



SAR Spotlight Forum

The following is an edited version of excerpts from the 2006 edition of *The Textbook for Managing Land Search Operations* by R. Skip Stoffel, et al, Emergency Response International.

Regions of Probability in Search Planning

One threshold question burns brightly in the mind of every incident commander and all members of overhead planning teams at the outset of every search. A deceptively simple question often holds the balance of life and death. That question is: “Where do we search?”

Once officially underway, a search quickly evolves and someone always defines the area by drawing lines on a map. They do this because resources are limited and to search everywhere would be a waste of time. This preliminary search area often gets reduced or expanded and more sharply defined during future operational periods and as additional information surfaces.

Basic investigation coupled with a thorough assessment of subjective terrain factors usually determines the smallest search area consistent with available information. Unfortunately though, searching often occurs when there is insufficient information available. In fact, sometimes the only available information is inconsistent or even contradictory. However, meticulous investigation will uncover subsets of available clues, evidence, investigative reports, and other pieces of information that are at least reasonably self-consistent and helpful.

(Subsets meaning that some data, facts or clues may lead to other data, facts or clues. Also keep in mind that individual pieces of data can belong to multiple subsets of information.) These subsets, along with carefully considered assumptions, form the basis for alternative scenarios about what may have happened to a missing subject. **This process builds the foundation for effective search planning.**

Regions of Probability

There are two separate, distinct, and largely independent reasons for subdividing the search area. The first reason revolves around speculating where the missing subject might be and the second centers more on logistics and physical resources. The first process (*figuring out where the subject might be*) is scenario based and involves identifying the locations of suspected activities, travel routes, hazards and incentives. We assign probabilities to these areas in a manner that prioritizes and identifies what we think likely occurred. The probability values come from careful assessment of all the known facts including: behavior statistics, cautious assumptions to fill voids, and a history of the area. All of this assessment gives weight to different scenarios. The final probabilities then emerge in distinct subdivisions of the search area through a consensus process. We will call these subdivisions “regions of probability” or just “regions” for short.

The second reason for subdividing the search area, as mentioned above, centers on physically searching the environment and managing that effort. Proper search management requires a specifically assigned area for each search resource within a specific operational period. We call these pieces of terrain “search segments” or just “segments” for short.

The size, shape, boundaries and location of regions of probability may coincide with or diverge completely from the logistical or management problems associated with searching a given area. Similarly, segment size, shape, boundaries and location usually relate to regions of probability only in the sense that both segments and regions partition the same search area—there is no

requirement that they subdivide the search area in the same way since regions of probability and segments solve different problems. Another way to state the difference between “regions” and “segments” follows:

- Regions of Probability answer the question, “Where in the search area is the subject more likely and less likely to be?”
- Segments answer the question, “How can the search area be subdivided into manageable pieces for the available resources?”

Regions of Probability and their associated POA values provide weight factors to help determine how to allocate available resources. Segments then provide a specific search assignment for each individual resource.

A region of probability is really the first subdivision of a potential search area. Essentially a planner creates this subdivision by determining where significant changes in probability occur. Ask the question: What do we think happened? Initially there are two general ways to determine where to make distinctions between probabilities. The first relies on subjective evaluations and suspected decision points based on information gathered at the start of the search. The other relies on distances collated from Lost/Missing Person Behavior data. One invariably leads to the other and their combination should always end with the construction of hypothetical scenarios.

Experienced planners have long advocated constructing scenarios based on speculation about what happened. Each hypothetical scenario should coincide with a specific area of terrain. As an example, imagine two scenarios. In one scenario if the missing person took the right fork in the trail they would likely make their way to Little Creek Campground at the lake. If the missing person took the left fork, they would end up at Ptarmigan or Pica Lakes. In either case, there would be a very specific geographic area consistent with the options. In fact, different scenarios could have consistent, diverging or separately defined geographic areas each as distinct regions of probability.

To be more specific, continuing a hypothetical search, within each scenario if the subject encounters a river or stream it requires a decision—to cross or not to cross. The probability of the subject crossing the stream substantially affects the POA values for another region of probability on the opposite side. If there is a bridge or recognized ford at a suspected crossing, then perhaps the other side of the stream is consistent with the suspected scenario. Or in a different example, walking off of a well-marked hiking trail also involves a decision for a hypothetical missing subject—left or right—that will in turn depend on a host of factors related to the subject’s probable behavior. This is where some deductive reasoning can influence the distribution of initial probability.

Remember that not all the decisions of the subject are conscious. For example, a game trail that intersects a hiking trail at a bend might cause an inattentive hiker to mistakenly follow the game trail and not realize his or her mistake until later when they recognize being lost. These kinds of considerations could lead to an assessment that the probability of leaving the trail to one side is greater than the probability of leaving the trail to the other. This hypothetical gives rise to two regions of probability with a trail as the boundary between them.

