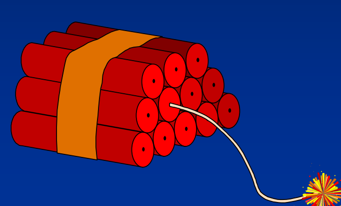
Land Search Planners…

Things have changed.

Foreword

Don't Shoot the Messenger



Background

March 2001: NSARC R&D Working Group hosted meeting --

USAF	USCG
Nat. SAR School	NPS
NASAR	NASA
FAA	DOT
DOD	Private Ind.

Background

Nov 2002: PMG, Inc. tasked to --

Review current published land search methods and identify which are compatible with formal search theory.

"Compatibility of Land SAR Procedures with Search Theory"

Primary Elements of a Successful Search

- Look in the right place.
- Be able to detect what it is you are looking for.

Therefore, the likelihood that a search will succeed is dependent on two related probabilities:

- The probability that the search object is in the area searched, and
- The probability of detecting the search object if it is there.

Search Probabilities

Probability of Area (POA):

The chances the object is in the area in which you are searching.

Search Probabilities

Probability of Detection (POD):

The chances the search object will be detected if it is in the area.

Search Probabilities

Probability of Success (POS):

The chances you will be successful.

Conventional Notation of Search Theory

POA x POD = POS

The theoretical goal of search planning is to maximize the overall probability of success.

SUCCESS

. . . is always desirable, but . . .

. . . if you want to save a life,
it must be achieved . . .

FAST

SUCCESS

This is the ultimate goal
of all search planning

FAST

SUCCESS

But, how do we get there?

FAST

Maximize **the chances of finding the object of the search in the** ***minimum*** **amount of time using the available resources.**

This is a primary objective of Search Theory

What is Search Theory?

A well developed branch of the applied sciences known as Operations Research.

- Applies to:
  - Finding lost car keys (everyday life)
  - Finding lost cities (Archeology)
  - Finding oil and minerals (mining)
  - Finding ancient shipwrecks (treasure hunting)
  - Finding lost persons (SAR, sea and land)

History

CLASSIFIED

World War II (1946)

U. S. Navy

Operations Eval. Grp 56

B.O. Koopman

History

1956: OEG 56 report declassified

1957: USCG SAR Manual

1959: First U.S. Nat. SAR Manual

1960’s: Capt. Waters’ “experiments”

1978: USCG Sweep Width exp.

1987: Update to U.S. NSM

History

1999: IAMSAR Manual

- Three volume set published jointly by both the ICAO and IMO for use by all countries.
- Provides a detailed baseline of SAR planning and operations

History

1999: IAMSAR Manual

Research Continues

(Stone, Washburn, et al.)

Why do we want to use Search Theory?

- Save more lives
- Save resources
- Save $$
- Reduce Risk
- It is a proven technology

"Compatibility of Land SAR Procedures with Search Theory"

Prepared for

U.S. Dept. of Homeland Security

U.S. Coast Guard

2003

GSAR Literature

May, W.G. (1973). *Mountain Search and Rescue Techniques*.

- Never mentioned "search theory"
- "Loose line" technique to "rapidly search only most likely locations"
- Few "man-hours" meant low probability

GSAR Literature

Kelley, D.E. (1973). *Mountain Search for the Lost Victim*.

- First published mention of search theory
- First published mention of “search is an emergency”
- Farquhar & Kelley Appendix (III) – “Probability of Success”

GSAR Literature

Kelley, D.E. (1973). *Mountain Search for the Lost Victim*.

- Mathematically described Koopman’s exponential detection function
- Effective sweep width was missing
- Defined “coverage ratio”
- Search theory not used or applied in any way

GSAR Literature

Wartes, J. (1974). *An Experimental Analysis of Grid Sweep Searching*.

- Detection experiments in Pacific NW
- Tried to relate POD to searcher spacing
- POD was initial objective – later discovered POS
- Sought, “most efficient spacing”
- Concluded, “There is no most efficient spacing”
- Did not address effective sweep width

GSAR Literature

Syrotuck, W.G. (1974). *Some Grid Search Techniques for Locating Lost Individuals*…

- Used “sweep width” – unlike search theory
- Provided tables showing “man-hours” to achieve POD (a la Wartes)
- Described USCG “POD tables” and “POD experiments”

