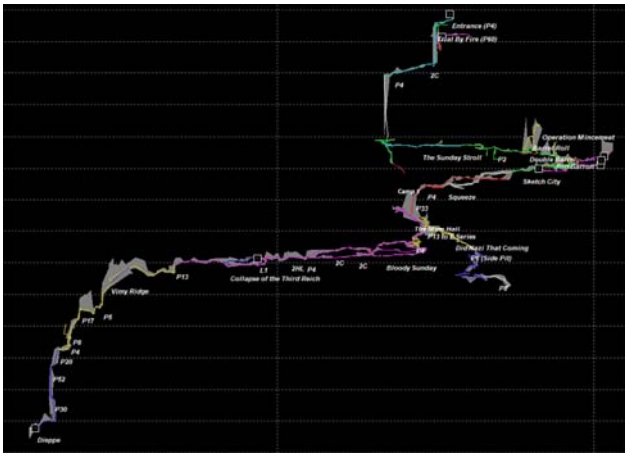
Mapping a Cave System



Bisaro Anima

https://www.canadiangeographic.ca/article/rcgs-supported-expedition-discovers-deepest-cave-canada

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Problem

- 12 children and their coach are trapped while exploring a cave in Thailand
- Rescue planning depends on accurate maps of the cave system
- Many methods are possible
  - Lidar/sonar
  - Radiolocation
  - Compass, clinometer, tape/laser rangefinder

Picture: Tham Luang Rescue Operation Center

CBC News

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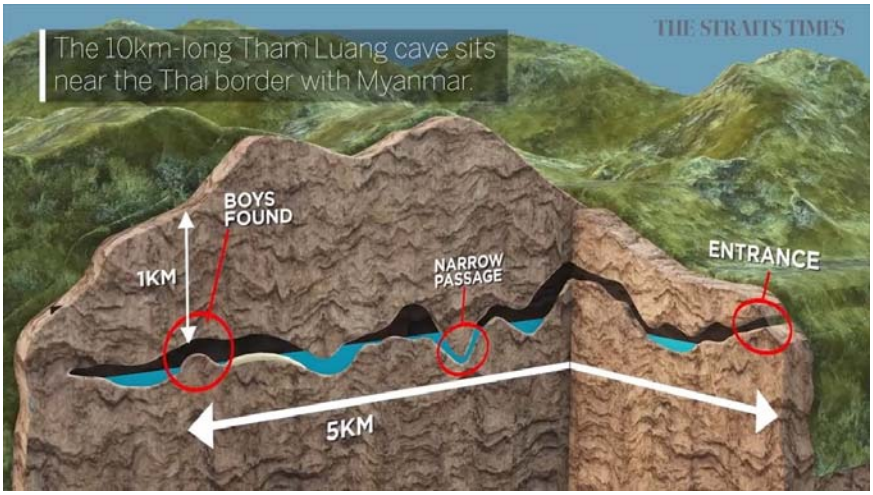
Need 3D mapping



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https://www.youtube.com/watch?v=TnbSkPXDEP0

Radiolocation Mapping

- Very Low Frequency transmissions
- Determine position and depth of a cave passage
- Transmitter in cave generates a magnetic field
- Receiver used to determine position at surface vertically above transmitter

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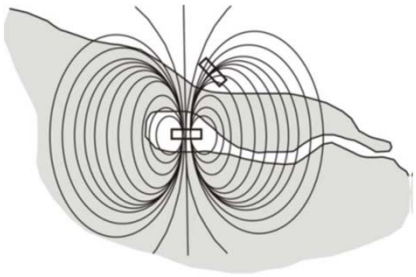
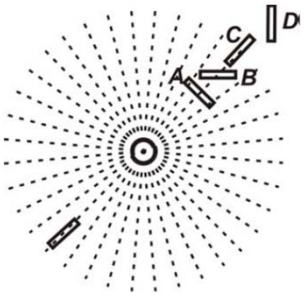
http://site2.caves.org.uk/radio/radioloc_for_cave.html

How?

