# Optimizing Wilderness Search and Rescue: Discovery and Outcome

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## Abstract

This article is a follow-up to a 2019 analysis that applied Bayesian probability techniques to the search for a missing hiker in Joshua Tree National Park. In February 2022, that hiker was found. Here, we compare the location of his remains with the results of our prediction model and discuss further implications for optimizing wilderness search and rescue.

**KEY WORDS:** *Wilderness Search and Rescue, Lost Persons, Bayesian Analysis, Resource Optimization*

## Introduction

In 2019, the *Journal of Search and Rescue* published an article in which we discussed the use of Bayesian methods to support wilderness search and rescue (WiSAR) efforts (Rossmo, Velarde, & Mahood, 2019). The case of William Ewasko, a hiker who went missing in Joshua Tree National Park (JTNP), was used to illustrate how different types of spatial evidence could be integrated into an optimal probability search map.

Ewasko disappeared in late June 2010. Twelve years later, in early February 2022, hikers discovered human remains and a backpack, with Ewasko's identification, in the northwest section of JTNP (Hazel, 2022). The San Bernardino County Sheriff's Department later confirmed his identity through dental records. In this follow-up article, we discuss the accuracy of our original prediction and further implications for WiSAR Bayesian analysis.

## William Ewasko's Disappearance

William Ewasko was an experienced hiker who regularly visited Joshua Tree National Park in Southern California (see Figure 1). On June 24, 2010, he set off on an ambitious day hike, planning to be finished around 5:00 pm (Mahood, 2012). While arguably not wild or remote, the 1,240 square mile (3,213 km$^2$) park can still be dangerous, with large rocks, deep canyons, and hot summer temperatures (Manaugh, 2018).

*Figure 1: Joshua Tree National Park*

When Ewasko failed to call in that evening, park rangers checked the trailheads on his itinerary. On June 26$^{th}$, a California Highway Patrol helicopter spotted his vehicle at the Juniper Flats Trailhead parking area. The search then focused on locations reachable from here, including Quail Mountain. At 6:50 am, Sunday, June 27$^{th}$, Ewasko's mobile phone registered ("pinged") with a cell phone tower on Serin Drive, Yucca Valley, just to the northwest of JTNP, indicating he had moved well beyond Quail Mountain. Searchers redeployed in response but were unable to find any trace of the missing man.

The official search was called off on July 5$^{th}$, though numerous follow-up searches were conducted over the years by experienced volunteers. The electronic GPS data in the JTNP Ewasko master file eventually totaled 1,772 person-miles (2,852 km) of official and volunteer search tracks (see Figure 2).

