ACCURACY EVALUATION OF AN ELECTROMAGNETIC LOCATING DEVICE

by
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ABSTRACT

There has existed a need for a method of accurately determining the horizontal position and elevation of underground points in mines, quarries and natural openings without the utilization of conventional precise surveying techniques. Electromagnetic locating devices provide a means of determining a point on the surface above the underground point and depth to the underground point. The capabilities and limitations of this equipment to accurately locate points are not fully known yet, but indications are that under certain conditions very accurate results can be obtained. Data from work which has been performed is summarized in this paper.

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Introduction

There has existed a need for a method of accurately determining the horizontal position and elevation of underground points in mines, quarries and natural openings without the utilization of conventional precise surveying techniques underground. Electromagnetic locating systems provide a means of determining a point on the surface above the underground point and depth to the underground point. Several situations exist where this would be very valuable information, the trapped miner being the most obvious. Depending on the accuracy with which the surface point can be located with respect to the underground point, the need for underground traverses could be eliminated.

The principle of operation of an electromagnetic locating device (EMLD) is that a transmitting unit is taken underground and the antenna is positioned on the underground point. A magnetic field is created around the antenna which is detected on the surface by a receiving unit. The physical properties of magnetic fields provide a basis for making measurements.

Magnetic fields are used because of their ability to penetrate rock masses and their well-understood physical characteristics. Radio wave frequencies, 10^6 to 10^{11} Hz, are absorbed to varying extents as they pass through rock, and absorption may be sufficient to prevent reception of the signal altogether. Low frequency (10^1 to 10^5 Hz), long wavelength magnetic fields are used for EMLD systems because of their ability to penetrate rock masses with little or no absorption of the signal. Results of experiments indicate that good results are obtained with wavelengths in the 400 to 1000 meter range, and over the 1000 meter range absorption appears to be only slight. EMLD's presently in use operate in the frequency range of 1000 to 4000 Hz which corresponds to wavelengths in the range of 10^5 meters.

Use of EMLD's to locate underground points on the surface has been limited to situations where very low-order surveys have been run underground and a check on their accuracy is desired. Only recently has the capability to accurately locate points been recognized. The capabilities and limitations of EMLD's are not fully known yet, but indications are that under certain conditions very accurate results can be obtained.

Development and Use

The use of low frequency magnetic fields for communication through rock masses was proven to be practical in 1928 by Eve and Keys at Mammoth Cave, Kentucky (8). With the development of transistors and miniaturized electronics the problems of size of transmitting and receiving units and power requirements for operation were overcome. Although it is not clear who first adopted transistor technology to electromagnetic communications, several articles were published in the late 1950's and early 1960's describing transistorized units which had been constructed and successfully operated. All these units were similar, utilizing circular coils for both the transmitting and receiving antennae, operating on frequencies of 1000 to 2000 Hz, and being powered by batteries (3, 16, 24, 32).

The principle of operation of all these units was similar. A.C. voltage was passed through a transmitting coil, thus causing an oscillating magnetic field to be set up. Coil diameters ranged from 1.5 to several feet in diameter. The receiving unit, which also had a coil for an antenna, detected the magnetic field as a simple consequence of the fact that magnetic lines of force passing through the plane of a loop of wire will cause a voltage in the loop. It is this voltage which is detected and amplified by the receiving loop.

Detection of the magnetic field by the receiving coil depends on the relationship between the plane of the coil and the direction of the magnetic field at the point where the receiving coil is located. Since the number of lines of force which pass through the loop is directly related to the angle between the plane of the receiving coil and the lines of force, the strength of the received signal is dependent on this. Figure 1 shows the relationship between the angle the coil makes with the lines of force which pass through it and the strength of the received signal. It can be seen that a sharp null exists when the angle equals zero. It is this null and its associated directional characteristics that are used to

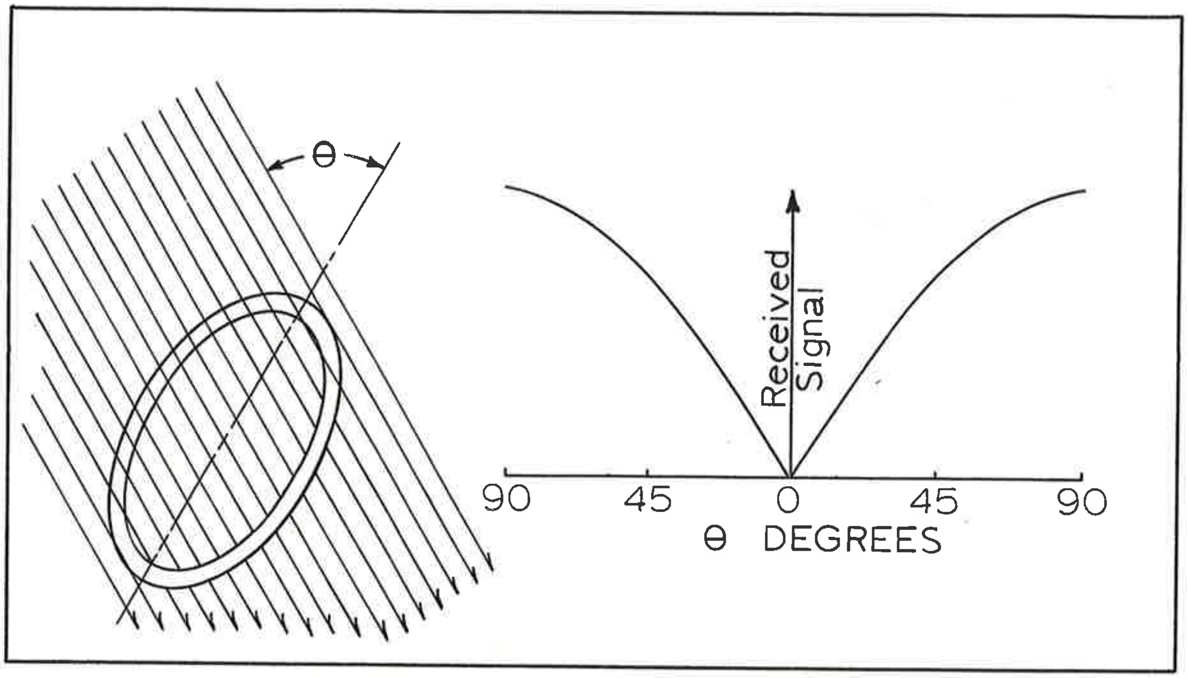


Figure 1. Relationship between the strength of the received signal and the orientation of the receiving coil to the magnetic field lines of force.

determine position and depth of the underground transmitting coil.

The directional characteristics and geometry of the magnetic field set up around a coil of wire are well understood. The geometry of the magnetic field is the same as that for a short bar magnet set vertically at the center of the transmitting coil. It can be seen that the field takes the shape of ellipses through the center of the coil and radiating in all directions from the coil. See Figure 2.