Find Ground Zero (GZ)



Transmitter in a cave



Magnetic field lines radiating from GZ

Farrant, Andrew & Mullan, Graham. (2018). Novel use of radio-location for a ground investigation at Pen Park Hole, Bristol, United Kingdom.

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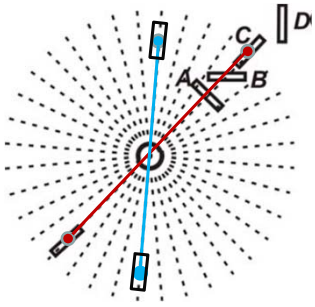
Find Ground Zero - How?

1. Hold radio receiver vertical
2. Walk along a line where the receiver receives a null signal all along the line
3. Mark two locations along the null line
4. Walk perpendicular to the first line until another null signal is located.
5. Walk along the second null line
6. Mark two locations along the second null line.
7. Intersection of the two null lines is Ground Zero (GZ)
8. Take a GPS reading at GZ



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Find Depth at GZ – How?

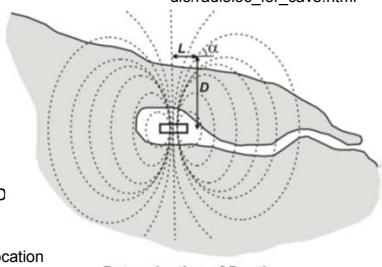
Method A

1. Hold radio receiver horizontal
2. Walk along a null line away from GZ
3. Stop and slant the receiver until a null signal is obtained
4. Measure the angle of the receiver α
5. Measure the distance to GZ (L)
5. Calculate Depth (D)

$$D = \frac{2 \times L}{\sqrt{(9 \times \tan^2\alpha + 8) - (3 \times \tan\alpha)}}$$

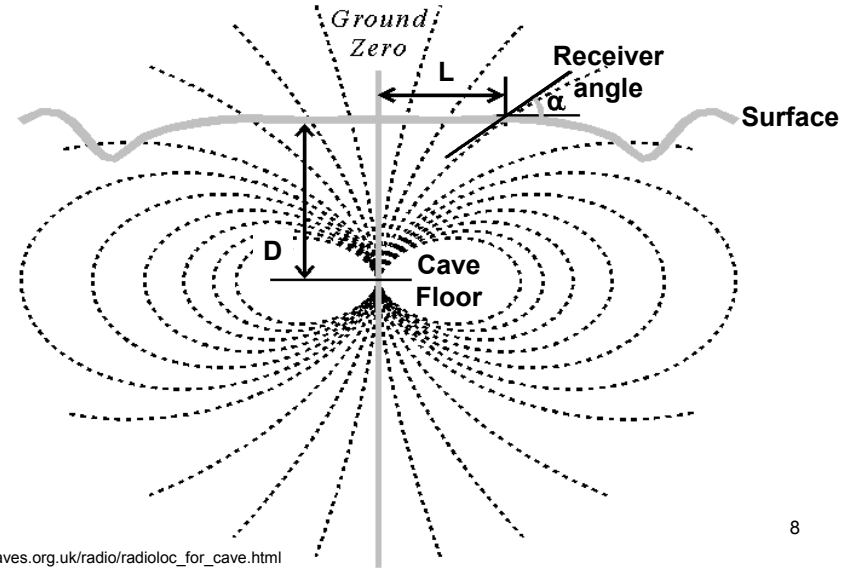
where x is multiplication and √ is square roo

http://site2.caves.org.uk/radio/radioloc_for_cave.html



Determination of Depth

Farrant, Andrew & Mullan, Graham. (2018). Novel use of radio-location for a ground investigation at Pen Park Hole, Bristol, United Kingdom.



http://site2.caves.org.uk/radio/radioloc_for_cave.html

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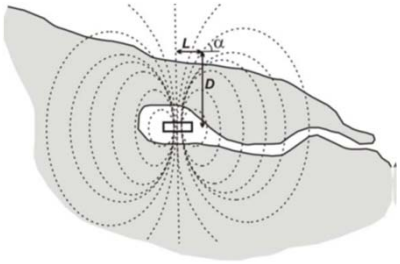
Find Depth at GZ – How?