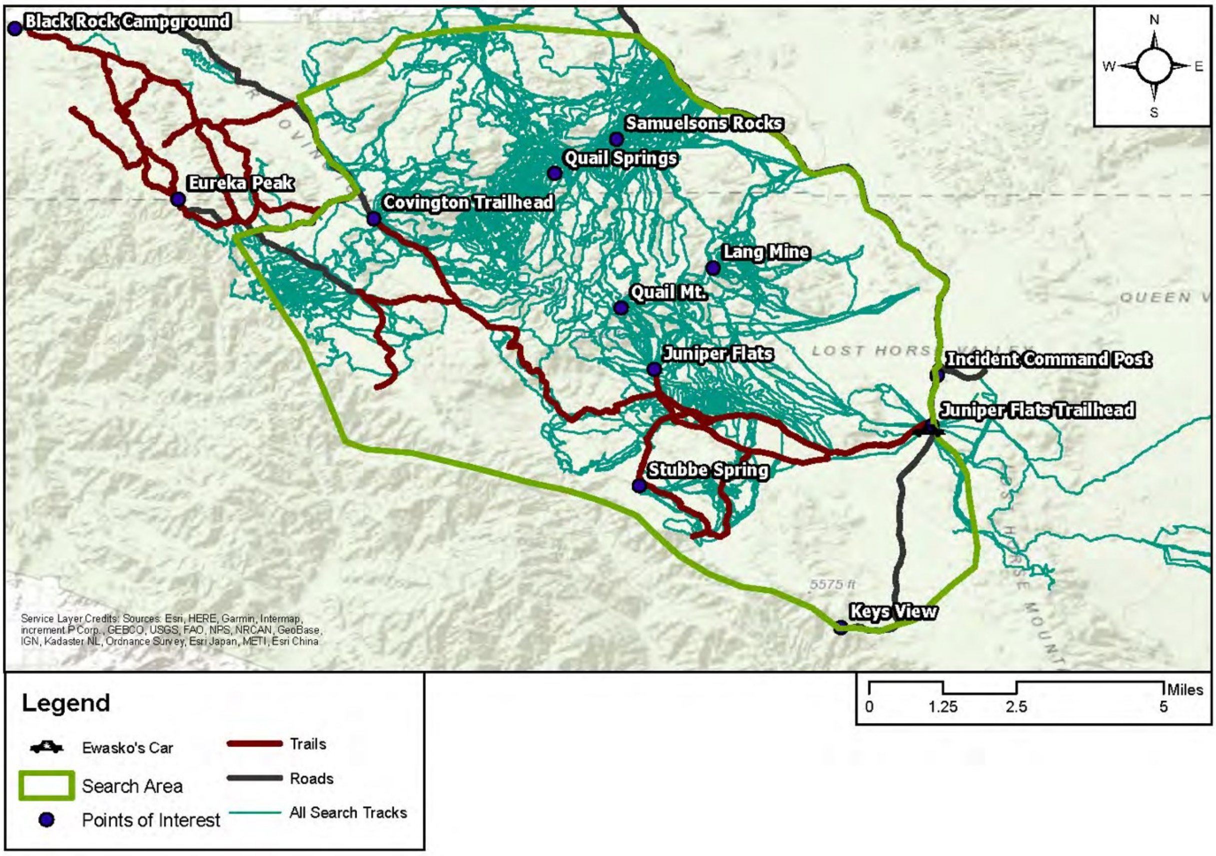


*Figure 2: Search Tracks, Trails, and Roads*

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## Bayesian Optimal Probability Analysis

The purpose of our original analysis was to demonstrate how Bayes' theorem can be used to generate priority search maps for WiSAR by combining different evidence sources – in the Ewasko case, the location of a cell phone tower, the range of its ping (approximately 10.6 miles, or 17.1 km), a terrain altitude viewshed analysis, and prior search tracks (Eddy, 2004; Iversen, 1984). Further details, including a full description of the Bayesian analysis, can be found in Rossmo, Velarde, and Mahood (2019).

Figure 3 shows our resulting optimal search map. Colors, ranging from blue to red, represent the various probabilities for finding Ewasko (the probability color scale in the legend lists relative numbers, not specific probabilities). The non-coterminous peak areas are all situated to the north of Quail Mountain. The inset map depicts the zone of highest probability.

