly, design another DP over a different route to achieve a lower CG.

(5) Level Surface. The departure OCS continues to increase until reaching 1,000 ft of ROC for non-mountainous regions (2,000 ft or 1500 ft as required for mountainous regions) to the highest obstacle located within the primary OEA (or secondary equivalent), and round the result to the next higher 100-ft increment. For example, 5,700 ft remains 5,700 ft and 5,701 ft becomes 5,800 ft.

(6) Accuracy standard. The obstacle accuracy for the 20:1 OCS area is 250 ft horizontal/50 ft vertical (Ref: Annex E, 2.11.3 b (3)).

(7) Calculate the ROC over an obstacle, the altitude at which the ROC is achieved, and the resulting required CG using Formula 6-2.

Formula 6-2: ROC/Min Alt/CG

(1) $input\ d,\ d_{secondary},\ OBS_{elev},\ adj,\ aircraft_{SOC}$

(2) $ROC_{OBS} = (250+adj)+\frac{96 \cdot d}{fpnm}$

(3) $OBS_{elev} = if\left[\left(OBS_{elev} - aircraft_{SOC} - \frac{d_{secondary}}{6}\right) \le 0, 0, OBS_{elev} - \frac{d_{secondary}}{6}\right]$

(4) $alt_{min} = OBS_{elev} + ROC_{OBS}$

(5) $CG_{minimum} = \mathrm{ceiling}\left[\frac{r}{d} \cdot \ln\left(\frac{r + alt_{min}}{r + aircraft_{SOC}}\right) \cdot fpnm\right]$

(6) $CG_{required} = \max[400,\ CG_{minimum}]$

(250+adj)+96*d/fpnm
if OBS in secondary, OBS_{elev}= OBS_{elev}- $d_{secondary}$/6
OBS_{elev}+ROC_{OBS}
ceiling(r/d*ln((r+alt_{min})/(r+$aircraft_{SOC}$))*fpnm)
max(400,$CG_{minimum}$)

8.6.10. Obstacle Distance Measurement. Obstacle distance (d) is measured using the shortest distance from each primary area obstacle to the JK line as illustrated in Figure 8-6-37 and Figure 8-6-38. Secondary area obstacles that occur during turn expansions have an obstacle distance that begins at the JK line and ends at the point on the edge of the primary boundary closest to the obstacle. Secondary area obstacles that do not occur during turn expansion have an obstacle distance that begins at the JK line and ends at the point of intersection of a line perpendicular to the flight path passing through the obstacle and boundary of the primary area. Secondary area obstacle evaluations are further reduced based on their distances to the primary edge boundary as shown in Formula 6-2. Detailed steps for obstacle distance measurements and calculations are found below:

a. **Obstacle in the Primary evaluation.** Determine obstacle evaluation distance (d), as the shortest distance within the primary area from the obstacle to the JK line.

b. Obstacle in the Secondary evaluation

(1) Determine the intersecting element of a line drawn from the obstacle to the closest point on the flight path.

(a) If the intersecting element is an arc, determine the Obstacle Primary Point as the closest point on the primary boundary to the obstacle.
(b) If the intersecting element is not an arc, determine the Obstacle Primary Point as the point of intersection between a line drawn from the obstacle perpendicular to the flight path and the Primary Boundary.

(2) Determine obstacle evaluation distance (d), as the shortest distance within the primary area to from the Obstacle Primary Point to the JK line.

(3) Determine distance into the secondary ($d_{secondary}$) as the distance from the obstacle to the Obstacle Primary Point.

Figure 8-6-37: Measuring Obstacle Distance (General)

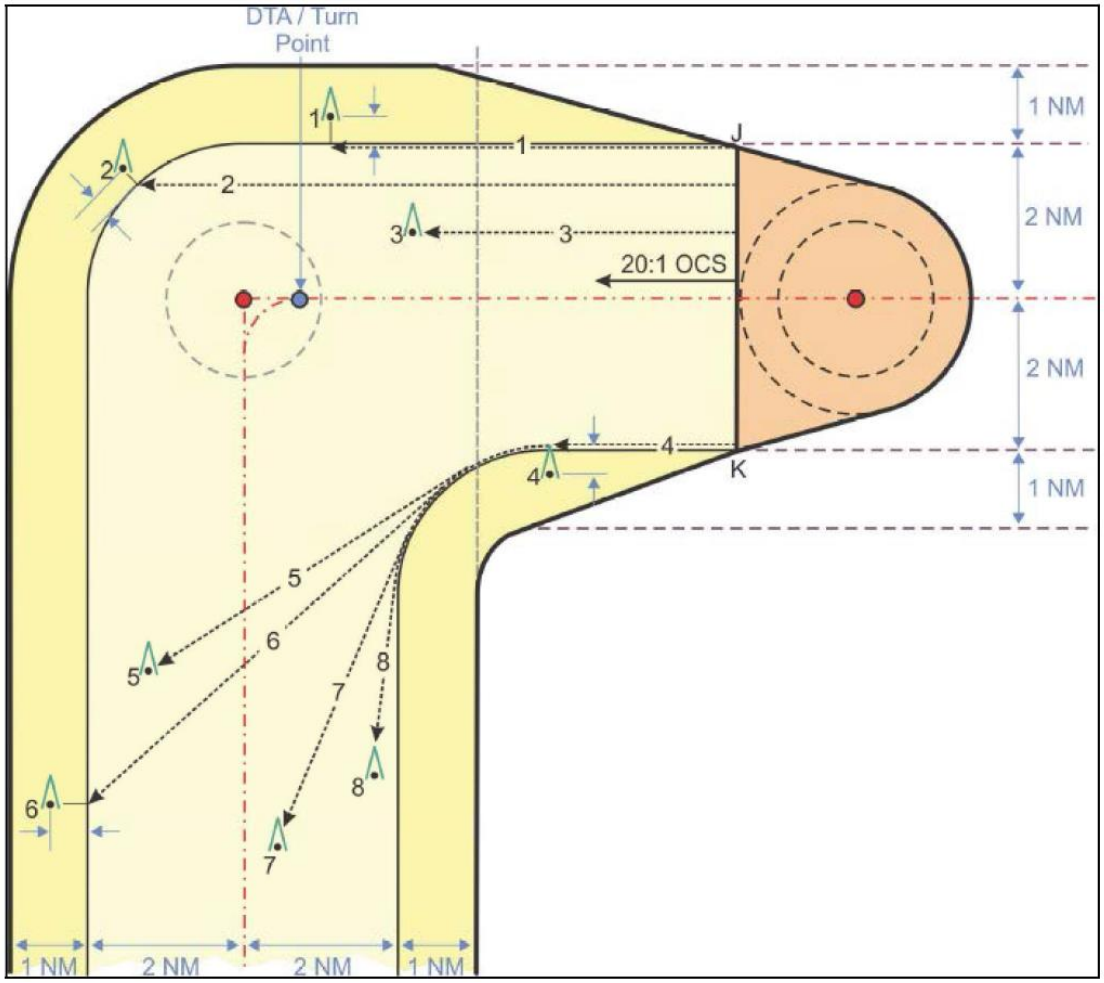


Figure 8-6-38: Reserved

8.6.11. **Reserved.**

Figure 8-6-39 to figure 8-6-42: Reserved.

8.6.12. Weather Minimums. Calculate ceiling and visibility weather minimums required for documenting the RNAV PinS DP.

a. **The minimum ceiling will correspond** with the IFR MSL altitude required at the IDF rounded up to the next higher 100-ft increment, or the highest ARP/HRP elevation rounded up to the next higher 100-ft increment, whichever is higher. For example, 500 ft remains 500 ft and 501 ft becomes 600 ft.

b. **The visibility for a DP** is in accordance with standard VFR minima. (i.e. “Proceed VFR from heliport to IDF”)

Appendix A. Reserved

1. Reserved.

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Appendix B. DF Leg Feasibility Analysis

1. Purpose. This analysis checks the DF leg for feasibility and is separate from the OEA evaluation. It is only intended to be a preliminary screening for flyability and does not ensure OEA construction.

2. Applicability. This analysis applies to DF legs used in departures and missed approaches.

a. DF following turn -at-altitude.

(1) Determine the earliest turn point (TP).

(a) Departure. Measure from the DRP at airport elevation with 1100 ft/NM climb gradient until reaching the earliest climb-to altitude or the DER, whichever occurs first. If the climb-to altitude is not reached by the DER, continue the climb determination starting at the DER using a climb gradient at 500 ft/NM until 10000 feet, then 350 ft/NM until 18000 feet, then 200 ft/NM above 18000 feet.

(b) Missed approach. The earliest TP is line C-D (see section 3-6).

(2) Determine the latest TP.

(a) Departure. Commencing at the DER at DER elevation, the latest TP is where an aircraft reaches the climb-to altitude at a climb gradient of 200 ft/NM or the minimum climb gradient required for obstacle clearance whichever is higher.

(b) Missed approach. Commencing at the start altitude of Section 2 [see paragraph 3.7.1.b], the latest TP is where an aircraft reaches the climb-to altitude at a climb gradient of 200 ft/NM or the minimum climb gradient required for obstacle clearance whichever is higher.

(3) Determine the turn radius. Use the highest altitude in the turn [see paragraph 1.2.5.c].

b. DF following FO fix (applicable to departure only).

(1) Determine the turn points. The early TP is ATT prior to the FO fix. The late TP is ATT + reaction and roll distance [see formula 1-2-12] after the FO fix.

(2) Determine the turn radius. Use the assumed altitude at the fix [see paragraph 1.2.5.c].

3. Analysis. Given the location of the DF leg termination fix and the outbound track from this fix, verify each of the following. When all three conditions are met, the DF leg is feasible.

a. DF fix location. The fix is on or outside all paths from the earliest TP until the latest TP based on the specified turn radius.

b. Turn following fix. The turn at the fix is 90 degrees or less.

c. DTA. Where the fix is a FB, the required DTA is available.

Figure B-1. DF Following Turn-at-Altitude

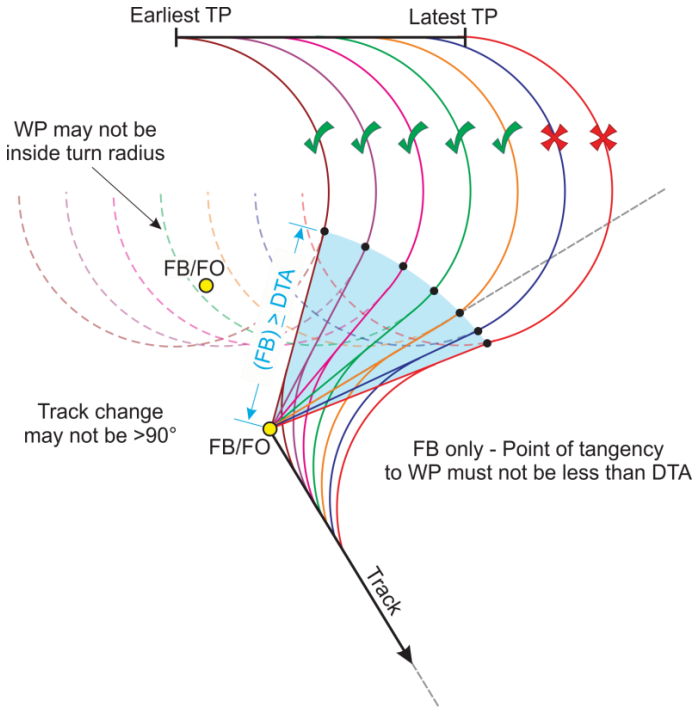
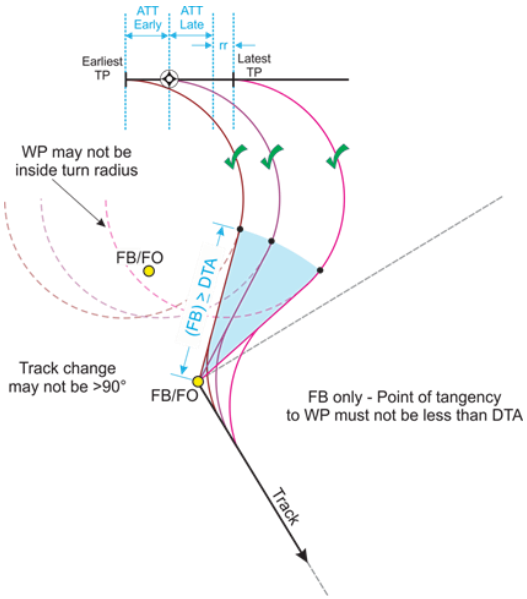


Figure B-2. DF Following FO Fix



Appendix C. PBN Transition to ILS/GLS/LPV Final

1. Purpose. When establishing an intermediate segment that transitions to an ILS/GLS/LPV final, the design must account for high temperature conditions that may cause higher than indicated true altitudes during the glide slope capture.

2. Transition to ILS/GLS/LPV final. Design steps.

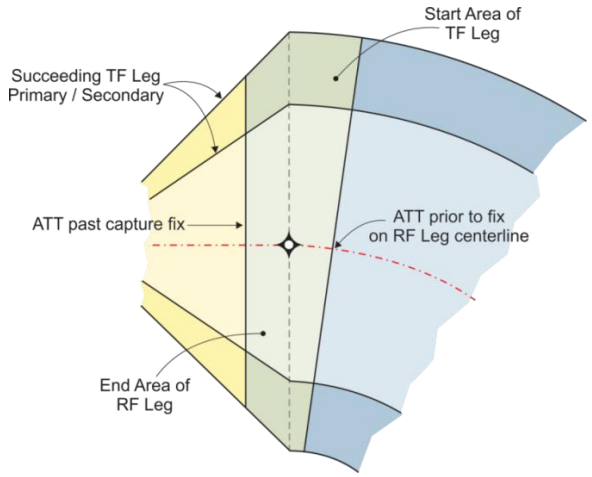
a. *Step 1*. Evaluate the final, intermediate, and initial segments in accordance with the applicable paragraphs, except:

(1) Establish a capture fix. Construct a TF leg aligned with the FAC that is common to all intermediate segments. The start fix of this leg is designated the capture fix. Alternatively where operationally necessary, the capture fix may be placed on or at the start of an RF leg. The preliminary location of the capture fix may be less than 2 NM but no closer than 1 NM prior to the PFAF.

(2) Intermediate OEA.

(a) RNAV (GNSS) construction [see Chapter 3]. The segment remains at full width until reaching 2 NM prior to the PFAF or the capture fix, whichever is closer to the PFAF. The primary and secondary boundaries abeam this point taper uniformly (relative to path) to the X and Y OCS outer boundaries abeam the PFAF. The preceding leg construction follows the tapering boundaries until reaching the appropriate ATT beyond the fix [see figure C-1 for RF example].

Figure C-1. Intermediate OEA, RNAV construction



(b) RNP AR [see chapter 4] and A-RNP [see chapter3] construction. Use the same RNP value throughout the entire intermediate construction and verify that the final segment supports the selected RNP with formula C-1. Where the selected RNP is less than the minimum, increase the RNP or decrease the length of final. The capture leg ends at the plotted position of the PFAF.

Formula C-1. Minimum RNP

$$\mathrm{Min}_{\mathrm{RNP}} = \frac{0.3048 \times \left(\mathrm{FAS}_{\mathrm{Length}} \times 0.10752 + 678.496\right)}{1852 \times 2}$$

Where:

$\mathrm{FAS}_{\mathrm{Length}}$ = length (feet) of the final approach segment

Example:

$$\mathrm{Min}_{\mathrm{RNP}} = \frac{0.3048 \times (50201.07 \times 0.10752 + 678.496)}{1852 \times 2}$$

$$\mathrm{Min}_{\mathrm{RNP}} = 0.5$$

b. Step 2. Specify a mandatory altitude at the capture fix which results in as close to a two-degree descent angle as operationally possible [see formula C-2]. Where the descent angle is greater than two degrees, lengthen the segment and/or alter the preceding segment to provide a lower fix altitude.

Formula C-2. Capture Leg Descent Angle

$$\mathrm{Capture}_{\theta} = \mathrm{atan}\left(\frac{\mathrm{Capture}_{\mathrm{alt}} - \mathrm{PFAF}_{\mathrm{alt}}}{\mathrm{Capture}_{\mathrm{Length}}}\right)$$

Where:

$\mathrm{Capture}_{\mathrm{alt}}$ = MSL altitude (feet) of the capture fix

$\mathrm{Capture}_{\mathrm{Length}}$ = distance (feet) between the capture fix and PFAF

Example:

$$\mathrm{Capture}_{\theta} = \mathrm{atan}\left(\frac{2300 - 2000}{8754.28}\right)$$

$$\mathrm{Capture}_{\theta} \approx 1.96°$$

c. *Step 3.* Calculate the actual aircraft altitude at the capture fix using the default 40°C ΔISA in formula C-3. Alternatively, determine the average hot temperature using a process similar to paragraph 3.3.4.a(1)(a) and calculate its deviation from ISA using formula 3-3-3.

Formula C-3. High Temperature Capture Fix Altitude

$$\text{High}_{\text{alt}} = \frac{(\text{Capture}_{\text{alt}} - \text{LTP}_{\text{elev}}) \times \Delta\text{ISA}_{\text{High}}}{288 + \Delta\text{ISA}_{\text{High}} - 0.5 \times 0.00198 \times \text{Capture}_{\text{alt}}} + \text{Capture}_{\text{alt}}$$

Where:

$\text{Capture}_{\text{alt}}$ = MSL altitude (feet) of the capture fix

$\Delta\text{ISA}_{\text{High}}$ = 40ºC or historical high temperature deviation from ISA

Example:

$$\text{High}_{\text{alt}} = \frac{(2300 - 1000) \times 40}{288 + 40 - 0.5 \times 0.00198 \times 2300} + 2300$$

$\text{High}_{\text{alt}} \approx 2459.64$ feet

d. *Step 4*. Calculate the minimum capture leg length using formula C-4. If the designed length is greater than or equal to the minimum, the design is satisfactory. Otherwise, lengthen the leg and re-evaluate if fix altitudes change.

Formula C-4. Minimum Capture Leg Length

$$\text{Min}_{\text{Length}} = \frac{r \times \pi}{180} \times \left(90 - \theta - \text{asin}\left[\frac{\cos(\theta) \times (r + \text{LTP}_{\text{elev}} + \text{TCH})}{r + \text{High}_{\text{alt}}}\right]\right) - \text{FAS}_{\text{Length}}$$

Where:

High_{alt} = Calculated high temperature capture fix altitude

$\text{FAS}_{\text{Length}}$ = length (feet) of the final approach segment

Example:

$$\text{Min}_{\text{Length}} = \frac{r \times \pi}{180} \times \left(90 - 3 - \text{asin}\left[\frac{\cos(3) \times (r + 1000 + 45)}{r + 2459.65}\right]\right) - 18221.16$$

$\text{Min}_{\text{Length}} \approx 8443.89$ feet

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Appendix D. Radar Vector SID Implementation

1. Purpose. When establishing a radar vector SID certain prerequisites should be considered, the design should account for radar coverage and operational need.

2. Radar Vector SID authorization. The use of a radar vector SID is not authorized when:

a. Radar surveillance is not available.

3. Radar Vector SID application. A radar vector SID that includes a vector leg between routes (Open SID) should only be used when:

a. The initial leg(s) off the runway requires a specific ground track,

b. The intermediate leg(s) is (are) anticipated to require frequent ATC vectoring, and

c. The final (PBN route) leg(s) require(s) a specific ground track.

Table D-1. Cases for Application of Open SID

	Initial (climb) leg(s) A	Intermediate (vector) leg B	Final (PBN route) leg(s) C
Case 1	Terrain or obstacles near the initial climb out path	Requires dispersion of ground tracks to distribute noise footprint	Requires a path to avoid terrain or obstacles terrain
Case 2	Noise sensitive areas or congested airspace near the initial climb out path	Frequently requires ATC intervention to separate departing traffic e.g. from hub/satellite airfields	Joins a PBN route (where containment is assumed at the entry point)
Case 3	Special Use Airspace (e.g., Prohibited or restricted area) near the initial climb out path	Requires attaining a minimum altitude that enables a large angle turn to be accomplished (to reduce DP departure track miles)	Requires a path around airspace

Note: If at least one condition from each of the three vertical columns is present, an Open SID may be considered. For example, where 1A, 1B, and 1C are present or if 1A, 2B, and 3C apply, an Open SID is a viable design option.

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Appendix E. Geospatial Standard

Section 1. General

1. Algorithms and methods. Algorithms and methods are described for calculating geodetic locations (latitudes and longitudes) on the World Geodetic System of 1984 (WGS-84) ellipsoid for PBN procedure construction. These algorithms utilize existing distance and azimuth methods to compute intersections and tangent points. The methods apply corrections to an initial spherical approximation until the error is less than the maximum allowable error.

2. Algorithm format and definitions. The algorithm prototypes and parameter descriptions are given below using a "C-like" syntax. However, the algorithm steps are described in pseudo-code to maintain clarity and readability. Because this appendix is intended for computer application, formulas are expressed in radians.

a. Geodetic locations. For convenience, a structure called LLPoint is used to represent both latitude and longitude of a geodetic coordinate.

b. Geodesic curves. A geodesic curve is the minimal-length curve connecting two geodetic locations. Since the planar geodesic is a straight line, we will often informally refer to a geodesic as a "line." Geodesics will be represented in data using two LLPoint structures.

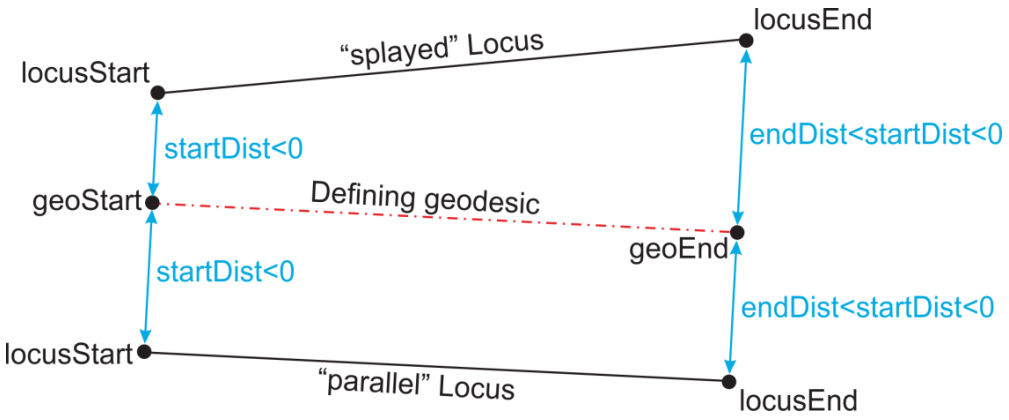
c. Fixed radius arc. A geodetic arc can be defined by a center point and radius distance. The circular arc is then the set (or locus) of points whose distance from the center point is equal to the radius. If an arc subtends an angle of less than 360 degrees, then its start azimuth, end azimuth, and orientation must be specified. The orientation is represented using a value of ±1, with +1 representing a counterclockwise arc and -1 representing a clockwise arc. The distance between the start and end points must be checked. If it is less than a predetermined tolerance value, then the arc will be treated like a complete circle.

d. Locus of points relative to a geodesic. A locus of points relative to a geodesic is the set of all points such that the perpendicular distance from the geodesic is defined by a continuous function w(P) which maps each point P on the geodesic to a real number. For the purposes of procedure design, w(P) will be either a constant value or a linear function of the distance from P to geodesic start point. In the algorithms that follow, a locus of points is represented using the following C structure:

```
typedef struct {
    LLPoint geoStart; /* start point of geodesic */
    LLPoint geoEnd; /* end point of geodesic */
    LLPoint locusStart; /* start point of locus */
    LLPoint locusEnd; /* end point of locus */
    double startDist; /* distance from geodesic to locus at geoStart */
    double endDist; /* distance from geodesic to locus at geoEnd */ int
    lineType; /* 0, 1, or 2 */
} Locus;
```

(1). The startDist and endDist parameters define where the locus lies in relation to the defining geodesic. If (*endDist = startDist*) then the locus will be described as being "parallel" to the geodesic, while if (*endDist ≠ startDist*) then the locus is "splayed." Furthermore, the sign of the distance parameter determines which side of the geodesic the locus is on. The algorithms described in this appendix assume the following convention: if the distance to the locus is positive, then the locus lies to the right of the geodesic; if the distance is negative, then the locus lies to the left. These directions are relative to the direction of the geodesic as viewed from the geoStart point.

Figure E-1. Two Examples Loci Defined Relative to a Single Geodesic



(2). If memory storage is limited, then either the startDist/endDist or locusStart/ locusEnd elements may be omitted from the structure, since one may be calculated from the other. However, calculating them once upon initialization and then storing them will reduce computation time.

(3). The lineType attribute is used to specify the locus's extent. If it is set to 0 (zero), then the locus exists only between geoStart and geoEnd. If (*lineType* = 1) then the locus begins at geoStart but extends beyond geoEnd. If (*lineType* = 2) then the locus extends beyond both geoStart and geoEnd.

3. Ellipsoidal formulas. Ellipsoidal formulas must be used in evaluating fixes, courses, and distance between fixes.

a. WGS-84 parameters. The semi-minor axis (b) is derived from the semi-major axis (a) and flattening parameters (f) using the relation $b = a \times (1 - f)$.

$a = 6{,}378{,}137.0$ meters

$b \approx 6{,}356{,}752.31$ meters

$$f = \frac{1}{298.257223563}$$

b. Direct and inverse algorithms. The Direct and Inverse cases utilize formulae from T. Vincenty's, Survey Review XXIII, No. 176, April 1975: Direct and Inverse Solutions of Geodesics on the Ellipsoid with Application of Nested Equations.

4. Spherical Approximations. An earth radius is needed for spherical approximations. The appropriate radius is the geometric mean of the WGS-84 semi-major and semi-minor axes:

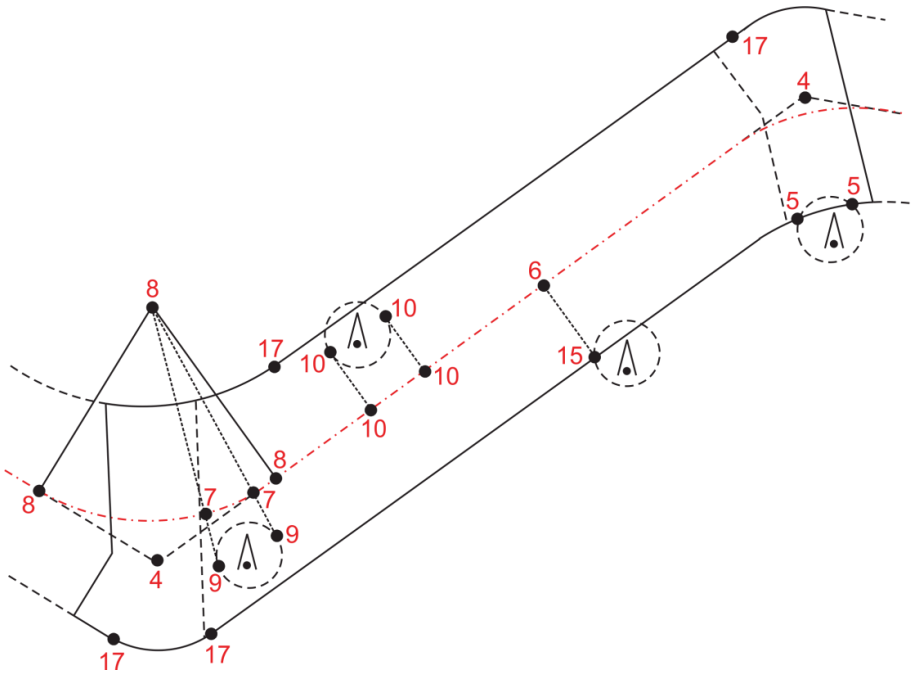
$SPHERE_{RADIUS} = \sqrt{a \times b}$

$SPHERE_{RADIUS} \approx 6{,}367{,}435.68\ meters$

5. Accuracy. Perform calculations to at least 15 significant digits. For the purpose of determining geodetic positions, perform sufficient iterations to converge within 1 cm in distance and 0.002 arc seconds in bearing. A locus of points must lie within 30 cm of the true locus to be considered compliant.

6. Geodetic processes. The following are required for evaluating PBN procedures. The numbers in figure E-2 refer to the process used to solve for the point.

Figure E-2. Geodetic Processes



a. Process 1. Find the destination latitude and longitude, given starting latitude and longitude as well as distance and starting azimuth (often referred to as the "direct" or "forward" calculation).

b. Process 2. Compute the geodesic arc length between two points, along with the azimuth of the geodesic at either point (often referred to as the "inverse" calculation).

c. Process 3. Given a point on a geodesic, find a second geodesic that is perpendicular to the

given geodesic at that point.

d. Process 4. Given two geodesics, find their intersection point(s).

e. Process 5. Given two constant-radius arcs, find their intersection point(s).

f. Process 6. Given a geodesic and a separate point, find the point on the geodesic nearest the given point.

g. Process 7. Given a geodesic and an arc, find their intersection point(s).

h. Process 8. Given two geodesics and a radius value, find the arc of the given radius that is tangent to both geodesics and the points where tangency occurs.

i. Process 9. Given an arc and a point, determine the geodesic(s) tangent to the arc through the point and the point(s) where tangency occurs.

j. Process 10. Given an arc and a geodesic, determine the geodesic(s) that are tangent to the arc and perpendicular to the given geodesic and the point(s) where tangency occurs.

k. Process 11. Compute the length of an arc.

l. Process 12. Determine whether a given point lies on a particular geodesic.

m. Process 13. Determine whether a given point lies on a particular arc.

n. Process 14. Given a geodesic and a locus, find their intersection point.

o. Process 15. Given a fixed-radius arc and a locus, find their intersection point(s).

p. Process 16. Given two loci, find their intersection.

q. Process 17. Given two loci and a radius, find the center of the arc tangent to both loci and the points of tangency.

Section 2. Useful Functions

1. Calculate angular arc extent. When calculating the angle subtended by an arc, one must take into account the possibility that the arc crosses the northern branch cut, where $\mathbf{0}° = \mathbf{360}°$. The following algorithm accounts for this case.

a. Input/Output. double WGS84GetArcExtent(double startCrs, double endCrs, int orientation, double tol) returns a double precision value containing the arc's subtended angle, where the input values are:

(1) double *startCrs* = Azimuth from center to start point of arc

(2) double *endCrs* = Azimuth from center to end point of arc

(3) int *orientation* = Integer that indicates the direction in which the arc is traversed to go from *startCrs* to *endCrs*.

(4) *orientation* = 1 if the arc is traversed counter-clockwise,

(5) *orientation* = -1 if the arc is traversed clockwise.

(6) double *tol* = Maximum error allowed in calculations

b. Algorithm steps.

(1) *Step 1*. If (*abs (startCrs – endCrs) < tol*) then return $2 \times \pi$.

(2) *Step 2*. If (orientation < 0) then orientation is clockwise. Cast the arc into a positive orientation (counter-clockwise) so only one set of calculations is required:

(a) $tremp = startCrs$

(b) *startCrs = endCrs*

(c) $endCrs = temp$

(3) *Step 3*. End if.

(4) *Step 4*. If (*startCrs > endCrs*) then: $angle = startCrs - endCrs.$

(5) *Step 5*. Else: $angle = 2 \times \pi + startCrs - endCrs.$

(6) *Step 6*. End if.

(7) *Step 7*. If (orientation $<$ 0) then: $angle = -angle.$

(8) *Step 8*. Return angle.

2. Converting geodetic latitude/longitude to ECEF coordinates. Geodetic coordinates may be converted to rectilinear ECEF coordinates using the following formulae[1]. Given geodetic latitude ($\boldsymbol{\varphi}$), geodetic longitude ($\boldsymbol{\theta}$), semi-major axis ($\boldsymbol{a}$) and flattening parameter ($\boldsymbol{f}$), calculate the square of the eccentricity $\boldsymbol{e^2 = f \times (2 - f)}$ and the curvature in the prime vertical:

$$N = \frac{a}{\sqrt{1 - e^2 \times sin(\varphi)^2}}$$

The ECEF coordinates are then:

$$x = N \times \cos(\varphi) \times \cos(\theta)$$
$$y = N \times \cos(\varphi) \times \sin(\theta)$$
$$z = N \times (1 - e^2) \times \sin(\varphi)$$

3. Signed azimuth difference. It is often necessary to calculate the signed angular difference in azimuth between two geodesics at the point where they intersect. The following functions casts the difference between two geodesics into the range $[-\boldsymbol{\pi}, \boldsymbol{\pi}]$:

$$SignedAzimuthDifference\ (a_1, a_2) = mod\ (a_1 - a_2 + \boldsymbol{\pi}, 2\boldsymbol{\pi}) - \boldsymbol{\pi}$$

c. This function returns the angle between the two geodesics as if the geodesic that is oriented along azimuth ss_1 were on the positive *x*-axis and the geodesic oriented along azimuth a_2 passed through the origin. In other words, if $SignedAzimuthDifference\ (a_1 a_2) > 0$ azimuth a_2 is to the left when standing at the geodesics' intersection point and facing in the direction of azimuth a_1.

d. The mod function in the definition of signedAzimuthDifference must always return a non-negative value.

Note: The C language's built in fmod function does not have this behavior, so a replacement must be supplied. The following code suffices:

```
double mod(double a, double b) { a
= fmod(a,b);
  if (a < 0.0) a = a + b;
return a;  }
```

4. Approximate fixed radius arc length. Section 3 algorithm 7 describes a method for computing the length of an arc to high precision. The following algorithm provides a solution accurate to one centimeter for an arc whose radius is less than about 300 nautical miles (NM). This algorithm approximates the ellipsoid at the center of the arc in question with a "best fit" sphere, whose radius is computed as the geometric mean of the meridional and prime-vertical curvatures at the arc's center.

[1] Dana, Peter H., "Coordinate Conversion Geodetic Latitude, Longitude, and Height to ECEF, X, Y, Z>", 11 February, 2003

a. Given the arc center's latitude (θ), the ellipsoidal semi-major axis (a) and flattening (f), compute the local radius of curvature R as follows:

$$e^2 = f \times (2 - f)$$

$$M = \frac{a \times (1 - e^2)}{[1 - e^2 \times sin(\theta)^2]^{\frac{3}{2}}}$$

$$N = \frac{a}{\sqrt{1 - e^2 \times sin(\theta)^2}}$$

$$R = \sqrt{M \times N}$$

b. If the radius and subtended angle of the of the constant radius arc are r and A, respectively, then the length of the arc is given by:

$$L = A \times R \times sin\left(\frac{r}{R}\right)$$

Section 3. Basic Calculations

1. Iterative approach. For most of the intersection and projection methods listed below, an initial approximation is iteratively improved until the calculated error is less than the required accuracy. The iterative schemes employ a basic secant method, relying upon a linear approximation of the error as a function of one adjustable parameter. To begin the iteration, two starting solutions are found and used to initialize a pair of two-element arrays.

a. The first array stores the two most recent values of the parameter being adjusted in the solution search. This array is named distarray when the search parameter is the distance from a known point. It is named crsarray when the search parameter is an angle measured against the azimuth of a known geodesic.