Method B:

1. Hold radio receiver horizontal
2. Walk along a null line away from GZ
3. Stop when a null signal is obtained
   (where magnetic field is parallel to ground, α is 0)
4. Measure the distance to GZ (L)
5. Calculate Depth

$$D = \frac{L}{\sqrt{2}}$$

where √ is square root



Determination of Depth

Farrant, Andrew & Mullan, Graham. (2018). Novel use of radio-location for a ground investigation at Pen Park Hole, Bristol, United Kingdom.

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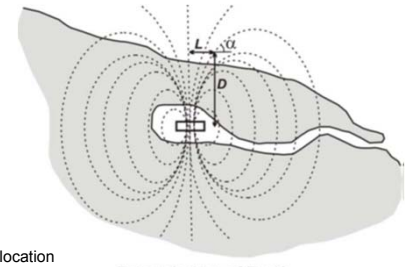
Find Depth at GZ – How?

Method C

1. Hold radio receiver horizontal
2. Walk along a null line away from GZ
3. Periodically stop and slant the receiver until a null signal is obtained
4. If the angle of the receiver α is 45˚, measure the distance to GZ (L)
5. Calculate Depth (D)

   D = 1.78 x L

http://site2.caves.org.uk/radio/radioloc_for_cave.html



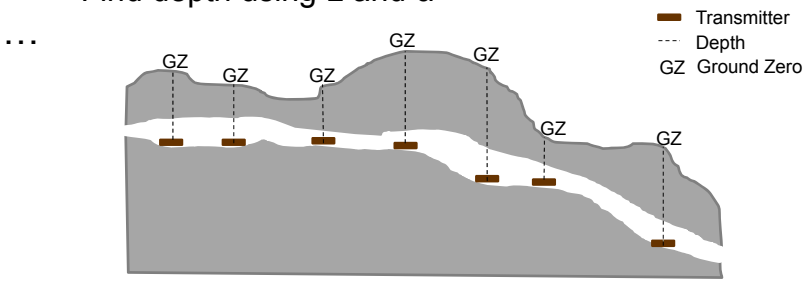
Determination of Depth

Farrant, Andrew & Mullan, Graham. (2018). Novel use of radio-location for a ground investigation at Pen Park Hole, Bristol, United Kingdom.

Obtain x,y and Depth for Multiple Locations

- Move transmitter to a new location in cave
  - Find GZ location, get GPS coordinates (x,y)
  - Find depth using L and α
- Move transmitter to a new location in cave
  - Find GZ location, get GPS coordinates (x,y)
  - Find depth using L and α

…



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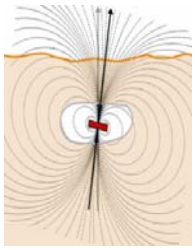
Accuracy?

- Transmitter must be horizontal
  - Determined using Spirit level (lack precision)
- Distortions in the magnetic field produced by the way the coils are manufactured (need to be flat)
- Rock characteristics, ground water may affect magnetic field
- GPS accuracy
- Variations on depth calculated from different locations around GZ
- Deeper caves - the deeper the signal source, the more effect small errors have



http://www.fountainware.com/compass/Tutorials/RadioLocations.htm

How to Approach?

Start simple,

- Assume the client knows the
  - location of Ground Zero
  - distance L from GZ to the null point
  - angle of the receiver α

Once working,

- adjust the formula for accuracy concerns
- calculate the depth at different distances around GZ and derive a best-fit curve for depth

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