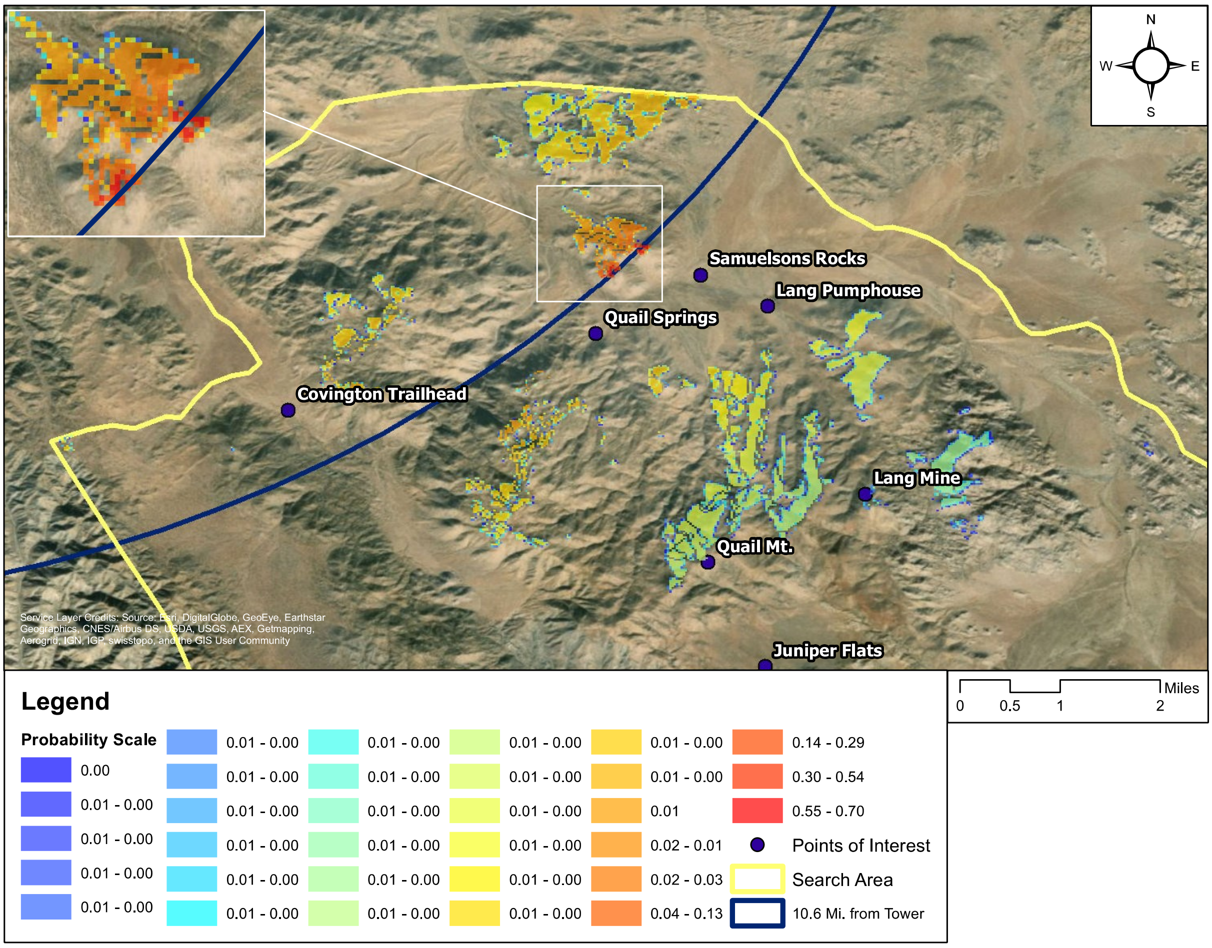


*Figure 3: Optimal Probability Search Map*

*Optimal search areas, ranked by color scale, shown in relationship to JTNP landmarks and 10.6-mile ping radius from Serin Drive cell phone tower. Inset box at upper left magnifies the highest probability region.*

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## Location of Remains

Ewasko's remains were discovered on a saddle along a ridge spine (see Figures 4 and 5). This spot was about 3.9 miles (6.3 km) north of Quail Mountain, his presumed destination, and 7.6 miles (12.2 km) northwest of his parked vehicle. Sadly, he was only about 1½ miles (2.4 km) from Park Boulevard when he succumbed, close enough that vehicles could be heard, though not seen.