GSAR Literature

Syrotuck, W.G. (1975). *An Introduction to Land Search Probability Calculations*

- Defined "sweep width" – unlike search theory
- "Described" equation: C = W / S

Sweep Width Variables

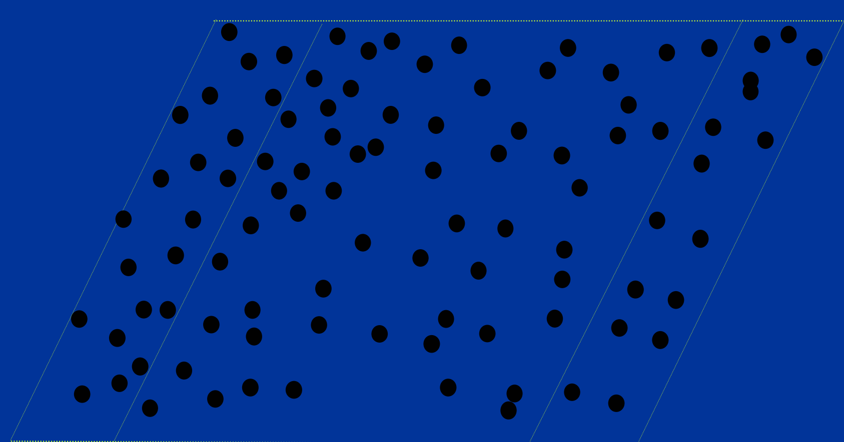
1. Search Object
2. Environment
3. Search Sensor

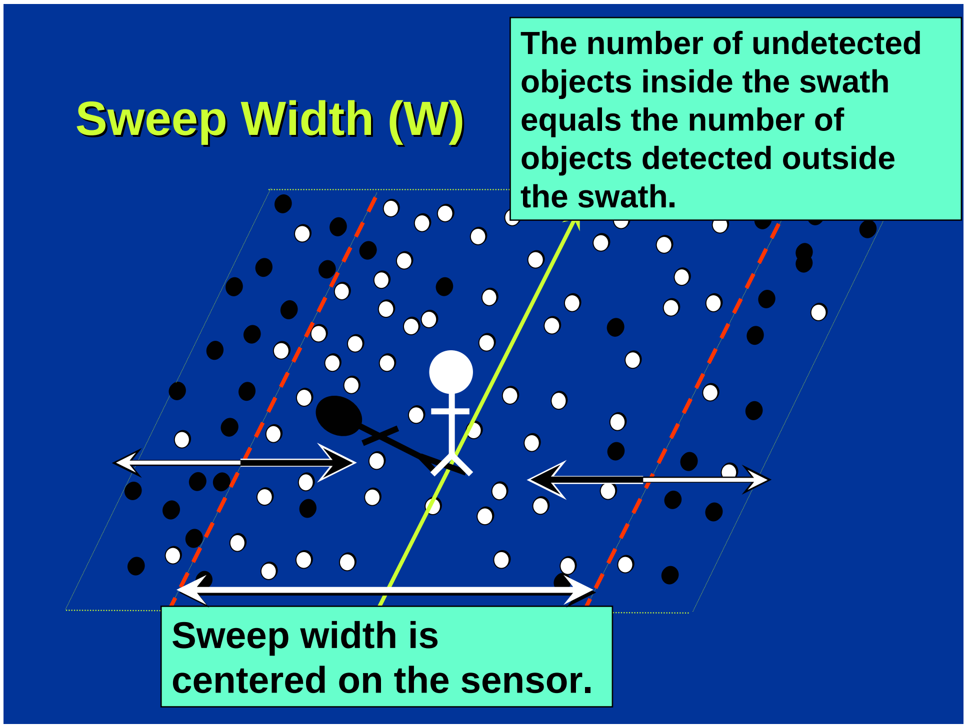
What can we use to measure average detectability?