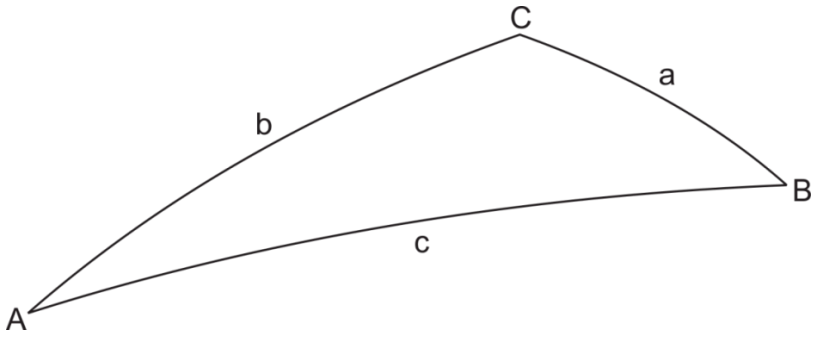
b. The second array (named errarray in the algorithms below) stores the error values corresponding to the two most recent parameter values. Thus, these arrays store a linear representation of the error function. The next solution in each iteration is found by solving for the root of that linear function using the findLinearRoot function. This function returns the value of the search parameter for which the linear error approximation is zero. The returned root is used as the next value in the adjustable parameter and the corresponding error value is calculated. Then the parameter and error arrays are updated and another new root is found.

```
static double findLinearRoot(double* x, double* y, long* err) { if
(x[0] == x[1]) {
    /* function has duplicate x values, no root */
    return x[0];
}
else if (y[0] == y[1]) {
    if (y[0]*y[1] == 0.0) return x[0];
    /* duplicate y values in root function */
    return 0.5*(x[0]+x[1]);
}
    return -y[0]*(x[1]-x[0])/(y[1]-y[0]) + x[0]
}
```

2. Starting solutions. Starting solutions must be provided to start iterating toward a precise solution. Initial solutions may be found in all cases by using spherical triangles to approximate the geodetic curves being analyzed, and then solve for unknown distance and azimuth values using spherical trigonometry formulas.

a. Spherical direction intersection. Given two points A and B and two bearings A to C and B to C, find C.

Figure E-3. Spherical Direction Intersection



(1) *Step 1*. Run Inverse to find arc length from A to B and bearings A to B and B to A. Compute differences of bearings to find angles A and B of the spherical triangle ABC. More than one valid solution may result. Choose the solution closest to the original points.

(2) *Step 2*. Apply the spherical triangle formulas to find the angle C and arc lengths from A to C and from B to C:

$$C = cos^{-1}\left[\cos(A) \times \cos(B) + \sin(A) \times cos\left(\frac{c}{R}\right)\right]$$

$$a = R \times cos^{-1}\left[\frac{\cos(A) + \cos(B) \times cos(C)}{\sin(B) \times \sin(C)}\right]$$

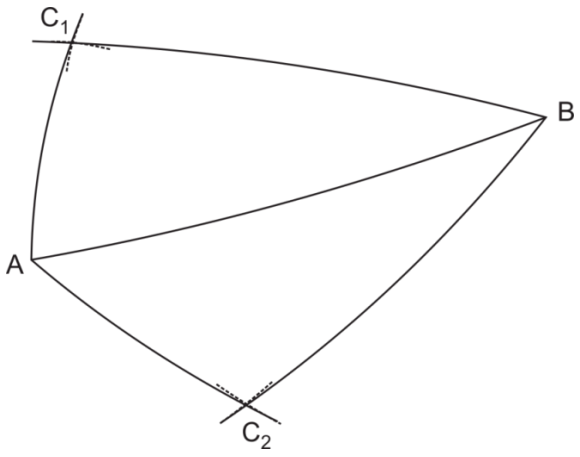
$$b = R \times cos^{-1}\left[\frac{\cos(B) + \cos(A) \times cos(C)}{\sin(A) \times \sin(C)}\right]$$

Note: If distances a or b result from a reciprocal bearing, assign appropriate negative sign(s).

(3) *Step 3*. Run Direct from A to find C. Use given bearing and computed length b.

b. Spherical distance intersection. Given A, B and distances AC and BC, find C_1 and C_2.

Figure E-4. Spherical Distance Intersection



(1) *Step 1*. Run Inverse to find length and bearings between A and B. Use spherical triangles to find angles $A = BAC_1 = BAC_2$, $B = ABC_1 = ABC_2$, and $C = BC_1A = BC_2A$:

$$A = cos^{-1}\left[\frac{\cos\left(\frac{a}{R}\right) - \cos\left(\frac{b}{R}\right) \times cos\left(\frac{c}{R}\right)}{\sin\left(\frac{b}{R}\right) \times \sin\left(\frac{c}{R}\right)}\right]$$

$$B = cos^{-1}\left[\frac{\cos\left(\frac{b}{R}\right) - \cos\left(\frac{a}{R}\right) \times cos\left(\frac{c}{R}\right)}{\sin\left(\frac{a}{R}\right) \times \sin\left(\frac{c}{R}\right)}\right]$$

$$C = cos^{-1}\left[\frac{\cos\left(\frac{c}{R}\right) - \cos\left(\frac{a}{R}\right) \times cos\left(\frac{b}{R}\right)}{\sin\left(\frac{a}{R}\right) \times \sin\left(\frac{b}{R}\right)}\right]$$

(2) *Step 2*. Run Direct from A to find C_1 and C_2.

(a) To compute the bearing from A to C_1, start with the bearing from A to B and subtract angle A.

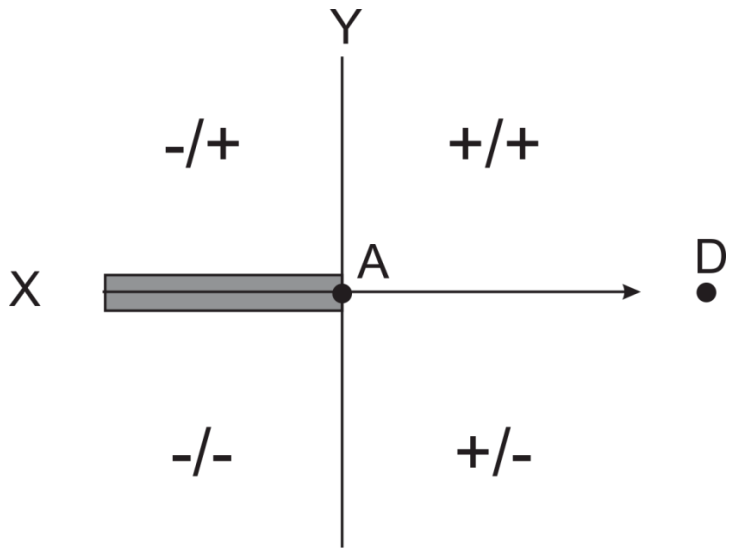
(b) To compute the bearing from A to C_2, start with the bearing from A to B and add angle A.

(3) *Step 3*. Use Inverse and spherical triangle formulas to get remaining bearings.

c. Spherical tangent point.

(1) Distance signs. In both cases of the tangent point, distances are signed according figure E-5, where the arrow indicates the bearing from the first point A to the target point D.

Figure E-5. Distance Signs



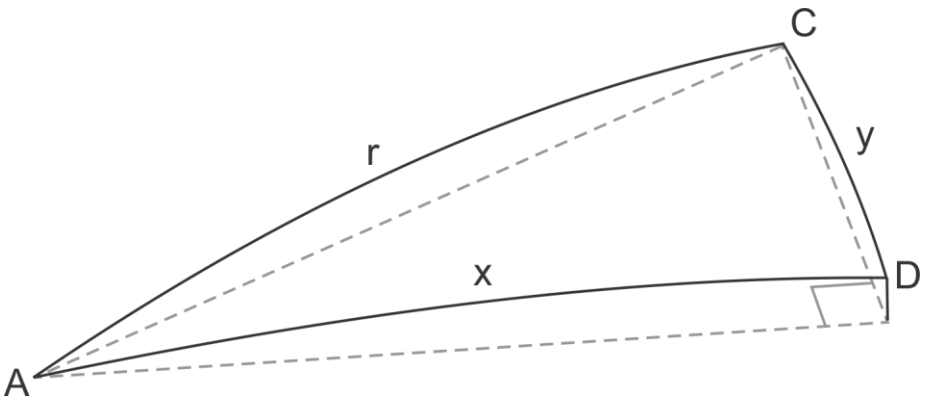
(2) Right spherical triangle. Calculate lengths y and x of the right spherical triangle with the following formulas:

$$y = R \times sin^{-1}\left[\sin\left(\frac{r}{R}\right) \times \sin(A)\right]$$

$$x = R \times cos^{-1}\left[\frac{\cos\left(\frac{r}{R}\right)}{\cos\left(\frac{y}{R}\right)}\right]$$

(3) Given two points and a bearing. Given two points, A and C, and a bearing from the first point (A), find the point D along the given bearing extended which is closest to C.

Figure E-6. Two Points and a Bearing



(a) *Step 1*. Run Inverse to find length and bearings between A and C.

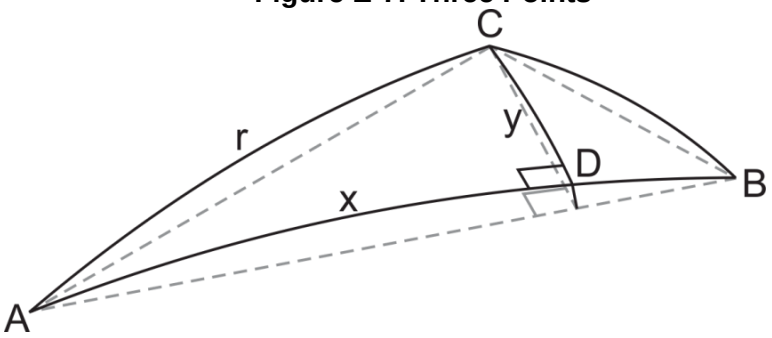
1. Find difference in bearings to compute angle A.

2. Use right spherical triangles to calculate y and x.

(b) *Step 2*. Run Direct from A to find D using given bearing and computed length x.

(4) Given three points. Given three points (A, B, C), find the point (D) on the geodesic line from the first two points which is the perpendicular foot from the third point.

Figure E-7. Three Points



(a) *Step 1*. Use Inverse to determine bearing from A to B.

(b) *Step 2*. Use Inverse to determine bearing and length from A to C.

(c) *Step 3*. Find the difference in bearings to determine angle A.

(d) *Step 4*. Use right spherical triangles to calculate y and x.

(e) *Step 5*. Use Direct to calculate D from A using the computed bearing from A to B and computed distance x.

3. Tolerances. Two different convergence tolerances must be supplied so that the algorithms cease iterating once the error becomes sufficiently small.

a. Forward and inverse. The first tolerance parameter is used in the forward and inverse routines; it is referred to as eps in the algorithm descriptions. Empirical studies have shown that $\text{eps} = 0.5 \times e^{-13}$ works well.

b. Intersection and projection. The second parameter, labeled tol, is used in the intersection and projection routines to limit the overall error in the solution. Since the intersection and projection routines make multiple calls to the forward and inverse algorithms, the eps parameter should be several orders of magnitude smaller than the tol parameter to ensure that the iteration methods return correct results. Empirical studies have shown that $\text{tol} = 1.0 \times e^{-9}$ works well.

c. Maximum iterations. A maximum iteration count must be supplied to ensure that no algorithms can remain in an infinite loop if convergence is not reached. This parameter can be set by the programmer, but should be greater than five to ensure that all of the algorithms can reach convergence.

4. Geodesic oriented at specified angle. In TP 308/GPH 209 procedure design, it is often required to find a geodesic that lies at a prescribed angle to another geodesic. For instance, the end lines of an obstacle evaluation area (OEA) are typically projected from the flight path at a prescribed angle. Since the azimuth of a geodesic varies over the length of the curve, the angle between two geodesics must be measured by comparing the azimuth of each geodesic at the point where they

intersect. The following pseudo-code represents an algorithm that will calculate the correct azimuth at any point on a geodesic described by its start and end points. This azimuth can easily be extended to find the azimuth of an intersecting geodesic at the point if the angle of intersection is known.

a. Input/Output. double WGS84GeodesicCrsAtPoint(LLPoint startPt, LLPoint endPt, LLPoint testPt, int length, double* startCrs, double* revCrs, double* distToPt, long* err, double tol, double eps) returns a double representing the azimuth of the intersecting geodesic, where the inputs are:

(1) LLPoint startPt = Coordinates of start point of given geodesic

(2) LLPoint endPt = Coordinates of end point of geodesic

(3) LLPoint testPt = Point at which course of geodesic is to be determined

(4) double* startCrs = Azimuth of geodesic at startPt in radians

(5) double* revCrs = Reciprocal azimuth of geodesic at endPt in radians

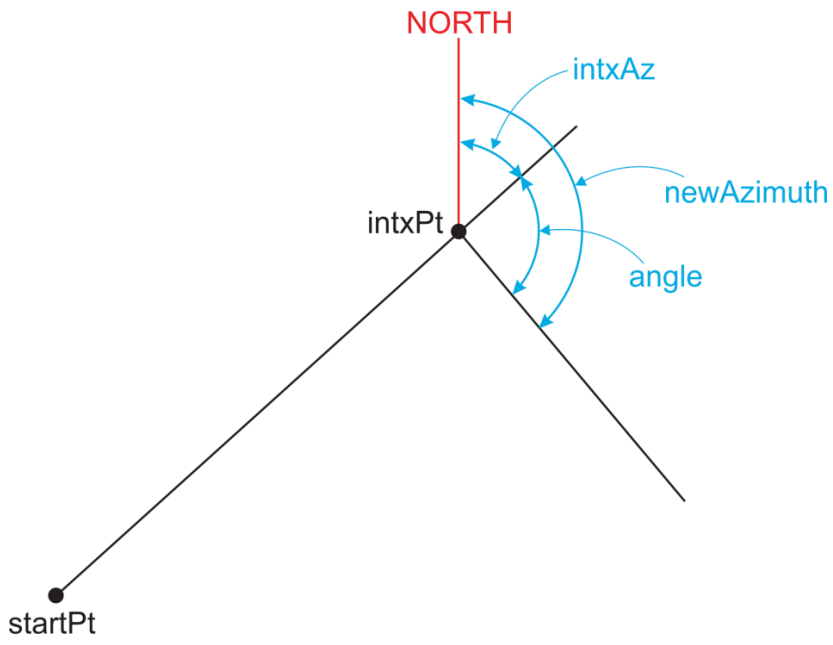
(6) double* distToPt = Distance from startPt to testPt in NM

(7) double tol = Accuracy tolerance for intersection calculation

(8) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

Figure E-8. Projecting a Geodesic Through a Point Along the Specified Azimuth



(1) *Step 1*. Use the WGS84PtIsOnLine algorithm to check that testPt actually lies on geodesic defined by startPt and endPt.

(2) *Step* 2. Use Inverse algorithm to determine course and distance from testPt to startPt. Denote course as crsToStart.

(3) *Step 3*. Use Inverse algorithm to determine course and distance from testPt to endPt. Denote course as crsToEnd.

(4) *Step 4*. If testPt lies on geodesic between startPt and endPt, then the correct azimuth is crsToEnd.

(5) *Step 5*. If testPt lies on the geodesic beyond endPt, then the correct azimuth is crsToStart + π.

(6) *Step 6*. Return the calculated azimuth.

Note: If an angle is positive, then the new geodesic will lie to the right of the given geodesic (from the perspective of standing at the start point and facing toward the end point); otherwise, the new geodesic will lie to the left.

5. Determine if point lies on geodesic. This algorithm returns a true value if a point lies on and within the bounds of a given geodesic. The bounds of the geodesic are specified by two pieces of information: the end point coordinates and an integer length code. If the length code is set to 0, then the geodesic is understood to exist only between its start and end points, so a value of true will be returned only if the test point also lies between the start and end points. If the length code is set to 1, then the geodesic is understood to extend beyond its end point to a distance of one half of earth's circumference from its end point. If the length code is set to 2, then the geodesic is understood to extend beyond both the start and end points. This algorithm relies on the concept of equality for two LLPoint structures. This will be defined to mean that the distance between the two LLPoints, as calculated using the inverse algorithm, is less than tol.

a. Input/Output. int WGS84PtIsOnLine(LLPoint startPt, LLPoint endPt, LLPoint testPt, LineType lengthCode, double tol, double eps) returns an integer value indicating whether testPt lies on geodesic, where the inputs are:

(1) LLPoint startPt = Geodetic coordinate of line start point

(2) LLPoint endPt = Geodetic coordinate of line end point

(3) LLPoint testPt = Geodetic coordinate of point to test

(4) LineType lengthCode = Integer that specifies extent of line.

(a) 0: geodesic exists only between startPt and endPt.

(b) 1: geodesic extends beyond endPt.

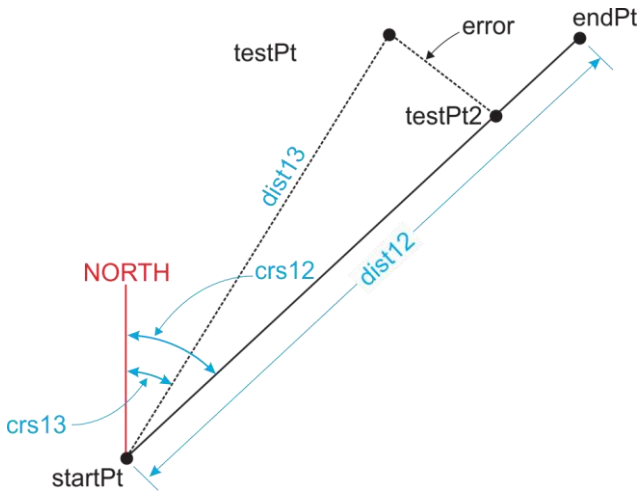
(c) 2: geodesic extends behind startPt.

(5) double tol = Maximum difference allowed in distance

(6) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

Figure E-9. Entities for Testing Whether a Point Lies on a Geodesic



(1) *Step 1*. Use inverse algorithm to calculate the azimuth and distance from startPt to endPt. Denote these values by crs12 and dist12, respectively.

(2) *Step 2*. Use WGS84PtIsOnCrs algorithm to determine if testPt lies on geodesic given by startPt and endPt:

(a) Use inverse algorithm to calculate the distance from startPt to testPt. Denote this value by tmpDist1Test.

(b) Use direct algorithm to project a point from startPt, along crs12, a distance equal to tmpDist1Test. Denote this point by comparePt.

(c) Use WGS84PointsAreSame algorithm to determine if testPt is equal to comparePt.

(3) *Step 3*. Examine error to determine whether testPt lies on the geodesic within tol as follows:

(a) If ($error \leq tol$) then,

1. If ($lengthCode > 0$) or ($dist13 - dist12 \leq tol$) then $online = true$.

2. Else *online* = *false*.

(b) End if.

(c) If (*lengthCode* = 2),

1. Use the direct algorithm to project point from startPt, along $crs12 + \pi$ a distance dist13. Again, denote this point again by testPt2.

2. Use the inverse algorithm to recalculate error, which is the distance from testPt to testPt2.

3. If ($error \leq tol$) then $online = true$, Else $online = false$.

(d) End if.

6. Determine if point lies on arc. This algorithm returns a non-zero (true) value if the sample point lies on and between the bounds of the given arc. The arc is defined by its center point, radius, start azimuth, end azimuth, and orientation. A positive orientation parameter indicates that the arc is traversed in a counterclockwise sense, while a negative orientation parameter indicates that the arc is traversed clockwise. This algorithm is used in conjunction with the arc intersection functions (section 5 algorithms 2, 3, and 6) to determine whether the computed intersections lie within the bounds of the desired arc.

a. Input/Output. int WGS84PtIsOnArc(LLPoint center, double radius, double startCrs, double endCrs, ArcDirection orientation, LLPoint testPt, double tol) returns an integer value indicating whether testPt lies on arc, where the inputs are:

(1) LLPoint center = Geodetic coordinates of arc center

(2) double radius = Arc radius

(3) double startCrs = True azimuth from center to start of arc

(4) double endCrs = True azimuth from center to end of arc

(5) ArcDirection orientation = Orientation of the arc [+1 for counter-clockwise; -1 for clockwise]

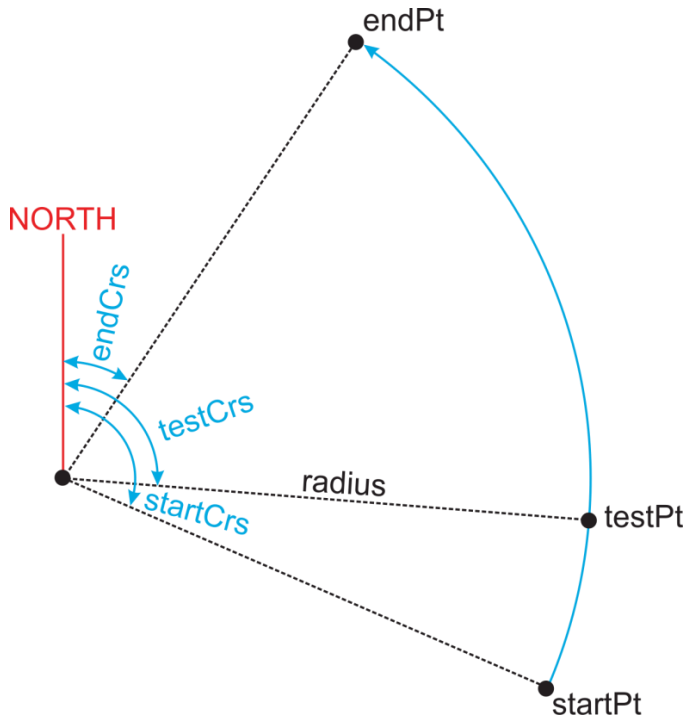
(6) LLPoint testPt = Geodetic coordinate of point to test

(7) double tol = Maximum error allowed in solution

(8) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

Figure E-10. Entities for Testing Whether a Point Lies on an Arc



(1) *Step 1*. Use inverse algorithm to calculate distance and azimuth from center to testPt. Denote values as dist and crs, respectively.

(2) *Step 2*. If ($abs\ (dist - radius) > tol$) then testPt is not correct distance from center, onArc = false.

(3) *Step 3*. Else

(a) Use section 2 algorithm 1, Calculate Angular Arc Extent, to calculate the angle subtended by the full arc. Denote this value by arcExtent.

(b) If ($arcExtent = 360°$) then $onArc = true$.

(c) Else

1. Use the inverse algorithm to calculate the azimuth from center to testPt. Denote this value by testCrs.

2. Use section 2 algorithm 1, Calculate Angular Arc Extent, to calculate the angle subtended by and arc starting at startCrs, but ending at testCrs, with the same orientation. Denote this value by subExtent.

3. If ($-.002 \leq subExtent \leq arcExtent + .002$) then traversing arc from startCrs to endCrs, one

would encounter testPt, so it must lie on arc, *onArc = true*.

(d) End if.

(4) *Step 4*. End if.

7. Calculate length of fixed radius arc. A fixed radius arc on an ellipsoid does not generally lie in a plane. Therefore, the length of the arc cannot be computed using the usual formula for the circumference of a circle. The following algorithm takes the approach of dividing the arc into many sub-arcs. Three points are then calculated on each sub-arc. Since any three points in space uniquely determine both a plane and an arc, the three points on each sub-arc are used to calculate the radius and subtended angle of the planar arc that contains all three points. The length of the approximating planar arc is then calculated for each sub-arc. The sum of the sub-arc lengths approaches the length of the original arc as the number of sub-arc increases (and each sub-arc's length decreases). A simpler method that is sufficiently accurate for arcs with radius less than about 300 NM is described in section 2 algorithm 4.

a. Input/Output. double WGS84DiscretizedArcLength (LLPoint center, double radius, double startCrs, double endCrs, int orient, int *n, double tol) returns a double precision value representing the length of the arc, where the inputs are:

(1) LLPoint center = Geodetic coordinates of arc center

(2) double radius = Arc radius

(3) double startCrs = True azimuth from center to start of arc

(4) double endCrs = True azimuth from center to end of arc

(5) int orient = Orientation of the arc [+1 for counter-clockwise; -1 for clockwise]

(6) int *n = Reference to integer used to return number of steps in discretized arc

(7) double tol = Maximum allowed error

(8) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

Figure E-11. Calculating Arc Length

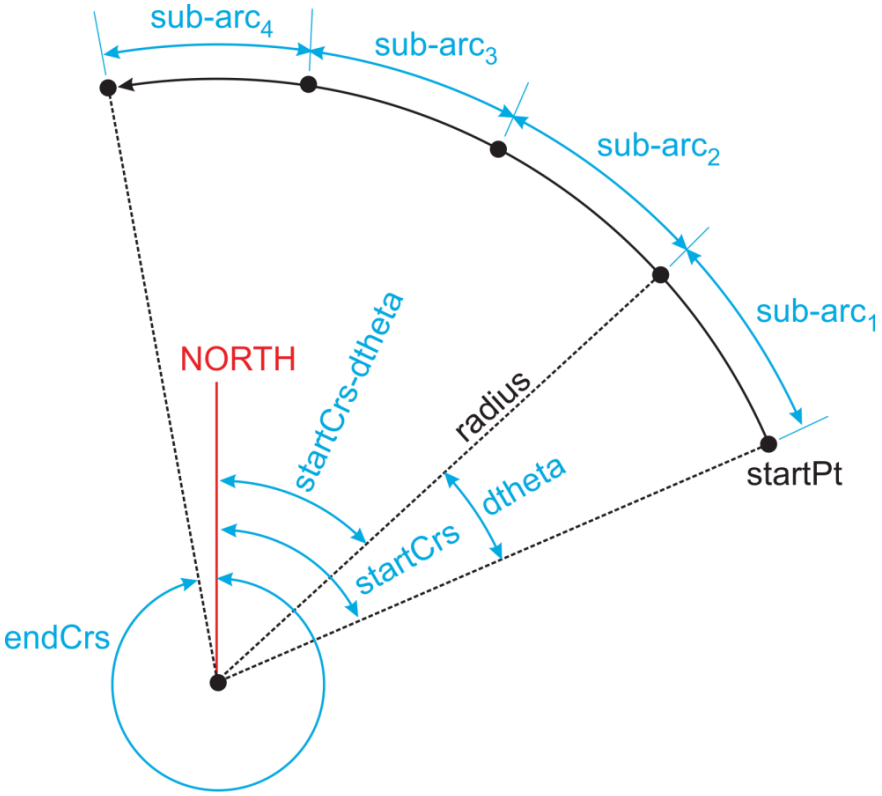
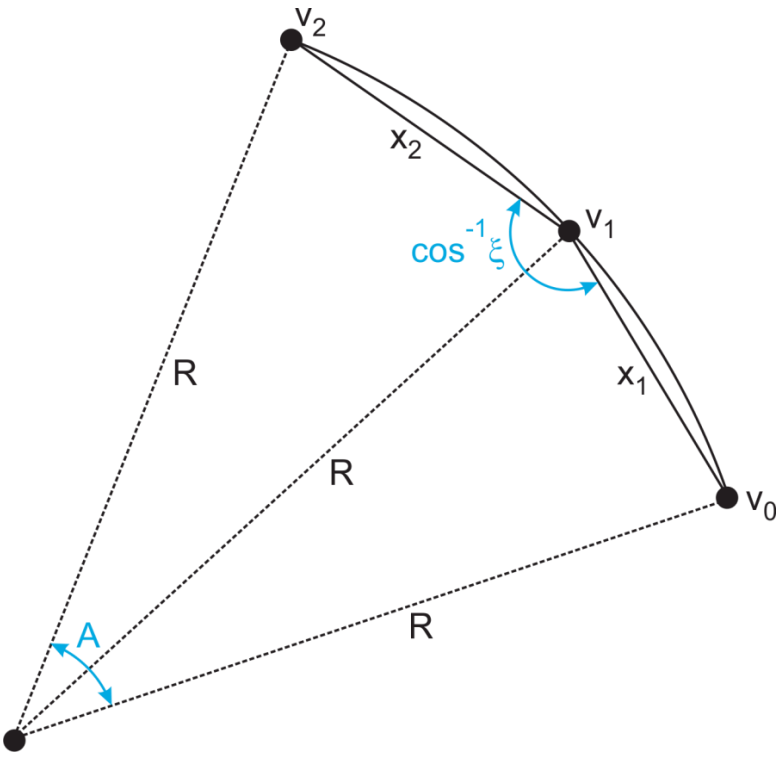


Figure E-12. Calculating the Sub-Arc Length



(1) *Step 1*. Set initial number of sub-arcs to use. The fixed value $n = 16$ has been found through trial-and-error to be a good starting value. Alternatively, the initial value of n may be calculated based on the arc's subtended angle and its radius (i.e., its approximate arc length).

(2) *Step 2*. Convert center point to Earth-Centered, Earth-Fixed (ECEF) coordinates, v0 according to section 2 algorithm 2.

(3) *Step 3*. Compute subtended angle, subtAngle, using section 2 algorithm 1.

(4) *Step 4*. Set iteration count, $k = 0$.

(5) *Step 5*. Do while k = 0 or ($error > tol$) and ($k \leq maximumIterationCount$)

(a) Calculate subtended angle of each sub-arc, $dtheta = subAgle/n$

(b) Use direct algorithm from center, using startCrs and distance radius, to project start point of arc. Denote this point by p1.

(c) Convert p1 to ECEF coordinates. Denote this vector by v1.

(d) Initialize $arcLenth = 0$.

(e) For $ee = 0$ to n:

1. Compute azimuth from arc center to end point of sub-arc number i: $theda = startCrs + i \times dtheta$.

2. Use direct algorithm from center, using azimuth $theta + 0.5 \times dtheta$ and distance radius, to project middle point of sub-arc. Denote this point by p2.

3. Convert p2 to ECEF coordinate v2.

4. Use direct algorithm from center, using azimuth $theta + dtheta$ and distance radius, to project endpoint of sub-arc. Denote this point by p3.

5. Convert p3 to ECEF coordinate v3.

6. Subtract v2 from v1 to find chord vector between p1 and p2. Denote this vector by chord1. Compute $x1 = |chord1|$.

7. Subtract v2 from v3 to find chord vector between p3 and p2. Denote this vector by chord2. Compute $x2 = |chord2|$.

8. Compute dot product of chord1 and chord2. Denote this value as d.

9. Use the following calculation to compute the length L of the sub-arc:

a. $xi = \frac{d}{x1 \times x2}$

b $sigma = \sqrt{1 - xi^2}$

c $R = \frac{x2 \times \sqrt{\left(\frac{x1}{x2} - xi\right)^2 + sigma}}{2 \times sigma}$

d $A = 2 \times [\pi - acos(xi)]$

e $L = R \times A$

$1\ \xi = \frac{d}{x_1 \times x_2}$

$2\ \sigma = \sqrt{1 - \xi^2}$

$3\ R = \frac{x_e \times \sqrt{\left(\frac{x_1}{x_2 - \xi}\right)^2 + \sigma^2}}{2 \times \sigma}$

$4\ A = 2 \times [\pi - cos^{-1}(\xi)]$

Note: Since the arc length is a planar (not geodetic) calculation, the subtended angle A is not equal to dtheta.

10. Add L to cumulative length to get total length of sub-arcs through sub-arc number i: $length = length + L$.

(f) End for loop.

(g) Compute error, which is the change in length calculation between this iteration and the last: $error = abs(length - oldlength)$.

(h) Increment the iteration count: $k = k + 1$.

(i) Double the number of sub-arcs: $n = 2 \times n$.

(j) Save the current length for comparison with the next iteration:

$oldlength = length$.

(6) *Step 6*. End while loop.

(7) *Step 7*. Return length.

8. Find distance from defining geodesic to locus. When computing a position on a locus of points, it is necessary to solve for the distance from the defining geodesic to the locus. This distance is constant if the locus is designed to be "parallel" to the defining geodesic. However, it is necessary to allow the locus distance to vary linearly with distance along the geodesic, since in some cases the locus will splay away from the defining geodesic. To account for this, we have included startDist and endDist attributes in the Locus structure defined above. For a given point

on the geodesic (or given distance from the geodesic start point), the distance to the locus can then be calculated. The two algorithms described below carry out the computation of locus distance for different input parameters. If the distance from the geodesic start point to the point of interest is known, then WGS84DistToLocusD may be used to calculate the locus distance. If instead a point on the defining geodesic is given, the WGS84DistToLocusP may be used. The latter algorithm simply computes the distance from the geodesic start point to the given point and then invokes the former algorithm. Therefore, steps are described for WGS84DistToLocusD only.

a. Input/Output.

(1) double WGS84DistToLocusD (Locus loc, double distance) returns the distance from the defining geodesic to the locus at the given distance from loc.geoStart, where the inputs are:

(a) Locus loc = Locus of interest

(b) double distance = Distance from locus start point to point where distance is to be computed

(2) double WGS84DistToLocusP (Locus loc, LLPoint geoPt, double *faz, double tol, double eps) returns the distance from the defining geodesic to the locus at the given point, where the inputs are:

(a) Locus loc = Locus of interest

(b) LLPoint geoPt = Point on defining geodesic

(c) double *faz = Pointer used to return forward azimuth of geodesic at geopt. This is needed if geopt is not between geoStart and geoEnd.

(d) double tol = Maximum allowable error

(e) double eps = Convergence parameter for forward/inverse algorithm

b. Algorithm steps. The following steps are followed if the distance from loc.geoStart is given. If a point on the geodesic (geoPt) is given instead, then first use the inverse algorithm to compute the distance from geoPt to loc.geoStart and then follow the following steps (note that distance must be signed negative if the locus's line type is 2 and geoPt is farther from geoEnd than it is from geoStart):

(1) *Step 1*. Use the inverse function to compute the length of the locus's defining geodesic. Denote this value as geoLen.

(2) *Step 2.* If ($geoLen = 0$) then $distToLoc = 0.0$.

(3) *Step 3*. Else.

$$distToLoc = loc.startDist + \frac{distance}{geoLen} \times (loc.endDist - loc.startDist)$$

(4) *Step 4*. End if.

(5) *Step 5*. Return distToLoc.