*Figure 4: Area of Ewasko Remains*

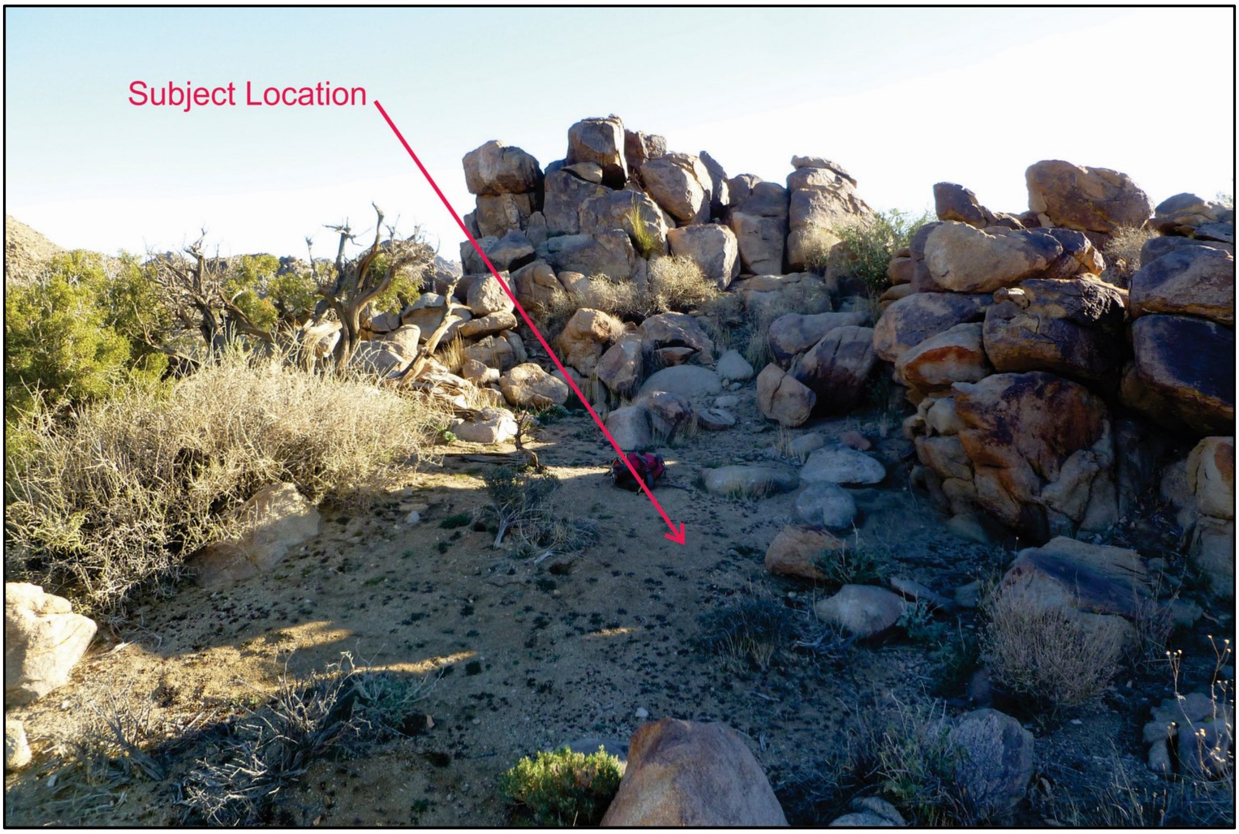

*Figure 5: Location of Ewasko Remains*

Figure 6 shows the locations of Ewasko's remains and his parked vehicle, overlaid on a map of the peak optimal search areas from our original analysis. The region of highest probability fell along the 10.6-mile ping radius from the Serin Drive cell phone tower, north-northeast of Quail Springs (see inset box Figure 3). Ewasko's remains were found just over a half-mile (0.83 km) northeast of this area, and only 0.28 miles (0.45 km) southeast of the nearest identified high probability area.
The distance from this spot to the Serin Drive cell phone tower is 10.25 miles (16.5 km). The exact location lacks cell phone coverage, but if Ewasko approached from the south, consistent with his travel direction, he would have passed through a small area of coverage close to the 10.6-mile ping radius. Given the temperature and three-day time lag, it was not expected he would have been able to walk much farther.