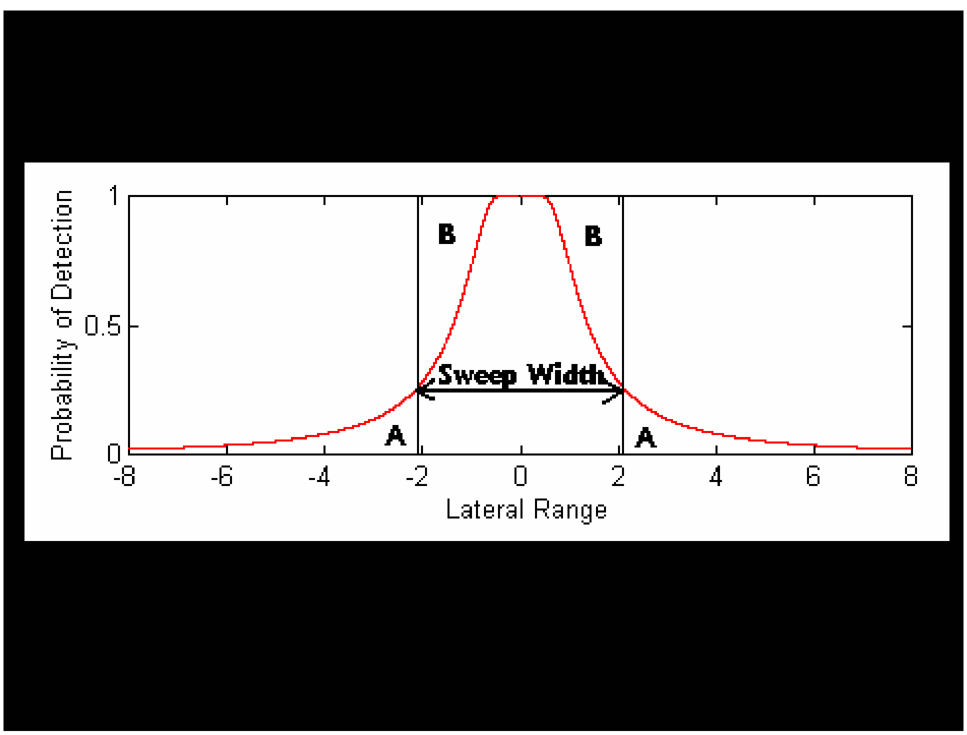
Sweep Width (W)

- Determined accurately only though experimentation
- Units of meters (width)
- Measures difficulty of detection
- Large sweep width = Easy to detect
- Small sweep width = Hard to detect
- Used in calculation of Area Effectively Swept (Z)

Sweep Width (W)




Sweep Width (W)
The number of undetected objects inside the swath equals the number of objects detected outside the swath.
Sweep width is centered on the sensor.


Probability of Detection
1
0.5
0
B
B
A
A
Sweep Width
-8
-6
-4
-2
0
2
4
6
8
Lateral Range

International Aeronautical and Maritime SAR Manual

Tables taken from the International Aeronautical Maritime Search and Rescue (IAMSAR) Manual, Volume II, Mission Coordination, IMO/ICAO, London/Montreal, 1999.

Search Object	Terrain	Recommended Altitudes
Person, light aircraft	Moderate Terrain	60-150 m (200-500 ft)
Large aircraft	Moderate Terrain	120-300 m (400-1000 ft)
Person, one-person raft, light aircraft	Water or Flat Terrain	60-150 m (200-500 ft)
Medium-sized liferaft and aircraft	Water or Flat Terrain	300-900 m (1000-3000 ft)
Pyrotechnical signal at night	Night	450-900 m (1500-3000 ft)
Medium-sized aircraft	Mountainous Terrain	150-300 m (500-1000 ft)

Table N-11 - Recommended altitudes according to nature of search object and terrain.

Tables taken from the International Aeronautical Maritime Search and Rescue (IAMSAR) Manual, Volume II, Mission Coordination, IMO/ICAO, London/Montreal, 1999.