9. Determine if point lies on locus. This algorithm compares the position of a given point with the position of the corresponding point on the locus. The corresponding point on the locus is found by projecting the given point onto the locus's defining geodesic curve, computing the correct distance from there to the locus, and then projecting a point at that distance perpendicular to the geodesic. If distance from the corresponding point to the given point is less than the error tolerance, then a reference to the projected point on the geodesic is returned. Otherwise a null reference is returned. An alternative implementation could simply return true or false, rather than references. However, it is more efficient to return the projected point as this is often needed in subsequent calculations.

a. Input/Output. int WGS84PtIsOnLocus (Locus loc, LLPoint testPt, LLPoint* ptOnGeo, double tol, double eps) returns a reference to the projection of testPt on the locus's defining geodesic if testPt lies on the locus and NULL otherwise, where the inputs are:

(1) Locus loc = Locus of Interest

(2) LLPoint testPt = Point to test against locus

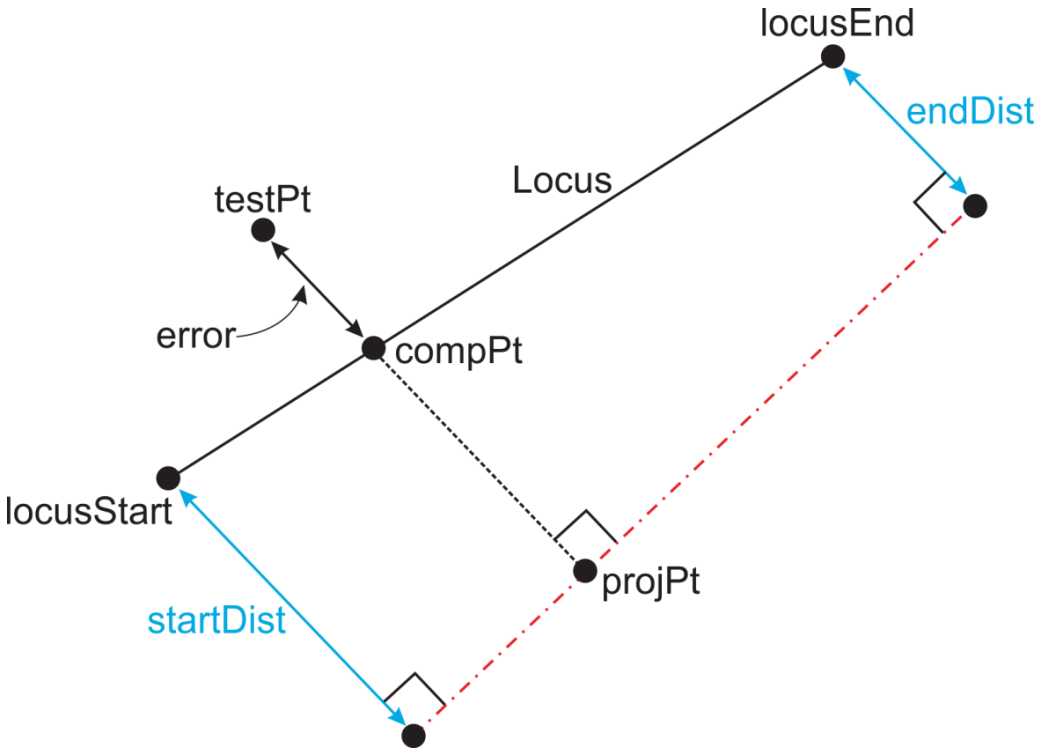
(3) LLPoint* ptOnGeo = Pointer to LLPoint, updated with point on defining geodesic abeam the given point on the locus.

(4) double tol = Maximum allowable error

(5) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

Figure E-13. Locating a Point Relative to a Locus



(1) *Step 1*. If testPt is the same as loc.geoStart or loc.geoEnd then return a reference to ptOnGeo containing the appropriate point.

(2) *Step 2*. Use section 4 algorithm 1 to project testPt onto the locus's defining geodesic. Denote the projected point as ptOnGeo.

(3) *Step 3*. Use section 3 algorithm 5 to determine whether ptOnGeo lies on the locus's defining geodesic. This will account for an infinite or semi-infinite locus. If it does not, then return 0 (false).

(4) *Step 4*. Use the inverse algorithm to find the course between loc.geoStart and testPt. Use this course to determine which side of the locus testPt falls. Apply the appropriate sign to this distance, distFromPoint.

(5) *Step 5*. Use section 3 algorithm 8 to calculate the correct expected locus distance, locDist.

(6) *Step 6*. If ($abs\ (distFromPoint - locDist) \leq tol$) then the point is on the locus.

Return a reference to the projection on the defining geodesic.

10. Compute course of locus. This algorithm is analogous to the inverse algorithm for a geodesic. It is used by other locus algorithms when the direction of the locus is needed.

a. Input/Output. double WGS84LocusCrsAtPoint (Locus loc, LLPoint testPt, LLPoint* geoPt, double* perpCrs, double tol) returns the course of the locus at the given point. Also sets values of calculation byproducts, including the corresponding point on the locus's geodesic and the course from the given point toward the geodesic point, where the inputs are:

(1) Locus loc = Locus of Interest

(2) LLPoint testPt = Point at which course will be calculated

(3) LLPoint* geoPt = Projection of testPt on defining geodesic

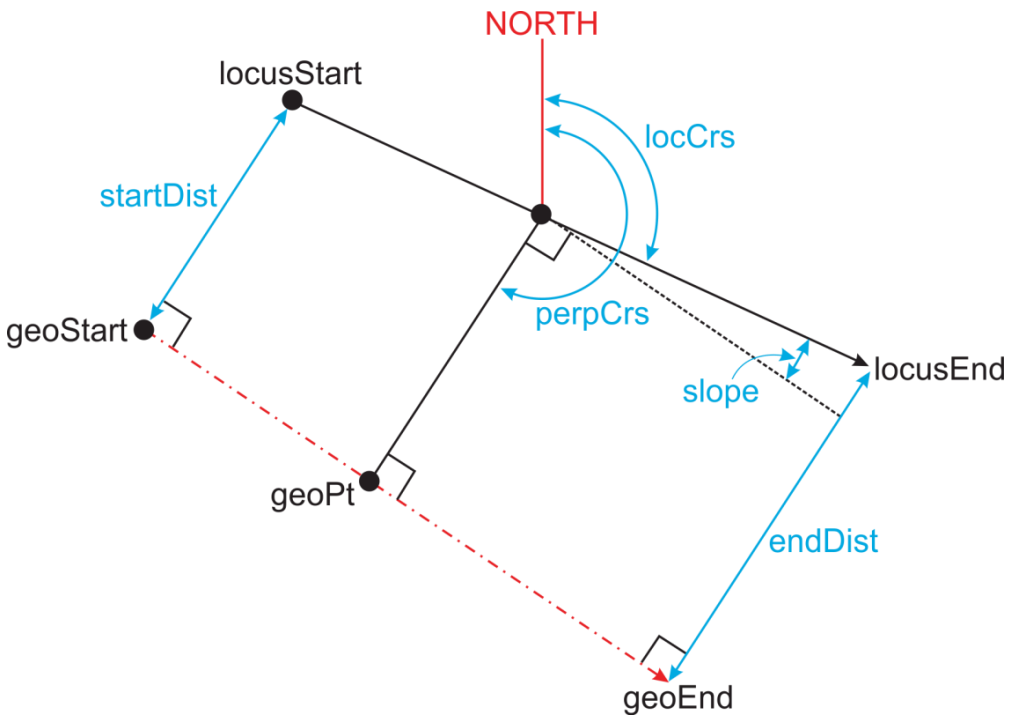
(4) double* perpCrs = Course for testPt to geoPt

(5) double tol = Maximum allowable error

(6) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

Figure E-14. Angle Used to Calculate the Course of a Locus



(1) *Step 1*. Use section 3 algorithm 9 to determine whether testPt lies on loc. This same step will return a reference to the projection of testPt onto the defining geodesic. Denote this reference as geoPt.

(2) *Step 2*. If (*geoPt = NULL*) then testPt is not a valid point at which to calculate the locus's course. Return -1.0. (Valid course values are in the range $[0, 2 \times \pi]$.)

(3) *Step 3*. Use the inverse algorithm to calculate the course and distance from testPt to geoPt, denoted by perpCrs and perpDist, respectively.

(4) *Step 4*. Use section 3 algorithm 8 to calculate distToLoc, the distance from the geodesic to the locus at geoPt. This step is required to determine which side of the geodesic the locus lies on because perpDist will always be positive.

(5) *Step 5*. Calculate the slope of the locus relative to the geodesic:

$$slope = \frac{loc.endDist - loc.startDist}{geoLen}$$

(6) *Step 6*. Convert the slope to angular measure in radians:

$$slope = atan(slope)$$

(7) *Step 7*. Adjust the value of the perpendicular course by slope. This accounts for how the locus is approaching or receding from the geodesic: $lleessllssssee = lleessllssssee + eellttllee$

(8) *Step 8*. If (*distToLoc* < 0) then testPt lies to the left of the geodesic, so *perpCrs* points to the right of the locus's course: $locCrs = perpCrs - \pi/2$

(9) *Step 9*. Else testPt lies to the right of the geodesic so *perpCrs* points to the left of the locus's course: $locCrs = perpCrs - \pi/2$

(10) *Step 10*. Return locCrs.

Section 4. Projections

(4) **Project point to geodesic.** This algorithm is used to determine the shortest distance from a point to a geodesic. It also locates the point on the geodesic that is nearest the given point.

a. Input/Output. long WGS84PerpIntercept (LLPoint pt1, double crs12, LLPoint* pt2, LLPoint pt3, double* crsFromPoint, double* distFromPoint, double tol) returns a reference to an LLPoint structure that contains the coordinates of the projected point, where the inputs are:

(1) LLPoint pt1 = Coordinates of geodesic start point

(2) double crs13 = Initial azimuth of geodesic at start point

(3) LLPoint pt3 = Coordinates of point to be projected to geodesic

(4) LLPoint* pt2 = Reference to LLPoint that will be updated with coordinates of projected point.

(5) double* crsFromPoint = Reference to azimuth of geodesic from pt3 to projected point, in radians.

(6) double* distFromPoint = Reference to distance from pt3 to projected point, in radians.

(7) double tol = Maximum error allowed in solution

(8) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps. This algorithm treats the geodesic as unbounded, so that projected points that lie “behind” the geodesic starting point pt1 will be returned. If it is desired to limit solutions to those that lie along the forward direction of the given geodesic, then *Step 4(g)* may be modified to return a NULL solution.

Figure E-15. Projecting a Point to a Geodesic

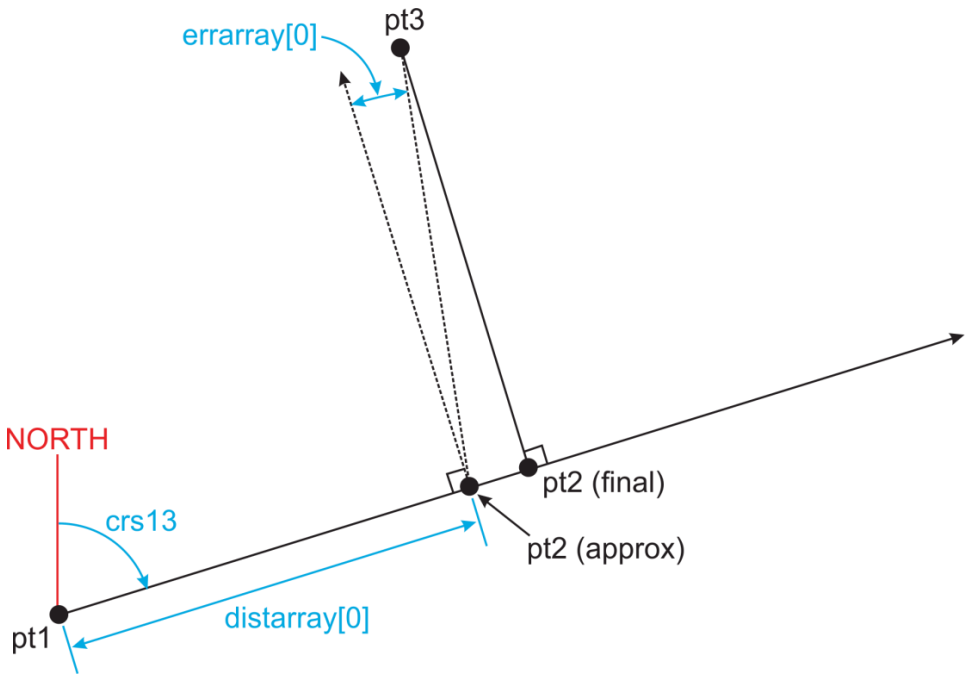
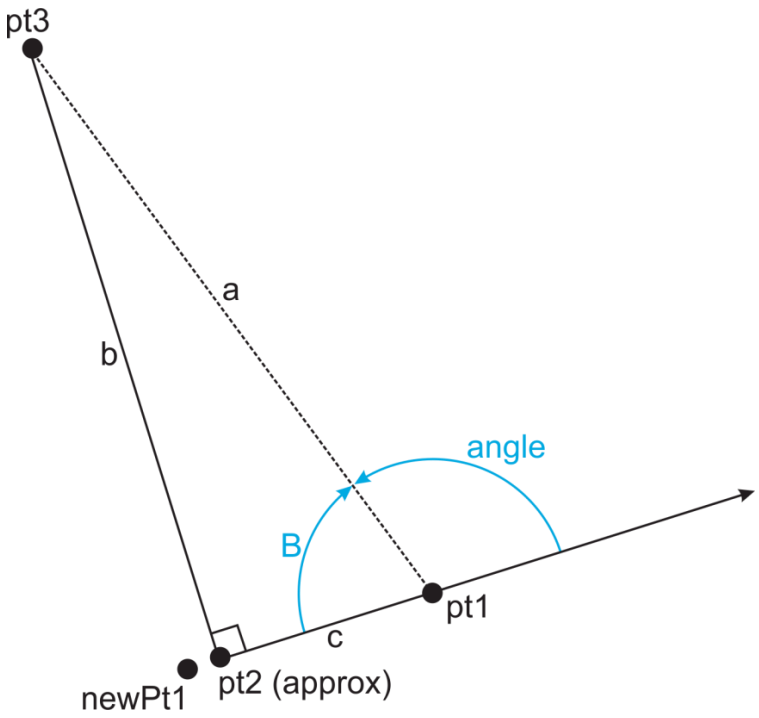


Figure E-16. Elements of Spherical Triangle Used to Determine New Geodesic Starting Point When Projected Point Lies Behind Given Starting Point



(1) *Step 1*. Use the inverse algorithm to calculate the distance, azimuth, and reverse azimuth from pt1 to pt3. Denote these values as crs13, crs31, and dist13, respectively.

(2) *Step 2*. Calculate the angle between the given geodesic and the geodesic between pt1 and pt3. This is accomplished using signedAzimuthDifference function [see section 2 algorithm 3]: angle $= \mathrm{abs}$ *(signedAzimuthDifference (crs13, crs12))*

(3) *Step 3*. If *(dist13* $\leq$ *tol)* then pt2 is the same point as pt1.

(4) *Step 4*. If *(*$\pi/2$ *–* $angle <$ *tol)* then the projected point pt2 is very close to or behind pt1 (the start of the geodesic), so extend the geodesic backward far enough to catch the projection. Use a spherical triangle approximation to calculate the needed extension distance:

(a) $B = angle$

(b) $a = \frac{dist13}{SPHERE_{RADIUS}}$

(c) $b = asin[sin(B) \times sin(a)]$

(d) $dist12 = 2 \times SPHERE_{RADIUS} \times \mathrm{atan}(tan[0.5 \times (a - b)]) \times \sin[0.5 \times (A - B)]$

(e) If (*abs (dist12)* $<$ *tol*) then the projected point is identical to pt1 to within the required accuracy:

1. *crsFromPoint* $= crs31$
2. *distFromPoint* $= dist13$
3. *Return pt2 = pt1*

(f) End if.

(g) Use the direct algorithm to move pt1 along reverse geodesic course. Use 1.1 × *dist12* for the distance, *crs12* + π for the azimuth, and then store the new location in the temporary variable newPt1. A distance greater than dist12 is used to compensate for possible errors in the spherical approximation.

(h) Use the inverse algorithm to calculate the azimuth from *newPt* to pt1. This value replaces the original azimuth value crs12, rename newPt1 as pt1: *pt1* $= newPt1$.

(5) *Step 5*. Calculate the approximate distance from pt1 to the projected point using the spherical triangle formula from Steps 4(a) through 4(d). Denote the approximate distance found as dist13.

(6) *Step 6*. Use the direct algorithm to project a point on the given geodesic distance dist13 from pt1. Use pt1 for the starting point, dist12 for distance, and crs12 for azimuth. Denote the computed point by pt2.

(7) *Step 7*. Use the inverse algorithm to calculate the azimuth crs21 from pt2 to pt1.

(8) *Step 8*. Use the inverse algorithm to calculate the azimuth crs23 and distance dist23 from pt3 to pt2.

(9) *Step 9*. Calculate the angle between the geodesics that intersect at pt3, and cast that angle into the range $[0, \pi]$ using the following formula:

$$angle = abs(signedAzimuthDifference(crs21, crs23))$$

(10) Step 10. Calculate the error and store it as the first element in the error function array: $errarray[0] = angle - \pi/2$.

(11) *Step 11*. Store the current distance from pt1 to pt2 in the distance function array: *distarray [0] =dist12*.

(12) *Step 12*. A second distance/error value must be calculated before linear interpolation may be used to improve the solution. The following formula may be used: *distarray* [1] = *distarray* [0] + *errarray* [0] × *dist*23.

(13) *Step 13*. Use the direct algorithm to project point on the given geodesic distance *distarray*[1] from pt1. Use pt1 for the starting point, *distarray*[1] for distance, and crs12 for azimuth. Denote the computed point by pt2.

(14) *Step 14*. Use the inverse algorithm to calculate the azimuth crs21 from pt2 to pt1.

(15) *Step 15*. Use the inverse algorithm to calculate the azimuth crs23 from pt2 to pt3.

(16) *Step 16*. Calculate the error in angle:

$$errarray[1] = abs\left(signedAzimuthDifference(crs21, cres23)\right) - \frac{\pi}{2}$$

(17) *Step 17*. Initialize the iteration count: $kk = 0$.

(18) *Step 18*. Do while ($k = 0$) or *(error>tol)* and *(k<maxIterationCount)*

a. Use linear approximation to find root of errarray as a function of distarray. This gives an improved approximation to dist12.

b. Use the direct algorithm to project point on the given geodesic distance dist12 from pt1. Use pt1 for the starting point, dist12 for distance, and crs12 for azimuth. Denote the computed point by pt2.

c. Use the inverse algorithm to calculate the azimuth crs21 from pt2 to pt1.

d. Use the inverse algorithm to calculate the distance dist23, azimuth crs32, and reverse azimuth crs23 from pt3 to pt2.

e. Update *distarray* and *errarray* with the new values:

1. *distarray* [0] = *distarray* [1]
2. *errarray* [0] = *errarray* [1]
3. *distarray* [1] = *dist*13
4. *errarray* [1] = $abs(signedAzimuthDifference\,(crs21, crs23)) - \pi/2$

f. Calculate the difference between the two latest distance values. This serves as the error function for measuring convergence: $error = abs(distarray\,[1] - distarray\,[0])$.

(19) *Step 19*. End while.

(20) *Step 20.* Set *crsToPoint* = *crs*32.

(21) *Step 21*. Set *distToPoint* = *dist*23.

(22) *Step 22*. Return pt2.

2. **Project point to locus from point on defining geodesic.** Given a point on the defining geodesic, this algorithm computes the corresponding point on the locus.

a. Input/Output. LLPoint WGS84PtOnLocusP (Locus loc, LLPoint geoPt, LLPoint* ptonloc, double* perpCrs, double tol, double eps) returns the point on the locus that is abeam the given point, where the inputs are:

(1) Locus loc = Locus of Interest

(2) LLPoint geoPt = Point on defining geodesic

(3) LLPoint* ptonloc = Pointer to LLPoint, updated with coordinates of point on locus abeam given point.

(4) double* perpCrs = Pointer to double, updated with azimuth from point on geodesic to point on locus.

(5) double tol = Maximum allowable error

(6) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

(1) *Step 1*. Use section 3 algorithm 8 (with point input) to determine the distance from geoPt to the locus. Denote this distance as distp.

(2) *Step 2*. If (*distp*= 0) then return geoPt.

(3) *Step 3*. Use the inverse algorithm to compute the course from geoPt to the start point of the defining geodesic. Denote this value as fcrs.

(4) *Step 4*. If (*distp* > 0.0) then the locus lies to the right of the geodesic. Let

∗ *perpCrs = fcrs* + π/2

(5) *Step 5*. Else the locus lies to the left of the geodesic. Let ∗ *perpCrs = fcrs* - π/2.

(6) *Step 6*. End if.

(7) *Step 7*. Use the direct algorithm to project a point along *perpCrs, distance abs(distp) from geoPt. Denote the point as ptonLoc.

(8) *Step 8*. Return ptonLoc.

3. **Project point to locus nearest given point.** This algorithm returns the point on a locus nearest the given sample point.

a. Input/Output. LLPoint* WGS84LocusPerpIntercept(Locus loc, LLPoint pt2, double* crsFromPoint, double* distFromPoint, double tol) returns a reference to an LLPoint structure that contains the coordinates of the projected point, where the inputs are:

(1) Locus loc = Locus structure to which point will be projected

(2) LLPoint pt2 = Coordinates of point to be projected to locus

(3) double* crsFromPoint = Reference to value that will store the course from pt2 to projected point

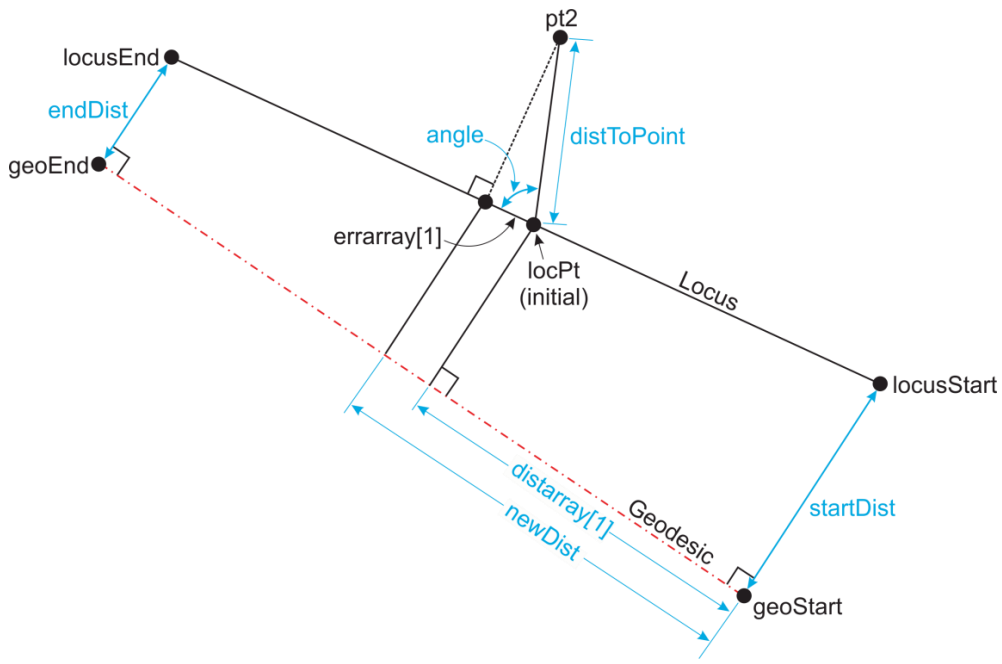
(4) double* distFromPoint = Reference to value that will store the distance from pt2 to projected point

(5) double tol = Maximum error allowed in solution

(6) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

Figure E-17. Projecting a Point to a Locus



(1) *Step 1*. Define the course and distance from loc.geoStart to loc.geoEnd as gcrs and gdist, respectively. This course and distance is a part of the locus structure:

(a) $gcrs = loc.geoAz$

(b) $gdist = loc.geoLength$

(2) *Step 2*. If (*abs* ($loc.startDist - loc.endDist$) $< tol$) then the locus is "parallel" to its defining geodesic. In this case, the projected point on the locus will lie on the geodesic joining pt2 with its projection on the defining geodesic, and the calculation is simplified:

(a) Apply section 4 algorithm 1 to project pt2 onto the defining geodesic of loc. Use loc.geoStart, gcrs, and pt2 as input parameters. The intersection point, perpPt, will be returned along with the course and distance from pt2 to perpPt. Denote the course and distance values as crsFromPoint and distFromPoint, respectively.

(b) Use section 4 algorithm 2 to project a point locPt on the locus from perpPt the geodesic.

(c) Use the inverse algorithm to recalculate distFromPoint as the distance between pt2 and locPt.

(d) Return locPt.

(3) *Step 3*. End if.

(4) *Step 4*. Use the inverse algorithm to compute lcrs, the course from loc.locusStart to loc.locusEnd.

(5) *Step 5*. Use section 4 algorithm 1 to project pt2 onto the geodesic approximation of the locus. Pass loc.locusStart, lcrs, and pt2 as parameters. Denote the computed point as locPt. (In general, this point will not exactly lie on the locus. We will adjust its position so that it is on the locus in a subsequent step.)

(6) *Step 6*. Calculate the locus inclination angle, relative to its geodesic:
$locAngle = atan\left(\frac{loc.startDist - loc.endDist}{gdist}\right)$

(7) *Step 7*. Use section 4 algorithm 1 to project locPt onto the locus's defining geodesic. Pass loc.geoStart, gcrs, and locPt as parameters. Denote the computed point as geoPt.

(8) *Step 8*. Use the inverse function to calculate the distance from loc.geoStart to geoPt. Store this value as distarray[1].

(9) *Step 9*. Initialize the iteration count: $k = 0$

(10) *Step 10*. Do while ($k = 0$) or $abs(errarray[1] > \text{tol})$ and ($k < maxIterationCount$)

(a) Use section 4 algorithm 2 with *distarray*[1] to project a point onto the locus. Reassign locPt as this point.

(b) Use section 3 algorithm 10 to recompute lcrs, the course of the locus at locPt.

(c) Use the inverse algorithm to compute crsToPoint and *distToPoint*, the course and distance from locPt to pt2.

(d) Compute the signed angle between the locus and the geodesic from locPt to pt2: $angle = singedAzimuthDifference(lcrs, crsToPoint)$

(e) Store the approximate error as: $errarray[1] = -distToPoint \times \cos(angle)$. This converts the error in angle into an error in distance which can be compared to tol.

(f) If ($k = 0$) then a direct calculation is used to improve the approximation: newDist= $distarray[1] + errarray[1] \times \cos(locangle)$

(g) Else use a linear root finder with distarray and errarray to solve for the distance value that makes the error zero. Denote this value as newDist.

(h) End if.

(i) Update the distance and error arrays:

1. *distarray* [0] = *distarray* [1]

2. *errarray* [0] = *errarray* [1]

3. *distarray* [1] = *newDist*

(11) *Step 11*. End while.

(12) *Step 12*. Return locPt.

4. **Tangent projection from point to arc.** This projection is used in obstacle evaluation when finding the point on an RF leg or fly-by turn path where the distance to an obstacle must be measured.

a. Input/Output. long WGS84PointToArcTangents(LLPoint point, LLPoint center, double radius, LLPointPair tanPt, int* n, double tol) returns a reference to an LLPoint structure that contains the coordinates of the points where geodesics through point are tangent to arc, where the inputs are:

(1) LLPoint point = Point from which lines will be tangent to arc

(2) LLPoint center = Geodetic centerpoint coordinates of arc

(3) double radius = Radius of arc

(4) LLPointPair tanPt = Two-element array of LLPoint objects that will be updated with tangent points' coordinates

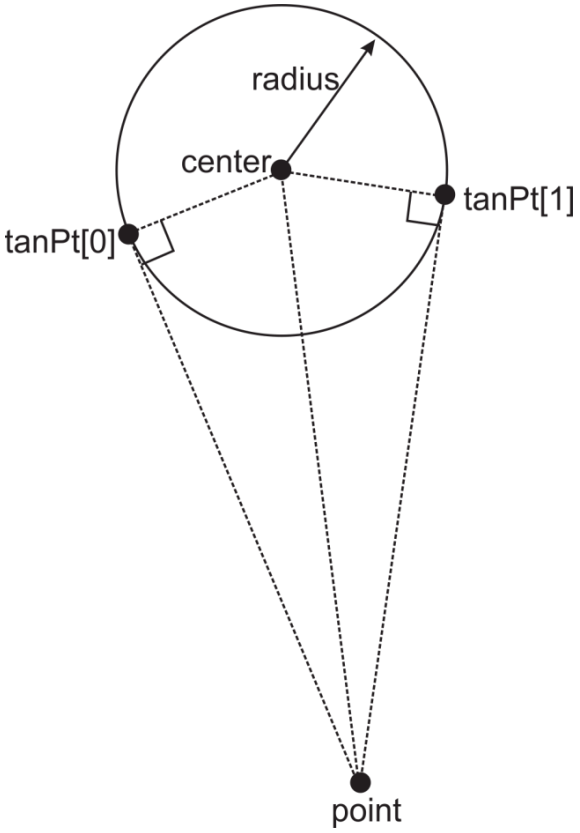
(5) int* n = Reference to number of tangent points found (0, 1, or 2)

(6) double tol = Maximum error allowed in solution

(7) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps. This algorithm treats the arc as a complete circle, so either zero or two tangent points will be returned. If the arc is bounded and two tangent points are found, then each point must be tested using section 3 algorithm 6 to determine whether they lie within the arc's bounds.

Figure E-18. Projecting Point to Tangent Points on an Arc



(1) *Step 1*. Use the inverse algorithm to calculate the distance, azimuth, and reverse azimuth from point to center. Denote these values by crsToCenter, crsFromCenter, and distToCenter, respectively.

(2) *Step 2*. If (*abs (distToCenter −radius) < tol*) then point lies on the arc and is a tangent point:

(a) Set $n = 1$.

(b) Return *tanPt = point*.

(3) *Step 3*. Else if (*distToCenter < radius*) then point lies inside of the arc and no tangent points exist, return no solution.

(4) *Step 4*. End if.

(5) *Step 5*. There must be two tangent points on the circle, so set $ee = 2$.

(6) *Step 6*. Use spherical trigonometry to compute approximate tangent points:

(a) $a = \frac{distToCenter}{SPHERE_{RADIUS}}$

(b) $B = \frac{radius}{SPHERE_{RADIUS}}$

(c) $C = \text{acos}\left[\frac{\tan(b)}{\tan(a)}\right]$ This is the approximate angle between the geodesic that joins point with center and the geodesic that joins center with either tangent point.

(7) *Step 7*. Initialize iteration count $k = 0$.

(8) *Step 8*. Do while ($k = 0$) or ($abs\ (error) > tol$) and ($k < maxIterationCount$):

(a) Use the direct algorithm to locate tanPt[0] on arc. Use center as the starting point, radius as the distance, and *courseFromCenter* + C as the azimuth.

(b) Use the inverse algorithm to calculate the azimuth from tanPt[0] to center. Denote this value as radCrs.

(c) Use the inverse algorithm to calculate the azimuth from tanPt[0] to point. Denote this value as tanCrs.

(d) Use the function in section 2 algorithm 3 to calculate the angle between the two courses and cast it into the range $[-\pi, \pi]$: *diff* = *singedAzimuthDifferrence (radCrs, taxCrs)*

(e) Compute the error $error = abs(diff) - \pi/2$.

(f) Adjust the value of C to improve the approximation $C = C + error$.

(g) Increment the iteration count $k = k + 1$.

(9) *Step 9*. End while loop.

(10) *Step 10*. Repeat *Steps 7-9* to solve for tanPt[1]. In each iteration; however, use crsFromPoint–C for azimuth in *Step 8(a)*.

(11) *Step 11*. Return tanPt[0] and tanPt[1].

5. **Project arc to geodesic.** This algorithm is used for obstacle evaluation when finding a point on the straight portion of TF leg where distance to an obstacle must be measured.

a. Input/Output. long WGS84PerpTangentPoints(LLPoint lineStart, double crs, LLPoint center, double radius, LLPointPair linePts, LLPointPair tanPts, double tol) updates geodesic intercepts, but returns no output, where input values are:

(1) LLPoint lineStart = Start point of geodesic to which arc tangent points will be projected

(2) double crs = Initial course of geodesic

(3) LLPoint center = Geodetic coordinates of arc center

(4) double radius = Arc radius

(5) LLPointPair linePts = Two-element array of projected points on Geodesic

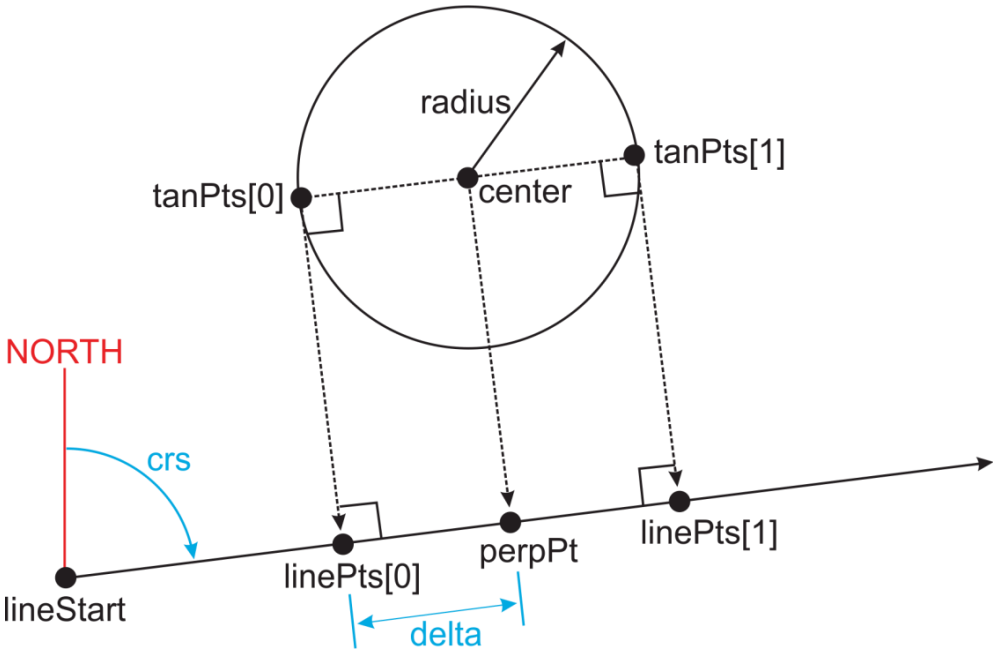
(6) LLPointPair tanPts = Two-element array of tangent points on arc

(7) double tol = Maximum error allowed in solution

(8) double eps = Convergence parameter for forward/inverse algorithms

b.Algorithm steps.

Figure E-19. Projecting an Arc to a Geodesic



(1) *Step 1*. Use the inverse algorithm to calculate the distance, azimuth, and reverse azimuth from lineStart to center. Denote these values as distStartToCenter, crsStartToCenter, and crsCenterToStart, respectively.

(2) *Step 2*. Compute the angle between the given geodesic and the geodesic that joins lineStart to center [see section 2 algorithm 3]:

$angle1 = signedAzimuthDifference\ (crs, crsStartToCenter)$

(3) *Step 3*. If (abs ($distStartToCenter \times (crsStartToCenter - crs)) < tol$) then center lies on the given geodesic, which is a diameter of the circle. In this case, the tangent points and project points are the same:

(a) Use the direct algorithm to compute tanPts[0]. Use lineStart as the starting point, crs as the azimuth, and $distStartToCenter - radius$ as the distance.