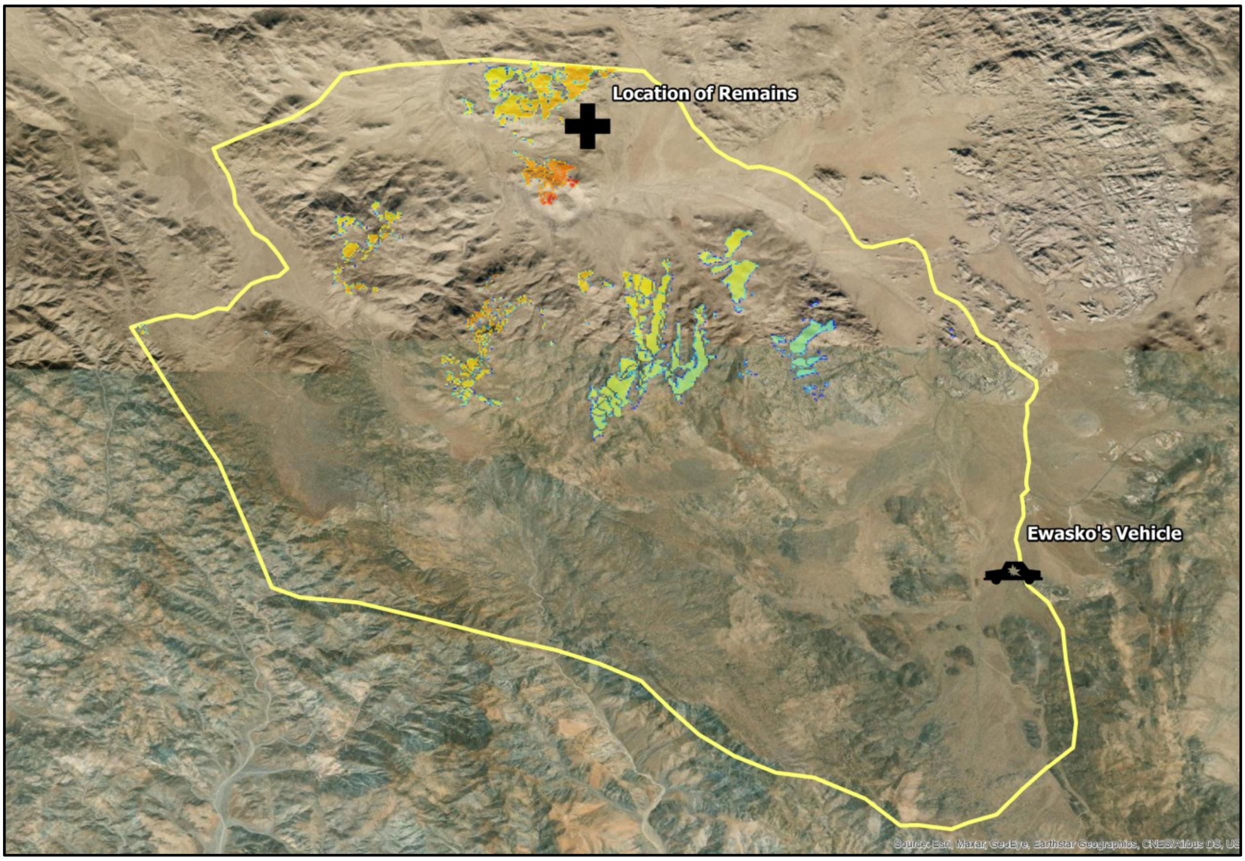


*Figure 6: Optimal Probability Search Map and Locations of Ewasko Remains and Vehicle*

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## Discussion

The outcome of the Ewasko case illustrates the importance of remembering that any analysis in a search and rescue effort is time dependent. While there was no cell phone coverage where Ewasko's remains were found, the viewshed analysis, park terrain, and tower ping radius all indicate he was headed north and passed through the peak probability area displayed inside the Figure 3 inset box. He was able to walk another half-mile before expiring. The possibility that a missing person will still be mobile must always be considered. Terrain and intent remain important considerations.

All of the assumptions in our original analysis appear to have been valid. There are only three possible paths between his parked vehicle and where he was found. While terrain constraints, cell phone coverage limitations, and timing suggest a few possible theories, unless Ewasko took notes or photographs we may never know for certain his exact hiking route or decision rationale. At best guess, it appears he was the victim of a lack of local knowledge regarding the difficulty of the specific area of JTNP he was hiking through, curving and disorienting canyon bottom trails, limited visibility, hot summer temperatures, and eventual dehydration. Circumstances suggest he may also have suffered an ambulatory injury, such as a bad sprain.

Recently, two of the authors were asked by Texas Search and Rescue (TEXSAR) and local law enforcement to assist in the search for a missing person. Optimization techniques similar to those used in the Ewasko case were applied to the effort. While there were no phone pings in the Texas case, the clothing of the missing person was discovered, while the road, fencing, and landscape provided some constraining influences on his movement. Data from the International Search & Rescue Incident Database (Koester, 2008) helped calibrate the distance-decay functions used in that analysis.

Tens of thousands of photographs of the relevant area were taken using drones (UAS, or unmanned aerial systems). Equipped with sensors for different spectral wavelengths, UAS can help locate human remains (Wescott, 2020). When bodies begin to decompose, the activities of bacteria and insects can generate enough heat or thermal energy to make the bodies detectable by infrared sensors. If the body has been scavenged and scattered, the near-infrared spectrum can detect the organically rich soil produced when bodily fluids leak during decomposition. Ultraviolet light is ideal for detecting bones as they fluoresce. If drones have been employed in a WiSAR effort, the Bayesian optimal probability search map provides an evidence-based strategy for prioritizing the review and inspection of large numbers of UAS photographs.

The Texas investigation remains unresolved, and may remain a mystery because of the high level of local carnivore animal activity (Haglund, 1997). This region has coyotes and feral hogs, the latter a problematic invasive species capable of eating large bones. However, the case does illustrate the flexibility of the Bayesian approach and its utility in managing information overload challenges.

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## Conclusion

The failure to find Ewasko was surprising as JTNP is lightly forested and its terrain is not difficult to survey (see Mahood, 2016, 2018). At the time of publication of our original article, there were no remaining viable theories as to his whereabouts. Subjects who are not quickly found by search and rescue personnel have usually done something unanticipated, such as traveling further than estimated, leaving the designated search area, or heading in an unexpected direction. All three of these happened in the Ewasko case.

Mahood, one of the coauthors of this article, has extensive search and rescue experience in Southern California. He initially believed it unlikely Ewasko would be found in the peak probability areas at the north of the Bayesian map as there was no known reason why he would climb there from Quail Wash. Except it turned out there was. And, while we don't know why, Ewasko must have considered it important.

It has been consistently shown that algorithms outperform human judgment (Kahneman, Sibony, & Sunstein, 2021). Despite the accuracy of the prediction here, however, more research and further testing is needed, and we recommend considering the two approaches as complimentary. What is indisputable is that as a search progresses, and as more and more areas become cleared, the unlikely becomes more probable. It is worth repeating a quote from Pete Carlson, Riverside Mountain Rescue Unit: "If you haven't found them, then they're someplace you haven't looked yet" (Manaugh, 2018).

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## About the authors

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## Abbreviations

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| GIS | geographic information system |
| GPS | global positioning system |
| JTNP | Joshua Tree National Park |
| WiSAR | wilderness search and rescue |

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