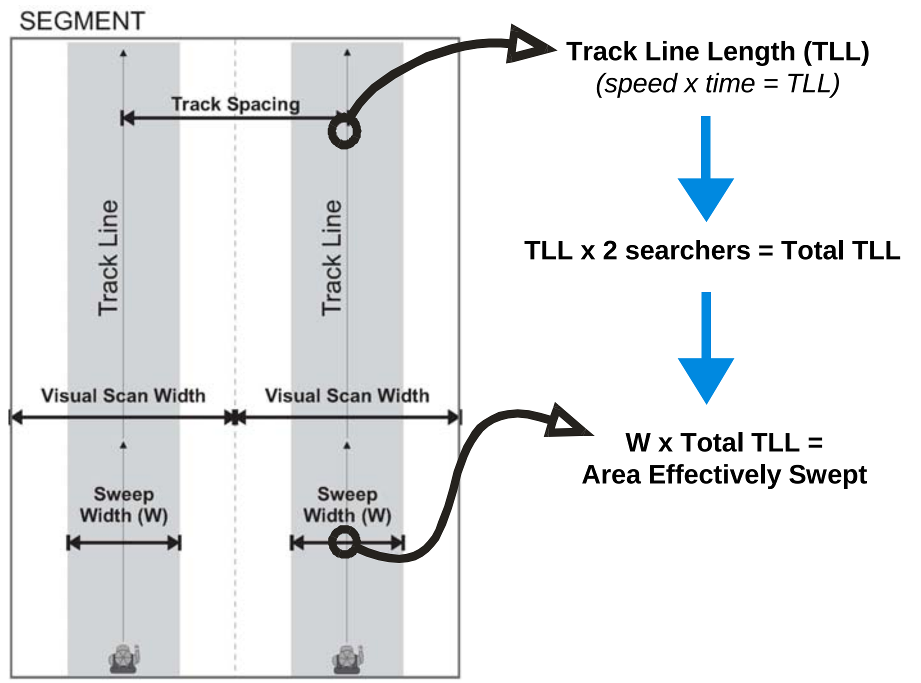
		Visibility (km(NM))				
Search Object	**Height (m(ft))**	**6 (3)**	**9 (5)**	**19 (10)**	**28 (15)**	**37 (20)**
Person	150 (500)	0.7 (0.4)	0.7 (0.4)	0.9 (0.5)	0.9 (0.5)	0.9 (0.5)
	300 (1000)	0.7 (0.4)	0.7 (0.4)	0.9 (0.5)	0.9 (0.5)	0.9 (0.5)
	450 (1500)	--	--	--	--	--
	600 (2000)	--	--	--	--	--
Vehicle	150 (500)	1.7 (0.9)	2.4 (1.3)	2.4 (1.3)	2.4 (1.3)	2.4 (1.3)
	300 (1000)	1.9 (1.0)	2.6 (1.4)	2.6 (1.4)	2.8 (1.5)	2.8 (1.5)
	450 (1500)	1.9 (1.0)	2.6 (1.4)	3.1 (1.7)	3.1 (1.7)	3.1 (1.7)
	600 (2000)	1.9 (1.0)	2.8 (1.5)	3.7 (2.0)	3.7 (2.0)	3.7 (2.0)
Aircraft less than 5700 kg	150 (500)	1.9 (1.0)	2.6 (1.4)	2.6 (1.4)	2.6 (1.4)	2.6 (1.4)
	300 (1000)	1.9 (1.0)	2.8 (1.5)	2.8 (1.5)	3.0 (1.6)	3.0 (1.6)
	450 (1500)	1.9 (1.0)	2.8 (1.5)	3.3 (1.8)	3.3 (1.8)	3.3 (1.8)
	600 (2000)	1.9 (1.0)	3.0 (1.6)	3.7 (2.0)	3.7 (2.0)	3.7 (2.0)
Aircraft over 5700 kg	150 (500)	2.2 (1.2)	3.7 (2.0)	4.1 (2.2)	4.1 (2.2)	4.1 (2.2)
	300 (1000)	3.3 (1.8)	5.0 (2.7)	5.6 (3.0)	5.6 (3.0)	5.6 (3.0)
	450 (1500)	3.7 (2.0)	5.2 (2.8)	5.9 (3.2)	5.9 (3.2)	5.9 (3.2)
	600 (2000)	4.1 (2.2)	5.2 (2.9)	6.5 (3.5)	6.5 (3.5)	6.5 (3.5)

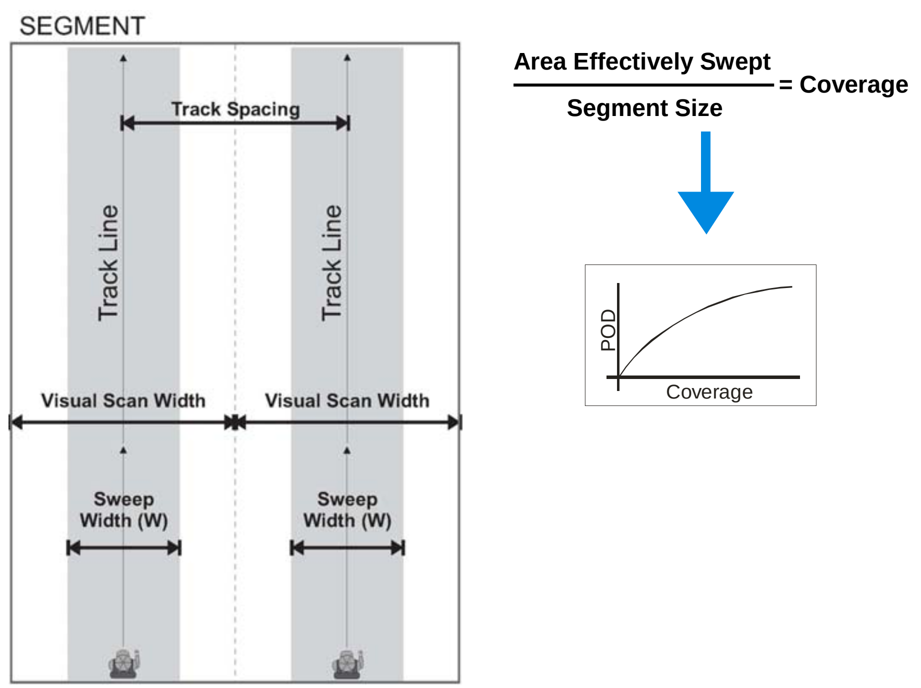
Table N-9 - Sweep widths for visual land search (km (NM)).