(b) Use the direct algorithm to compute tanPts[0]. Use lineStart as the starting point, crs as the azimuth, and $distStartToCenter + radius$ as the distance.

(c) Set $linePts[0] = tanPts[0]$.

(d) Set $linePts[1] = tanPts[1]$.

(e) Return all four points.

(4) *Step 4*. End if.

(5) *Step 5*. Use section 4 algorithm 1 to project center to the geodesic defined by lineStart and crs. Denote the projected point by perpPt.

(6) *Step 6*. Use the inverse algorithm to calculate the distance, azimuth, and reverse azimuth from perpPt to lineStart. Denote these values by dist12 and crs21, respectively.

(7) *Step 7*. Set $delta = radius$.

(8) *Step 8*. Initialize iteration count: $k = 0$.

(9) *Step 9*. Do while ($k = 0$) or (abs ($error$) $> tol$) and ($k < maxIterationCount$):

(a) Use the direct algorithm to compute linePts[0]. Use perpPt as the starting point, delta as the distance, and $crs21 + \pi$ as the azimuth.

(b) Use the inverse algorithm to calculate the course from linePts[0] to perpPt. Denote this value by strCrs.

(c) Calculate the azimuth, perpCrs, from linePts[0] to the desired position of tanPts[0]. The azimuth depends upon which side of the line the circle lies, which is given by the sign of angle1:crs

1. If the circle lies to the right of the line: $perpCrs = strCrs + \pi/2$

2. If the circle lies to the left of the line: $perpCrs = strCrs + \pi/2$

(d) Use section 4 algorithm 1 to project center onto the geodesic passing through linePts[0] at azimuth perpCrs. Section 4 algorithm 1 will return the projected point, tanPts[0], along with the distance from center to tanPts[0]. Denote this distance by radDist.

(e) Calculate the error, the amount that radDist differs from radius: $error = radDist - radius$.

(f) Adjust the distance from lineStart to linePts[0]: $delta = delta - error$.

(g) Increment the iteration count: $k = k + 1$.

(10) *Step 10*. End while loop.

(11) *Step 11*. Repeat *Steps 7-10* to solve for linePts[1] and tanPts[1]. In each iteration; however, use crs21 for azimuth in *Step 9(a)*. Using the final delta value for the first iteration in the search for linePts[1] will make the code more efficient (i.e., don't repeat *Step 7*).

(12) *Step 12*. Return linePts[0], linePts[1], tanPts[0], and tanPts[1].

Section 5. Intersections

1. Intersection of two geodesics. The following algorithm computes the coordinates where two geodesic curves intersect. Each geodesic is defined by its starting coordinates and azimuth at that coordinate. The algorithm returns a single set of coordinates if the geodesics intersect and returns a null solution (no coordinates) if they do not.

a. Input/Output. long WGS84CrsIntersect(LLPoint pt1, double crs13, double* crs31, double* dist13, LLPoint pt2, double crs23, double* crs32, double* dist23, LLPoint* intx, double tol) returns a reference to an LLPoint structure that contains the intersection coordinates, where the inputs are:

(1) LLPoint pt1 = Start point of first geodesic

(2) double crs13 = Azimuth from pt1 to intersection point

(3) double* crs31 = Reference to azimuth from intersection point to pt1

(4) double* dist13 = Reference to distance from pt1 to intersection

(5) LLPoint pt2 = Start point of second geodesic

(6) double crs23 = Azimuth from pt2 to intersection point

(7) double* crs32 = Reference to azimuth from intersection to pt2

(8) double* dist23 = Reference to distance between pt2 and intersection point

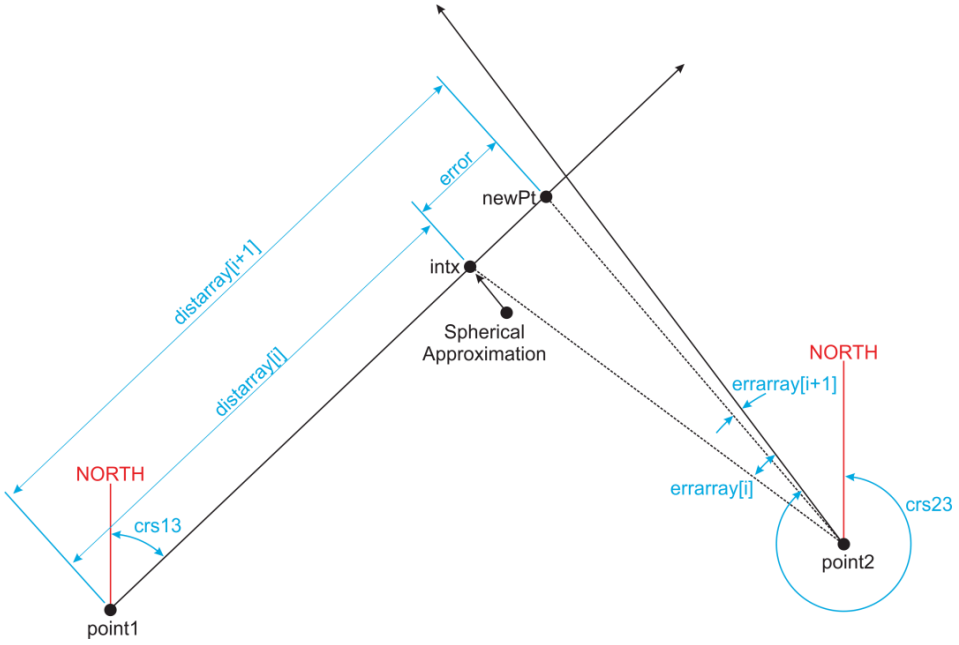
(9) LLPoint* intx = Reference to intersection point

(10) double tol = Maximum error allowed in solution

(11) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

Figure E-20. Finding the Intersection of Two Geodesics



(1) *Step 1*. Use inverse algorithm to calculate distance, azimuth and reverse azimuth from pt1 to pt2. Denote these values by dist12, crs21 and crs12, respectively. Run a check to see if pt1 lies on the geodesic defined by pt2 and crs23 and if pt2 lies on the geodesic defined by pt1 and crs13:

(a) If pt1 falls on geodesic 2 and pt2 falls on geodesic 1.

1. Return an error. Courses are collinear. There are infinite intersections.

2. If pt1 falls on geodesic 2. Return pt1.

3. If pt2 falls on geodesic 1. Return pt2.

(2) *Step 2*. Calculate the signed azimuth difference in angle between crs12 and crs13, denoted by angle1.

(3) *Step 3*. Calculate the signed azimuth difference in angle between crs21 and crs23, denoted by angle2.

(4) *Step 4*. If ($sin\ (angle1) \times sin\ (angle\ 2) < 0$) then the courses lay on opposite sides of the pt1-pt2 line and cannot intersect in this hemisphere. Use reciprocal course so that the nearest intersection may be found:

(a) If ($abs\ (angle\ 1) > abs\ (angle\ 2)$)

1. $angle1 = (\mathrm{crs13} + \pi) - \mathrm{crs12}$.

2. Else $angle2 = \mathrm{crs21} - (\mathrm{crs23} + \pi)$.

(5) *Step 5*. End if.

(6) *Step 6*. Locate the approximate intersection point, intx, using a spherical earth model [see section 3 paragraph 2].

(7) *Step 7*. The following steps describe the function iterateLineIntersection which is called once the initial approximation, intx, of the line intersection is found. The purpose of the iterateLineIntersection function is to further refine the solution.

(8) *Step 8*. Use the inverse algorithm to calculate dist13, the distance from pt1 to intx.

(9) *Step 9*. Use the inverse algorithm to calculate dist23, the distance from pt2 to intx.

(10) *Step 10*. If ($dist13 < tol$) then the intersection point is very close to pt1.Calculation errors may lead to treating the point as if it were beyond the end of the geodesic. Therefore, it is helpful to move pt1 a small distance along the geodesic:

(a) Use the direct algorithm to move pt1 from its original coordinates 1 NM along azimuth $crs13 + \pi$.

(b) Use the inverse algorithm to calculate the azimuth acrs13 for the geodesic from the new pt1.

(11) *Step 11*. Repeat *Step*s *10, 10(a),* and *10(b)* for pt2 and crs23.

(12) *Step 12*. If ($dist\ 23 < dist\ 13$) then the intersection point is closer to pt2 than pt1. In this case, the iterative scheme will be more accurate if we swap pt1 and pt2.This is because we iterate by projecting the approximate point onto the geodesic from pt1 and then calculating the error in azimuth from pt2. If the distance from pt2 to the intersection is small, then small errors in distance can correspond to large errors in azimuth, which will lead to slow convergence. Therefore, we swap the points so that we are always measuring azimuth errors farther from the geodesic starting point:

(a) newPt = pt1

(b) pt1 = pt2

(c) pt2 = newPt

(d) acrs13 = crs13

(e) crs13 = crs23

(f) crs23 = acrs23

(g) dist13 = dist23. We only need one distance so the other is not saved.

(h) $swapped = 1$. This is a flag that is set so that the solutions can be swapped back after they are found.

(13) *Step 13*. End if.

(14) *Step 14*. Initialize the distance array: $distarray[0] = dist13$. Errors in azimuth from pt2 will be measured as a function of distance from pt1. The two most recent distances from pt1 are stored in a two element array. This array is initialized with the distance from pt1 to intx.

(15) *Step 15*. Use the direct algorithm to project intx onto the geodesic from pt1. Use pt1 as the starting point, and a distance of distarray[0] and azimuth of crs13.

(16) *Step 16*. Use the inverse algorithm to measure the azimuth acrs23 from pt2 to intx.

(17) *Step 17*. Initialize the error array:

$$errarray[0] = signedAzimuthDifference(acrs23, crs23)$$

(18) *Step 18*. Initialize the second element of the distance array using a logical guess: $distarray[1] = 1.01 \times dist13$.

(19) *Step 19*. Use the direct algorithm to project the second approximation of intx onto the geodesic from pt1. Use pt1 as the starting point, and a distance of distarray[1] and azimuth of crs13.

(20) *Step 20*. Use the inverse algorithm to measure the azimuth acrs23 from pt2 to intx.

(21) *Step 21*. Initialize the error array:

$$errarray[1] = signedAzimuthDifference(acrs23, crs23)$$

(22) *Step 22*. Initialize $k = 0$

(23) *Step 23*. Do while ($k = 0$) or ($error > tol$) and ($k \leq MAX_{ITERATIONS}$):

(a) Use linear approximation to find root of errarray as a function of distarray. This gives an improved approximation to dist13.

(b) Use the direct algorithm to project the next approximation of the intersection point, newPt, onto the geodesic from pt1. Use pt1 as the starting point, and a distance of dist13 (calculated in previous step) and azimuth of crs13.

(c) Use inverse algorithm to calculate the azimuth acrs23 from pt2 to intx.

(d) Use the inverse algorithm to compute the distance from newPt to intx (the previous estimate). Denote this value as the error for this iteration.

(e) Update distarray and errarray with new values:

1. $distarray\,[0] = distarray\,[1]$
2. $distarray\,[1] = dist13$
3. $errarray\,[0] = errarray\,[1]$
4. $errarray\,[1] = signedAzimuthDifference\,(acrs23, crs23)$

(f) Increment k: $k = k + 1$

(24) *Step 24*. End while loop.

(25) *Step 25*. Check if k reached $MAX_{ITERATIONS}$. If so, then the algorithm may not have converged, so an error message should be displayed.

(26) *Step 26*. The distances and azimuths from pt1 and pt2 to intx are available at the end of this function, since they were calculated throughout the iteration. It may be beneficial to return them with the intx coordinates, since they may be needed by the calling function. If this is done, and if ($swapped = 1$) then the original identities of pt1 and pt2 were exchanged and the azimuths and distances must be swapped again before they are returned.

(27) *Step 27*. Return intx.

2. Intersection of two arcs. The following algorithm computes the intersection points of two arcs. Each arc is defined by its center point coordinates and radius. The algorithm will return a null solution (no points) if the arcs do not intersect; it will return a single set of coordinates if the arcs intersect tangentially; and it will return two sets of coordinates if the arcs overlap.

a. Input/Output. long WGS84ArcIntersect(LLPoint center1, double radius1, LLPoint center2, double radius2, LLPointPair intx, int* n, double tol) returns a reference to an LLPoint structure array that contains the coordinates of the intersection(s), where the inputs are:

(1) LLPoint center1 = Geodetic coordinates of first arc center

(2) double radius1 = Radius of first arc in nautical miles

(3) LLPoint center2 = Geodetic coordinates of second arc center

(4) double radius2 = Radius of second arc in nautical miles

(5) LLPointPair intx = Two-element array of LLPoint objects that will be updated with intersections' coordinates

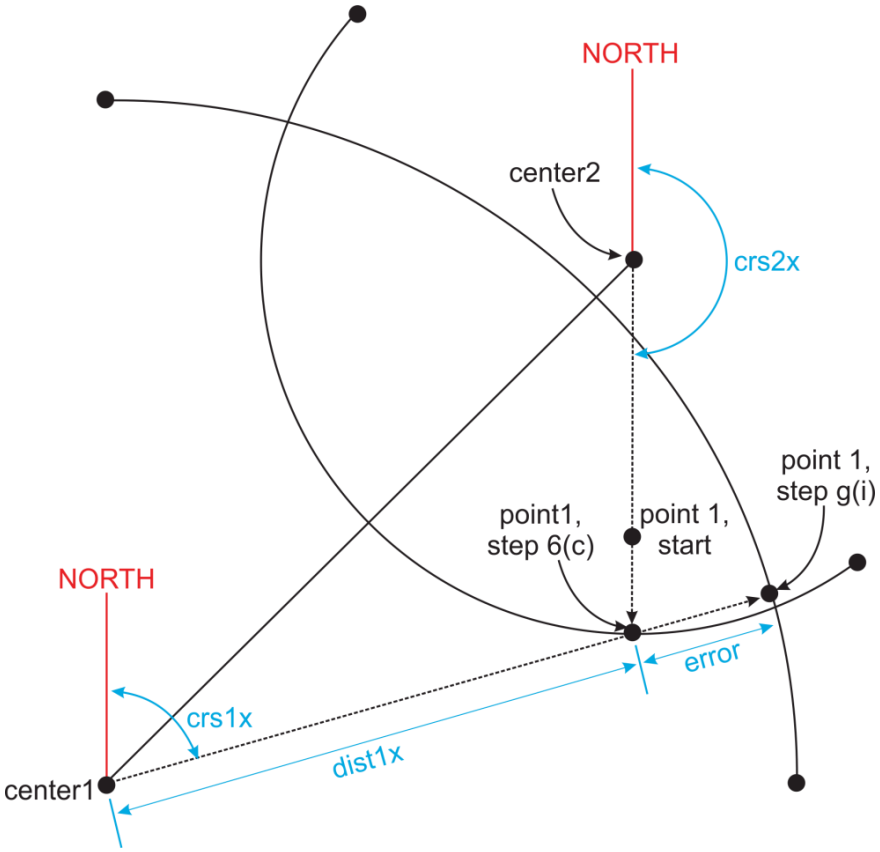
(6) int* n = Reference to integer number of intersection points returned

(7) double tol = Maximum error allowed in solution

(8) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps. This algorithm treats the arcs as full circles. Once the intersections of the circles are found, then each intersection point may be tested and discarded if it does not lie within the bounds of the arc.

Figure E-21. Intersection of Two Arcs



(1) *Step 1*. Use inverse algorithm to calculate the distance and azimuth between center1 and center2. Denote these values as dist12 and crs12, respectively.

(2) *Step 2*. If ($radius1 + radius2 - dist12 + tol < 0$) or ($abs\,(radius\,1 - radius2) >$ ddeeeeee12) then the circles are spaced such that they do not intersect. If the first conditional is true, then the arcs are too far apart. If the second conditional is true, then one arc is contained within the other. Return no intersections.

(3) *Step 3*. Else if ($abs\,(radius1 + radius2 - dist\,12) \leq tol$) then the circles are tangent to each other and intersect in exactly one point:

(a) Use direct algorithm to project point from center1, along crs12, distance radius1.

(b) Return projected point.

(4) *Step 4*. End if.

(5) *Step 5*. Calculate approximate intersection points, intx[0] and intx[1], according to section 3 paragraph 2.

(6) *Step 6*. Iterate to improve approximation to pt:

(a) $k = 0$

(b) Use inverse algorithm to find azimuth from center2 to pt, denote this value as crs2x.

(c) Use direct algorithm to move pt along crs2x to circumference of circle 2. Use center2 as starting point, crs2x as azimuth, radius2 as distance.

(d) Use inverse algorithm to compute distance and azimuth from center1 to pt. Denote these values as dist1x and crs1x, respectively.

(e) Compute error at this iteration step: $error = radius1 - dist1x$.

(f) Initialize arrays to store error as function of course from center1:

1. $errarray[1] = error$

2. $crsarray[1] = crs1x$

(g) While ($k \leq maximumIterationCount$) and ($abs\ (errarray\ [1]) > tol$), improve approximation:

1. Use direct function to move pt along crs1x to circumference of circle1. Use center1 as starting point, crs1x as azimuth, and radius1 as distance. Note that crs1x was calculated as last step in previous iteration.

2. Use inverse function to find azimuth from center2 to pt, crs2x.

3. Use direct function to move pt along crs2x to circumference of circle2. Use center2 as starting point, crs2x as azimuth, and radius2 as distance.

4. Use inverse algorithm to compute distance and azimuth from center1 to pt. Denote these values as dist1x and crs1x, respectively.

5. Update function arrays:

a. $crsarray[0] = crsarray\ [1]$
b. $crsarray\ [1] = crs1x$
c. $errarray[0] = errarray\ [1]$
d. $errarray\ [1] = error$

6. Use linear root finder to find the azimuth value that corresponds to zero error. Update the variable crs1x with this root value.

7. Increment k: $k = k + 1$

(h) End while loop.

(7) *Step 7*. Store point in array to be returned: $intx[0] = point$.

(8) *Step 8*. Repeat *Step 6* for approximation intx[1].

(9) *Step 9*. Return array intx.

3. Intersections of arc and geodesic. The following algorithm computes the point where a geodesic intersects an arc. The geodesic is defined by its starting coordinates and azimuth. The arc is defined by its center point coordinates and radius. The algorithm will return a null solution (no points) if the arc and geodesic do not intersect; it will return a single set of coordinates if the arc and geodesic intersect tangentially; and it will return two sets of coordinates if the arc and geodesic overlap.

a. Input/Output. long WGS84LineArcIntersect(LLPoint pt1, double crs1, LLPoint center, double radius, LLPointPair intx, int* n, double tol) returns a reference to an LLPoint structure array that contains the coordinates of the intersection(s), where the inputs are:

(1) LLPoint pt1 = Geodetic coordinates of start point of geodesic

(2) double crs1 = Initial azimuth of geodesic at start point

(3) LLPoint center = Geodetic coordinates of arc center point

(4) double radius = Arc radius in nautical miles

(5) LLPointPair intx = Two-element array of LLPoint objects that will be updated with intersections' coordinates

(6) int* n = Reference to number of intersection points returned

(7) double tol = Maximum error allowed in solution

(8) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps. This algorithm treats the arc and geodesic as unbounded. Once intersection points are found, they must be tested using section 3 algorithms 5 and 6 to determine which, if any, lie within the curves' bounds. This algorithm fails if the arc and geodesic describe the same great circle. A test for this case is embedded in *Step 7*.

Figure E-22. Locating First Intersection of Geodesic and Arc

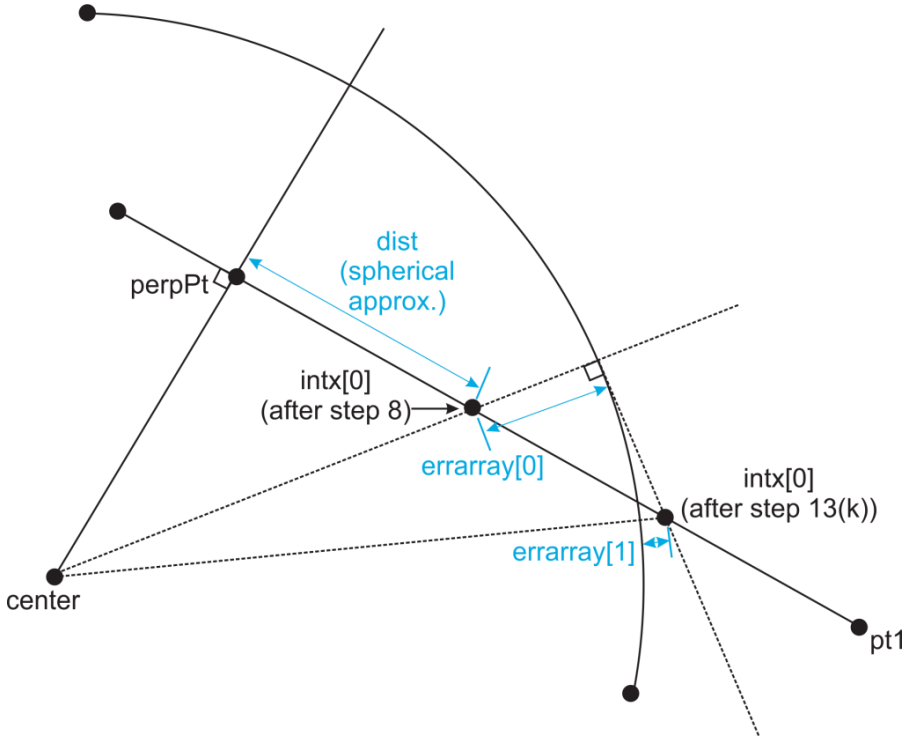
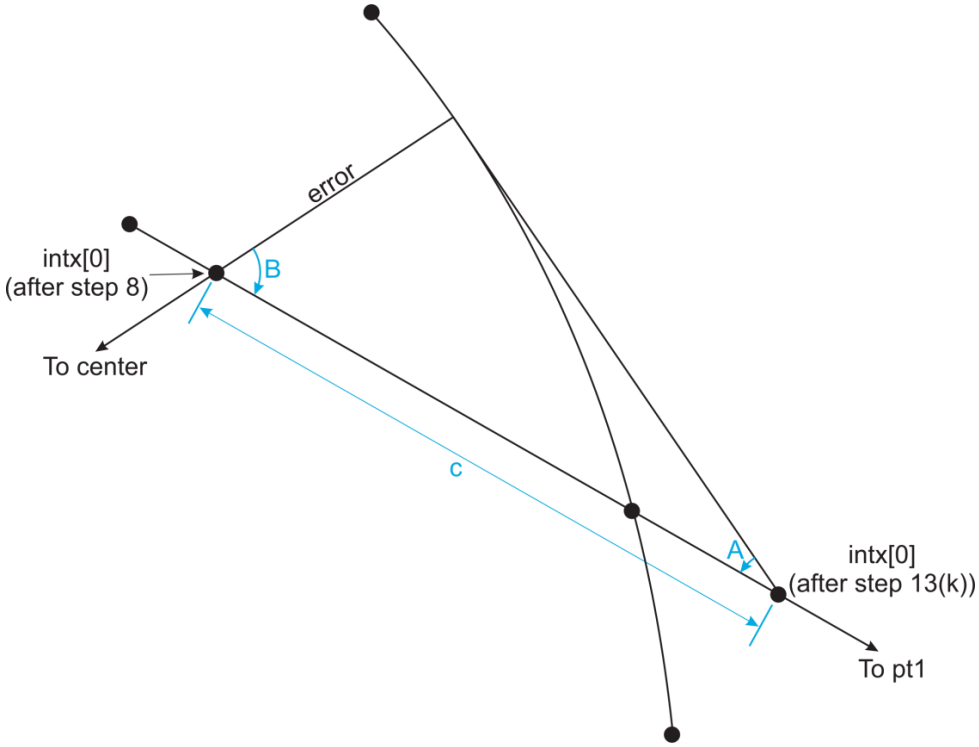


Figure E-23. Near the Appropriate Geodesic-Arc Intersection Point With Spherical Triangle Components That Are Used to Improve the Solution



(1) *Step 1*. Use section 4 algorithm 1 to find the perpendicular projection point from arc

center point (center) to the geodesic defined by starting point pt1 and azimuth crs1. Denote this point by perpPt. Denote the distance as perpDist.

(2) *Step 2*. Use inverse algorithm to calculate the azimuth of the geodesic at perpPt. Denote the azimuth from perpPt to pt1 as crs.

(3) *Step 3*. If (*abs* ($perpDist - radius$) $< tol$) then the geodesic is tangent to the arc and intersection point is at perpPt, return *intx*[0] = $perpPt$.

(4) *Step 4*. Else if ($perpDist > radius$) then geodesic passes too far from center of circle; there is no intersection, return empty array.

(5) *Step 5*. End if.

(6) *Step 6*. Use spherical triangle approximation to find distance from perpPt to one intersection points. Since the spherical triangle formed from center, perpPt, and either intersection point has a right angle at the perpPt vertex, the distance from perpPt to either intersection is:

$$dist = SPHERE_{RADIUS} \times acos\left[\frac{cos\left(\frac{radius}{SPHERE_{RADIUS}}\right)}{cos\left(\frac{perpDist}{SPHERE_{RADIUS}}\right)}\right]$$

Note: A test must be performed so that if ($\cos\left(\frac{perpDist}{SPHERE_{RADIUS}}\right)$) then no solution is returned.

(7) *Step 7*. Find ellipsoidal approximation intx[0] to first intersection by starting at perpPt and using direct algorithm with distance dist and azimuth crs. This will place intx[0] on the geodesic.

(8) *Step 8*. Initialize iteration count $k = 0$.

(9) *Step 9*. Use inverse algorithm to calculate the distance from center to intx[0]. Denote this value by radDist. In the same calculation, calculate azimuth from intx[0] to center. Denote this value by rcrs; it will be used to improve the solution.

(10) Step 10. Calculate error for this iteration: *error* = $radius - radDist$.

(11) *Step 11*. Initialize arrays that will hold distance and error function values so that linear interpolation may be used to improve approximation:

(a) *distarray* [0] = $dist$

(b) *errarray* [0] = $error$

(12) *Step 12*. Do one iterative step using spherical approximation near intersection point:

(a) Use the inverse algorithm to calculate the azimuth from intx[0] to perpPt. Denote this value by bcrs.

(b) Compute the angle between the arc's radial line and the geodesic at intx[0].

$$B = abs(signedAzimuthDifference\ (bcrs,rcrs))$$

(c) Calculate the angle opposite the radial error:

$$A = acos\left(\sin(B) \times cos\left[\frac{abs(error)}{SPHERE_{RADIUS}}\right]\right)$$

(d) If ($abs\ (\sin(A)) < eps$) then the triangle is nearly isosceles, so use simple formula for correction term c: $c = error$.

(e) Else if ($abs\ (A) < eps$) then the error is very small, so use flat approximation:
$c = \frac{error}{\cos\ (B)}$

(f) Else use a spherical triangle approximation for c:

$$c = SPHERE\ _{RADIUS}\ \times asin\left[\frac{\sin\left(\frac{error}{SPHERE_{RADIUS}}\right)}{\sin\ (A)}\right]$$

(g) If ($error > 0$) then intx[0] is inside the circle, so approximation must be moved away from perpPt: $dist = dist + c$.

(i) Else $dist = dist - c$.

(j) End if.

(k) Use the direct algorithm to move intx[0] closer to solution. Use perpPt as the starting point with distance dist and azimuth crs.

(l) Use the inverse algorithm to calculate the distance from center to intx[0]. Denote this value again as radDist.

(m) Initialize second value of distarray and errarray:

1. $distarray[1] = dist$

2. $errarray[1] = radius - radDist$

(13) *Step 13.* Do while ($abs\ (error) > tol$) and ($k < maximumIterationCount$):

(a) Use a linear root finder to find the distance value that corresponds to zero error. Update the variable dist with this root value.

(b) Use the direct algorithm again to move intx[0] closer to solution. Use perpPt as the starting point with distance dist and azimuth crs.

(c) Use the inverse algorithm to calculate the distance from center to intx[0]. Denote this value radDist.

(d) Update distarray and errarray with the new values:

1. distarray [0] = distarray [1]
2. errarray [0] = errarray [1]
3. distarray [1] = dist
4. errarray [1] = error

(e) Increment the iteration count: $k = k + 1$

(14) *Step 14*. End while loop.

(15) *Step 15*. Prepare variables to solve for second solution, intx[1]:

(a) Second solution lies on other side of perpPt, so set $crs = crs + \pi$.

(b) Use direct algorithm to find intx[1]. Start at perpPt, using crs for the azimuth and dist for the distance, since the distance from perpPt to intx[0] is a very good approximation to the distance from perpPt to intx[1].

(c) Use inverse algorithm to calculate radDist, the distance from center to intx[1].

(d) Initialize the error function array: $errarray\ [0] = radius - radDist$.

(16) *Step 16*. Repeat *Step*s *13-14* to improve solution for intx[1].

(17) *Step 17*. Return intx[0] and intx[1].

4. Arc Tangent to two geodesics. This algorithm is useful for finding flight path arcs, such as fitting a fly-by turn or radius-to-fix (RF) leg between two track-to-fix (TF) legs. For the arc to be tangent to both the incoming and outgoing geodesics, the two tangent points must be different distances from the geodesics' intersection point.

a. Input/Output. long WGS84TangentFixedRadiusArc(LLPoint pt1, double crs12, LLPoint pt3, double crs3, double radius, ArcDirection* dir, double tol) returns a reference to an LLPoint structure array that contains the coordinates of the center point and both tangent points of the arc that is tangent to both given geodesic, where the inputs are:

(1) LLPoint pt1 = Geodetic coordinates of start point of first geodesic

(2) double crs12 = Azimuth of first geodesic at pt1

(3) LLPoint pt3 = Geodetic coordinates of end point of second geodesic

(4) double crs3 = Azimuth of second geodesic at pt3

(5) double radius = Radius of desired arc

(6) ArcDirection* dir = Reference to an integer that represents direction of turn.

(a) dir = 1 for left hand turn

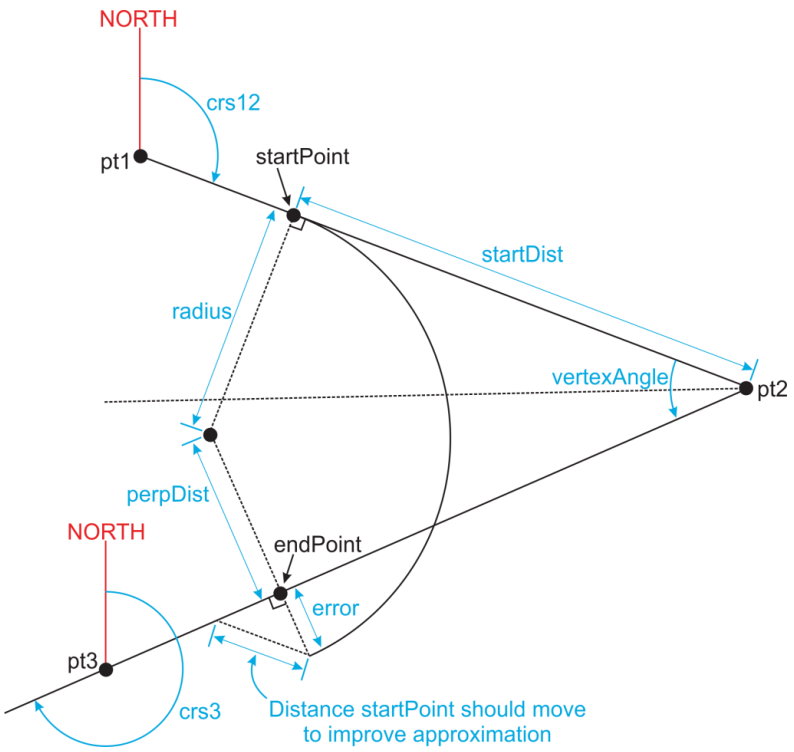
(b) dir = -1 for right hand turn

(7) double tol = Maximum error allowed in solution

(8) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

Figure E-24. Finding Arc Center and Points at Which Arc is Tangent to Two Geodesics



(1) *Step 1*. Use section 5 algorithm 1 to locate the intersection point of the given geodesics. The first geodesic has azimuth crs12 at pt1, while the second geodesic has azimuth crs3 at pt3. Denote their intersection point by pt2.

(2) *Step 2*. If intersection point pt2 is not found, then no tangent arc can be found, return empty array.

(3) *Step 3*. End if.

(4) *Step 4*. Use the inverse algorithm to calculate the distance from pt1 to pt2 (denoted by dist12). Also calculate the azimuth at pt2 to go from pt2 to pt1. Denote this value by crs21.

(5) *Step 5*. Use the inverse algorithm to compute the azimuth at pt2 to go from pt2 to pt3. Denote this value by crs23.

(6) *Step 6*. Calculate angle between courses at pt2 [see section 2 algorithm 3]. Denote this value by vertexAngle: $vertexAngle = signedAzimuthDifference(crs21, crs23)$

(7) *Step 7*. If (abs (sin($vertexAngle$) $< tol$) then either there is no turn or the turn is 180 degrees. In either case, no tangent arc can be found, return empty array.

(8) *Step 8*. Else if ($vertexAngle > 0$) then course changes direction to the right: $dir = -1$.

(9) *Step 9*. Else the course changes direction to the left: $dir = 1$

(10) *Step 10*. End if.

(11) *Step 11*. Use spherical triangle calculations to compute the approximate distance from pt2 to the points where the arc is tangent to either geodesic. Denote this distance by distToStart:

(a) $B = \frac{vertexAngle}{2}$

(b) If ($radius > SPHERE_{RADIUS} \times B$) then no arc of the required radius will fit between the given geodesics, return empty array.

(c) End if.

(d) Calculate distToStart using the approximate formula from Napier's Rule of Circular Parts.

$$distToStart = SPHERE_{RADIUS} \times asin\left[\frac{tan\left(\frac{radius}{SPHERE_{RADIUS}}\right)}{\tan(B)}\right]$$

(12) *Step 12*. Initialize the iteration count: $k = 0$

(13) *Step 13*. Initialize the error measure: $error = 0.0$

(14) *Step 14*. Do while ($k = 0$) or ($abs(error) > tol$) and ($k \leq maximumIterationCount$)

(a) Adjust the distance to tangent point based on current error value (this has no effect on first pass through, because $error = 0$):

$$distToStart = distToStart + \frac{error}{\sin(vertexAngle)}$$

(b) Use the direct algorithm to project startPt distance distToStart from pt1. Use pt1 as the starting point with azimuth of crs12 and distance of distToStart.

(c) Use the inverse algorithm to compute azimuth of geodesic at startPt. Denote this value by perpCrs.

(d) If (dir < 0) then the tangent arc must curve to the right. Add π/2 to perpCrs to get the azimuth from startPt to center of arc: $perpCrs = perpCrs + \pi/2$

(e) Else the tangent arc must curve to the left. Subtract π/2 from perpCrs to get the azimuth from startPt to center of arc: $perpCrs = perpCrs - \pi/2$

(f) End if.