Birchenough and Jones, 1962 (3) were among the first to describe in detail procedures for determining position and depth. The procedure they describe relies on the geometry of the magnetic field and the directional character of the null associated with the receiving antenna. With the transmitting coil leveled on the underground point, the point on the surface directly above the underground point coincides with the axis of the transmitting coil and corresponds to the point where the magnetic field is vertical. This point is called ground zero. To locate ground zero the plane of the receiving coil is held vertical and

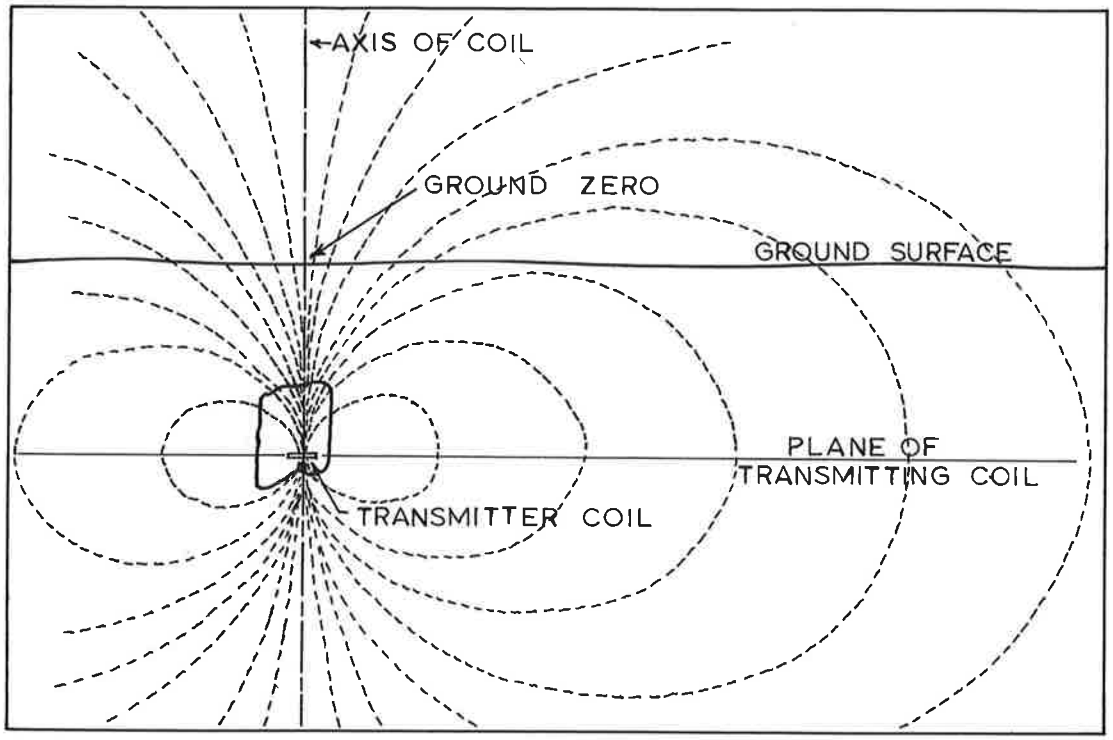


Figure 2A. Side view of the transmitter in position underground, looking toward the transmitter along the plane of the coil. Dashed lines represent the magnetic lines of force.

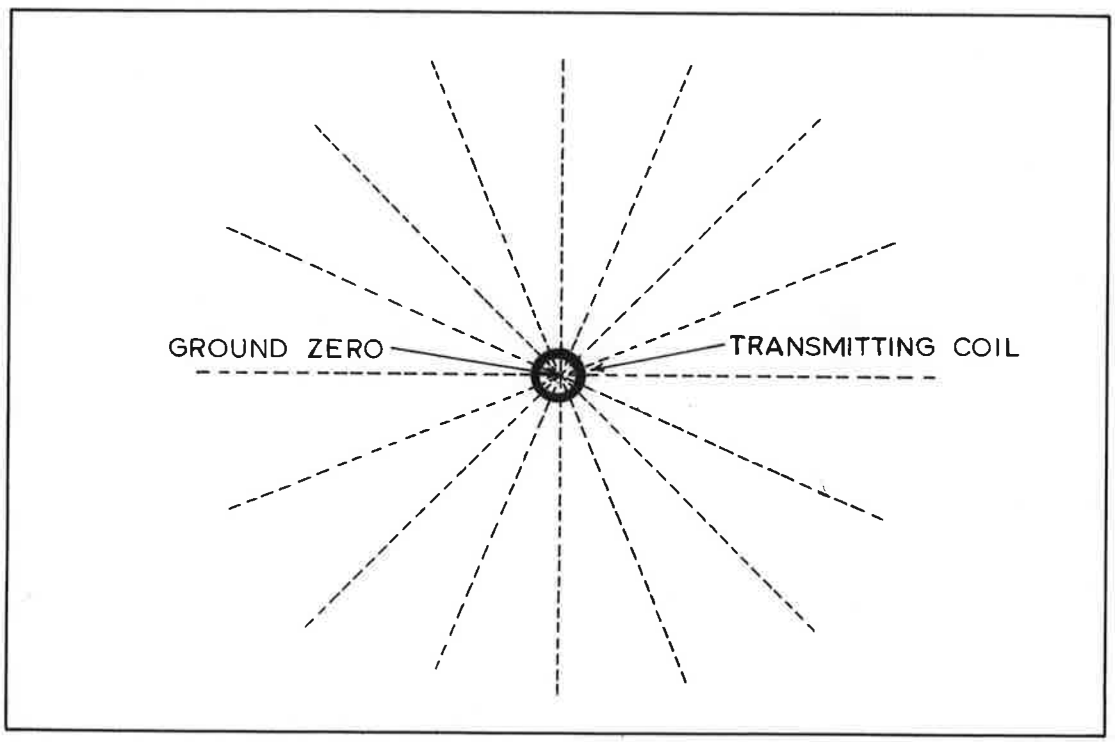


Figure 2B. Vertical view looking down on the transmitter along the axis of the coil. Dashed lines represent the magnetic lines of force which appear to radiate from the coil.

the point where a null exists in all directions is sought. To determine depth, the angle of the lines of force is measured at various distances from ground zero. For this purpose an angular measuring device is attached to the receiving coil and a null signal is sought at the predetermined distance from ground zero. The null will occur at some angle from the vertical. By having previously calibrated the instrument with regard to angle of null, distance from ground zero, and depth, a value for depth can be obtained from tables or graphs for any measured angle. A similar procedure was also described by Lord in 1963 (16).

Numerous articles appeared between 1960 and 1970 describing modifications and development of new equipment and procedures for use. Work was being conducted along the lines of both communication and position finding. Most notable of the articles appearing with regard to position finding was one by Mixon and Blenz, 1964 (19) which brought together all the developed knowledge with regard to location and depth determinations. Methods which had been successfully used and had given good results were described. Introduced in the article was a set of curves for determining transmitter depth. These curves related angle of the magnetic field from the vertical, distance from ground zero and depth to the transmitter. To develop these curves the shape of the magnetic field about the transmitter was taken to be that of a magnetic dipole which is approximated by the relationship given below:

$$\theta = \mathrm{Tan}^{-1}\left(\frac{3ld}{2d^2-l^2}\right)$$

d = depth
l = distance from ground zero
θ = angle of magnetic lines of force

Figure 3 shows a plot of these curves. Application of the curves and the relationship given above have proven to give very acceptable results. Several other articles appearing in this time span describe very similar procedures to those described by Mixon and Blenz (1, 2, 4, 5, 7, 18, 20, 21, 22, 23, 25, 28, 33).