The second step, which refines the regions of probability within each scenario, is to overlay Lost/Missing Person Behavior data on top of the initial regions of probability. A major benefit of lost and missing person behavior statistics comes from not only clues about behavior, but distances from the IPP where specific numbers and categories of similar subjects were found. For instance, if we look at a median distance for a given category of subject, then we know that 50% of the subjects in that category were found between the IPP and the median and 50% were

found beyond the median. These statistics also provide distances for the 25 and 75 percent zones as well as the statistically significant maximum zone. Within each of the initial regions of probability that were established based on suspected scenarios, we can very clearly estimate probability distributions for each category of missing or lost persons.

Regions are defined by probabilities (*that often largely depend on subject behavior*). Regions are usually too large to be considered as candidates for search segments, and most often it makes sense to further subdivide regions of probability into segments. As a practical matter, geographic features that make good region boundaries usually make good segment boundaries as well. If the same features work as boundaries, common sense also dictates that segment boundaries will sometimes coincide with portions of region boundaries.

When evaluating the definitions of regions and segments remember that explanations are presented here in an attempt to convey the way a theory works. Analogies are powerful but at the same time limiting. Similarly when we say a region can be any size and shape, larger or smaller than a segment, we mean region size is independent of segment size. Segment size (*as they have traditionally been constructed in land SAR*) depends on specific parameters unrelated to the subject's suspected location within the search area. Traditional segmentation rules include:

- Segments have a size such that the assigned resource should be able to search the segment to the desired coverage within the time allotted (*4-6 hours*).
- A segment should contain no internal barriers to searcher movements.
- A segment's boundaries should be clear, corresponding to obvious natural or man-made features whenever possible, especially those found on maps of the area.
- It should be easy for searchers to locate their assigned segments both on the ground and on the maps provided.

The time required to search a segment varies with: the size of that geographic area, terrain type, vegetation density and other environmental factors, and also the level of coverage (*or "thoroughness"*) desired. (*Can we search that segment in the next operational period with that resource?*) Regions of Probability, on the other hand, depend on entirely different criteria. Region values are determined based on likelihoods the subject is in one particular area versus another particular area. The boundaries between these different geographical areas are defined by subjective analysis. Remember, these boundaries help us divide the map based on where we think the subject traveled, or did not travel.

Imagine, for example, another hypothetical search. We speculate that a young boy went into an area containing beaver ponds to explore or play. If resources are sent to search the area, several things must be considered for planning purposes. Each small beaver pond in the area may only encompass the area of a few thousand square feet or even less. However, mathematically we have to separate the probability beneath the surface of those ponds from the probability of the surrounding forest area. Additionally to search one of those ponds compared to a similar sized piece of forest requires a different resource and time frame (*i.e. divers, underwater scenting dogs etc*). In this case we say each pond represents a separate region of probability (*they are all large enough to be small segments*) that must be searched and allocated POA separately. In a different scenario, if those beaver ponds were caves, wells, cisterns or other underground features, the same analysis and conclusion would apply.

Segmentation of Regions

Throughout the world, searchers give subdivisions of search areas different names: segments, sectors, zones etc... All are acceptable. Dividing a search area into regions of probability, and then those regions into segments (*or sectors etc.*) can help prioritize resource application at any one time. Subdividing probability regions allows resources to cover assigned search segments

in a specific time period. Remember, designation of segments in the search area is a management function about time and effort only and provides a snapshot of searchable areas contained in a region of probability for one operational period.

Defining Region and Segment Boundaries

The drawing of boundaries requires careful thought, good map reading and, ideally, knowledge of the geographic area. Segment and region of probability boundaries should be based on what searchers can readily see and identify in the field.

The following features provide suitable boundaries:

- Man-made: Fences, roads, ditches, power lines, trails, firebreaks, survey/boundary lines, cut lines, railroad tracks, and even walls.
- Natural: Ridge lines, canyon bottoms, rivers, streams, creeks, topographic breaks, vegetation breaks, geomorphologic features (*boulder fields, scree slopes, and cliffed areas*).
- Improvised: Compass lines (*stringed or flagged*), point-to-point (*line of sight*).

Conclusion

Regions of probability” and the associated search theory are new to the land search scene. For decades segments or “sectors” were the only subdivision of a search area. We now know that this was not consistent with the principles of search theory established in operations research from the 30s and 40s. Regions of probability make sense because they address our best idea about what happened. Regions set the parameters for an experiment: “This is what we think happened; this is the geographic terrain that we think is involved; and now we will send resources to the field to either prove us right or wrong.” The concept of assigning probability to given geographic regions provides a sound methodology to meld the subjective information gathered at the beginning of a search with objective statistics as the operation unfolds. Regions of probability set the stage and help answer the question “Where do we search?”