(g) Use the direct algorithm to locate the arc center point, centerPoint. Use startPt as the starting point, perpCrs for the azimuth, and radius for the distance.

(h) Use section 4 algorithm 1 to project centerPoint to the second geodesic. Denote the projected point by endPt. This is approximately where the arc will be tangent to the second geodesic. Denote the distance from centerPoint to endPoint as perpDist.

(i) Calculate the tangency error: $error = radius - perpDist$. This error value will be compared against the required tolerance parameter. If its magnitude is greater than tol, then it will be used to adjust the position of startPoint until both startPoint and endPoint are the correct distance from centerPoint.

(15) *Step 15*. End while.

(16) *Step 16*. Return the values for centerPoint, the center of the arc, startPoint, the tangent point on the first geodesic, and endPoint, the tangent point of second geodesic.

5. Intersections of geodesic and locus. This algorithm is useful for finding the corner points of TF sub-segment's OEA, where a parallel (represented as a locus of points) intersects the geodesic end line.

a. Input/Output. long WGS84GeoLocusIntersect(LLPoint geoSt, LLPoint geoEnd, LLPoint* point, Locus loc, double tol) returns a reference to an LLPoint structure array that contains the coordinates of the intersection point, where the inputs are:

(1) LLPoint geoSt = Geodetic coordinates of start point of geodesic

(2) LLPoint geoEnd = Geodetic coordinates of end point of geodesic

(3) Locus loc = Structure defining locus of points

(4) LLPoint* pint = Reference to LLPoint that will be updated with intersection coordinates.

(5) double tol = Maximum error allowed in solution

(6) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

Figure E-25. Intersection of Geodesic with Locus of Points

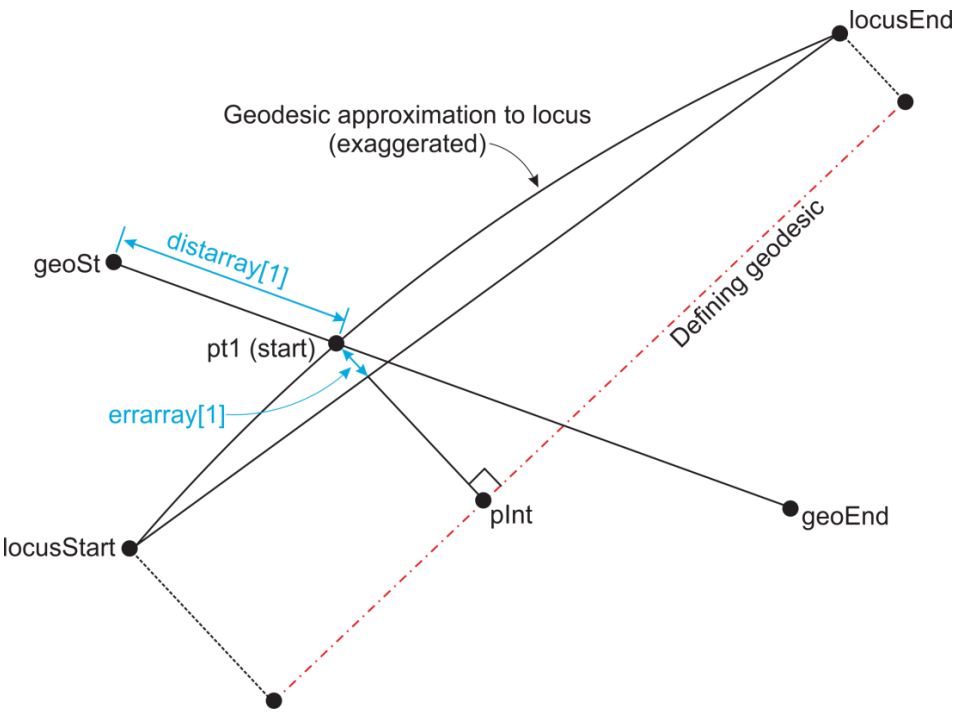
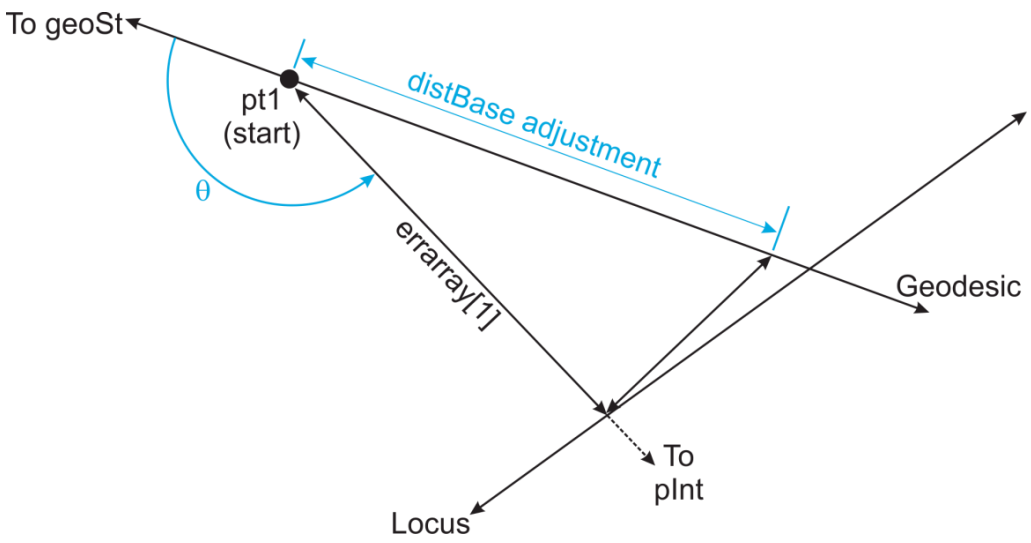


Figure E-26. Computing First Update to Locus-Geodesic Intersection



(1) *Step 1*. Use the geodesic intersection algorithm [see section 5 algorithm 1] to find a first approximation to the point where the given geodesic and locus intersect. Use the start and end coordinates of the locus along with the start and end coordinates of given geodesic as inputs to the geodesic intersection algorithm. This will erroneously treat the locus as a geodesic; however, the calculated intersection will be close to the desired intersection. The geodesic intersection algorithm will return the approximate intersection point, pt1, along with the courses and distances from the pt1 to the start points of the locus and given geodesic. Denote these courses and distances as crs31, dist13, crs32, dist23, respectively.

(2) *Step 2*. If pt1 is not found, then the locus and geodesic to not intersect, so return empty point.

(3) *Step 3*. End if.

(4) *Step 4*. Use the inverse algorithm to calculate the course from geoSt to geoEnd. Denote this value as fcrs. This value is needed by the direct algorithm to locate new points on the given geodesic.

(5) *Step 5*. Use the inverse algorithm to calculate the distance and course from pt1 to geoSt. Denote these values as distBase and crsBase, respectively.

(6) *Step 6*. Obtain the forward course of the locus's defining geodesic. This course is stored as loc.geoAz. Denote this course as tcrs. This value is needed to project the approximate point onto the defining geodesic in order to calculate the appropriate locus distance.

(7) *Step 7*. Use section 4 algorithm 1 to project pt1 onto the locus's defining geodesic. Use pt1, loc.geoStart, and tcrs as inputs. Denote the returned point as pInt, the returned course as crsFromPt, and the returned distance as distFromPt.

(8) *Step 8*. Use section 3 algorithm 8 to calculate the distance from the defining geodesic to the locus at pInt. Denote this value as distLoc.
Note: distLoc may be positive or negative, depending on which side of defining geodesic the locus lays.

(9) *Step 9*. Calculate the distance from pt1 to the locus. This is the initial error:

$errarray[1] = distFromPt - abs(distLoc)$

(10) *Step 10*. Save the initial distance from geoSt to the approximate point: $geodarray[1] = distBase$. We will iterate to improve the approximation by finding a new value for distBase that makes errarray zero.

(11) *Step 11*. Calculate a new value of distBase that will move pt1 closer to the locus. This is done by approximating the region where the given geodesic and locus intersect as a right Euclidean triangle and estimating the distance from the current pt1 position to the locus.

(a) Calculate the angle between the geodesic from pt1 to pInt and the geodesic from pt1 to geoSt:

$theta = abs(signedAzimuthDifference(crsFrompt, crsBase))$

(b) Calculate a new value for distBase:

$$newdistbase = \frac{distbase - errarray[1]}{cos(theta)}$$

(12) *Step 12*. Initialize the iteration count: $k = 0$.

(13) *Step 13*. Do while ($abs(errarray[1]) > tol$) and ($k < maxIterationCount$):

(a) Use geoSt, fcrs, and newDistBase in the direct algorithm to update the value of pt1.

(b) Save the current values of errarray and geodarray:

1. $errarray[0] = errarray[1]$

2. $geodarray[0] = geodarray[1]$

(c) Set $geodarray[1] = newDistBase$.

(d) Repeat *Steps 7*, *8*, and *9* to calculate the distance from pt1 to the locus, distloc, and the corresponding update to errarray[1].

(e) Use a linear root finder with geodarray and errarray to find the distance value that makes the error zero. Update newDistBase with this root value.

(14) *Step 14*. End while.

(15) Step 15. Return *pint*=*pt*1.

6. Intersections of arc and locus. This algorithm solves for the intersection of a fixed radius arc and a locus. It is very similar to section 5 algorithm 3, which computes the intersections of an arc and a geodesic. It begins by treating the locus as a geodesic and applying section 5 algorithm 3 to find approximate intersection points. The approximation is improved by traveling along the locus, measuring the distance to the arc center at each point. The difference between this distance and the given arc radius is the error. The error is modeled as a series of linear functions of position on the locus. The root of each function gives the next approximation to the intersection. Iteration stops when the error is less than the specified tolerance.

a. Input/Output. long WGS84LocusArcIntersect(Locus loc, LLPoint center, double radius, LLPointPair intx, int* n, double tol) returns a reference to an LLPoint structure array that contains the coordinates of the intersection(s), where the inputs are:

(1) Locus loc = Locus of interest

(2) LLPoint center = Geodetic coordinates of arc

(3) double radius = Arc radius

(4) LLPointPair intx = Two-element array of LLPoint that will be updated with intersection coordinates

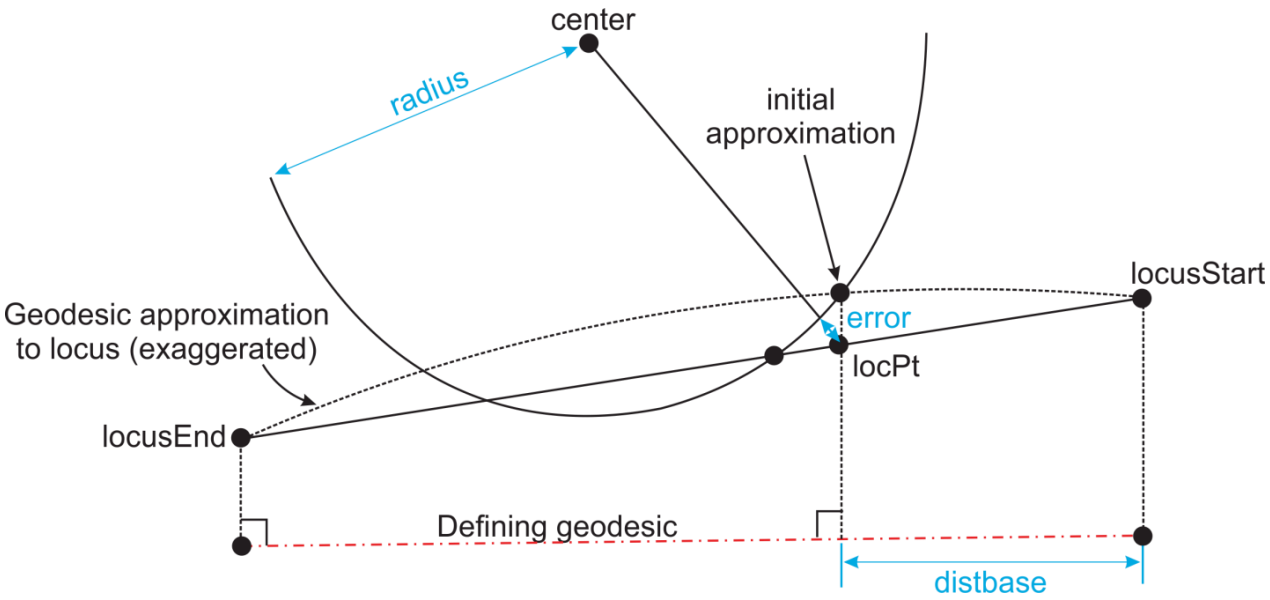
(5) int* n = Number of intersections found

(6) double tol = Maximum error allowed in solution

(7) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

Figure E-27. Finding the Intersection of an Arc and a Locus



(1) *Step 1*. Initialize number of intersections $n = 0$.

(2) *Step 2*. Use the inverse algorithm to compute the course from loc.locusStart to loc.locusEnd. Denote this value as fcrs.

(3) *Step 3*. Use section 4 algorithm 3 to project the center of the arc to the locus. Denote the projected point as locpt. Denote the distance and course from center to locpt as distFromPoint and crsFromPoint, respectively. If locpt is on or within the radius of the arc, then it will be used to find the intersection(s) of the locus and the arc, intx.

(4) *Step 4*. If ($distFromPoint > radius$) then no approximate intersections were found. Return NULL.

(5) *Step 5*. End if.

(6) *Step 6*. Else if distFromPoint is equal to radius within tolerance level, then:

(a) Locus is tangent to arc. One intersection exists.

(b) $intx\,[0] = locpt$.

(7) *Step 7*. End if.

(8) *Step 8*. Otherwise, distFromPoint must be less than radius, meaning there are two possible intersections. These two approximate intersections are found using spherical trigonometry and the direct algorithm. Denote the approximate intersections as intx[0] and

intx[1].

(9) *Step 9*. Use the inverse algorithm to compute the forward and reverse course from loc.geoStart to loc.geoEnd. Store these values as fcrs1 and bcrs, respectively.

(10) Step 10. For *i = 0, i < n1:*

(a) Use section 4 algorithm 1 to project intx[0] to the locus's defining geodesic. Denote the projected point as perpPt.

(b) Use the inverse algorithm to calculate distbase, the distance from perpPint to loc.geoStart.

(c) Use section 4 algorithm 2 to project locPt onto the locus from perpPint.

(d) Use the inverse algorithm to calculate distCent, the distance from locPt to center.

(e) Calculate the error and store it in an array:

$errarray[1] = distCent - radius$

(f) If $(abs(errarray[1]) < tol)$ then locPt is close enough to the circle. Set $intx[n] = locPt$, $n = n + 1$, and continue to the end of the "for" loop, skipping *Steps (10)(g)* through *(10)(m)*below.

(g) Save the current value of distbase to an array: $geodarray[1] = distbase$.

(h) Initialize the iteration count: $k = 0$

(i) Perturb distbase by a small amount to generate a second point at which to measure the error: $newDistbase = 1.001 \times distbase$

(j) Do while $(k < maxIterationCount)$ and $(abs(errarray[1]) < tol)$.

(k) Project Pt1 on the defining geodesic a distance newDistbase along course fcrs1 from loc.geoStart.

1. Use section 4 algorithm 2 to project locPt onto the locus from Pt1.

2. Use the inverse algorithm to calculate dist1, the distance from locPt to center.

3. Calculate the error: error= dist1−radius.

4. Update the distance and error arrays:

a. $geodarray[0] = geodarray[1]$

b. $geodarray[1] = newDistbase$

c. errarray[0] = errarray[1]

d. errarray[1] = error

5. Use a linear root finder with geodarray and errarray to find the distance value that makes the error zero. Update newDistbase with this root value.

(l) End while.

(m) If locPt is on the locus according to section 3 algorithm 9, then

1. Copy locPt to the output array: $intx[n] = locPt$.

2. Update the count of intersection points found: $n = n + 1$.

(11) Step 11. End for loop.

(12) Step 12. Return intx.

7. Intersections of two loci.

a. Input/Output. long WGS84LocusIntersect(Locus loc1, Locus loc2, LLPoint* intx, double tol) returns a reference to an LLPoint structure array that contains the intersection coordinates, where the inputs are:

(1) Locus loc1 = First locus of interest

(2) Locus loc2 = Second locus of interest

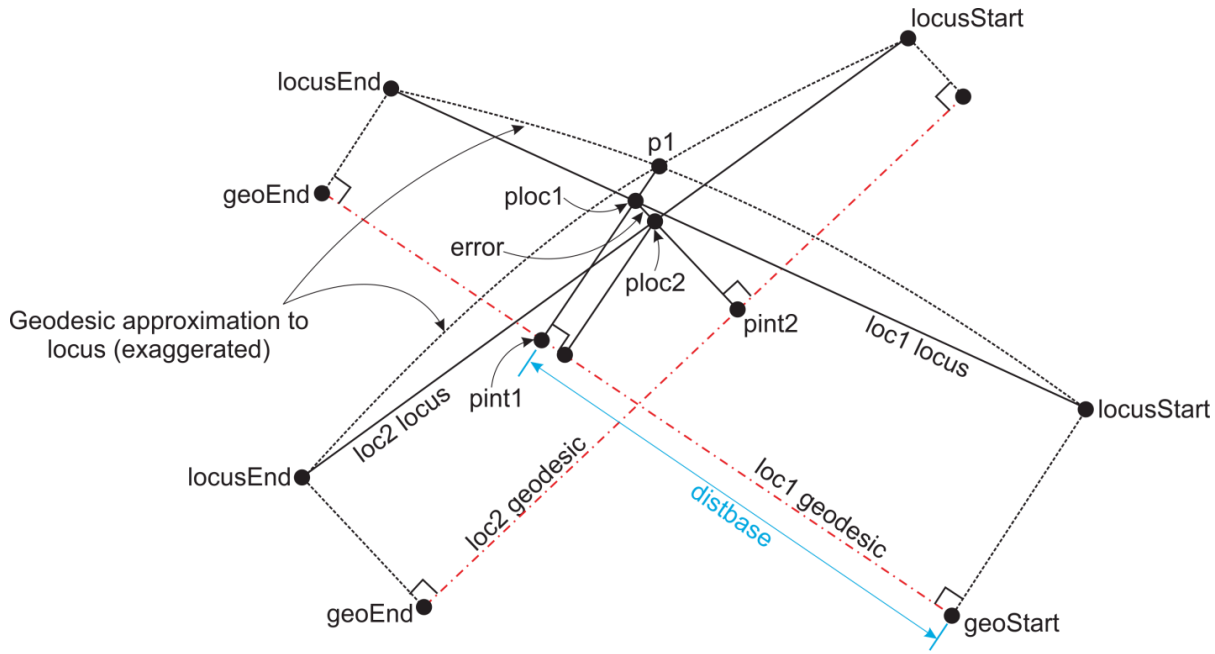
(3) LLPoint* intx = Reference to LLPoint that will be updated with intersection coordinates.

(4) Double tol = Maximum error allowed in solution

(5) Double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

Figure E-28. Computing the Intersection of Two Loci



(1) *Step 1*. Use the inverse algorithm to calculate the course of the geodesic approximation to loc1. Use loc1.locusStart and loc1.locusEnd as start and end points. Denote this course as crs1.

(2) *Step 2*. Use the inverse algorithm to calculate the course of the geodesic approximation to loc2. Use loc2.locusStart and loc2.locusEnd as start and end points. Denote this course as crs2.

(3) *Step 3*. Use loc1.locusStart, crs1, loc2.locusStart, and crs2 as input to section 5 algorithm 1 to calculate an approximate solution to the locus intersection. Denote the approximate intersection point at p1.

(4) *Step 4*. If ($p1 = NULL$) then the loci do not intersect, so return NULL.

(5) *Step 5*. Use the inverse algorithm to calculate the course of loc1's defining geodesic. Use loc1.geoStart and loc1.geoEnd as the start and end points, and denote the course as tcrs1.

(6) *Step 6*. Project p1 to the geodesic of loc1 using section 4 algorithm 1 with loc1.geoStart and tcrs1 as input parameters. Store the projected point as pint1.

(7) *Step 7*. If ($pint1 = NULL$) then no projected point was found so return NULL.

(8) *Step 8*. Use the inverse algorithm to calculate distbase, the distance from loc1.geoStart to pint1.

(9) *Step 9*. Initialize iteration counter: $k = 0$

(10) *Step 10*. Do while ($k = 0$) or ($k < maxIterationCount$) and ($abs\,(error) > tol$)

(a) If ($k > 0$) then apply direct algorithm to project new pint1 on loc1. Use starting point loc1.geoStart, course tcrs1, and distance distbase.

(b) Use section 4 algorithm 2 to project a point on loc1 from the current pint1. Denote the projected point as ploc1.

(c) Project ploc1 to the geodesic of loc2 using section 4 algorithm 1 with loc2.geoStart and tcrs2 as input parameters. Store the projected point as pint2.

(d) Use section 4 algorithm 2 to project a point on loc2 from pint2. Denote the projected point as ploc2. If ploc1 were truly at the intersection of the loci, then ploc2 and ploc1 would be the same point. The distance between them measures the error at this calculation step.

(e) Compute the error by using the inverse algorithm to calculate the distance between ploc1 and ploc2.

(f) Update the error and distance arrays and store the current values:

1. errarray[0] = errarray [1]

2. errarray [1] = error

3. distarray[0] = distarray [1]

4. distarray [1] = distbase

(g) If ($k = 0$) then project ploc2 onto loc1 to get a new estimate of distbase:

1. Project ploc2 to the geodesic of loc1 using section 4 algorithm 1 with loc1.geoStart and tcrs1 as input parameters. Store the projected point as pint1.

2. Use the inverse algorithm to calculate distbase, the distance from loc1.geoStart to pint1.

(h) Else use a linear root finder with distarray and errarray to find the distance value that makes the error zero. Update distbase with this root value. This is possible only after the first update step because two values are required in each array.

(i) End if.

(j) Increment iteration count: $k = k + 1$.

(11) *Step 11*. End while.

(12) *Step 12*. Use section 3 algorithm 9 with inputs of loc1 and ploc1 to determine if ploc1 lies on the loc1. Then use section 3 algorithm 9 with inputs of loc2 and ploc1 to determine if ploc1 lies on the loc2. If ploc1 does not lie on both loci, return NULL.

(13) *Step 13*. Return ploc1.

8. Arc tangent to two loci. Computing a tangent arc of a given radius to two loci is very similar to fitting an arc to two geodesics. The following algorithm uses the same basic logic as section 5 algorithm 4.

a. Input/Output. long WGS84LocusTanFixedRadiusArc(Locus loc1, Locus loc2, double radius, LLPoint* centerPoint, LLPoint* startPoint, LLPoint* endPoint, ArcDirection* dir, double tol) returns a reference to an LLPoint structure array that contains the coordinates of the center point and both tangent points of the arc that is tangent to both given loci, where the inputs are:

(1) Locus loc1 = Structure defining first locus

(2) Locus loc2 = Structure defining second locus

(3) double radius = Radius of desired arc

(4) LLPoint* centerpoint = Reference to LLPoint that will contain arc's center coordinates.

(5) LLPoint* startPoint = Reference to LLPoint that will contain arc's start point coordinates.

(6) LLPoint* endpoint = Reference to LLPoint that will contain arc's endpoint coordinates.

(7) ArcDirection* dir = Reference to an integer that represents direction of turn.

(a) dir = 1 for left hand turn

(b) dir = -1 for right hand turn

(8) double tol = Maximum error allowed in solution

(9) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

Figure E-29. Arc Tangent to Two Loci

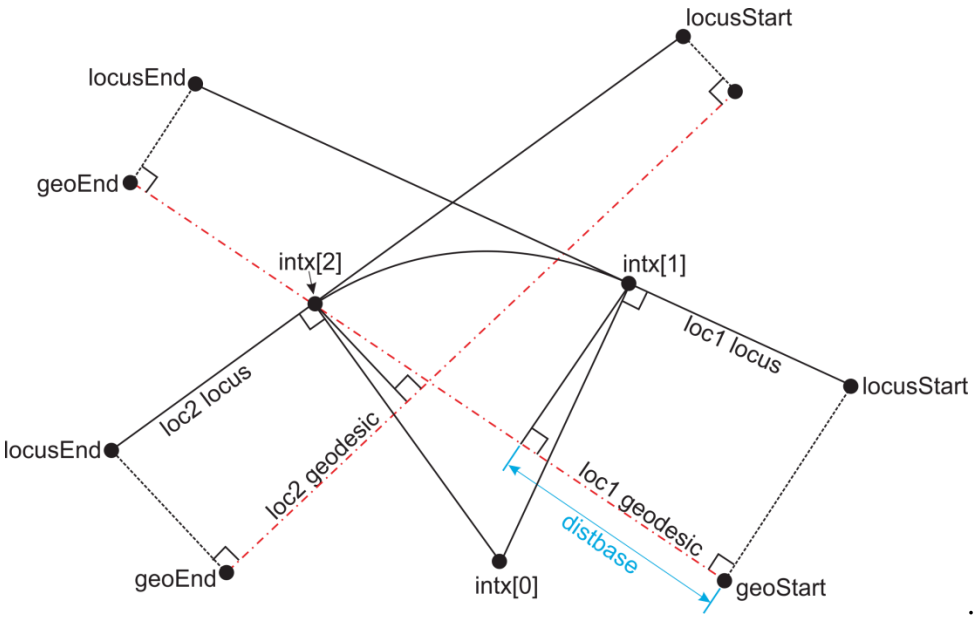
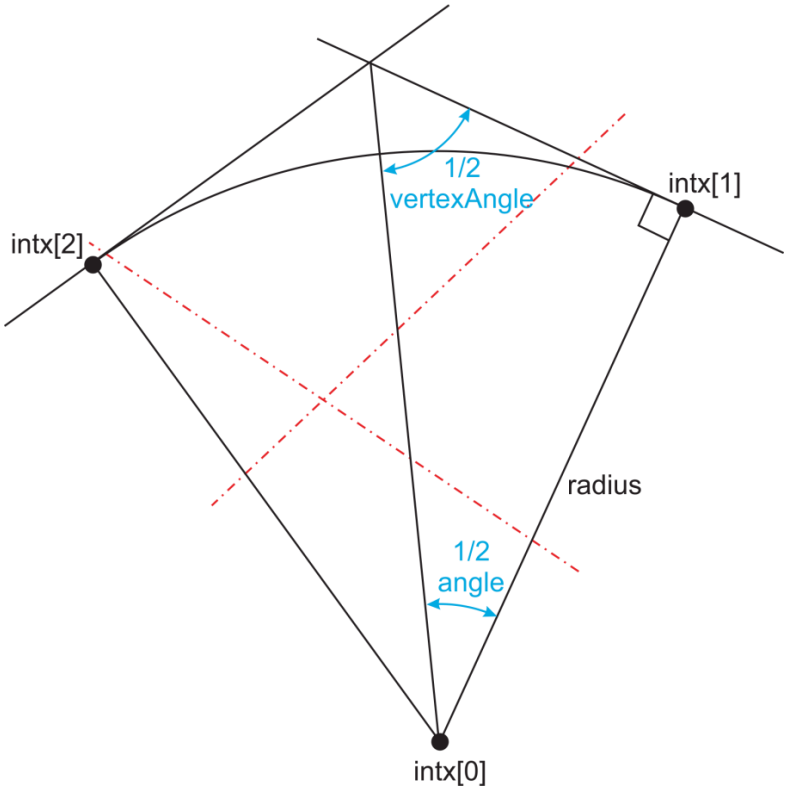


Figure E-30. Spherical Triangle Construction Used for Calculating the Approximate Vertex Angle at the Intersection of Two Loci



(1) *Step 1*. Use inverse algorithm to calculate crs12, the course from loc1.locusStart to loc1.locusEnd.

(2) *Step 2*. Use inverse algorithm to calculate gcrs1 and geoLen1, the course and distance from loc1.geoStart to loc1.geoEnd.

(3) *Step 3*. Use inverse algorithm to calculate crs32, the course from loc2.locusEnd to loc2.locusStart. Convert crs32 to its reciprocal: $crs32 = crs\ 32 + \pi$.

(4) *Step 4*. Apply section 5 algorithm 4 to find the arc tangent to the geodesic approximations to loc1 and loc2. Use loc1.locusStart, crs12, loc2.locusEnd, crs32, and radius as input parameter. Denote the array of points returned as intx. intx[0] will be the approximate arc center point, intx[1] will be the tangent point near loc1, and intx[2] will be the tangent point near loc2. Also returned will be the direction of the arc, dir.

(5) *Step 5*. If (*intx=NULL*) then there is no tangent arc. Return NULL.

(6) *Step 6*. Calculate the approximate angle at the vertex where loc1 and loc2 intersect. This will be used only to estimate the first improvement to the tangent point intx[1]. Thus we use an efficient spherical triangles approximation:

(a) Use the spherical inverse function to calculate the rcrs1, the course from intx[0] (the approximate arc center) to intx[1] (the approximate tangent point on loc1).

(b) Use the spherical inverse function to calculate the rcrs2, the course from intx[0] to intx[2] (the other approximate tangent point).

(c) Calculate the angle difference between rcrs1 and rcrs2:

$$angle = abs(singedAzimuthDifference\ (rcrs1, rcrs\ 2))$$

$$vertex\ Angle = 2\ \times acos\left[sin\left(\frac{angle}{2}\right)\ \times cos\left(\frac{radius}{SPHERE_{RADIUS}}\right)\right]$$

Step 7. Calculate the inclination angle of loc1 relative to its geodesic:

$$locAngle = atan\left(\frac{loc1.endDist - loc1.startDist}{geoLen1}\right)$$

(8) *Step* 8. Initialize $ddeeeeeebbsseeee = 0.1$.

(9) *Step 9*. Initialize the iteration count: $k = 0$.

(10) *Step 10*. Do while ($k = 0$) or ($k < maxiterationCount$) and ($abs\ (error) > tol$)

(a) Use direct algorithm with starting point loc1.geoStart, course gcrs1, and distance distbase to project point geoPt.

(b) Use section 4 algorithm 2 to project a point on loc1 from the current geoPt1. Denote the projected point as intx[1].

(c) Use section 3 algorithm 10 to calculate lcrs1, the course of loc1 at intx[1].

(d) Convert lcrs1 into the correct perpendicular course toward the arc center (note that dir> 0 indicates a left-hand turn): $lcrs1 = lcrs\ 1 - dir \times \pi/2$.

(e) Use the direct algorithm with starting point intx[1], course lcrs1, and distance radius to project the arc center point, intx[0].

(f) Use section 4 algorithm 3 to project intx[0] onto loc2. Reassign intx[2] as the projected point.

(g) Use the inverse algorithm to calculate r2, the distance from intx[0] to intx[2].

(h) Calculate the error: $error = r2 - radius$.

(i) Update the distance and error function arrays:

1. *distarray*[0] = *distarray* [1]
2. *distarray* [1] = *distbase*
3. *errarray*[0] = *errarray* [1]
4. *errarray* [1] = *error*

(j) If $(k = 0)$ then estimate better distbase value using spherical approximation and calculated error:

$$distbase = distbase + error \times \frac{\cos(locAngle)}{sin(vertexAngle)}$$

(k) Else use a linear root finder with distarray and errarray to find the distance value that makes the error zero. Update distbase with this root value.

(l) End if.

(11) *Step 11*. End while.

(12) *Step 12*. Return intx.

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ANNEXES

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ANNEX A

ACRONYMS AND ABBREVIATIONS

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ANNEX A: ACRONYMS AND ABBREVIATIONS

1. Acronyms and Abbreviations. Many acronyms and abbreviations for old and new aviation terms are used throughout this document. Definitions can be found in the Aeronautical Information Manual and/or within Annex B of this document. Users of TP308/GPH209 can refer to the following alphabetical listing of frequently used acronyms and abbreviations (see table A-1).