The accuracy of locations and depths obtained using this equipment was not known. Several intuitive evaluations were made based on the diameter of the null at ground zero, and in

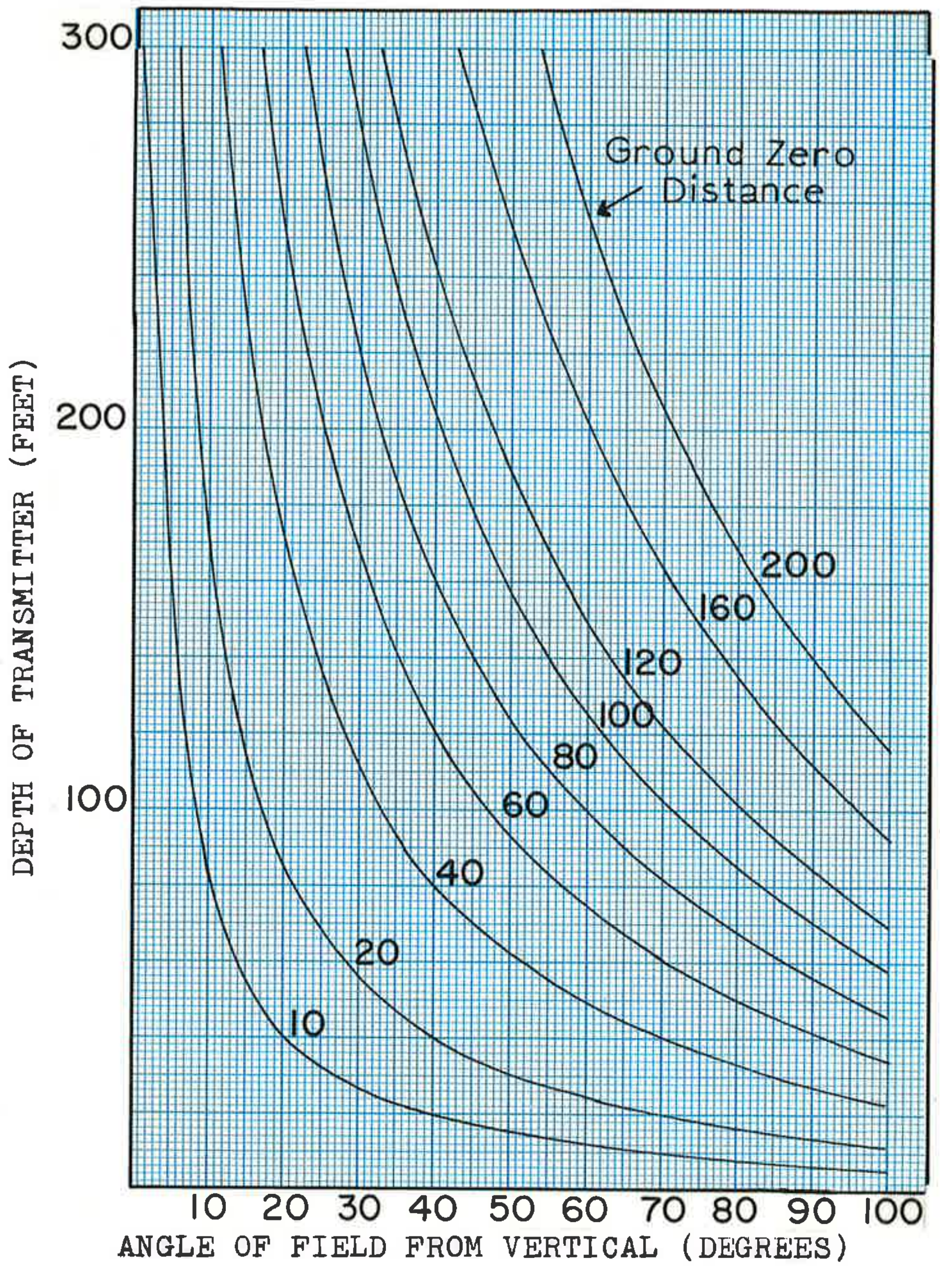


Figure 3. Curves for determining transmitter depth. The curves give depth as a function of the angle of the magnetic lines of force (see Figure 2A) and distance from ground zero point.

a few instances drill holes into underground rooms were placed based on EMLD results. The first published approximation for accuracy was by Birchenough and Jones, 1962 (3). Using an antenna 24 inches in diameter at a depth of 200 feet, the null at ground zero was approximately 3.5 feet in diameter. Lord, 1963 (16) speculated that the horizontal position of the underground coil could be located with an accuracy of about 2% of the depth, and the depth determination was assessed to be about ± 10% of the actual value providing the surface topography was reasonably flat. Christopher, 1968 (5) reported on work done where an EMLD was used to close low-order surveys which had been run for considerable distances underground. The EMLD was used to provide a closing link to a traverse which had been run over the surface. He reported that the error of closure corresponded closely to the theoretical error of closure which had been calculated based on the surveying techniques used underground. Charlton, 1966 (4) referenced work performed by Weightman in 1962 using equipment with 19" coils to locate two air shafts in Meramac Caverns in Missouri. Depth to the cave passages below the surface was approximately 40 feet. The shafts hit within inches of the indicated points. Also in 1964 a shaft was located at Jewel Cave, South Dakota for the National Park Service. Depth was approximately 200 feet and the shaft missed its target by about 7 feet, but a later check showed that the drill hole had drifted 6 feet. Reports similar to these and individual speculations based on experience with the equipment were the only evaluations of accuracy made prior to 1970.

In the early 1970's the U.S. Bureau of Mines became involved with electromagnetic communications between underground and surface. Their interest followed the lines of communicating with and locating trapped miners following a mine disaster. Several individuals and groups were employed to research and develop equipment and procedures. Their approach was similar to what had been done previously and they obtained similar results. Optimum frequencies were found to be between 500 and 3000 Hz. Antenna configurations took the form of small coil antennas or long wire antennas which could be coiled around mine pillars or laid out straight on the ground. Most of this work was published in the period between 1972 and 1974 (9, 10, 11, 13, 15, 17).

The approach taken to determine location was to measure the strength of the magnetic field at the surface. The horizontal and vertical components of the field were measured separately and compared to determine the ground zero point. At ground zero the field strength in the vertical direction is at a maximum and the horizontal is zero. At any other point than ground zero the horizontal component has some value. By taking a ratio of the horizontal field strength to the vertical field strength a relationship can be developed for locating the ground zero point. This method requires traversing the area several times in an organized search pattern to locate the ground zero point (29, 30).

Several factors enter into the problem of determining locations based on field strengths. Most important is the fact that the rock overburden is conductive and will affect the field strength. When locating on relatively flat-lying topography this is of little significance since the signal must propagate through equal thicknesses of rock at all points. But when working on steep hillsides in mountainous terrain it is possible to get a higher field strength reading downhill of the actual ground zero point due to the lesser thickness of rock through which the signal must propagate. Figures 4 and 5 show plots of field strength vs. distance from ground zero for both terrain situations. A procedure has been developed to adjust the position determined for ground zero in such a manner as to place it closer to its correct position. The effects of hill slope diminish as the depth of the transmitting unit becomes larger compared to the differences in elevation on the surface (11, 29).