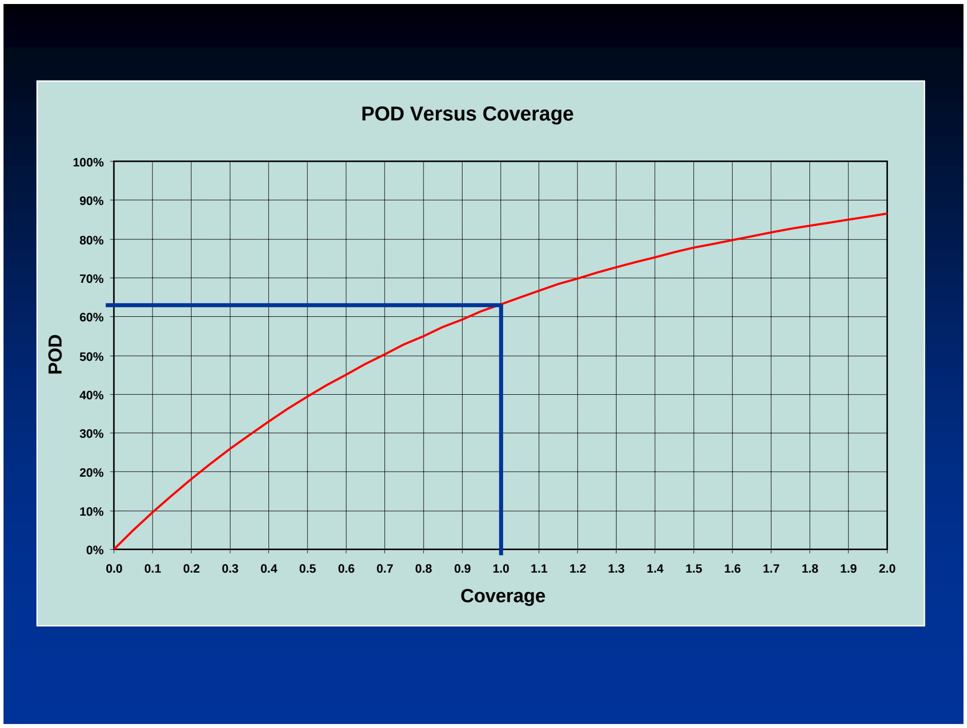
Tables taken from the International Aeronautical Maritime Search and Rescue (IAMSAR) Manual, Volume II, Mission Coordination, IMO/ICAO, London/Montreal, 1999.