Table A-1. Acronyms and Abbreviations

AAF	Airway Facilities Service
AARN	Air Navigation Services and Airspace
ABM	abeam
AC	Advisory Circular
ACT	Average Cold Temperature
ADF	automatic direction finder
AER	Approach end of runway
AGL	above ground level
AIM	Aeronautical Information Manual
AIS	Aeronautical Information Services
ALSF-1	Standard Approach Lighting System with Sequenced Flashers (CAT I Configuration)
ALSF-2	Standard Approach Lighting System with Sequenced Flashers (CAT II Configuration)
APT	Airport
APV	approach with vertical guidance
ARA	airborne radar approach
ARC	Airport Reference Code
ARDH	achieved reference datum height
A RNP	Advance RNP
ARP	aerodrome reference point
ARSR	air route surveillance radar
ASBL	approach surface baseline
ASL	above sea level
ASOS	automated surface observing system
ASR	airport surveillance radar
AT	Air Traffic
ATC	Air Traffic Control
ATS	Air Traffic Service
ATD	along track distance
ATRK	along track
ATS	Air Traffic Service
ATT	Along-track tolerance
AVN	Aviation System Standards
AWO	all weather operations
AWOS	automated weather observation system
AWS	Aviation Weather System
BaroVNAV	Barometric vertical navigation
BAZ	back azimuth
BC	back course
BPOC	before proceeding on course
CAR	circling approach radius
CAT	Category
CF	course to fix
CFIT	controlled flight into terrain
CG	climb gradient
CGL	circling guidance light
CIH	climb-in-hold
CMDA	circling minimum descent altitude
COP	change over point
CP	critical point
CRM	collision risk model
CW	course width
DA	decision altitude
dB	decibel
DCG	desired climb gradient
DER	departure end of runway
DF	direct to fix
DG	descent gradient

DH	decision height
DME	distance measuring equipment
DND	Department of National Defense
DP	departure procedure
DR	dead reckoning
DRL	departure reference line
DRP	departure reference point
Drr	Reaction & Roll Distance
DTA	distance of turn anticipation
DVA	diverse vector area
EARTS	en route automated radar-tracking system
EDA	elevation differential area
ELEV	elevation
EOR	end of runway
ETP	Early Turn Point
ESA	emergency safe altitudes
ESV	expanded service volume
FAC	final approach course
FAF	final approach fix
FAP	final approach point
FAS	final approach segment
FATO	final approach and takeoff area
FAWP	final approach waypoint
FDC	Flight Data Control
FDR	Flight Data Record
FDT	fix displacement tolerance
FEP	final end point
FHP	Fictitious helipoint
FIFO	Flight Inspection Field Office
FMP	first maneuver point
FMPD	first maneuver point distance
FMS	flight management system
FMWP	first maneuver waypoint
FPAP	flight path alignment point
FPCP	flight path control point
FROP	final roll-out point
FSC	final straight course
FSS	Flight Service Station
FTE	flight technical error
FTIP	foreign terminal instrument procedure
FTP	fictitious threshold point
FWP	feeder waypoint
GA	General Aviation
GARP	GNSS azimuth reference point
GCA	ground controlled approach
GH	Geoid Height
GLONASS	Global Orbiting Navigation Satellite System
GLS	GNSS Landing System
GNSS	Global Navigation Satellite System
GP	glidepath
GPA	glidepath angle
GPI	ground point of intercept
GPS	Global Positioning System
GRI	group repetition interval
GS	glide slope
HAA	height above aerodrome
HAE	height above ellipsoid
HAH	height above heliport
HAI	Helicopter Association International
HAL	height above landing
HAS	height above surface
HAT	height above touchdown zone elevation (TDZE)
HATh	height above threshold
HCH	helipoint crossing height
HF	high frequency
HIALS	High Intensity Approach Lighting System
HIRL	high intensity runway lights
HRP	heliport reference point
HUD	heads-up display
IAC	initial approach course
IAF	initial approach fix
IAP	instrument approach procedure
IAPA	instrument approach

	procedure automation
IAWP	initial approach waypoint
IC	intermediate course
ICA	initial climb area
ICAB	ICA baseline
ICAE	ICA end-line
ICAO	International Civil Aviation Organization
ICPS	Instrument Check Pilot School
ICWP	initial course waypoint
IDF	initial departure fix
IAF	Initial approach fix
IF	intermediate fix
IF/IAF	intermediate/initial approach fix
IFR	instrument flight rules
ILS	instrument landing system
IMC	instrument meteorological conditions
INOP	Inoperative
INS	inertial navigation system
IPV	instrument procedure with vertical guidance
IRU	inertial reference unit
ISA	International Standard Atmosphere
IWP	intermediate waypoint
kHz	kilohertz
KIAS	knots indicated airspeed
LAAS	Local Area Augmentation System
LAB	landing area boundary
LAHSO	land and hold short operations
LDA	landing distance available
LDIN	lead-in lighting system
LF/mf	low frequency/medium frequency
LGSA	Lateral guidance sector angle
LIRL	low intensity runway lights
LNAV	lateral navigation
LP	Localizer Performance
LPV	Lateral Precision Performance with Vertical Guidance
LOA	Letter of Agreement
LOB	lines of business
LOC	localizer
LORAN	long-range navigation system
LTP	landing threshold point
MAHWP	missed approach holding waypoint
MALS	medium intensity approach lighting system
MALSF	medium intensity approach lighting system with sequenced flashing
MALSR	medium intensity approach lighting system with runway alignment indicator lights
MAP	missed approach point
MAWP	missed approach waypoint
MCA	minimum crossing altitude
MDA	minimum descent altitude
MEA	minimum en route altitude
MHA	minimum holding altitude
MHz	megahertz
MIA	minimum IFR altitudes
MIRL	medium intensity runway lights
MLS	Microwave Landing System
MOA	military operations area
MOC	minimum obstacle clearance
MOCA	minimum obstruction clearance altitude
MOU	Memorandum of Understanding
MRA	minimum reception altitude
MSA	minimum safe/sector altitude
MSL	mean sea level
MTA	minimum turn altitude
MVAC	minimum vectoring altitude chart
NAD	North American Datum

NAVAID	navigational aid
NDB	nondirectional radio beacon
NCFIO	NAVCANADA Flight Inspection Office
NM	nautical mile
NOTAM	Notice to Airmen
NOZ	normal operating zone
NPA	nonprecision approach
NTZ	no transgression zone
OC	obstruction chart
OCA	obstacle clearance altitude
OCH	obstacle clearance height
OCL	obstacle clearance limit
OCS	obstacle clearance surface
ODALS	omnidirectional approach lighting system
ODP	obstacle departure procedure
OEA	obstruction evaluation area
OE/AAA	Obstruction Evaluation/Airport Airspace Analysis
OEE	Obstacle effective elevation
OFA	object free area
OIS	obstacle identification surface
ORE	obstacle rich environment
OSAP	off-shore approach procedure
PA	precision approach
PAPI	precision approach path indicator
PAR	precision approach radar
PCG	positive course guidance
PDA	preliminary decision altitude
PFAF	precision final approach fix
PGPI	pseudo ground point of intercept
PinS	point-in-space
PINSA	point-in-space approach
PLS	precision landing system
POC	point of contact
PRM	precision runway monitor
PT	procedure turn
PVG	positive vertical guidance
PVGSI	pseudo visual glide slope indicator
QMS	Quality management system
RA	radio altimeter
RAIL	runway alignment indicator lights
RAPCON	radar approach control
RASS	remote altimeter setting source
RCL	runway centerline
RDP	reference datum point
REIL	runway end identifier lights
RF	radius to fix
RNAV	area navigation
RNP	required navigation performance
ROC	required obstacle clearance
RPI	runway point of intercept
RRP	runway reference point
RVR	runway visual range
RWP	runway threshold waypoint
RWT	runway threshold
RWTE	runway threshold elevation
RWY	runway
SALS	short approach lighting system
SATNAV	satellite navigation
SCG	standard climb gradient
SDF	simplified directional facility
SDF	step-down fix
SER	start end of runway
SIAP	standard instrument approach procedure
SID	standard instrument departure
SM	statute mile
SSALF	short simplified approach lighting system with sequenced flashers
SSALR	Simplified Short Approach Lighting System with Runway Alignment

	Indicator Lights
STAR	standard terminal arrival route
STOL	short takeoff and landing
TAA	terminal arrival area
TACAN	tactical air navigational aid
TC	Transport Canada
TCH	threshold crossing height
TD	time difference
TDP	touchdown point
TDZ	touchdown zone
TDZE	touchdown zone elevation
TDZL	touchdown zone lights (system)
TERPS	terminal instrument procedures
TF	track to fix
THLD	threshold
TLOF	touchdown and lift-off area
TLS	transponder landing system
TODA	take-off distance available
TORA	takeoff runway available
TP	tangent point
TPD	tangent point distance
TRACON	terminal radar approach control facility
TWP	turn waypoint
UHF	ultra high frequency
VA	heading to altitude
VASI	visual approach slope indicator
VCA	visual climb area
VCOA	visual climb over airport
VDA	vertical descent area
VEB	vertical error budget
VFR	visual flight rules
VGA	vertically guided approach
VGS	Vertical Guidance Surface
VGSI	visual glide slope indicator
VHF	very high frequency
VI	heading-to-an-Intercept
VLF	very low frequency
VMC	visual meteorological conditions
VNAV	vertical navigation
VOR	very high frequency omnidirectional radio range
VOR/DME	very high frequency omnidirectional radio range collocated with distance measuring equipment
VORTAC	very high frequency omnidirectional radio range collocated with tactical air navigation
VPA	vertical path angle
VSDA	visual segment descent angle
VTOL	vertical take-off and landing
WAAS	Wide Area Augmentation System
WATCO	Wing Air Traffic Control Officer
WCH	wheel crossing height
WICP	wing instrument check pilot
WP	waypoint
XTRK	crosstrack
XTT	Cross-track tolerance

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ANNEX B

DEFINITIONS

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ANNEX B: DEFINITIONS

1- 3 Dimensional (3D). Approach procedures that provide longitudinal, lateral, and vertical path deviation information are 3D procedures. Instrument landing system (ILS), microwave landing system (MLS), precision approach radar (PAR), lateral navigation/vertical navigation (LNAV/VNAV), Localizer Performance with Vertical Guidance (LPV), and required navigation performance (RNP) are examples of 3D procedures.

2- Aerodrome: any area of land, water (including the frozen surface thereof) or other supporting surface used or designated, prepared, equipped or set apart for the use either in whole or in part for the arrival or departure, movement of servicing of aircraft and includes any buildings, installations and equipment in connection therewith.

3- Aerodrome authorization for part VII operations: Where an aerodrome does not meet the full requirements for certification, an aerodrome authorization may be issued to accommodate Part VII operations. An Aerodrome Authorization is required by the aerodrome operator for each air operator applying to use the aerodrome. The requirements for issuing an Aerodrome Authorization are available from Transport Canada Aerodrome Safety in the document entitled *"Aerodrome Authorization for Part VII Operations"*.

4- Aerodrome elevation: the elevation of the highest point of the landing area measured to the nearest foot above or below mean sea level.

5- Aerodrome operator attestation: A formal record of the aerodrome physical characteristics to support the development of a public instrument approach procedure (IAP) at a non-certified aerodrome. This formal record is also required to obtain minima lower than 500 feet for restricted IAPs at non-certified aerodromes.

6- Aerodrome Reference Point (ARP). For the purpose of this publication, the designated geographical location of an aerodrome given to the nearest second of latitude and longitude. The ARP is located as near as practicable to the geometric centre of the landing area (the approximate geometric center of all usable runways at an airport) taking into account possible future development. The official horizontal geographic location of an airport.

7- Air Traffic Service (ATS) Route. A generic term that includes airways, air route, jet routes, and RNAV routes. The term "ATS route" does not replace these more familiar route names, but serves only as an overall title when listing the types of routes that comprise the Canadian en-route structure.

8- Airport (APT) waypoint (WP). A WP located on the FAC at or abeam the first usable landing surface, which is used for construction of the final approach area for a circling-only approach.

9- Along-Track Distance (ATD). A distance specified in nautical miles (NM) along a defined track to an area navigation (RNAV) fix.

10- Along-Track (ATRK) Tolerance (ATT). The amount of possible longitudinal fix positioning error on a specified track expressed as a ± value.

Note: The acronym ATRKFDT (along-track fix displacement tolerance) has been used instead of ATT in the past. The change to ATT is a step toward harmonization of terms with International Civil Aviation Organization (ICAO) Pans-Ops.

11- Altitude: The vertical distance of a level, a point or an object considered as a point, measured from mean sea level.

12- Angle of divergence (Minimum). The smaller of the angles formed by the intersection of two courses, radials, bearings, or combinations thereof.

13- Approach end of runway (AER): The first portion of the runway available for landing. If the runway threshold is displaced, use the displaced threshold Lat/Long as the AER.

14- Approach procedure with vertical guidance (APV): An instrument approach procedure that utilizes lateral and vertical guidance that do not meet the requirements established for a precision approach. Minima shall be expressed as DA(H).

15- Approach Surface Baseline (ASBL). The ASBL is a line aligned to the runway centerline (RCL) that lies in a plane parallel to a tangent to the WGS-84 Ellipsoid at the landing threshold point (An imaginary horizontal line at threshold elevation). It is used as a baseline reference for vertical measurement of the height of glidepath and obstacle clearance surface (OCS).

16- Area Navigation (RNAV). A method of navigation which permits aircraft operation on any desired flight path within the coverage of ground or spaced-based navigation aids or within the limits of the capability of self-contained aids, or a combination of these.

17- Authorization Required (AR). Aircraft may be equipped beyond the minimum standard for public required navigation performance (RNP) criteria and aircrews trained to achieve a higher level of instrument approach performance. AR criteria are based on a higher level of equipage and additional aircrew requirements. Procedures that utilize AR design criteria must be appropriately annotated.

18- Average Coldest Temperature (ACT). A value in Centigrade (°C) and/or Fahrenheit (°F) scale for the lowest temperature a Baro-VNAV (including RNP) procedure can be utilized. It is derived from historical weather data, or in the absence of historical data, a standardized temperature value below airport ISA is used.

19- Barometric Altitude. A barometric altitude measured above mean sea level (MSL) based on atmospheric pressure measured by an aneroid barometer. This is the most common method of determining aircraft altitude.

20- Barometric Vertical Navigation (Baro-VNAV). Positive vertical guidance relative to a computed glidepath that is based on the difference between published altitudes at two specified points or fixes.

21- Baseline. Where a turn area expansion arc(s) may be centered, a line perpendicular to the inbound course after the leg termination fix ATT area. For CA, CI, VA or VI legs, the baseline is located at the leg termination point.

22- Bearing: The horizontal angle at a given point, measured clockwise from a specific reference datum, to a second point. Bearings are expressed as True, Magnetic, Relative, Astronomic, Grid, etc. according to the reference datum used.

23- Change over point (COP): A point defined between navigation facilities along airway/route segments, which indicate the pilot should change over his navigation equipment to receive course guidance from the facility ahead of the aircraft instead of the one behind.

24- Circling approach: The visual maneuvering required, after completing an instrument approach, to bring an aircraft into position for landing on a runway that is not suitably indicated for straight-in landing.

25- Circling approach area or circling maneuvering area: The area in which aircraft circle to land under visual conditions after completing an instrument approach.

26- Climb gradient (CG). A climb requirement expressed in feet/NM.

27- Common route. The segment(s) of a STAR/SID procedure that provides a single route serving an airport/runway or multiple airports/runways. The common route may consist of a single point.

28- Controlling obstacle. The obstacle on which the design of a procedure or establishment of a minimum altitude or angle is based on.

29- Course. A specified track measured in degrees from magnetic north.

30- Course Change. A course change is the mathematical difference between the inbound and outbound tracks at a single fix.

31- Course-to-a-Fix (CF). A defined, repeatable course (track over the ground) to a specific database fix.

32- Course-to-an-Altitude (CA). A defined, repeatable course to a specific altitude at an unspecified position.

33- Course-to-an-Intercept (CI). A defined, repeatable course to intercept the subsequent leg.

34- Cross-Track (XTT) Tolerance. The amount of possible lateral positioning error expressed as a ± value.

Note: The acronym XTRKFDT (cross-track fix displacement tolerance) has been used instead of XTT in the past. The change to XTT is a step toward harmonization of terms with ICAO Pans-Ops.

35- Dead reckoning: The estimating or determining of position by advancing an earlier known position by the application of direction and speed data. For example, flight based on a heading from one VORTAC azimuth and distance fix to another is dead reckoning.

36- Decision Altitude (DA). The DA is a specified barometric altitude at which a missed approach must be initiated if the required visual references to continue the approach have not been acquired. DA is referenced to MSL. The DA applies to approach procedures where the pilot is provided with glidepath deviation information; e.g., ILS, MLS, TLS, GLS, LNAV/VNAV, Baro VNAV, or PAR.

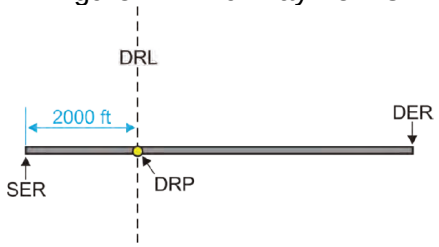
37- Departure End of Runway (DER). The DER is the end of the runway that is opposite the landing threshold. It is sometimes referred to as the stop end of runway.

38- Decision height (DH): The DH is the value of the DA expressed in feet above the threshold elevation. This value is also referred to as HATh.

39- Departure Reference Line (DRL). An imaginary line of indefinite length perpendicular to the runway centerline at the DRP.

40- Departure Reference Point (DRP). A point on the runway centerline 2000ft from the start end of runway (SER) (see figure B-1).

Figure B-1. Runway Terms



41- Departure route. A specified course and altitude along a track defined by positive course guidance (PCG) to a clearance limit, fix, or altitude.

42- Departure sector. Airspace defined by a heading or a range of headings for aircraft departure operations.

43- Descent Gradient (DG). Description of aircraft descent profile specified in feet per nautical mile.

44- Direct-to-a-Fix (DF). An unspecified non-repeatable track starting from an undefined position to a specific database fix.

45- Distance of Turn Anticipation (DTA). The distance from (prior to) a fly-by fix at which an aircraft is expected to start a turn to intercept the course/track of the next segment.

46- Distance measuring equipment (DME) Arc. A course, indicated as a constant DME distance, around a navigation facility which provides distance information.

47- Diverse vector area (DVA): An area in which a prescribed departure route is not required. Radar vectors may be issued below the minimum vectoring or minimum IFR altitude. It can be established for diverse departure, departure sectors, and/or video map radar areas portraying obstacles and terrain.

48- DME arc: A track, indicated as a constant DME distance, around a navigation facility that provides distance information.

49- DME distance. The line of sight distance (slant range) from the source of the DME signal to the receiving antenna.

50- Early Turn Point (ETP). Represents the earliest location where a flight track turn may commence.

51- Earth Curvature (EC). Allowance for the curvature of the earth used in distance calculations based on a spherical earth model with a radius of 20890537 ft.

52- En route transition. The segment(s) of a SID/STAR that connect to/from en route flight.

53- Elevation (Elev): The vertical distance of a point or a level, on or affixed to the surface of the earth measured from mean sea level.

54- Fictitious Helipoint (FHP). The equivalent of the LHP when the final approach path is not based on the location and elevation of the helipoint.

55- Fictitious Threshold Point (FTP). The FTP is the equivalent of the landing threshold point (LTP) when the final approach course is offset from the runway centerline. It is not aligned through the LTP. It is located on the final approach course the same distance from the intersection of the final approach course and runway centerline extended as the LTP. FTP elevation is the same as the LTP. For the purposes of this document, where LTP is used, FTP may apply as appropriate (see Figure B-2).

56- Final approach: That part of an instrument approach procedure from the time the aircraft has

a. completed the last procedure turn or base turn, where one is specified; or
b. crossed the final approach fix or point; or
c. intercepted the last track specified for the procedure;

until it reaches the missed approach point. It is in this portion of the procedure that alignment and descent for landing are accomplished.

57- Final approach and takeoff area (FATO). A defined area over which the final phase of the approach to a hover, or a landing, is completed and from which the takeoff is initiated. A FATO is applicable only at a heliport; guidance for a FATO is published in TP312.

58- Final Approach Course (FAC). Magnetic and/or true heading definition of the final approach lateral path.

59- Final Approach Fix (FAF). A fly-by waypoint (WP) for nonprecision GPS procedures that marks the beginning of the final approach segment. A fix that indicates the commencement of the final approach segment of a non-precision instrument approach procedure.

60- Final Approach Segment (FAS). The segment of an instrument approach procedure that begins at the PFAF and ends at the MAP (or LTP/FTP, whichever is encountered last) and/or DA.

61- Final Roll-Out Point (FROP). A point in the final approach segment after which not turns are permitted. After the FROP, the FAC must comply with final approach course alignment requirements.

62- Fix: A geographical location determined by means of radio aids or other navigation devices.

63- Fix Displacement Tolerance (FDT). FDT is a legacy term providing 2-dimensional (2D) quantification of positioning error. It is now defined as a circular area with a radius of ATT centered on an RNAV fix. The acronym ATT is now used in lieu of FDT.

64- Fix-to-NAVAID. Horizontal distance from the plotted position of the holding fix to the NAVAID.

65- Flight Control Computer (FCC). Aircraft computers which process information from various inputs to calculate flight path and flight guidance parameters.

66- Flight Management System (FMS). An FMS is a specialized computer system that automates a wide variety of in-flight tasks, reducing the workload on the flight crew to the point that modern aircraft no longer carry flight engineers or navigators. A primary function is in-flight management of the flight plan. Using various sensors (such as GPS and INS often backed up by radio navigation) to determine the aircraft's position, the FMS can guide the aircraft along the flight plan. From the cockpit, the FMS is normally controlled through a Control Display Unit (CDU) which incorporates a small screen and keyboard or touchscreen. The FMS sends the flight plan for display on the EFIS, Navigation Display (ND) or Multifunction Display (MFD).

67- Flight Path Alignment Point (FPAP). A point in the same lateral plane as the LTP/FTP that is used to establish the alignment of the FAS. For approaches aligned with the runway centerline, the FPAP is located at or beyond the opposite threshold of the runway. The delta length offset from the opposite threshold defines its location.

68- Flight Path Control Point (FPCP). The FPCP is a 3D point defined by the LTP geographic position, MSL elevation, and threshold crossing height (TCH) value. The FPCP is in the vertical plane of the final approach course and is used to relate the glidepath angle of the final approach track to the landing runway. It is sometimes referred to as the TCH point or reference datum point (RDP).

69- Flight Technical Error (FTE). FTE is the measure of the pilot or autopilot's ability to control an aircraft so that it's indicated position matches the desired position.

70- Flight Validation (flight check/flight evaluation): A process which helps ensure that instrument flight procedures meet the intended operational requirements and that obstacle assumptions during the design process are correct (see Annex F).

71- Fly-By (FB) Fix. Fly-by fixes/waypoints are used when an aircraft should begin a turn to the next course prior to reaching the waypoint separating the two route segments.

72- Fly-Over (FO) Fix. Fly-over fixes/waypoints are used when the aircraft must fly over the point prior to starting a turn.

73- Geoid Height (GH). The GH is the height of the Geoid relative to the WGS-84 ellipsoid. It is a positive value when the Geoid is above the WGS-84 ellipsoid and negative when it is below. The value is used to convert a mean sea level (MSL) elevation to an ellipsoidal or geodetic height, the height above ellipsoid (HAE).

Note: The Geoid is an imaginary surface within or around the earth that is everywhere normal to the direction of gravity and coincides with MSL in the oceans. It is the reference surface for MSL heights.

74- Geographic Positioning Navigation (GPN). Navigation based on geodetic calculation of geographic position referenced to the WGS-84 ellipsoid. Global positioning system (GPS), wide area augmentation system (WAAS), local area augmentation system (LAAS), flight management system (FMS), RNP, and RNAV are examples of GPN.

75- Glidepath (GP)/ glide slope (GS): A descent profile that is electronically determined for vertical guidance during a final approach.

76- Glidepath Angle (GPA). The GPA is the angle of the specified final approach descent path relative to a horizontal line tangent to the surface of the earth at the runway threshold.

77- Global Azimuth Reference Point (GARP). Global Navigation Satellite System (GNSS) Azimuth Reference Point. A calculated point 1000 ft beyond the FPAP lying on an extension of a geodesic line from the LTP/FTP through the FPAP. It may be considered the location of an imaginary localizer antenna.

78- Global Navigation Satellite System (GNSS). A worldwide position and time determination system that includes one or more satellite constellations, aircraft receivers and system integrity monitoring. GNSS is augmented as necessary to support the required navigation performance for the actual phase of operation.

79- Gradient: A slope expressed in feet per mile, or as a ratio of the horizontal to the vertical distance. For example, 40:1 means 40 feet horizontally to 1 foot vertically.

80- Ground Point of Intercept (GPI). A point in the vertical plane on the runway centerline at which it is assumed that the straight line extension of the glide slope intercepts the runway approach surface baseline. The glidepath intercepts the ASBL at the GPI. The GPI is expressed as a distance in feet from the LTP. The GPI is derived from TCH and glidepath angle values: $\mathrm{GPI} = \frac{\mathrm{TCH}}{\tan(\theta)}$.

81- Heading: The direction in which longitudinal axis of the aircraft is pointed expressed in degrees from north (true, magnetic, compass or grid).

82- Heading-to-an-Altitude (VA). A specified heading to a specific altitude at an unspecified position. The resulting track is not wind corrected.

83- Heading-to-an-Intercept (VI). A specified heading to intercept the subsequent leg at an unspecified position. The resulting track is not wind corrected.

84- Height: The vertical distance of a level, a point or an object considered as a point, measured from a specified datum.

85- Height above aerodrome (HAA): The height in feet of the MDA above the published aerodrome elevation. HAA will be published for all circling minima.

86- Height Above Ellipsoid (HAE). The heights relative to the WGS-84 ellipsoid smooth mathematical surface which represent the earth’s surface.

87- Height above landing (HAL). The height above the landing area elevation.

88- Height above surface (HAS). The height of the MDA above the highest terrain/obstacle within a 5200-foot radius of the MAP in a point-in-space (PinS) procedure.

89- Height Above Threshold (HATh). The HATh is the height of the DA above LTP elevation.

90- Height above touchdown zone elevation (HAT): The height in feet above the touchdown zone elevation.

91- Helipoint. The helipoint is the aiming point for the visual segment of an approach to a heliport and is normally centered in the touchdown and lift-off area (TLOF). The TLOF is normally centered in the FATO.

92- Helipoint crossing height (HCH). The height of the vertical guidance path above the heliport elevation at the helipoint.

93- Heliport. An area of land, water, or structure used or intended to be used for helicopter landings and takeoffs and includes associated buildings and facilities.

94- Heliport Elevation (HE). The highest elevation of all landing areas within the heliport, expressed as the distance above mean sea level (MSL).

95- Heliport Reference Point (HRP). The geographic position of the helipoint, measured at the center of the FATO or the central point of multiple FATOs, expressed as (WGS-84/NAD-83) latitude and longitude to the nearest hundredth of a second. The HRP elevation is equal to the heliport elevation.

96- Holding procedure: A predetermined manoeuvre which keeps an aircraft within a specified airspace while awaiting further clearance.

97- Initial approach: That part of an instrument approach procedure in which the aircraft has departed an initial approach fix and is maneuvering to enter the intermediate segment of the approach.

98- Initial Approach Fix (IAF). A fix at which an aircraft leaves the en route phase of operations in order to commence the approach. Normally a fly-by waypoint that marks the beginning of the initial segment and the end of the feeder segment, if applicable.

99- Initial Climb Area (ICA). A segment variable in length starting at the DER which allows the aircraft sufficient distance to reach an altitude of at least 400 ft above the DER.

100- ICA baseline (ICAB). A line at DER, perpendicular to runway centerline, denoting the beginning of the ICA.

101- ICA end-line (ICAE). A line at end of ICA perpendicular to the departure course.

102- Initial approach fix (IAF). A fix that identifies the beginning of an initial approach segment.

103- Initial Course. The course established initially after take-off beginning at the DER.

104- Initial Departure Fix (IDF). The first fix/waypoint used for the departure. The IDF denotes the beginning portion of the SID.

105- Instrument approach procedure (IAP): A series of predetermined maneuvers for the orderly transfer of an aircraft under instrument flight conditions from the beginning of the initial approach to a point from which a landing may be made visually.

106- Instrument Flight Procedure (IFP): A published procedure used by aircraft flying in accordance with the instrument flight rules which is designed to achieve and maintain an acceptable level of safety in operations. IFPs include instrument approach procedures, standard instrument departures, obstacle departure procedures and standard terminal arrivals.

107- IFP design service: A service established for the design, documentation, validation, maintenance and periodic review of instrument flight procedures necessary for the safety, regulatory and efficiency of air navigation.

108- IFR Heliports. For the purpose of this publication, consider IFR Heliport to mean instrument heliport.

109- IFR Runway. For the purpose of this publication, consider IFR Runway to mean instrument runway.

110- Instrument Landing System (ILS). A precision instrument approach system which normally consists of a localizer, glide slope and an approach lighting system.

111- Intermediate approach: That part of an instrument approach procedure in which aircraft configuration, speed and positioning adjustments are made for entry into the final approach.

112- Intermediate fix (IF). The fix at which the aircraft enters the intermediate approach segment of an instrument approach. The fix that identifies the beginning of the intermediate approach segment of an instrument approach procedure. The fix is not normally identified on the instrument approach chart as an IF.

113- International Standard Atmosphere (ISA). A model of standard variation of pressure and temperature.

114- Knots Indicated Airspeed (KIAS). The speed shown on the aircraft airspeed indicator.

115- Landing area: That part of the movement area intended for the landing or take-off run of aircraft.

116- Landing area as used in helicopter operations. The portion of the heliport or airport runway used or intended to be used for the landing and takeoff of helicopters.

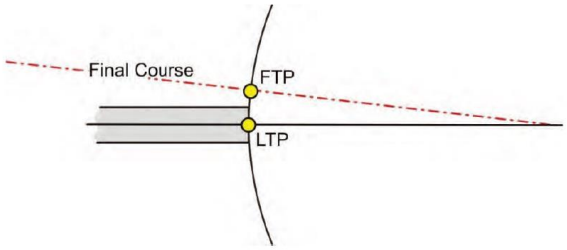
117- Landing area boundary (LAB). The beginning of the landing area of the heliport or runway.

118- Landing and Takeoff Site. The area of intended landing and takeoff. It can be a heliport, or other point of landing designated for a PinS Approach.

119- Landing Threshold Point (LTP). The LTP is the intersection of the runway centerline and the runway threshold. It is defined by latitude/longitude coordinates, and MSL elevation. LTP

elevation applies to the FTP when the final approach course is offset from runway centerline (see figure B-2).

Figure B-2. Landing Threshold Point and Fictitious Threshold Point



120- Lateral Navigation (LNAV). LNAV is RNAV lateral navigation. This type of navigation is associated with non-precision approach procedures (NPA) because vertical path deviation information is not provided. LNAV criteria are the basis of the LNAV minima line on RNAV GPS approach procedures.

121- Lateral Navigation/Vertical Navigation (LNAV/VNAV). An approach with vertical guidance (APV) evaluated using the Baro VNAV obstacle clearance surfaces conforming to the lateral dimensions of the LNAV obstruction evaluation area (OEA).

122- Leg. A subdivision of an RNAV IFP defined by a path and a terminator. Also used in reference to the length of holding patterns.

123- Localizer Performance (LP). An LP approach is an RNAV NPA procedure evaluated using the lateral obstacle evaluation area dimensions of the precision localizer trapezoid, with adjustments specific to the WAAS. These procedures are published on RNAVGPS approach charts as the LP minima line.

124- Localizer (LOC). The component of the ILS which provides lateral guidance with respect to the runway centerline.

125- Localizer Performance with Vertical Guidance (LPV). An approach with vertical guidance (APV) evaluated using the OCS dimensions (horizontal and vertical) of the precision approach trapezoid, with adjustments specific to the WAAS. These procedures are published on RNAVGPS approach charts as the LPV minima line.

126- Localizer type directional aid: A facility of comparable utility and accuracy to a LOC, but which is not part of a full ILS and may not be aligned with the runway.

127- Minimum descent altitude (MDA): A specified altitude referenced to sea level for a non-precision approach below which descent must not be made until the required visual reference to continue the approach to land has been established.

128- Minimum sector altitude (MSA): The lowest which will provide a minimum clearance of 1,000 feet, under conditions of standard temperature and pressure, above all obstacles located in an area contained within a defined sector of a circle of 25 nautical miles radius centred on an identified navigational facility or waypoint.

129- Maximum Allowable Descent Rate (MDR). A vertical velocity limit.

130- Missed Approach Point (MAP). A fly-over waypoint that marks the end of the final approach segment and the beginning of the missed approach segment. That point on the final approach track which signifies the termination of the final approach and the commencement of the missed approach. It may be:

a. the intersection of an electronic glide path with a Decision Height;
b. a navigational facility located on the aerodrome;
c. a suitable fix (e.g., DME);
d. specified distance past the facility or final approach fix, not to exceed the distance from that facility or fix to the nearest boundary of the aerodrome.

131- Missed approach procedure: The procedure to be followed, if for any reason, after an instrument approach, a landing is not affected.

132- Minimum Descent Altitude (MDA). The lowest altitude, expressed in feet above mean sea level, to which descent is authorized on final approach where no glide slope is provided, or during a circle-to-land maneuver.

133- Minimum En Route Altitude (MEA). The lowest published altitude between radio fixes which assures acceptable navigational signal coverage and meets obstacle clearance requirements between those fixes. The MEA prescribed for a Federal airway or segment thereof, area navigation low or high route, or other direct route applies to the entire width of the airway, segment, or route between the radio fixes defining the airway, segment, or route.

134- Minimum obstruction clearance altitude (MOCA). The lowest published altitude between fixes on an ATS route or STAR which meets obstacle clearance requirements for the entire segment.

135- Non-directional beacon (NDB) airborne automatic direction finder (ADF). A combined term which indicates that an NDB provides an electronic signal for use with ADF equipment.

136- Non-precision approach (NPA): An instrument approach procedure which does not utilize vertical guidance. Minima shall be expressed as MDA(H).

137- Non-Vertically Guided Procedures (NVGP). Instrument approach procedures without vertical guidance. As used in this Order, NVGP include LNAV and LP approach procedures.

138- Non-VOR/DME RNAV. It is not dependent upon a reference. It utilizes positioning inputs from DME/DME, DME/DME/IRU, or GNSS. A Multi-Sensor System based on any VOR/DME or non-VOR/DME certified approved system or a combination of certified approved systems may also provide positioning inputs.

139- Obstacle Free Zone (OFZ). The airspace above the Precision Obstacle Free Zone, Approach Surface, Inner Transitional Surface, and that portion of the strip bounded by these surfaces, which is not penetrated by any obstacle, except for frangible visual NAVAIDs that need to be located in the OFZ because of their function.

140- Obstacle. An object, structure, terrain feature, or vegetation, at a fixed geographical location, or which may be expected at a fixed location within a prescribed area, with reference to which vertical clearance must be provided during flight operation. With reference to mobile objects, a moving vehicle 17 feet high is assumed to be on an Highway, 15 feet high for any other public roadway, 10 feet high on private roads, and 23 feet high on a railroad track, except where limited to certain heights controlled by use or construction. The tallest point of a watercraft (for example, the mast) is assumed according to the types of watercraft known to use an anchorage or to transit a waterway. Includes taxiing aircraft except where operational restrictions prevent taxi operations during takeoff and landings. Any mobile object may be ignored provided positive controls are applied by the airport authority or by air traffic control established to exclude their presence during flight operations.

141- Obstacle clearance. The vertical distance between the lowest authorized flight altitude and a prescribed surface within a specified area.

142- Obstacle clearance limit (OCL): The lowest altitude that will satisfy the obstacle clearance requirement for the particular segment of an instrument approach procedure that is under consideration.

143- Obstacle clearance height (OCH) point: The point where the VGS area start for NPA.

144- Obstacle Clearance Surface (OCS). An OCS is an upward or downward sloping surface used for obstacle evaluation where the flight path is climbing or descending. The separation between this surface and specified glidepath angle or minimum required climb path defines the MINIMUM required obstruction clearance at any given point. A surface above which obstacles may not penetrate if the required obstacle clearance is to be maintained.

145- Obstacle limitation surface (OLS): A surface that establishes the limit to which objects may project into the airspace associated with an aerodrome so that aircraft operations at the aerodrome may be conducted safely. Obstacle limitation surfaces consist of the following:

a. Take-off/Approach surface. An incline plane beyond the end of the runway and preceding the threshold of a runway. The origin of the plane comprise:

(1) An inner edge of specified length (strip width), perpendicular to and evenly divided on each side of the extended centre line of the runway, and beginning at the end of the runway strip;
(2) Two sides originating at the ends of the inner edge, diverging uniformly at a specified rate in the direction of take-off;
(3) The elevation of the inner edge is equal to the elevation of the threshold.

b. Transitional surface. A complex surface sloping up at a specified rate from the side of the runway strip and from part of the take-off/approach surface. The elevation of any point on the lower edge of the surface is:
(1) Along the side of the take-off/approach surface, equal to the elevation of the take-off/approach surface at that point; and,
(2) Along the runway strip, equal to the elevation of the centre line of the runway, perpendicular to that point.

146- Obstacle Evaluation Area (OEA). An area within defined limits that is subjected to obstacle evaluation through application of required obstacle clearance (ROC) or an OCS.

147- Obstacle Identification Surface (OIS). The OIS is an inclined surface conforming to the lateral dimensions of the OEA used for identification of obstacles that may require mitigation to maintain the required level of safety for the applicable segment. An OIS is normally associated with the visual portion of the FAS.

148- Obstacle Positions ($OBS_{X,Y,Z}$). $OBS_{X, Y, Z}$ are the along track distance to an obstacle from the LTP, the perpendicular distance from the centerline extended, and the MSL elevation, respectively, of the obstacle clearance surfaces.