In 1973 a report published by Westinghouse Electric Corporation summarized work they had performed on the development and use of EMLD equipment (11). The equipment they developed and used on this project consisted of Westinghouse EM Manpack transmitters and two Manpack receiving units. Several trans-

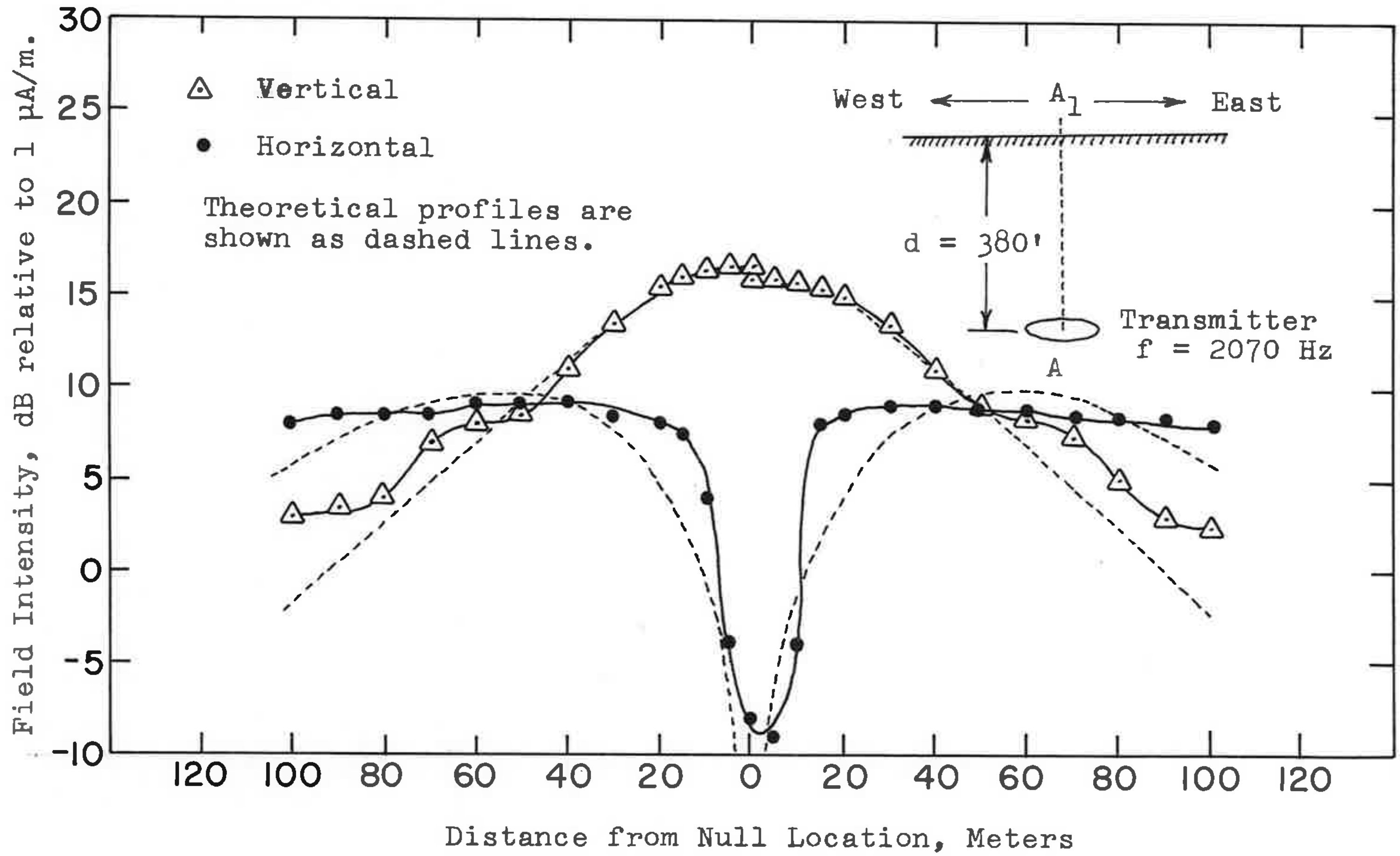


Figure 4. Field intensity profile above vertical magnetic dipole at Putnam Mine, Elmwood, West Virginia (taken from reference 11).

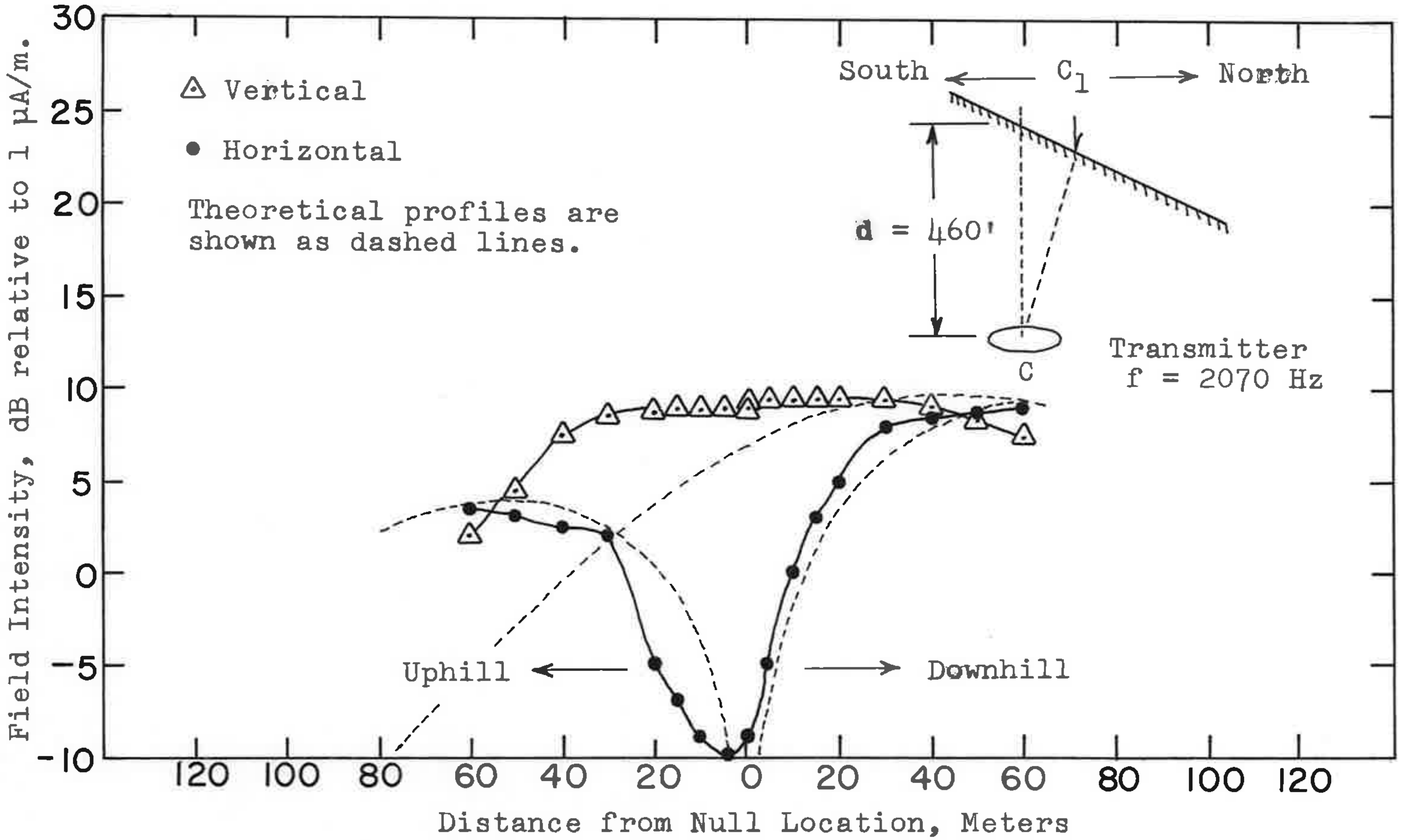


Figure 5. Field intensity profile above vertical magnetic dipole at Putnam Mine, Elmwood, West Virginia (taken from reference 11).