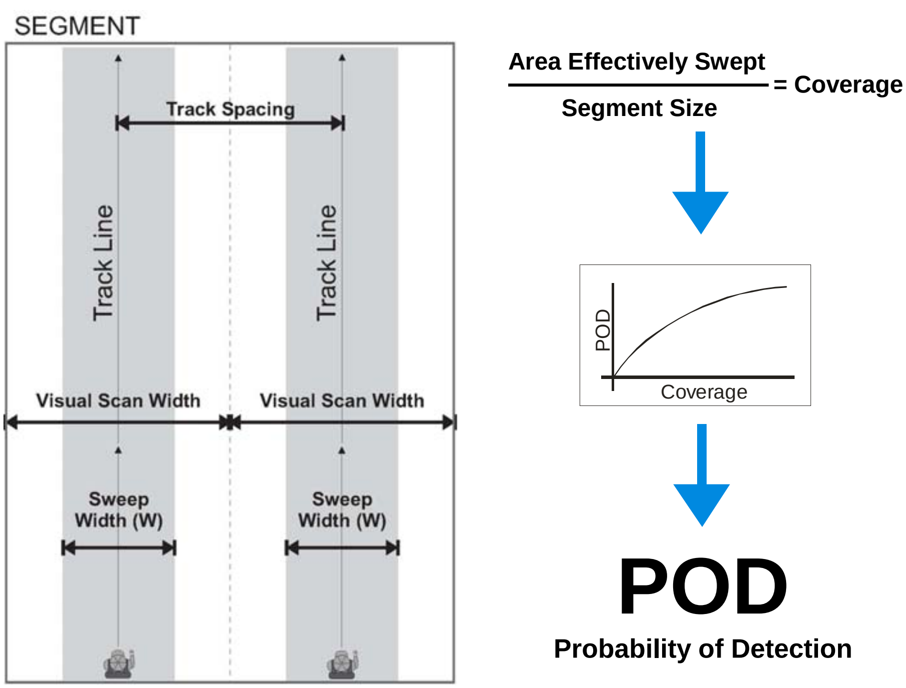
Search Object	**15-60% Vegetation or Hilly**	**60-85% Vegetation or Mountainous**	**Over 85% Vegetation**
Person	0.5	0.3	0.1
Vehicle	0.7	0.4	0.1
Aircraft less than 5700 kg	0.7	0.4	0.1
Aircraft over 5700 kg	0.8	0.4	0.1

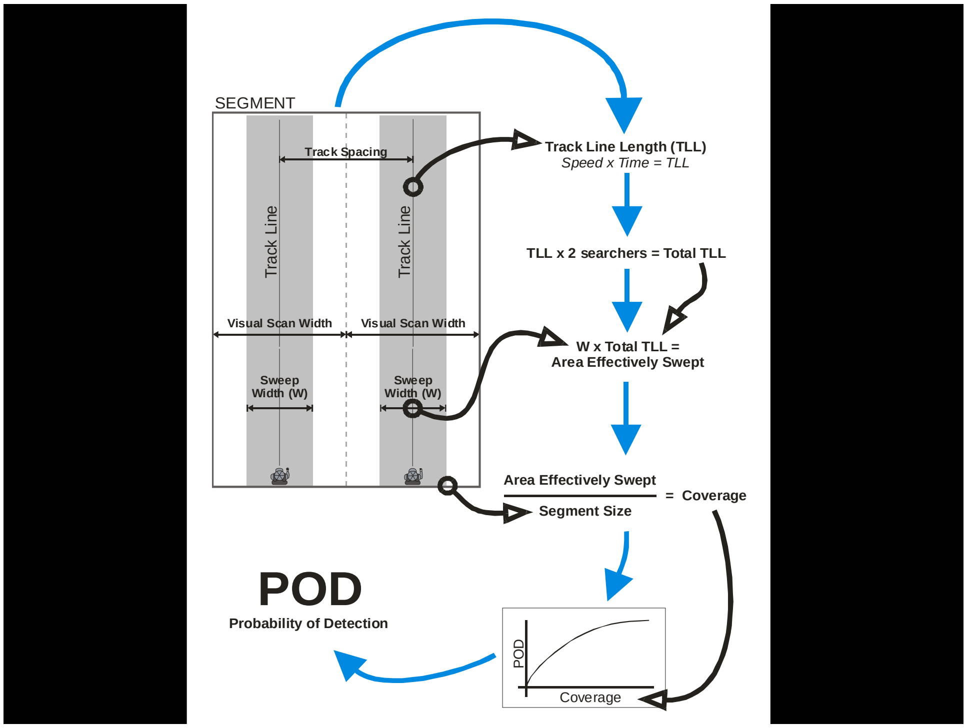
Table N-10 - Correction factors - vegetation and high terrain.


SEGMENT
Track Spacing
Track Line
Track Line
Visual Scan Width
Visual Scan Width
Sweep Width (W)
Sweep Width (W)
Track Line Length (TLL)
(speed x time = TLL)
TLL x 2 searchers = Total TLL
W x Total TLL =
Area Effectively Swept


SEGMENT
Track Spacing
Track Line
Track Line
Visual Scan Width
Visual Scan Width
Sweep Width (W)
Sweep Width (W)
Area Effectively Swept
Segment Size
= Coverage
POD
Coverage


POD Versus Coverage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
POD
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
Coverage


SEGMENT
Track Spacing
Track Line
Track Line
Visual Scan Width
Visual Scan Width
Sweep Width (W)
Sweep Width (W)
Area Effectively Swept
Segment Size
= Coverage
POD
Coverage
POD
Probability of Detection



Thank You for Your Patience and Attention

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Enjoy the conference!