149- Obstacle rich environment (ORE): An environment is obstacle rich when it is not possible to construct an unguided discontinued approach using procedural means. Approach operations in an ORE require supplementary guidance to proceed along the published course to the missed approach point and achieve a climb to the minimum vectoring altitude or minimum IFR altitude.

150- Omnidirectional facility: A facility capable of receiving or transmitting in all directions. Omnidirectional facilities include VOR, TACAN, VORTAC, NDB and DME.

151- Operational advantage. An improvement which benefits the users of an instrument procedure. Achievement of lower minimums or authorization for a straight-in approach with no derogation of safety is an example of an operational advantage. Many of the options in TP308/GPH209 are specified for this purpose. For instance, the flexible final approach course alignment criteria may permit the ALS to be used for reduced visibility credit by selection of the proper optional course.

152- Penetration turn: That part of the initial approach segment, which permits a high performance aircraft to reverse direction and to lose altitude while remaining within a limited area.

153- Positive course guidance (PCG). A continuous display of navigational data which enable an aircraft to be flown along a specific course line.

154- Precipitous terrain. Terrain characterized by steep or abrupt slopes.

155- Precise Final Approach Fix (PFAF). The PFAF is a calculated WGS-84 geographic position located on the final approach course where the designed glidepath (APV and PA procedures) intercepts the intermediate segment altitude (glidepath intercept altitude). The PFAF marks the beginning of the FAS. The calculation of the distance from LTP to PFAF includes the earth curvature.

156- Precision approach (PA): An instrument approach procedure utilizing precision lateral and vertical guidance with minima as determined by the category of operation.

157- Precision approach radar (PAR): Primary radar equipment used to determine the position of an aircraft during final approach, in terms of lateral and vertical deviations relating to a predetermined approach path, and in range relative to a predetermined touchdown point.

158- Precision and non-precision: These terms are used to differentiate between navigational facilities that provide a combined azimuth and glide slope guidance to a runway (Precision) and those that do not. The term non-precision refers to facilities without a glide slope, and does not imply an unacceptable quality of course guidance.

159- Primary area. The area within a segment in which full obstacle clearance is applied.

160- Procedure turn (PT): A manoeuvre in which a turn is made away from a designated track, followed by a turn in the opposite direction, both turns being executed so as to permit the aircraft to intercept and proceed along the reciprocal of the designated track

NOTE: Procedure turns are designated left or right according to the direction of the initial turn.

161- Procedure course (Track) guidance: A continuous display of navigational data which enables an aircraft to be flown along a specific course (track).

NOTE: Radar vectors are considered meeting the requirements of positive course (track) guidance.

162- Proceed VFR: Point-in-space procedure which allows an aircraft to fly an IFR approach to a point in which a transition to VFR is conducted. Aircraft are expected to continue from the MAP under VMC while maintaining VFR minimums. The aircraft is allowed to fly from the MAP to the landing area by any route desired by the pilot which will afford obstacle and terrain avoidance. An IFR recovery procedure is not provided between the MAP and landing area.

163- Q Routes. ‘Q’ is the designator assigned to published high altitude RNAV-based ATS routes in Canada.

164- Radial: A bearing extending from a VOR, or TACAN facility.

165- Radio altimeter height (RA). An indication of the vertical distance between a point on the nominal glidepath at DA and the terrain directly beneath this point.

166- Radius to Fix (RF) Leg. An RF leg is a constant radius circular repeatable path about a defined turn center that begins and terminates at a fix.

167- Reference Datum Point (RDP). The RDP is a 3Dpoint defined by the LTP or FTP latitude/longitude position, MSL elevation, and a threshold crossing height (TCH) value. The RDP is in the vertical plane associated with the FAC and is used to relate the GPA of the final approach track to the landing runway. It is also referred to as the TCH point or FPCP.

168- Reference facility. A VOR/DME, VORTAC or TACAN facility used for the identification and establishment of an RNAV route, WP, or instrument approach procedure.

169- Reference Fix. A point of known location used to geodetically compute the location of another fix.

170- Reference Line. For fix turns less than 90 degrees, a line parallel to the course line after the turn fix where an additional set(s) of turn area expansion arcs are centered.

171- Reference Navigational Aid (NAVAID). A navigational facility required for various leg construction (e.g., CF) to assign a magnetic variation to the course.

172- Required Navigation Performance (RNP). RNP is a statement of the 95 percent navigation accuracy performance that meets a specified value for a particular phase of flight or flight segment and incorporates associated on-board performance monitoring and alerting features to notify the pilot when the RNP for a particular phase or segment of a flight is not being met.

173- Required Obstruction Clearance (ROC). Sometimes referred to as required obstacle clearance, ROC is the minimum vertical clearance (in feet) that must exist between aircraft and the highest ground obstruction within the OEA of instrument procedure segments.

174- Runway (RWY): A defined rectangular area, on a land aerodrome, prepared for the landing and take-off of aircraft along its length.

175- Runway environment: The runway threshold, lighting aids, markers or markings identifiable with the runway.

176- Runway Threshold (RWT). The RWT marks the beginning of the portion of the runway usable for landing. It extends the full width of the runway. Threshold elevation is equal to the highest MSL point along the RWT line (see figure B-3).

Figure B-3. Runway Threshold

177- Runway visual range (RVR): The maximum distance in the direction of take-off or landing at which the runway or specified lights or markers delineating it can be seen from a position above a specified point on its centreline at a height corresponding to the average eye-level of pilots at touchdown.

NOTE: A height of 16 feet is regarded as corresponding to average eye-level of pilots at touchdown. RVR is determined from information provided by a transmissometer located near the touchdown point on a runway and where CAT II ILS is installed a second transmissometer is located near the midpoint of the runway length.

178- Runway (RWY) WP. A WP located at the runway threshold and used for construction of the final approach area when the FAC meets straight-in alignment criteria.

179- Safe altitude 100 NM: The lowest altitude that may be used that will provide a minimum clearance of 1,000 feet (1500 ft or 2000 ft for appropriate mountainous region), under conditions of standard temperature and pressure, above all obstacles located in an area contained within a circle of 100 nautical miles radius of the aerodrome reference point.

180- Secondary area. The area within a segment in which ROC is reduced as distance from the prescribed course is increased.

181- Segment. The basic functional division of an instrument approach procedure. The segment is oriented with respect to the course to be flown. Specific values for determining course alignment, obstacle clearance areas, descent gradients, and obstacle clearance requirements are associated with each segment according to its functional purpose.

182- Service volume. That volume of airspace surrounding a VOR, TACAN, or VORTAC facility within which a signal of usable strength exists and where that signal is not operationally limited by co-channel interference. The advertised service volume is defined as a simple cylinder of airspace for ease in planning areas of operation.

183- Slant-range. The actual distance from the aircraft to the DME facility.

184- Slant-range/geographical distance. The slant-range distance at a given altitude converted to geographical distance across the ground.

185- Sponsor: A “sponsor” is deemed to be an individual or organization that has agreed to assume the regulatory responsibility for an Instrument Flight Procedure (IFP) at an aerodrome or operational location. This includes the responsibility for the initial design, ground validation, flight validation and continuous maintenance of the IFP, including the periodic review.

186- Standard Instrument Approach Procedure (SIAP). Instrument approach procedures published (IAP) in the Canada Air Pilot (CAP).

187- Start end of runway (SER). The beginning of the takeoff runway available.

188- Standard Instrument Departure (SID). A preplanned instrument flight rule (IFR) air traffic control (ATC) departure procedure printed for pilot/controller use in graphic form to provide obstacle clearance and a transition from the terminal area to the appropriate en route structure. SIDs are primarily designed for system enhancement to expedite traffic flow and to reduce pilot/controller workload. ATC clearance must always be received prior to flying a SID.

189- Standard Terminal Arrival (STAR). A preplanned instrument flight rule (IFR) ATC arrival procedure published for pilot use in graphic and/or textual form. STARs provide transition from the en route structure to an outer fix or an instrument approach fix/arrival waypoint in the terminal area.

190- Start of Climb (SOC). The SOC is a point located at a calculated flat-surface length distance from the decision altitude for LNAV/VNAV or the missed approach point for LNAV and LP or at the end of section 1 for LPV/GLS procedures.

191- Straight-in approach: An instrument approach where final approach is begun without first having executed a procedure turn. Straight-in approaches are not necessarily completed with a straight-in landing or made to straight-in landing minimums.

192- Straight-in landing minima: Approach minima published in association with an instrument approach procedure that conforms with specified final approach alignment and descent gradient criteria.

193- Strip: An area of specified dimensions enclosing a runway, intended to reduce the risk of damage to aircraft running off a runway, and to protect aircraft flying over it during take-off and landing operations.

194- Take-off distance available (TODA). The Take-off Run Available (TORA) plus the length of any remaining runway or clearway beyond the far end of the TORA.

195- Take-off run available (TORA). The runway length declared available and suitable for the ground run of an aircraft taking off.

196- Tangent point (TP). The point on the VOR/DME RNAV route centerline from which a line perpendicular to the route centerline would pass through the reference facility.

197- Tangent point distance (TPD). Distance from the reference facility to the TP.

198- Three-Dimensional (3D) Point/Waypoint. A waypoint defined by WGS-84 latitude and longitude coordinates, MSL elevation, and GH.

199- Threshold: The beginning of that portion of the runway usable for landing.

200- Threshold Crossing Height (TCH). The height of the glidepath above the threshold of the runway measured in feet. The LPV glidepath originates at the TCH value above the LTP.

201- Track to Fix (TF) Leg. A TF leg is a geodesic path between two fixes. The resulting track is wind corrected.

202- Touchdown and lift-off area (TLOF). A TLOF is a load bearing, generally paved area, normally centered in the FATO, on which the helicopter lands or takes off from (see CARs Standard 325-Heliports).

203- Touchdown zone (TDZ). The first 3000 feet of runway beginning or the first one-third which ever is less, measured from the threshold in the direction of landing. For helicopter procedures it is identical to the landing area.

204- Touchdown zone elevation (TDZE). The highest runway centerline elevation of the touchdown zone.

205- Track: The projection on the earth's surface of the path of an aircraft, the direction of which path at any point is usually expressed in degrees from North (true, magnetic, or grid).

206- Transition level. The altitude below which heights are expressed in feet MSL and are based on an approved station altimeter setting. The transition level in the United States is 18000 MSL. Altitudes at and above the transition level are expressed in flight levels (FL). For example, 11000 feet, 17,900 feet, FL 180, FL 230, etc.

207- True Airspeed (KTAS). The airspeed of an aircraft relative to undisturbed air. KTAS is the KIAS corrected for air density error. KTAS increases with altitude when KIAS remains constant.

208- Turn Anticipation. The capability of RNAV airborne equipment to determine the location of the point along a course, prior to a FB fix which has been designated a turn fix, where a turn is initiated to provide a smooth path to intercept the succeeding course.

209- Turn Fix. A FB or FO fix denoting a course change.

210- Turn Initiation Area (TIA). The straight portion of a missed approach OEA whose end is identified by a turn at a specified altitude.

211- Turn WP. A WP which identifies a change from one course to another.

212- Two-Dimensional (2D) Point/Waypoint. A waypoint defined by WGS-84 latitude and longitude coordinates.

213- Vertical descent angle (VDA). An advisory angle provided on most non-precision approach procedures representing the calculated descent angle from the PFAF (or SDF). The VDA is intended to assist the pilot in maintaining a stable vertical path within the final segment.

214- Vertical Error Budget (VEB). The VEB is a set of allowable values that contribute to the total error associated with a VNAV system. Application of equations using the VEB values determines the minimum vertical clearance that must exist between an aircraft on the nominal glidepath and ground obstructions within the OEA of instrument procedure segments. When the VEB is used in final segment construction, its application determines the OCS origin and slope ratio.

215- Vertical guidance surface (VGS). The VGS is a narrow inclined plane centered on the runway centerline that is evaluated for obstructions between the DA/OCH point and LTP for all straight-in aligned approach procedures.

216- Visibility: The ability, as determined by atmospheric conditions and expressed in units of distance, to see and identify prominent unlighted objects by day and prominent lighted objects by night.

217- Visual climb area (VCA). Areas around the aerodrome reference point (ARP) to develop a VCOA procedure.

218- Visual climb over airport (VCOA). Option to allow an aircraft to climb over the airport with visual reference to obstacles to attain a suitable altitude from which to proceed with an IFR departure.

219- VFR Heliports. For the purpose of this publication, consider VFR Heliport to mean non-instrument heliport.

220- VFR Runway. For the purpose of this publication, consider VFR Runway to mean non-instrument runway.

221- $\mathbf{V_{mini}}$, Minimum instrument meteorological condition airspeed ($\mathbf{V_{mini}}$). It means instrument flight minimum speed, utilized in complying with minimum limit speed requirements for instrument flight. This is the certified minimum airspeed that a specific helicopter is approved to enter instrument meteorological flight conditions.

222- Visual Glide Slope Indicator (VGSI). The VGSI is an airport lighting aid that provides the pilot with a visual indication of the aircraft position relative to a specified glidepath to a touchdown point on the runway. PAPI and VASI are examples of VGSI systems.

223- Visual Segment. The visual segment is the portion of the FASOEA between the DA and the LTP.

224- Visual Segment Descent Angle (VSDA). The angle of descent in the visual segment.

225- Visual Segment Reference Line (VSRL). A line perpendicular to the final course at a distance of 75 ft (22.9 m) from the helipoint for heliports with instrument procedures.

226- VOR/DME RNAV. It is dependent on VOR/DME, VORTAC, or TACAN. It is a system using radials and distances to compute position and flight track and will hereinafter be referred to as VOR/DME.

227- Waypoint (WP). A predetermined geographical position used for route definition and progress reporting purposes that is defined by latitude/longitude. For VOR/DME systems, it is defined by the radial/distance of the position from the reference facility.

228- Wide Area Augmentation System (WAAS). The WAAS is a navigation system based on the GPS. Ground correction stations transmit position corrections that enhance system accuracy and add satellite based VNAV features.

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CRITERIA FOR THE DEVELOPMENT OF INSTRUMENT PROCEDURES

TP 308 / GPH 209 – CHANGE 9.0

ANNEX C

PRECIPITOUS TERRAIN

TRANSPORT CANADA
NATIONAL DEFENSE

1 January 2024

Canada

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ANNEX C: PRECIPITOUS TERRAIN ALGORITHMS

1.0. General

Precipitous Terrain Equations, Parameters, Interests, Weights, and Adjustment Values. A digital terrain data base (100 m or 3 arcsecond separation density or better) must be used for the determination of precipitous terrain. The precipitous terrain area will contain the prescribed segment (both primary and secondary, if applicable) and a 2 NM buffer surrounding that segment. For segments that are comprised of multiple legs, each leg should be evaluated separately. The digital terrain data within that defined area will be analyzed electronically to determine the values of five specific parameters [g(1) through g(5)], which will be transformed into interest values [I(1) through I(5)], weighted [W(1) through W(5)] and combined to determine the base precipitous adjustment,

a. Step 1. The equations, minimum and maximum thresholds, and weight values for each parameter are:

Average elevation

$$g(1) = \Sigma \frac{h(x,y)}{n}$$

min(1) = 600 $meters$

max(1) = 3000 $meters$

W(1) = 0.05

98th percentile – 2nd percentile height differential

$$g(2) = h_{98percentile} - h_{\ 2percentile}$$

min(2) = 250 $meters$

max(2) = 2500 $meters$

W(2) = 0.30

Slope gradient

$$g(3) = \sqrt{\left(\frac{D_a}{D}\right)^2 + \left(\frac{D_b}{D}\right)^2}$$

min(3) = 0.015

max(3) = 0.060

W(3) = 0.10

Note: min(x,y) returns the least (closest to negative infinity) of real values x or y; e.g., **min(-3,-5)=-5**, **min(3,5)=3.** **max(x,y)** returns the greatest (closest to positive infinity) of real values x or y; e.g., **max(-3,-5)=-3, max(3,5)=5.**

Standard deviation from plane of best fit

$$g(4) = \sqrt{\frac{\Sigma\left[h(x,y) - \left(\frac{D_a \times x}{D} + \frac{D_b \times y}{D} + \frac{D_c}{D}\right)\right]^2}{n}}$$

$min(4) = 40$ meters

max(4) = 200 meters

W(4) = 0.35

98th percentile max - min height differential within 0.50 NM of each terrain posting

$g(5) = (h_{max} - h_{min})_{98percentile}$

min(5) = 100 meters

max(5) = 1000 meters

W(5) = 0.20

b. Step 2. The interest values are based on the parameter thresholds and are found via this piecewise function:

$g(i) < min(i)$:

$I(i) = 0$

$min(i) \leq (i) \leq max(i)$:

$$I(i) = \frac{g(i) - min(i)}{max(i) - min(i)}$$

$g(i) > max(i)$:

$I(i) = 1$

c. Step 3. The combined interest (CI) is computed as follows:

$CI = W(1) \times I(1) + W(2) \times I(2) + W(3) \times I(3) + W(4) \times I(4) + W(5) \times I(5)$

d. Step 4. The base precipitous adjustment (BA) is also a piecewise function with a minimum threshold of 0.20 and a maximum of 0.60.

$CI < 0.20$:

$BA = 0$

$0.20 \leq CI \leq 0.60$:

$BA = 500 \times CI - 50$

$CI > 0.60$:

$BA = 250$

e. Step 5. Finally, BA is applied and rounded varyingly depending on the evaluated segment to derive the actual adjustment (A) [see Note 1].

Rounded to the next higher 1 foot increment:

Precision and APV finals [see Note 2]

$A = 0.10 \times HAT$

Rounded to the next higher 10 foot increment:

Non precision finals

$A = BA$

Intermediate

$A = 1.25 \times BA$

Initial, holding, and missed approach OEA

$A = 1.5 \times BA$

Note 1: Precipitous terrain evaluation is not required for departures and the sloping portion of missed approach. Where precipitous terrain evaluation is required, refer to additional guidance provided by criteria.

Note 2: When $BA > 0$, use the HAT output based on final and missed approach assessment, excluding remote altimeter adjustments.

Explanation of variables:

$h(x,y)$ = height (meters) of the selected terrain posting

x = x coordinate of the selected terrain posting

y = y coordinate of the selected terrain posting

n = number of terrain postings in the area

$h_{98percentile}$= height (meters) of the 98th percentile terrain posting

$h_{2percentile}$ = height (meters) of the 2nd percentile terrain posting

h_{max}=height (meters) of the highest terrain posting within 0.50 NM of the selected post

h_{min}=height (meters) of the lowest terrain posting within 0.50 NM of the selected post

$$D = \begin{vmatrix} \sum x^2 & \sum x \times y & \sum x \\ \sum x \times y & \sum y^2 & \sum y \\ \sum x & \sum y & n \end{vmatrix}$$

$$D_a = \begin{vmatrix} \sum x \times h(x,y) & \sum x \times y & \sum x \\ \sum y \times h(x,y) & \sum y^2 & \sum y \\ \sum h(x,y) & \sum y & n \end{vmatrix}$$

$$D_b = \begin{vmatrix} \sum x^2 & \sum x \times h(x,y) & \sum x \\ \sum x \times y & \sum y \times h(x,y) & \sum y \\ \sum x & \sum h(x,y) & n \end{vmatrix}$$

$$D_c = \begin{vmatrix} \sum x^2 & \sum x \times y & \sum x \times h(x,y) \\ \sum x \times y & \sum y^2 & \sum y \times h(x,y) \\ \sum x & \sum y & \sum h(x,y) \end{vmatrix}$$

To compute the determinant, use the following:

$$\text{Matrix} = \begin{vmatrix} A & B & C \\ D & E & F \\ G & H & I \end{vmatrix}$$

$$D = A \times E \times I + B \times F \times G + C \times D \times H - A \times F \times H - B \times D \times I - C \times E \times G$$

CRITERIA FOR THE DEVELOPMENT OF INSTRUMENT PROCEDURES

TP 308 / GPH 209 – CHANGE 9.0

ANNEX D

MATHEMATICS CONVENTION

TRANSPORT CANADA
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1 January 2024

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ANNEX D: MATHEMATICS CONVENTION

1 Mathematical Functions and Constants.

a. Functions.

(1) $a+b$ indicates addition.

(2) $a-b$ indicates subtraction.

(3) $a \times b$, ab, a·b, or a*b indicates multiplication.

(4) $\frac{a}{b}$, a/b, or a÷b indicates division.

(5) $(a-b)$ indicates the result of the process within the parenthesis.

(6) $|a-b|$ indicates the absolute value and that result of a-b is assigned a positive sign.

(7) ≈ indicates approximate equality.

(8) $\sqrt{a}$, $a^{0.5}$, or a^0.5 indicates the square root of quantity “a.”

(9) a^2 or a^2 indicates a×a.

(10) ln(a) indicates the natural logarithm of “a.”

(11) tan(a) indicates the tangent of “a” degrees.

(12) atan(a) indicates the arc tangent of “a.”

(13) sin(a) indicates the sine of “a” degrees.

(14) asin(a) indicates the arc sine of “a.”

(15) cos(a) indicates the cosine of “a” degrees.

(16) acos(a) indicates the arc cosine of “a.”

(17) max(a,b) = maximum value of a and b

(18) round(a,b) = rounds a to b decimal places

(19) ceiling(a) = rounds a to next integer toward positive infinity

2 Operational Precedence (Order of Operation).

a. First. Grouping Symbols: parentheses, brackets, braces, fraction bars, etc.

b. Second. Functions: tangent, sine, cosine, arcsine, and other defined functions

c. Third. Exponentiations: Powers and roots

d. Fourth. Multiplication and Division: Products and quotients

e. Fifth. Addition and Subtraction: sums and differences

Notes on calculator usage:

1. Most calculators are programmed with standard mathematical rules of precedence.

2. When possible, let the calculator maintain all of the available digits of a number in memory rather than re-entering a rounded number. For highest accuracy from a calculator, any rounding that is necessary should be done at the latest opportunity.

3 Formulas/Calculations. Formulas in TP308/GPH209 use degree calculations. The examples provided use only two decimal places; therefore, the answers are approximate values. Actual calculations must use the maximum number of values after the decimal place for each step. Rounding of the final result should be for documentation purposes only. For the purposes of this document, the term "r" represents the mean radius of the earth used in spherical calculations and is equal to 20890537 feet.

4 Data Resolution. Perform calculations using an accuracy of at least 15 significant digits; i.e., floating point numbers must be stored using at least 64 bits. Unless otherwise noted, do not round intermediate results. Round only the final result of calculations for documentation purposes. Required accuracy tolerance is 1 centimeter for distance and 0.002 arc-second for angles. The following list specifies the minimum accuracy standard for documenting data expressed numerically. This standard applies to the documentation of final results only; e.g., a calculated adjusted glide path angle of 3.04178 degrees is documented as 3.05 degrees. The standard does not apply to the use of variable values during calculation. Use the most accurate data available for variable values. Rounding of the final result should be for documentation purposes only.

5 Mathematics Convention. Most formulas in TP308/GPH209 are written for degree calculation.

Note: The value ft-per-NM (fpnm) value for 1 NM was previously defined as 6,076.11548 ft. For the purposes of RNAV criteria, 1 NM is defined as the result of the following calculation:

$$\boldsymbol{fpnm = \frac{1852}{0.3048}}$$

6 Conversions:

- Degree measure to radian measure:
  $radians = degrees \times \frac{\pi}{180}$
- Radian measure to degree measure:
  $degrees = radians \times \frac{180}{\pi}$
- Feet to meters:
  $meters = feet \times 0.3048$

- Meters to feet:
  $$feet = \frac{meters}{0.3048}$$
- Feet to Nautical Miles (NM):
  $$NM = feet \times \frac{0.3048}{1852}$$
- NM to feet:
  $$feet = NM \times \frac{1852}{0.3048}$$
- NM to meters:
  $$meters = NM \times 1852$$
- Meters to NM:
  $$NM = \frac{meters}{1852}$$
- Temperature Celsius to Fahrenheit:
  $$T_{Fahrenheit} = 1.8 \times T_{Celcius} + 32$$
- Temperature Fahrenheit to Celsius:
  $$T_{Celcius} = \frac{T_{Fahrenheit} - 32}{1.8}$$
- Feet per NM:
  $$fpnm = \frac{1852\ ft}{0.3048\ NM}$$

7 Definition of Mathematical Constants.

a. e The constant e is the base of the natural logarithm and is sometimes known as Napier's constant, although its symbol (e) honors Euler. With the possible exception of π, e is the most important constant in mathematics since it appears in myriad mathematical contexts involving limits and derivatives. Its value is approximately 2.71828182845904523536028747135266249775 7...

b. r The TERPS constant for the mean radius of the earth for spherical calculations in feet. r = 20890537

8 **Common equation terms:** These terms/variables are common to all calculations.

a. **AMSL** is above mean sea level.

b. **φ** is bank angle.

c. **β** is magnitude of heading change in degrees.

d. **θ** is glidepath angle in degrees.

e. **DA** is decision altitude in feet AMSL.

f. **alt** is altitude in feet AMSL.

g. **ATT_i** is the along-track error for the segment initial fix.

h. **ATT_t** is the along-track error for the segment termination fix.

i. **V_{KIAS}** is knots indicated airspeed.

j. **apt_{elev}** is the published airport elevation in feet AMSL.

k. **LTP_{elev}** is the published threshold elevation in feet AMSL.

l. **TCH** is threshold crossing height in feet above threshold.

m. **$PFAF_{alt}$** is the minimum intermediate segment altitude in feet AMSL.

n. **O_{MSL}** is the obstacle elevation in feet AMSL.

o. **OBS_X** is the along track distance in feet from LTP to obstacle.

p. **HATh** is the difference between DA and LTP elevation rounded to the next higher foot value.

q. **HAL** is the difference between DA and FHP elevation rounded to the next higher foot value.

r. $\mathbf{d_{FauxOrigin}}$ is the distance from RDP to the phantom LTP for OEA construction

s. **FTE** means .Flight Technical Error.

t. **HAS** is the height in feet above the surface beneath (within 5,200 radius of) RDP

u. **LTP** means .landing threshold point.

v. **MSL** in this document is synonymous with AMSL

w. $\mathbf{OBS_{elev}}$ is the obstacle AMSL elevation

x. $\mathbf{OBS_x}$ is the along-track distance from reference datum point

y. $\mathbf{PFAF_{alt}}$ is the minimum AMSL altitude at the PFAF

z. **RDP** means .reference datum point.

CRITERIA FOR THE DEVELOPMENT OF INSTRUMENT PROCEDURES

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ANNEX E

PROCEDURES

TRANSPORT CANADA
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ANNEX E: PROCEDURES

1 Reserved

2 General Procedures

2.1-2.10 Reserved

2.11 Obstacle Data

2.11.1-2.11.2 Reserved

2.11.3 Obstacle data accuracy standards. This paragraph identifies the minimum requirement for accuracy of obstacle data used in the development of minimum vectoring altitudes (MVA), minimum IFR Altitude (MIAs) and instrument procedures. The primary purpose of obstacle evaluation is to determine how an obstacle will affect instrument flight procedures. The evaluations provide accurate, consistent, and meaningful results only if procedure specialists apply the same rules, criteria, and processes during development, revision, periodic review and maintenance. The minimum standards, regardless of the data source, are to be applied by instrument procedure specialists in all instrument procedure obstacle evaluations.

a. Concept. Obstacle data accuracy is not absolute, and the accuracy depends on the datasource. The magnitude of the error does not preclude the use of these data, provided it is identified and accounted for. In some cases, upgrading obstacle accuracy can provide relief from operational restrictions in an instrument procedure. This will allow expenditure of funds for obstacle surveys in areas where benefit to the aviation community would result. In no case; however, will the application of obstacle data accuracy preempt the requirement for the flight check of an instrument procedure for discrepancies.

b. Standards. The minimum accuracy standards are listed in paragraphs 2.11.3.b(1) through 2.11.3.b(5). Adjust the location and/or elevation of the segment-controlling obstacle by the actual accuracy value assigned to the obstacle only if the horizontal and/or vertical accuracy assigned to the obstacle does not meet the standards listed below. For example, if the nonprecision final segment controlling obstacle has an assigned accuracy of 250 feet horizontal and 50 feet vertical, artificially adjust its location by 250 feet laterally, and increase its elevation by 50 feet; this is because 250/50 does not meet the minimum accuracy requirement of 50 feet horizontal and 20 feet vertical as required by a nonprecision final segment. Conversely, if the assigned accuracy is 60 feet horizontal and 15 feet vertical, adjust only the obstacle location by 60 feet; do not increase the obstacle elevation by 15 feet because the assigned vertical accuracy does not meet the vertical accuracy requirement for a nonprecision final segment.

(1)±20 feet horizontal and ±3 feet vertical accuracy . Precision and APV final and section 1 of the missed approach segment.

(2) ±50 feet horizontal and ±20 feet vertical accuracy. Nonprecision final segments; missed approach 40:1 surface evaluation; circling areas; Visual Climb Over Airport (VCOA) level surface; and the initial climb area (ICA) for all departure procedures.

(3) ±250 feet horizontal and ±50 feet vertical accuracy. Intermediate segment. For DPs: all areas outside of the ICA, including VCOA sloping surface.

(4) (non-mountainous) ±500 feet horizontal and ±125 feet vertical accuracy; [1000 feet ROC and Special required obstacle clearance (ROC) {e.g., MVA/MIA reduced ROC in mountainous areas}];. Initial segments; feeder segments; en route areas; missed approach segment (when determinining the minimum missed approach obstruction altitude); missed approach holding and climb-in-holding level surface evaluation; MSA; Safe Altitude 100 NM; MVA; MIA. For DPs and SIDs: level route portion.

(5) (mountainous) ±1000 feet horizontal and ±250 feet vertical accuracy; (1500 feet/ 2000 feet ROC). Feeder segments; en route areas; MVA; MIA; Safe Altitude 100 NM. For DPs and SIDs: level route portion.

Note : NAV CANADA maintains an obstacle database which contains obstacle location and elevation data. The data contains both verified and unverified obstacles. Discrepancies in the obstacle database found in the development, review, and revision of instrument procedures must be identified to Aeronautical Information Management, NAV CANADA.

2.11.4 Accuracy Standards Application

Adjust the instrument procedure to meet the requirements of the minimum accuracy standards. Accuracy adjustments are not applied to obstacles evaluated relative to Vol 1, paragraph 2.8.10 (Obstacles Close to FAF or Final Approach Segment SDF), visual portion of final and/or when evaluating the vertical guidance surface (VGS). Additionally, do not apply an accuracy adjustment to low close-in obstacles or when determining ceiling and/or visibility for departure procedures.

a. When developing the procedure, identify all controlling obstacles in coordinates to the second, and assign the highest order of accuracy known for the data source.

b. Apply the accuracy standards as follows:

(1) Obstacle accuracy standards must be applied when determining the altitude(s) to be charted. Additionally, apply the accuracy standard in the evaluation of a proposed obstruction and in the development/revision of any affected procedures.

(2) If segment altitude adjustments are made to meet the requirements of the minimum accuracy standards, state the reason for the adjustment.

(3) Non-RNP (AR) procedure evaluation sequence. In either paragraph 2.11.5.b or 2.11.5.c., first determine the controlling obstacle(s) using raw obstacle data only (i.e., accuracy adjustments not applied), then apply horizontal/vertical accuracy adjustments to the raw values. [see Vol 2, chapter 3, for LNAV/VNAV final]. The adjustment(s) must be applied in the most critical direction; e.g., applied in the horizontal and/or vertical direction which most adversely affect the procedure.

2.11.5 Controlling obstacles.

a. Determine the controlling obstacle as follows:

(a) For PA and APV final segments, the controlling obstacle is that obstacle which, having penetrated the obstacle clearance surface requires the highest glidepath angle (GPA) above three degrees and/or causes, the most adverse decision altitude (DA).

(b) For missed approach segments, the controlling obstacle is that obstacle which, having penetrated the 40:1 obstacle clearance surface (OCS) causes one of the following:

1. Highest DA/minimum descent altitude (MDA);
2. Most adverse MAP relocation;
3. Highest climb gradient and climb gradient termination altitude (may be different obstacles).

(c) For departure areas, the controlling obstacle is that obstacle (or obstacles) that penetrate the 40:1 OCS which require:

1. The highest climb gradient and climb gradient termination altitude (may be different obstacles); and if applicable.

2. The most adverse ceiling and visibility to be published (may be different obstacles).

b. A VCOA requires an assessment of both a level and sloping surface to determine the controlling obstacle. The controlling obstacle is one which determines the “climb-to” altitude (see Vol 1) and is located either within the visual climb area (VCA) or is the obstacle outside the VCA that is creating the need to raise the 40:1 surface.

Note: Obstacles that do not penetrate the sloping surface are not subject to the minimum accuracy standards and should not be called controlling obstacle.

2.11.6 Datums. Use the following guidance relating to geodetic datums:

a. The NAV CANADA vertical obstruction file and airport surveys are used in TP308 evaluation.

b. Satellite based instrument procedures should be designed and evaluated using data based on the geospatial Standards described in Vol 2 paragraph 1.2.3. For LPV and GLS procedures only, document with the FAS data block information the datum on which the LTP/FTP latitude and longitude and ellipsoidal height values are based.
Note: The LTP/FTP HAE and its reference datum must be reported for procedures developed in Canada. For WAAS/GBAS procedures, document the height above ellipsoid (HAE) and thereference datum used in calculations.

2.12 Non Standard Approaval Request – Reserved

3 Route Procedures – Reserved

4 Terminal Procedure – Reserved

4.1 General. – Reserved

4.2 Standard Instrument Aprpoach Procedures (SIAP) – Reserved

4.3 Category II and III ILS – Reserved

4.4 Departure Procedure (DP) – Reserved

4.5 Standard Terminal Arrival (STAR) – Reserved

4.6 RNAV Procedure Developemnt

4.6.1- 4.6.2 – Reserved

4.6.3 General. Sub paragraph 4.6 contains supplementary guidance for the development of RNAV instrument procedures. RTCA DO-201A, Standards for Aeronautical Information, has established operational requirements and standards that aviation authorities, procedure designers,and airspace planners must consider when developing en route, arrival, approach and departure.

4.6.4 RNAV Approach Procedure design. Criteria for the development of RNAV instrument procedures can be found in Vol 2.

a. All RNAV instrument approach procedures should be connected to the en route airway system in order to provide a seamless transition into the Terminal Area. Accomplish this by one of the following methods:

Note: This policy is recommended but not required and may not be practicable for helicopter procedures.

(1) Establish a feeder route from the en route airway to initial approach fixes (IAFs) not on an airway.

(2) Extend the “T” leg initial segment to place the IAF on an en route airway. Do not extend the “T” leg more than 10 nautical miles from the intermediate fix.

(3) Deleted.

(4) Establish a Terminal Arrival Area (TAA) as prescribed in Vol 2, chapter 2.