mitting units were built, each operating at a different frequency in the range between 500 and 3000 Hz. The electronics for the transmitter consisted of a small printed circuit card which could be enclosed in the underside of the miner's lamp battery cap. The antenna for the transmitting unit consisted of 90 feet of flat ribbon cable which was stored in a measuring tape reel. For use, the antenna cable could be looped into a coil or laid out straight along the ground. The two receiving units which were built detected and measured the two components of field strength. Several field tests were conducted in the eastern U.S. All tests were successful to varying degrees.

To determine the accuracy of the locations which were made a precise survey was conducted. Table 1 presents a summary of the accuracies for the locations. This table is compiled from two reports published in 1973 by Westinghouse Electric Corporation (10, 11). These data represent the first published results for locations where surveys of relatively high accuracy were involved both above and below ground. It should be noted in reviewing the table that null error refers to the error in the ground zero position and that adjustments have been applied for surface slope. Both unadjusted and adjusted values for error appear. An important point should be considered with regard to the results for the Geneva Mine in Utah. The antenna configuration used was to wrap the wire around a mine pillar, the dimensions of which were 70 by 180 feet. This means that the errors in position are within the dimensions of a pillar and are therefore relatively accurate. All data presented in this table are based on locations made using field intensity measurements.

The first published account of EMLD equipment being used specifically for higher-order surveying appeared in 1973 (12). It describes how a group in France used an EMLD to survey underground quarries. The equipment used was similar to what has been previously described, with the exception of the receiving coil which consisted of a coil of wire wound around a small bar of ferrite which was half a meter long. Accuracy of the position of the point on the surface with regard to the

Mine Name	Frequency (Hz)	Depth (ft.)	Surface Slope	Null Error (ft.) Unadjusted	Adjusted
Guyan Mine No. 1A	2010	403	3°	0	0
	1050	439	7°	0	1
Amherstdale, W. Va.	2070	403	3°	0	0
	2010	439	7°	0	1
	3030	403	8°	13	10
Putnam Mine	2070	380	0°	0	0
Elmwood, W. Va.	1050	440	32°	40	29
	2070	460	24°	12	34
	2010	540	8°	30	24
	2010	395	0°	16	16
	2070	395	0°	0	0
Robena Mine No. 4	2070	800	16°	18	27
	2010	725	0°-13°	27	27-3
Green County, Pennsylvania	3030	725	0°-13°	50	50-26
	1050	990	16°	8	67
	2070	990	16°	17	58
Geneva Coal Mine	2500	1152	22°	200	--
	983	1152	22°	130	--
Dragerton, Utah	922	1425	30°	350	--
	1900	1500	22°	130	--
	983	1500	22°	130	--
	2900	1425	22°	130	--
	1900	1650	27°	700	--

Table 1. Summary of horizontal position data for work performed by Westinghouse Electric Corporation for the Bureau of Mines (compiled from references 10 and 11).

underground transmitter was reported to be in the order of 1 cemtimeter at depths in the range of 20 meters and smaller than 1 meter at a 300-meter depth. To determine the position a technique employing the direction of the horizontal component of the magnetic field was used. A triangulation procedure was used based on the direction of the horizontal components at two points along a base line. Locations obtained using the EMLD replaced the need for underground traverses in this situation.

Development and use of EMLD equipment has been by scattered individuals and groups. The work performed by Westinghouse represents the first funded research effort on the subject. Results of all the work performed is encouraging but can only be considered preliminary since most of the equipment and techniques used were original designs by the persons doing the work. The two methods used for position finding, field intensity and direction, appear to work and give reasonable results. Further evaluations by field testing will determine the capabilities and limitations of EMLD equipment.

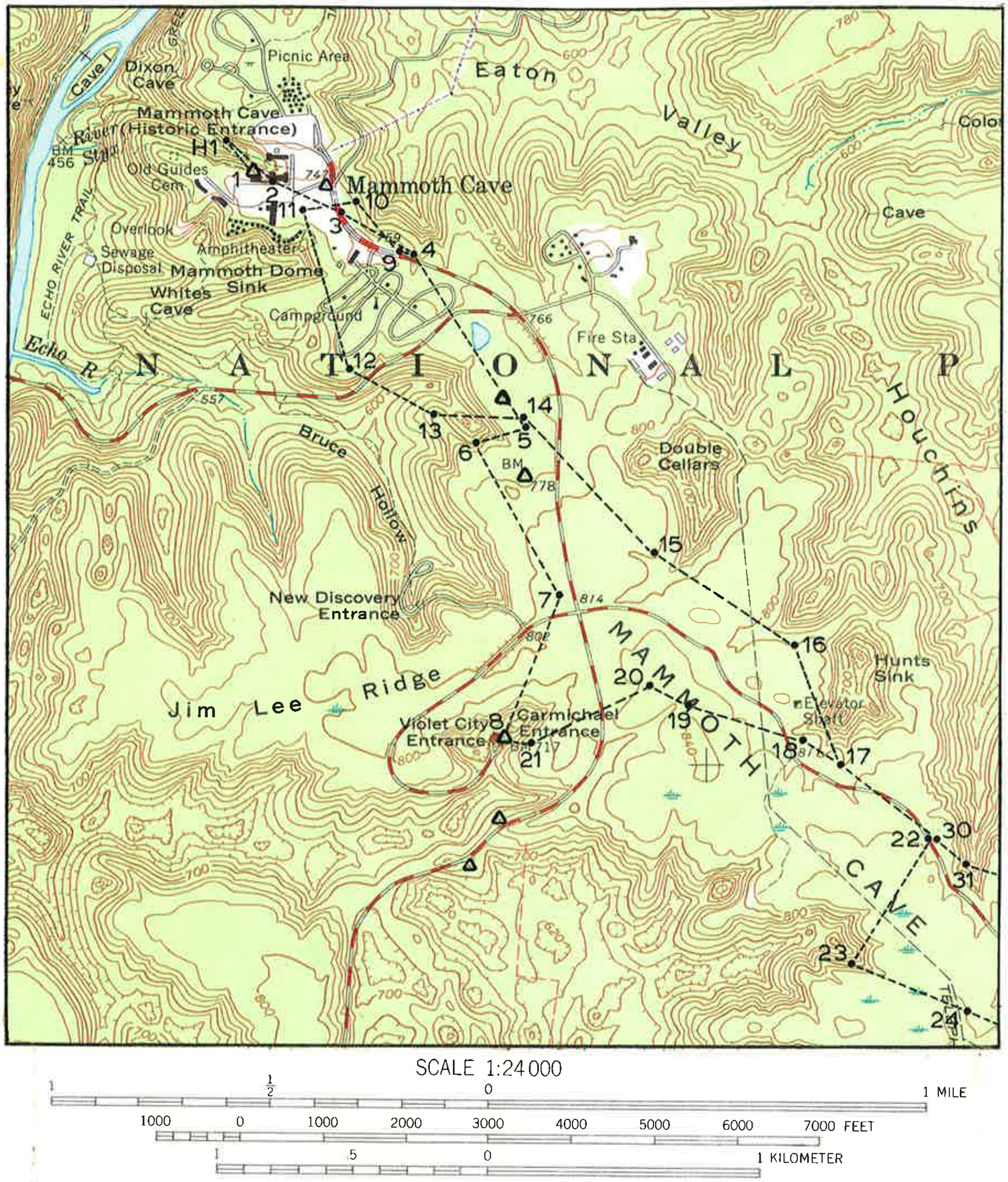
Sites for EMLD Evaluation

Prior to 1975 no work had been performed specifically for the purpose of evaluating the accuracy of horizontal positions and depths obtained using EMLD's. All previous work, summarized in the earlier part of this report, included position accuracy as a small part of the data associated with a larger project or just as an approximation based on personal experience. To fully evaluate results a large number of position and depth determinations would be needed and precise surveys required to provide a check.

During the fall of 1974 planning and field work was begun to obtain the required data. The site chosen for performing the field work was Mammoth Cave in Mammoth Cave National Park, Kentucky. This site provided the unique situation of having numerous surface and underground bench marks which are well monumented. Thirty-four bench marks were placed in the cave during the 1935-36 survey by H.D. Walker. All marks in the Park are of third order traverse accuracy and all marks in the cave have both horizontal position and elevation determined. See Figure 6 for a section of the Mammoth Cave 7.5 minute topographic map which shows the position of surface and underground bench marks, along with the underground traverse lines for the 1935-36 survey.

In order to evaluate the possible effects of variations in depth on the results obtained with the EMLD, three depth ranges were chosen for testing. The depth ranges were 100, 200, and 300 feet. All bench marks in the cave were evaluated with regard to depth below the surface and proximity to surface control. Based on the results of these evaluations the marks chosen for use were TT5W, located in Wright's Rotunda at a depth of 198 feet; TT21W, located at Rocky Mountain at a depth of 210 feet; and TT14W, located in Silliman Avenue at a depth of 298 feet. Bench marks at 100 feet in depth could not be used for a variety of reasons, principally lack of useable control on the surface and proximity to heavily used visitor areas. Therefore Blue Springs Cave in Indiana was chosen for making locations in the 100 foot depth range. The problem existed that control surveys would have to be run, but to go from the point in the cave where the transmitter would be set up to the point on the surface would require a traverse of less than 1000 feet. Also optimum conditions existed for communication between the surface and underground teams, as it involved only a few minutes to travel between transmitter and receiver sites.

The surface topography above the points to be located varied. At Mammoth Cave the surface above TT5W and TT14W is very flat and wooded. Relief is moderate, varying less than 5 feet for a distance of 200 feet in any direction. Above TT 21W the surface is sloping into a sink valley. The location points were on the transition slope between the flat ridge tops and steep hillside (see figure 6). The topography at Blue Springs is that of a rolling sinkhole plain. Location points were in a grass pasture where relief in a 100 foot radius of the ground zero points was ± 10 feet (see photograph in Figure 11).



CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

Surface Bench Marks △ Underground Bench Marks •
Underground Traverse Lines ------

Section of Mammoth Cave Quadrangle
7.5 Minute Topographic Map

FIGURE 6

The effect of surface topography was not a factor to be evaluated in this project, so the near-textbook conditions created a desirable situation.

The geologic setting for the location sites was similar. Overburden at both consists of sedimentary rocks of Mississippian age, principally limestones. Topography development has been controlled by the solutioning of the limestone. At Mammoth Cave the magnetic field propagated through limestone to a point near the surface where a sandstone caprock approximately 60 to 70 feet thick was encountered; a relatively thin soil layer covered the sandstone. Blue Springs was in a similar geologic setting without the sandstone. A soil layer approximately 10 or more feet thick lies directly on the limestone. Geologic factors were not expected to have major effects on the results.

Accuracy of Control Surveys

Having control surveys of known accuracy was a very important aspect of this project. They provided the basis for placing confidence limits on the results obtained. Without appropriate levels of accuracy the data obtained could be meaningless.

In Mammoth Cave the Walker surveys provided the control. They were run using third order transit and tape techniques. Six angles were turned at each station both above and below ground using a 30-second transit. Distances were double-taped and further checked with stadia rod readings. Observations on Polaris were made at surface stations which tied to underground lines (14). Third order traverse accuracy calls for a closure precision of not less than 1:5000 for the unadjusted traverse data. As a check on survey accuracy the latitudes and departures were summed for one loop through the cave and over the surface using data from the Walker field books, which are stored in the archives at Mammoth Cave National Park (31). The resulting value for closure presision was 1:14,524. This indicates that the surveys are more precise than published data indicate, and provide ideal horizontal control.

Level lines were also run through the cave to determine elevations for the bench marks. The level lines were run using a Dumpy level and Philadelphia rods or sawed-off New York rods where low ceilings required (14). These were also run to third order accuracy. Review of the field books shows no error of closure greater than 0.1 foot.

Supplementary surveys were run to provide ground control in close proximity to ground zero positions. At Blue Springs Cave an open traverse was required to provide control both in the cave and on the surface. These traverses were run using a Wild T2, 1-second instrument. Two positions (four angle measurements) were made at each instrument setup. Distances were measured twice using either a 100-foot steel tape under 20 lbs. pull with slope and temperature corrections being applied, or with a Wild DI-10 electronic distance meter. These procedures provided comparable accuracy to work performed by Walker.

To provide elevation control temporary bench marks were set in close proximity to the ground zero positions. Elevation of the TBM's was determined from the bench marks set by Walker. Three-wire leveling procedures were used to include the TBM in a closed loop back to the known bench mark. In all cases closures of 0.05 foot or less resulted.

A summary of the accuracy of all control points used for this project is as follows:

1. Blue Springs Cave: Open traverse with control points being located at either end. Length of traverse was 780 feet. Theoretical closure error was 0.10 foot with a closure precision of 1:8650.
2. TT5W located in Wrights Rotunda, Mammoth Cave: Closed traverse loop including surface and underground bench marks. Length of traverse loop was 22,546 feet. Calculated error of closure was 1.55 feet with a closure precision of 1:14,500.
3. TT14W located in Silliman Avenue, Mammoth Cave: Closed traverse loop including surface and underground bench marks. Length of traverse loop was 33,913 feet. Assumed closure precision based on third order traverse requirements was 1:5000, and closure error was 6.78 feet.

4. TT21W located at Rocky Mountain, Mammoth Cave: TT21W was included as part of the traverse loop with TT14W and TT8W which was used for surface control for Rocky Mountain. An open traverse from TT21W to TT8W to the ground zero points for locations would be less than 1000 feet in length. Therefore assuming an open traverse combining the Walker survey and the supplementary survey, closure precision was 1:5000 and closure error was 0.200 feet.