(5) In lieu of the above, use a STAR that terminates at an IAF or IAF/IF.

b. The RNAV procedure should, whenever and wherever possible, match the ILS at the same runway in the following respects: final and intermediate segment procedure ground track, missed approach, altitudes, fix locations/names, GPAs, and TCHs. Nothing in this policy requires an RNAV procedure to emulate a procedure turn used on an underlying ILS procedure. Due to the many variables involved in procedure design, especially relating to the very different aspects of ILS and RNAV design, it is impractical to set standards for all possible ILS/RNAV

designs; therefore, in lieu of hard and fast design standards, use the following design guidelines:

(1) When designing an RNAV procedure at an ILS equipped runway, the RNAV procedure should emulate the ILS procedure to the maximum extent possible. In other words, if the ILS needs updating (i.e., PFAF placement to meet new/current standards), publish updated ILS and RNAV procedures concurrently. In emulating an ILS, do not include either a basic “T” or TAA in the RNAV IAP unless specifically requested by Air Traffic.

(2) If the ILS PFAF occurs at the LOC FAF, emulation of the ILS by the RNAV procedure may be a simple matter. In this case, the RNAV PFAF can be placed at the LOC FAF location and thus coincidence will have been achieved for the ILS PFAF, LOC FAF, and RNAV PFAF. Use the LOC FAF name for the RNAV PFAF name. Revising the ILS procedure will, in all likelihood, not be necessary.

(3) For a variety of reasons, the situation described in paragraph 4-6-2.b(2) is seldom found in practice. Where the ILS PFAF is not collocated with the existing LOC FAF, the associated LOC portion of the ILS procedure may have to be revised at the same time the new RNAV IAP is developed.

(a) If the present LOC FAF is defined by DME, intersection or radar, revise the ILS procedure by relocating the LOC FAF to coincide with the RNAV PFAF which can be placed at the vertical descent angle interception point for the given ILS glide slope angle/TCH and LOC FAF altitude. Use the LOC FAF name for the RNAV PFAF name.

c. Establish an LNAV FAF for all new RNAV procedures at a location that will support a collocated PFAF for future RNP, LNAV/VNAV, and/or WAAS/GBAS procedures.

d. RNAV RNP procedures may be designed to support minimums with different RNP values in the final approach segment. The largest RNP value is the one that will be coded into the avionics database (pilots will have the ability to enter the lower values if their equipment permits).

4.6.5 Developing RNAV waypoint.

a. In establishing the position of a waypoint fix, determine which category of fix will best meet the airspace, route of flight, obstacle clearance, and operational requirements. Fly-by and fly-over fixes are the two basic types of waypoint fixes that are used in transitioning from one route segment to another when conducting instrument approach, en route arrival, or departure procedures.

(1) Fly-by (FB) waypoint fixes identify a position where a change in course occurs from one specified route segment to another. Turn anticipation is required and expected as the aircraft executes the turn maneuver. The FB waypoint fix is the most desired and useful type for use in RNAV procedure design due to the conservation of airspace. Unless otherwise required by the procedure design, all waypoint fixes defining a course change must be coded in the navigation database as FB.

(2) Fly-over (FO) waypoint fixes may or may not identify a change in course from one specified route segment to another. Turn anticipation is not permitted. FO fixes require substantially more airspace to protect for the turn than FB fixes, and should be used only where special design problems necessitate.

b. Design must document waypoint type for all waypoint fixes used in RNAV procedure design. Because of the different obstacle assessments conducted, FO and FB information is critical to flight crews and should be consistently displayed on aeronautical charts and in navigational databases. The waypoint type (FO/FB) is documented as applicable [see paragraph 8-6-4.a(6)].

c. En route. Do not establish RNAV WPs at conventional en route fixes when used as feeder fixes for RNAV procedures.

d. Terminal. Develop terminal use RNAV WPs based on usage as follows:

(1) Missed approach point. Normally the MAP is at the threshold but may be located prior to the threshold, on or off runway centerline.

(2) MAP not located at threshold. The landing threshold will be the reference point. True bearing is from reference point to MAP. If the MAP is on runway centerline extended, use the reciprocal of the landing runway true bearing. Distance is from reference point to MAP.

(3) Final approach fix. Establish the location of the FAF as a true bearing and distance asfollows:

(a)Final approach course aligned through threshold. Use landing threshold as reference point.

(b)Final approach course not aligned through threshold. Use MAP as reference point.

(4) Intermediate fix (IF). Establish the location of the IF as a true bearing and distance asfollows:

(a)No course change at FAF. Utilize the same reference point used to establish the FAF.

(b)Course change at the FAF. Use the FAF as the reference point.

(5) Initial approach fix. Establish the location of the IAF as a true bearing and distance as follows:

(a)No course change at the IF or FAF. Utilize the same reference point used to establish the FAF.

(b)No course change at the IF, with a course change at the FAF. Use the FAF as the reference point.

(c)Course change at the IF. Use the IF as the reference point.

(6) Feeder fix. If a WP is required for use as a feeder fix, and will *not* be an en route fix, establish the location of the feeder fix as a true bearing and distance as follows:

(a)No course change at the IAF. Utilize the same reference point used to establish the IAF.
(b)Course change at the IAF. Use the IAF as the reference point.

(7) Missed approach. For all WPs in the missed approach, after the MAP, use the preceding WP as the reference point.

(8) Stepdown fixes within segments. Establish the location of waypoints used as stepdown fix(es) within a segment as a bearing and distance *from* the waypoint/fix that marks the beginning of the next segment in the procedure sequence (e.g., IAF, IF, FAF, etc.). For example, the forward true bearing from IF to IAF is 290.34 degrees. Establish the coordinates for stepdown fix waypoints on bearing 290.34 degrees from the IF at the desired distance(s) between the IF and IAF.

Note: Use this method to determine stepdown fixes in *all* segments.

4.6.6 RNAV leg types.

a. Different types of arrival, approach, departure, and en route segments are required for RNAV. Consideration of these requirements during procedure design will result in a more efficiently designed flight path for all operators using airspace; particularly those equipped with computer-based navigation systems. These systems require encoding RNAV route segment flight paths into a format usable in navigation databases.

b. The aviation industry has adopted a route segment definition called “path and terminator.” This concept is used for transforming arrival, approach, and departure procedures into coded flight paths that can be interpreted and used by a computer-based navigation system. A path terminator instructs the aircraft to navigate from a starting point along a defined path to a specified point or terminating condition. The path terminators are identified by a set of two alpha-characters, each of which has a meaning when describing a flight maneuver to a navigation computer. The first character indicates the types of flight path to be flown, and the second indicates where the route segment terminates. For example, a designated route from a NAVAID to a fix would be coded as “TF.” The “T” indicates that a track is to be flown, and the “F” indicates that the segment terminates at a fix. There are over twenty different path and terminator sets (“leg types”) used by the aviation industry to accommodate the coding of procedure route segments. However, only a limited few are suitable for use in RNAV procedure design.

4.6.7 RNAV leg type descriptions.

a. Initial fix. This is the point or fix where a flight segment begins. An IF is not a route segment and does not define a desired track in and of itself. It is used in conjunction with other leg types such as a TF leg in order to define the desired segment.

Note: “IF” in this context is not to be confused with IAF or IF; however, it may be located at one of these locations for coding purposes.

b. Track-to-fix (TF) leg. This designates a track or geodesic path between two fixes. If theTF leg is the first route segment of a flight path, the TF leg begins at an IF; otherwise, the first fix of the TF leg is the termination fix of the previous route segment. The TF leg is the primary straight route segment for RNAV.

c. Constant radius to a fix (RF) leg. An RF leg defines a curved path route segment about a defined turn center that terminates at a fix. The RF leg begins at the termination fix of the previous route segment. The previous segment is tangent to the arc of the RF leg at that fix. Waypoints defining the beginning and end point of the RF turn must be designated as “Fly-by.”

d. Course-to-altitude (CA) leg. A CA leg defines a specified path terminating at an altitude. A CA leg must specify a course and altitude. See Vol 2 for conditions when use of a CA leg required.

e. Direct-to-fix (DF) leg. A DF leg is used to define a route segment (geodesic path) that begins at an aircraft present position, or unspecified position, and extends to a specified fix.

f. Heading-to-an-altitude (VA) leg. The VA leg is used in a departure route segment where a heading rather than a track has been specified for climb. The VA segment terminates at a specified altitude without a terminating position defined.

g. Course-to-fix (CF) leg. The CF leg is defined as a magnetic course that terminates at afix.

h. Heading to a manual termination (VM) leg. A VM leg is a manual termination leg used for whenever a departure or arrival route description specifies a course or heading to fly in expectation of a radar vector.

i. Heading to an intercept (VI) leg. A VI leg defines a specified heading to intercept the subsequent leg at an unspecified position.

j. Fix to a manual termination (FM) leg. A course from a fix to a manual termination leg used in departure or arrival procedures when a route segment is expected to be terminated by radar vectors.

k. Table 4-1-1 shows permissible leg types for use with RNAV DPs. See Vol 2 for leg type definitions and examples.

Table 4-1-1. Permissible leg types

FROM	VIA (leg type)	TO
AER	VI[1]	See 1
AER	VA[2]	ALT
AER	VM[8]	HDG
AER	CF[3], DF[4]	FB/FO
ALT	CF[3], DF[4]	FB/FO
ALT	VM[2]	ALT
FB	TF[5]	FB/FO
FO	DF[4], TF[5]	FB/FO
IF[7]	DF[4], TF[5]	FB/FO
FB	RF[6]	FB
FO	VM[8]	HDG
FO/FB	FM[9]	Course

[1] VI (Heading-to-intercept) may only be used as the first leg of a departure and must be followed by a course-to-fix (CF) leg.

[2] VA (Heading-to-an-altitude) may only be used as the first leg of a departure and must be followed by a direct-to-fix (DF) leg or a heading-to-manual termination (VM). The altitude must be an at-or-above altitude; a mandatory (i.e., “at”) altitude must not be used at the first fix.

[3] CF may only be used as the first leg of a departure or as the leg following a departure VI leg.

[4] DF may be used as the first leg of a departure, the leg following a departure VA leg, and for any leg thereafter preceded by a fly-over (FO) waypoint (WP) only.

[5] TF (Track-to-fix) is not used as the first leg of a departure. TF is the preferred leg after the first leg of a departure.

[6] RF (Constant radius arc) may only be used when necessary because some users do not have RF capability. An RF leg may only be used after a TF, CF, or another RF leg.

[7] IF (Initial fix) is used to designate the first fix of a departure transition, i.e., the IF is coincident with the DP termination fix. IF is also used to designate the point at which RNAV begins when used in conjunction with radar vectors.

[8] VM legs are only to be used in conjunction with ATC radar vectoring.

[9] FM (Course from a fix-to-manual termination) legs are used when requested by ATC and must be at an altitude at or above the minimum vectoring altitude or minimum IFR altitude for direction of flight.

Note: AER – approach end of runway; ALT – altitude; FB– fly-by fix; FO– fly-over fix.

4.6.8 Final Approach Segment (FAS) data.

a. FAS data is described and attained using established Vol 2,chapter 3. This data is compiled and formed into what is called the FAS data block. The method of protection required for this flight data is known as the cyclic redundancy check (CRC).

b. Document FAS data block information in the design documentation as applicable.

c. FAS data block coordinates must be in same coordinate system as the ground survey data (WGS-84 preferred).

4.6.9 Remote altimeter setting for Baro-VNAV. Baro-VNAV systems cannot fly to approach minimums based on a remote altimeter setting. Therefore, when the primary altimeter source is from a remote location, LNAV/VNAV is not authorized to be flown using Baro-VNAV. When the primary altimeter source is local and a secondary altimeter source is remote, LNAV/VNAV minimums must be noted as not authorized (NA) to be flown with Baro-VNAV when the secondary altimeter is in use.

4.6.10 Critical temperature. Temperature limits above and below which Baro-VNAV operations not authorized are published on RNAV instrument approach procedures. Current RNAV criteria standards provide the formulas to compute the critical temperatures for the airport of intended landing.

4.6.11 Reserved

4.6.12 Additional documentation with Baro-VNAV (LNAV/VNAV and RNP), GBAS, and/or WAAS Instrument Approach Procedures.

a. A 5-digit WAAS/GBAS channel number is allocated to the Aeronautical Information Services by NAV CANADA. GBAS channel numbers must be calculated using a specific frequency that is currently obtained from NAV CANADA. This paragraph does not apply to RNAV RNP procedures.

b. Use the approach ID, e.g., W09A/G18A into the Additional Flight Data block. This is the same as the Reference Path Identifier part of the FAS data block. Publish the following data for RNAV procedures:

(1) For RNAV (VOR/DME), use the reference facility elevation; e.g., “Reference facility elevation XYZ VORTAC 1160.”

(2) For LPV and LP, use the WAAS channel number, and reference path identifier (approach ID) using the following example.

WAAS CHANNEL #43210
REFERENCE PATH ID: W17A

(3) For LNAV/VNAV. Use “Chart WAAS Symbol” when it has been determined that a WAAS signal may be unreliable for vertical navigation use.

(4) For WAAS/GBAS procedures, document the height above ellipsoid (HAE) and the reference datum used in calculations [see paragraph 2-11-6.b].

(5) For GBAS procedures, use the GBAS channel number, and reference path identifier (approach ID) using the following example.

GBAS CHANNEL #20662
REFERENCE PATH ID: GSTU

c. Use “Critical Temp” data as specified in paragraph 4-6-8.

d. Normally, WAAS-based approaches will only be designed and published where the nominal availability of the required service is greater than 99%. However, there may be aerodromes on the fringe of WAAS coverage areas, for which an LPV, LP, or WAAS-based LNAV/VNAV approach is published because of local demand by operators. In the event that an approach is located in a region of marginal WAAS availability, pilots will be alerted to this fact by a negative “W” (white on a black background) on the approach plate.

e. Document the applicable performance based navigation (PBN), navigation specification(NavSpec) required on the chart. See paragraph 8-6-8.b.

5 Airspace – Reserved

6 Military Procedures – Reserved

7 Planning – Reserved

8 Instrument Approach Procedures Data Documentation – Reserved

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CRITERIA FOR THE DEVELOPMENT OF INSTRUMENT PROCEDURES

TP 308 / GPH 209 – CHANGE 9.0

ANNEX F

FLIGHT VALIDATION (FLIGHT CHECK/EVALUATION)

TRANSPORT CANADA
NATIONAL DEFENSE

1 January 2024

Canada

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ANNEX F – FLIGHT VALIDATION (FLIGHT CHECK/EVALUATION)

1.0 Introduction. This Annex provides direction to aircrews conducting Flight Validation.

a. These procedures are in addition to and do not supersede regulations such as Canadian Aviation Regulations (CARs), authorized Aircraft Flight Manuals, appropriate Operations Certificates and Specifications, and approved Flight Operations Manuals and Checklists that currently apply to the aircraft used.

b. The flight procedures described in this Annex are designed to accomplish the objectives of the flight validation in a safe and efficient manner. They are not intended to be limiting nor may they cover all possible circumstances or contingencies (for further on Flight Validation (FV) see ICAO Quality Assurance Manual for Flight Procedure (DOC 9906), Flight Validation of Instrument Procedures (Volume 5)). Since it is impossible to foresee and accommodate every operational environment, and there will undoubtedly be occasions when deviations from these procedures will be necessary, pilots must exercise good judgment and airmanship. Any change from the planned mission or deviation from standard operating procedures (SOPs) must be clearly communicated to the crew and understood prior to execution. When safety of flight is in jeopardy, the flight validation shall be discontinued until the condition is resolved.

c. The full validation process includes ground validation and flight validation. For further on Ground Validation (GV) see ICAO DOC 9906 Volume 5.

d. If the aircraft is certified for single pilot operation, the flight validation shall not be undertaken without a safety pilot.

2.0 General.

a. Flight evaluation (validation) must be accomplished by a qualified and experienced Flight Validation Pilot (FVP).

b. The FVP must occupy a seat in the cockpit with visibility adequate to conduct the flight validation and additional crew members must be briefed on FV requirements. Only task related persons should normally be allowed on such flights.

c. Ground track path error performance varies with mode of flight guidance system coupling. It is recommended to evaluate new procedures coupled to the flight director and autopilot (when not prohibited). Evaluate for lateral and vertical disconnects from the autopilot/flight director.

d. Procedure design is based on true altitudes. Flight evaluation should be conducted at true altitudes with consideration for temperature variations from standard day. Lateral and vertical transitions from departure, enroute, descent, and approach must produce a seamless path that ensures flyability in a consistent, smooth, predictable, and repeatable manner.

e. The procedure must be flown in the relevant navigation mode using the correct sensor, or with navigation equipment that permits the flight to be conducted at an equivalent level

of performance, as required by the design. For example, for RNAV (GNSS) IP, ensure that only the GNSS sensor is utilized during the FV. All following required steps should be adapted to the specifics of each design and IP.

3.0 Objectives.

3.1 The objectives of the flight evaluation of instrument procedures are to:

i. Conduct an assessment of flyability to determine that the procedure can be safely flown.
ii. Provide the final assurance that adequate terrain and obstacle clearance has been provided.
iii. Verify that the navigation data to be published is correct.
iv. Verify that all required infrastructure, such as runway markings, lighting, and communications and navigation sources are in place and operative.
v. Ensure the documentation of navigation systems confirms the applicable navigation system(s) (navigation aid/sensor, GNSS, Radar, etc.) supports the procedure.
vi. Evaluate other operational factors, such as charting, required infrastructure, visibility, intended aircraft category, etc.
vii. Verify that mitigation for deviations from design criteria do not compromise safety.
viii. Validate the intended use of IP as defined by Stakeholders and described in the conceptual design.

Note 1: *For complex procedures, additional flyability checks may be required in the proponent's aircraft or simulator.*

Note 2: *For validation purposes, Helicopter PINSA and RNP should be considered complex procedures.*

3.2 SBAS and GBAS IP(s). SBAS and GBAS IP(s) require analysis of additional parameters contained in the Final Approach Segment (FAS) Data Block and datalink. These parameters include:

i. Glide Path Angle (GPA);
ii. Threshold Crossing Height (LTP or FTP);
iii. Landing Threshold Point (LTP) Coordinates or Fictional Threshold Point (FTP); and
iv. Final Path Alignment Point (FPAP) Coordinates.

a. These parameters also apply to Instrument Landing Systems (ILS).

b. For GBAS, additional inspection requirements are specified in the ICAO Manual on testing of Radio Navigation aids (Doc 8071, Vol II; Chapter 4). Verification of the spatial data contained in the final approach segment definition is required. Any error in the coded data with respect to the proper reference datum may result in improper final approach guidance to the pilot. The FAS data evaluation system must be capable of performing the necessary analysis in a documented, quantitative process as described in Paragraph 4.1.

4.0 Verify Data

It is essential that the data used in the procedure design is consistent in the charts, flight management system (FMS) data, or suitable navigation system data. The validation flights (simulator and aircraft) should be recorded with a collection/recording device that archives the procedure and aircraft positioning data (see Paragraph 9.0 Record Flight Validation). The procedure development package, charts, and airport data must match. It is recommended that PBN procedures are packed and loaded electronically into the FMS or suitable navigation system without manually coding the ARINC 424 path/terminator data. Integrity measures such as Cyclic Redundancy Check (CRC) should be used to assure that data is not corrupted. This allows evaluation of the data as designed, without manipulation. If the procedure waypoint data must be manually entered into the FMS, it must be independently compared to the procedure data to ensure the data match. FAS data block must be coded and loaded for the flight validation.

4.1 Steps to Data Verification:

i. Ensure the data from the flight validation database matches that used in the procedure design;

ii. Ensure the data produces the desired flight track; and

iii. Ensure that the final approach course glide path deliver the aircraft to the desired point in space.

4.2 SBAS/GBAS FAS Data Requirements.

For SBAS and GBAS FAS data, the LTP/FTP latitude and longitude, the LTP/FTP ellipsoid height and the FPAP latitude and longitude contribute directly to the final approach alignment and angle. Corrupted data may skew lateral, vertical, and along track alignment from the intended design. A direct assessment should be made of the LTP latitude/longitude, LTP Ellipsoid Height, and FPAP latitude/longitude coordinates used in the procedure design. This may be accomplished using a survey grade GNSS receiver on the runway threshold while making a comparison with the actual final approach segment data to be published. Another indirect method is to evaluate the following IP characteristics as a means of validating the FAS data.

i. Horizontal Course Characteristics:

   1) Misalignment type, linear or angular; and
   2) Measured angular alignment error in degrees (when applicable) and linear course error/offset at the physical runway threshold or decision altitude point.

ii. Vertical Path Characteristics:

   1) Achieved/measured TCH/RDH (reference datum height); and
   2) Glide path angle.

5.0 Assess Obstacles.

Detailed guidance regarding obstacle assessment is contained in DOC 9906 Volume 5 - Appendix A. In general, obstacles should be visually assessed to the lateral limits of the procedure design segment. The aircraft should be positioned in a manner that provides a good view of the obstacle environment that is under consideration. This may require flying the lateral limits of the procedure protection areas in order to detect if unaccounted obstacles exist. The controlling obstacle should be verified for each segment of the IP. Should unaccounted obstacles be observed, further investigation by the FVP is required.

6.0 Assess Flyability and Human Factors.

a. Fly at least one on-course/on-path evaluation of the proposed procedure in an appropriate aircraft capable of conducting the procedure. See DOC 9906 Volume 5 - Appendix B for more detailed human factors information. The objectives of flyability assessment of instrument flight procedures are to:

i. Evaluate aircraft maneuvering areas for safe operations for each category of aircraft for which the procedure is intended;

ii. Review the flyability of the instrument procedure as follows:

1) Fly each segment of the IP on-course and on-path;
2) Validate the intended use of IP as defined by Stakeholders and described in the conceptual design;
3) Evaluate other operational factors, such as charting, required infrastructure, visibility, intended aircraft categories, etc;
4) Evaluate the aircraft maneuvering area for safe operations for each category of aircraft to use the IP;
5) Evaluate turn anticipation and the relationship to standard rate turns and bank angle limits;
6) Evaluate the IP complexity, required cockpit workload, and any unique requirements;
7) Check that waypoint spacing and segment length are suitable for aircraft performance;
8) Check distance to runway at Decision Altitude/Height or Minimum Descent Altitude/Height that are likely to be applied by operators and evaluate the ability to execute a landing with normal maneuvering;
9) Evaluate required climb or descent gradients, if any;
10) Evaluate the proposed charting for correctness, clarity, and ease of interpretation;
11) Evaluate TAWS warnings.

b. The flyability assessment must be flown at speeds and aircraft configurations consistent with the normal instrument flight rules (IFR) operations and meet the design intent (Aircraft Category). The Final Approach Fix (FAF) to threshold of an instrument approach procedure must be flown in the landing configuration, on profile, on speed with the Terrain Awareness Warning System (TAWS) active. Flyability should be evaluated with the aircraft coupled to the autopilot (to the extent allowed by the aircraft flight manual or SOP(s)) and may require additional evaluation by hand flying.

c. Aircraft category restrictions might be published and must be confirmed acceptable. In every case, the pilot is required to pay particular attention to the general safe conduct of the procedure and efficiency of the flight for the intended aircraft category.

Note: *It is recommended that if different minima are provided for the same final segment (e.g. LNAV, LNAV/VNAV, LPV), that the evaluation of the final segment is accomplished on separate runs. Alternatively, an assessment of the ability to perform a safe landing from all levels of service should be performed.*

7.0 Conduct Associated Validation Tasks.

The following associated tasks may be performed in conjunction with the obstacle or flyability assessment as appropriate:

i. Verify that all required runway markings, lighting, and communications are in place and operative. Compare all lighting and airport environment relates to depicted information. As required request strength 5;

ii. Verify that any required navigation aids/sensors have been satisfactorily flight inspected to support the procedure design;

iii. Ensure that the components of the Visual Approach Segment Indicator System (VASIS) angles appear as intended or charted when evaluating vertically guided procedures;

iv. Where required, ensure radar coverage is available for all portions of the procedure;

v. Indicate any TAWS warnings or alerts. Record details of the alert to include latitude/longitude, aircraft configuration, speed, and altitude;

vi. If night evaluation is required, determine the adequacy of airport lighting systems prior to authorizing night operation. Conduct night evaluations during VMC following appropriate daytime evaluation;

vii. Evaluate the light system for:

1) Correct light facilities (particularly if pilot activated) and light patterns as charted; and

2) Local lighting pattern in the area surrounding the airport to ensure they do not distract, confuse, or incorrectly identify the runway environment.

viii. Verify that mitigations for deviations from design criteria do not compromise safety.

Note 1: *TP 308 specifies that ILS GP and PBN IAP descent angle and TCH should coincide with VGSI (values: +/- 0.2° and +/- 3'). Ensure operational note on the plan view is published when VGSI not coincident with the procedure GPA.*

Note 2: *TP 308 volume 1, Para 120 e) specifies: In controlled airspace air-to-ground communication with an ATS facility shall be available at the initial approach fix minimum altitude and at the missed approach clearance limit altitude. At lower altitude, communications shall be required where essential to the safe and efficient use of airspace.*

8.0 Verify Chart Depiction and Details.

i. Check to ensure the chart has sufficient detail to safely navigate and identify significant terrain or obstacles;

ii. Ensure all required notes are included (e.g. DME required, non-standard approach angle, etc.);

iii. Ensure that the chart accurately portrays the procedure in both plan and profile view and is easily interpreted. Ensure flight track matches chart and takes aircraft to desired point;

iv. Verify true and magnetic course to next waypoint indicated on the FMS or GNSS receiver accurately reflects the procedure design. (Magnetic courses displayed by the FMS/GNSS navigator may be dependent upon the manufacturer's software processing of magnetic variation);

v. Verify segment distances indicated by the aircraft navigation system accurately reflect the procedure design;

vi. Verify the Flight Path Angle (FPA) indicated on the FMS or GNSS Receiver accurately reflects the procedure design; and

vii. Check that waypoint spacing and segment length are sufficient to allow the aircraft to decelerate or change altitude on each leg without bypassing.

9.0 Record Flight Validation.

a. ICAO DOC 9906, Volume 5 recommends that the Flight Inspection/Validation organization recording device use a recording device that is capable of the following: IP storage, time and 3-dimensional position in space with an acceptable sampling rate (not less than 1 Hz), and ability to post-process recorded data.

b. Record and save the minimum following flight data:

i. Processing date and time;
ii. Number of satellites in view;
iii. Minimum number of satellites;
iv. Average Position Dilution of Precision (PDOP);
v. Maximum Observed Horizontal Dilution of Precision (HDOP) [SBAS Procedures only];
vi. Vertical Protection Level (VPL) [SBAS/GBAS Procedures only];
vii. Horizontal Protection Level (HPL) [SBAS/GBAS Procedures only];
viii. Maximum Observed Vertical Dilution of Precision (VDOP) [SBAS Procedures only];
ix. For each segment, the maximum and minimum altitude, ground speed, climb rate, and climb gradient; and
x. A printed graphic or an electronic file of sufficient detail that depicts the horizontal (and the vertical for VNAV procedures) flight track flown referenced to the desired track of the approach procedure, including procedure fixes.

Note: *The recording of HDOP, PDOP, VDOP, HPL and VPL are a collection of data in a limited timeframe and their purpose is to document the actual situation at the time of the validation flight.*

c. SBAS and GBAS IFP(s) require analysis of additional parameters contained in the Final Approach Segment (FAS) Data Block. FAS Data Block validation requires verification of the coordinates and heights used in the FAS or by indirect flight inspection system analysis of the IFP characteristics described in Paragraph 4.2.

10.0 Produce Validation Report.

10.1 Assess the Results of the Validation Process.

i. Review all aspects of the validation process to complete the assessment; and
ii. Make a determination of satisfactory or unsatisfactory results, based on established criteria.

10.1.1 Analysis.

a. The procedure must be safe, practical, flyable, and easily interpreted with minimal additional cockpit workload. Supporting facilities/systems must meet TP 308 criteria and ICAO Annex 10 – Aeronautical Telecommunications, tolerances and not contribute to operational confusion.

b. Flight validation determines that the procedure is safe and flyable. If a new or revised procedure is unsatisfactory, the FVP must suggest the necessary changes to the designer by filing the report forms in a detailed manner. Coordination with the designer might be necessary.

c. When an existing procedure is found unsatisfactory due to obstructions, navigation source, charting error a report must be filed.

10.1.2 Depiction Standards.

Depiction is as per the appropriate NAV CANADA CAP Specs. However, due to potential misunderstanding of the designer intent, recommended changes to the proposed IP plate should be forwarded to the designer via the FV report in accordance to depiction standard published in CAP GEN.

10.1.3 Night Flight Evaluation.

a. Conduct the night evaluation in the following circumstances (these circumstances should have been identified during GV):

i. IP developed for airport with no prior IFR services;
ii. IP to newly constructed runways or to runways lengthened or shortened; and
iii. Addition or reconfiguration of lights to an existing system already approved for IFR.

b. If night evaluation is required to determine the adequacy of airport lighting systems prior to authorizing night operation, conduct night evaluations during VMC following appropriate daytime evaluation.

c. Verify published information regarding light system for:

i. Correct light pattern as charted;
ii. Operation in the manner proposed (e.g. radio control); and
iii. Local lighting patterns in the area surrounding the airport do not distract, confuse or incorrectly identify the runway environment.

d. In any other cases, FVP might identify a potential hazard and recommend a night flight evaluation.

10.1.4 RCAP Procedure.

a. An RCAP Procedure is not a substandard procedure and deviations from criteria should offer an equivalent level of safety. Mitigation could be published such as special aircraft equipment, crew training, weather conditions, etc.

b. IP Package should include proposed mitigations to assure no degradation of safety. Crews should respect RCAP procedure conditions during FV and evaluate pertinence of mitigations and if required, suggest any other.

10.2 Satisfactory Validation.

For satisfactory validation, complete the IP processing:

i. Ensure the completeness and correctness of the IP package to be forwarded; and
ii. Propose suggestions for improved operation of the procedure, where such factors are outside the scope of the procedure design (e.g. ATC issues).

10.3 Unsatisfactory Validation.

For unsatisfactory validation, return the IP to the Procedure Design Service provided for corrections.

i. Provide detailed feedback to the procedure designer(s) and other stakeholders;
ii. Suggest operational mitigations and/or corrections for unsatisfactory results;
iii. Provide operation mitigation (example: new altitude in case of reception issue or GPWS alert); and
iv. Provide pictures, maps, coordinates (example: in the case of a new obstacle or an obstacle not there anymore).

10.4 Document the results of the validation process.

i. Complete a detailed written report of the results of the validation process including justification for any steps in the validation process deemed not required.

This involves a compilation of reports provided by the individual steps in the validation process;

ii. Ensure any findings and operational mitigations are documented;

iii. Ensure uncharted controlling obstacle position and elevation data are documented; and

iv. Ensure recorded data is processed and archived together with the validation report.

10.5 Templates for Fixed-Wing Aircraft

a. The following sample checklist and report templates contain suggested minimum data and information required to be recorded during the validation process. If certain items are not applicable to the intended IAP, identify those items by striking them out or using the term “N/A”. These forms must be signed.

b. Users may develop their own version for other types of IFPs as required.

Sample Checklist A: Preflight Validation Checklist – Fixed Wing

Preflight Validation Checklist – Fixed Wing				
Date:	Validation type (new/amended procedure)			
Organization:				
Procedure Title:				
Location:				
Airport:	Runway:			
Evaluator:				
PBN nav spec:				
Preflight Validation				
			Satisfactory	
			YES	**NO**
IFP package forms, charts and maps				
Data verification (e.g. aerodrome/heliport, aeronautical, obstacle, ARINC coding)				
Location of the controlling obstacles				
Correctness and complexity of the graphical depiction (chart)				
Intended use and special requirements				
Overall design (i.e. practical, complete, clear and safe)				
Impact on the procedure of waivers to standard design criteria				
Segment lengths and descent gradients allow for deceleration/configuration				
Comparison of FMS navigation database with the IFP design, coding and relevant charting information				
Charting of notification of cold/warm temperature limits				
Flight inspection reports available				
Remarks				
Simulator evaluation needed			YES	NO
Flight evaluation needed			YES	NO
Procedure	PASS		FAIL	
Evaluators Signature:				
Date:				

Sample Checklist B: Flight Evaluation Checklist - Fixed Wing

Flight Evaluation Checklist - Fixed Wing		
Date:	Validation type (new/amended procedure)	
Organization:		
Procedure Title:		
Location:		
Airport:	Runway:	
Evaluator:		
PBN nav spec:		
Planning		
	Completed	
Check that all the necessary items from the IFP package are available, including: graphics, text, maps, submission form		
Check that the necessary flight validation forms are available		
Check that the aircraft and avionics are appropriate for the IFP being evaluated		
Does the procedure require use of autopilot or flight director?		
Preflight		
	Completed	
Review preflight validation assessment		
Review simulator evaluation assessment (if applicable)		
Obstacle assessment planning: areas of concern; ability to identify and fly lateral limits of obstacle assessment area (if required)		
Verify source of IFP data for aircraft FMS (electronic or manual creation)		
Evaluate navigation system status at time of flight (NOTAM, RAIM, outages)		
Weather requirements		
Night evaluation requirement (if applicable)		
Required navigation (NAVAID) support (if applicable)		
Combination of multiple IFP evaluations		
Necessary equipment and media for electronic record of validation flight		
General		
	Satisfactory	
	YES	**NO**
IFP graphic (chart) is complete and correct		
Check for interference: document all details related to detected RFI		
Satisfactory radio communication		
Required radar coverage is satisfactory		
Verify proper runway markings, lighting and VASIS		
Altimeter sources		
Extra consideration given to non-surveyed areas		
For approach procedures with circling minima, verify controlling obstacle for each circling category		

Sample Checklist C: Flyability

Flyability		
	Satisfactory	
	YES	**NO**
Comparison of FMS navigation database and source documents, including proper ARINC 424 coding. *Note.— If manual entry is used, this field is marked "N/A", and a note must be inserted in the remarks section to alert the approving authority of the procedure that a table top review of the coded procedure, or an operational assessment by a company pilot, should be completed prior to operational approval being granted.*		
Human Factors and general workload are satisfactory		
Was there any loss of RAIM?		
Was there any loss of required RNP (where applicable)?		
Missed approach procedure		
Descent/climb gradients		
Procedure flown auto-coupled		
Segment length, turns and bank angles, speed restrictions and deceleration allowance		
TAWS		
Instrument Approach Procedure		
	Satisfactory	
	YES	**NO**
Segment lengths, headings/tracks and waypoint locations match procedure design		
Final segment vertical glide path angle (if applicable)		
Threshold crossing height (LTP or FTP), if applicable.		
Course alignment		
Along-track alignment		
FAS data block		
Remarks		

Procedure	PASS		FAIL	

Evaluators Signature:

Date:

Sample Checklist D: Validation Report Checklist - Fixed Wing

Validation Report Checklist - Fixed Wing				
Date:	Validation type (new/amended procedure)			
Organization:				
Procedure Title:				
Location:				
Airport:	Runway:			
Evaluator:				
PBN nav spec:				
Post Flight				
				Completed
Evaluate collected data				
Submit flight validation report with recorded electronic flight data for archives				
Request NOTAM action (if appropriate)				
Sign and submit the IFP submission documentation				
Remarks				
Procedure	PASS		FAIL	
Evaluators Signature: Date:				

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