It should be noted that these closure errors are for unadjusted survey data. In the case of closed loops the traverse lines have been adjusted. Since it appears that the Walker survey exceeds 1:5000 precision, these values represent maximum values for the closure errors.

EMLD Equipment and Procedures Used

The EMLD equipment used on this project was built by Frank Reid of Bloomington, Indiana in 1971. It had been successfully operated on numerous occasions prior to its use on this project. The unit operates at a frequency of 3500 Hz, having a transmitting antenna 2 feet in diameter and a receiving antenna 2½ feet in diameter. The transmitting antenna is permanently affixed to ½"-thick plywood to maintain its circular shape as a planar coil. Electronics for the transmitter are contained in a 3" x 6" x 1" case. The 12-volt rechargable battery which powers the unit is 2" x 2" x 5" in size. Battery, transmitter electronics and connection cables are easily stored and transported in a small ammunition can. The receiving antenna is likewise attached to a ½"-thick piece of plywood. Receiver electronics are more involved than the transmitter and require a 1' x 6" x 1½" case to contain them. Output from the receiving unit is through headphones. The receiving coil is equipped with a bubble level attached to an angular measuring device, in order to determine angle of null from vertical. See Figures 7 and 8 for photographs of transmitting and receiving equipment.

Procedures for transmitter setup underground were as follows:

Figure 7. Transmitting antenna and associated electronic equipment being set up and leveled at underground point.

Figure 8. Receiving antenna with attached angular measuring device being used to determine the angle of the null from vertical for depth determination.

1. A transmitter position was chosen in the proximity of the bench mark or a purposely located control point, and the antenna was approximately positioned.
2. All electrical connections were made and the battery and electronics were moved several feet away to allow room to work while leveling.
3. The transmitting coil was leveled utilizing an attached bull's-eye level on the plywood. Fine adjustments for leveling were obtained utilizing wedges which could be slipped under the coil. See Figure 7.
4. Horizontal position of the transmitting coil was obtained by one of several means. Trilateration was the easiest, quickest and most successfully used. Horizontal chaining techniques were used to obtain distances from bench marks and control points to a small knob in the center of the coil. See Figure 7 to note the knob in the center of the coil.
5. Next the elevation of the knob was obtained by differential leveling techniques. Elevations were obtained from the bench marks.
6. The coil was then checked again to make sure it was level, any needed minor adjustments were made and the rod reading for elevation was retaken.
7. On completion of these procedures the transmitter was turned on. As a check to make sure the equipment was operating, a small neon bulb was wired into the antenna circuitry, blinking as the transmitter operated.

The transmitter was then allowed to operate for a predetermined time interval so that the needed measurements on the surface could be made.

On the surface the transmitter signal could be received and detected in a 1000-foot radius of the transmitter position. To locate the ground zero point the following procedure was followed:

1. The angular measuring device was set to read zero. Therefore when the null was found such that the bubble level was level, the lines of force of the magnetic

field would be vertical. See Figure 9.

2. To locate the direction of the ground zero point the operator oriented the plane of the receiving antenna such that it was approximately vertical. Then he rotated the antenna in azimuth about its center to locate the azimuth of the null. See Figure 10, in which the operator is at position A.
3. Once the azimuth was determined, the ground zero point could be in either direction along this azimuth. The antenna was then turned to receive maximum signal. The operator then arbitrarily walked in one direction along the azimuth and noted whether the signal increased or decreased in strength. If it decreased he was moving away from ground zero; likewise if it increased he was moving toward ground zero.
4. Once the direction of ground zero was determined the operator would search for the vertical null in that direction. This involved repeated checks on the null inclination (field inclination) as he moved in that direction. As the operator moved toward the ground zero point the angle of the null continually decreased, approaching zero. If the vertical point was passed, the angle would begin to increase in the opposite direction.
5. Once the vertical null was found the antenna was rotated 90 degrees and the null inclination was checked in that direction. If it was not vertical, as was usually the case, the operator moved along that direction, which was perpendicular to his previous direction of travel. The operator would be at point B in Figure 10 at this stage of the procedure.
6. When the vertical null was found in this direction the antenna was rotated 90 degrees and the null inclination was checked again. If it was not vertical, the operator searched for the vertical null in this plane again.
7. When a point was located where a vertical null existed in two directions 90 degrees to each other, the antenna

Figure 9. Level and angular measurement device attached to receiving antenna. Position of bubble and angle reading is that which would occur at the ground zero point. Note that the angle units are 100 units = 180 degrees, or 2 x angle units = grads.

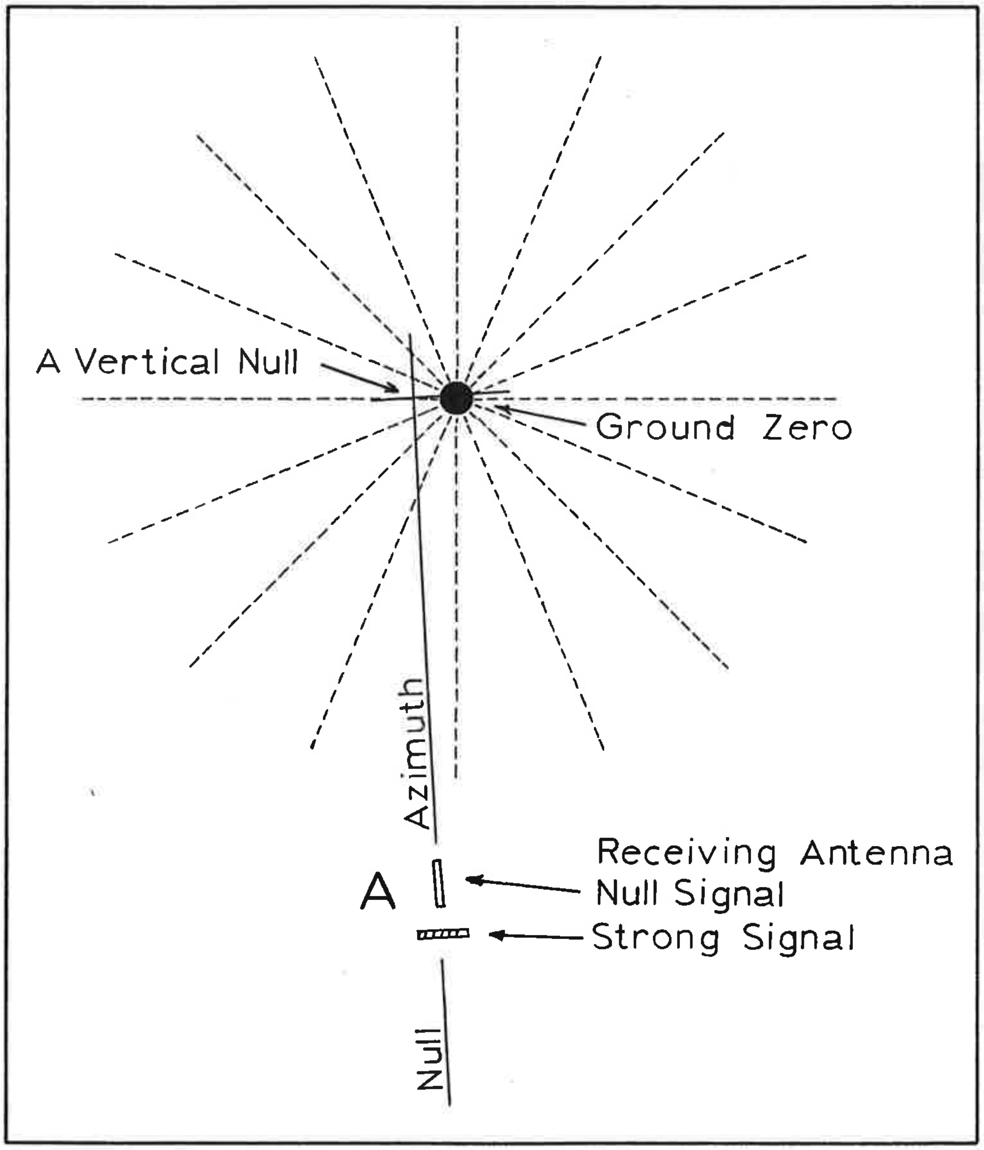


Figure 10. Vertical view looking down on transmitter antenna along the axis of the coil. Various positions of receiving antenna shown to indicate strong signal and null position. Dashed lines represent magnetic lines of force.

Figure 11. Depth determination data being taken at Blue Springs Cave, Indiana. Note stake at ground zero point and survey tape along the ground in the direction of the operator.

was rotated 45 degrees and the null inclination was checked. If it was not vertical the vertical point was sought.

This procedure allowed the operator to spiral in on the ground zero point. Usually no more than three 90 degree rotations were required to approximately locate the ground zero point and only one or two sets of 45 degree rotations were required to establish the exact point. A stake was then driven at the point determined. This locating procedure is similar to those described in the earlier section of this report.

Once the ground zero point was determined the measurements required to determine the depth of the transmitter below the ground zero point were made. Data required to find depth included angle of null from vertical and inclination of magnetic field from vertical at known distances from ground zero. Also needed was the difference in elevation from the ground zero point to the point where the field inclination was being measured. The procedure used to obtain these data was as follows:

1. A chain or measuring tape was laid out in a straight line along the ground with the zero end at the ground zero point. The direction chosen to lay the chain was the one with least elevation change in relation to the ground zero point.
2. The angle of inclination of the null was then measured at predetermined distances from ground zero. Ten to twenty measurements were made. To determine distances where measurements were to be taken, the graph in Figure 3 of this report was consulted. Based on an estimation of depth, distances from ground zero where the curves are steeply inclined were avoided. As an example, for depths of 100 feet measurements should be taken no closer to ground zero than 20 feet and should be taken at 5 foot intervals since beyond 100 feet the field inclination is very steep and difficult to measure. 70 degrees is about the practical limit to measure. At a depth of 300 feet the first measurements should be taken no closer than 50 feet to ground zero

and preferably 100 since the curves are very steeply inclined in that area. A small error in angular measurement would result in a large error in depth. It is desirable to obtain approximately 20 measurements to determine depth. Figures 8 and 11 show field inclination data being taken for depth determination. See Appendix B for data sheets.

3. The difference in elevation from ground zero to each measurement point was then obtained using differential leveling techniques.

On completion of the needed measurements for depth determination the position and elevation of the ground zero point was obtained. In order to provide control in the immediate area of the ground zero points, supplementary surveys had been run from the surface bench marks and stakes set as control points. The position of ground zero was determined by one of two methods: turn angle and distance, or trilateration, which involved measuring the distance from two control points. All distances were obtained using horizontal taping procedures. Temperature corrections were not applied due to the fact that the point to be located was a survey stake of finite size and any correction would be less than the size of the stake. To establish the elevation of the ground zero point differential leveling procedures were used to tie to a control point of predetermined elevation.

Data Reduction

In order to determine the relative accuracy of horizontal positions obtained using EMLD equipment, plane coordinate systems would need to be used. At Mammoth Cave the obvious choice was the Kentucky State Plane Coordinate System which is based on the Lambert conformal conic projection. The published data on the location of bench marks at Mammoth Cave give the geodetic positions to the hundredth of a second. These published values have been adjusted to the national control network. During the 1935-36 survey Walker calculated values for geodetic position to the thousandth of a second. These values appear in his field books and were used for this project because it was felt that they would more truly represent the relationships between bench marks in the Park. Plane coordinates were calculated for all bench marks which would be used as control points. They were calculated based on procedures given in the U.S. Coast and Geodetic Survey's Plane Coordinate Projection Tables in Kentucky, publication G-115. For all surveys used to locate control points scale corrections appropriate for calculation of state plane coordinates were applied to distances (14, 31).

At Blue Springs Cave in Indiana an arbitrary coordinate system was used. Difference in elevation between the cave and surface was less than 100 feet so no scale correction for distance was required. A straight reduction of the traverse data was used to obtain coordinates.

All survey data to determine horizontal positions were reduced on the IBM-370 electronic computer at the University of Kentucky. To determine coordinates of points the ICES-COGO computer program was used. Output consisted of plane coordinates for the underground transmitter and stake on the surface. These coordinates were then entered into a second program which calculated differences in coordinates, error in position, and direction of error. Also a comparison was made between the distance from an underground point to all other underground points and the corresponding distances between the same points on the surface. The average of the differences in distance for each location point is contained in the tables. The input and output data for this program are contained in Appendix A of this report. Also a copy of the program is included in the back of that appendix.

Calculations for depth determination were made based on the equation given earlier in this report. The equation was solved for depth using the quadratic formula, with distance from ground zero, l, and angle of the field, θ, being the variables input to the equation. The equation takes the form given below:

$$d = \frac{l\left(3+\sqrt{9+8\ \text{Tan}^2\ \theta}\right)}{4\ \text{Tan}\ \theta}$$

This equation was solved for each field inclination measurement made. On the data sheets in Appendix B the solution of this equation is located in column 3. It should be noted that the angle units shown on the data sheet are for a situation where 100 units = 180 degrees, therefore 2 x θ units = grads. Calculations were made using either a Hewlett-Packard HP-45 hand calculator or HP-25 programmable hand calculator.

The importance of the difference in elevation between the ground zero point and the measurement point is illustrated in Figure 12. Depth of the transmitter below the ground zero point, d, is the desired result. When measurements are taken at A and B, depth values of d_A and d_B are obtained. These must be corrected by $\Delta H1$ and $\Delta H2$ to obtain a value for d. The ΔH corrections for difference in elevation are applied in the last column of the data sheets in Appendix B.

The value for depth at a location point was obtained by averaging the depths in column 5 of the data sheets. Using a preprogrammed function on the Hewlett-Packard calculator a value for the standard deviation of the depth values was also determined.

To evaluate the depth determination the difference in elevation between the surface point and the transmitter was determined based on elevations established by leveling. These values were compared by means of a ratio of determined depth to actual depth expressed as a percentage.

Results of all data reduction are presented in Tables 2 through 9. Tables 2, 3, 4, and 5 contain results for horizontal position and Tables 6, 7, 8, and 9 contain results for depth determination.

Evaluation of Results for Horizontal Position

A summary of the results for the errors in horizontal positions of location points is contained in Tables 2 through 5. Table 2 contains the data for the work done at Blue Springs Cave in Indiana. In reviewing the table it should be noted that the range of values for error is 0.02' to 1.18'. The 1.18' value is at location point 9 and is more than twice the next closest value; therefore it should be considered as being in

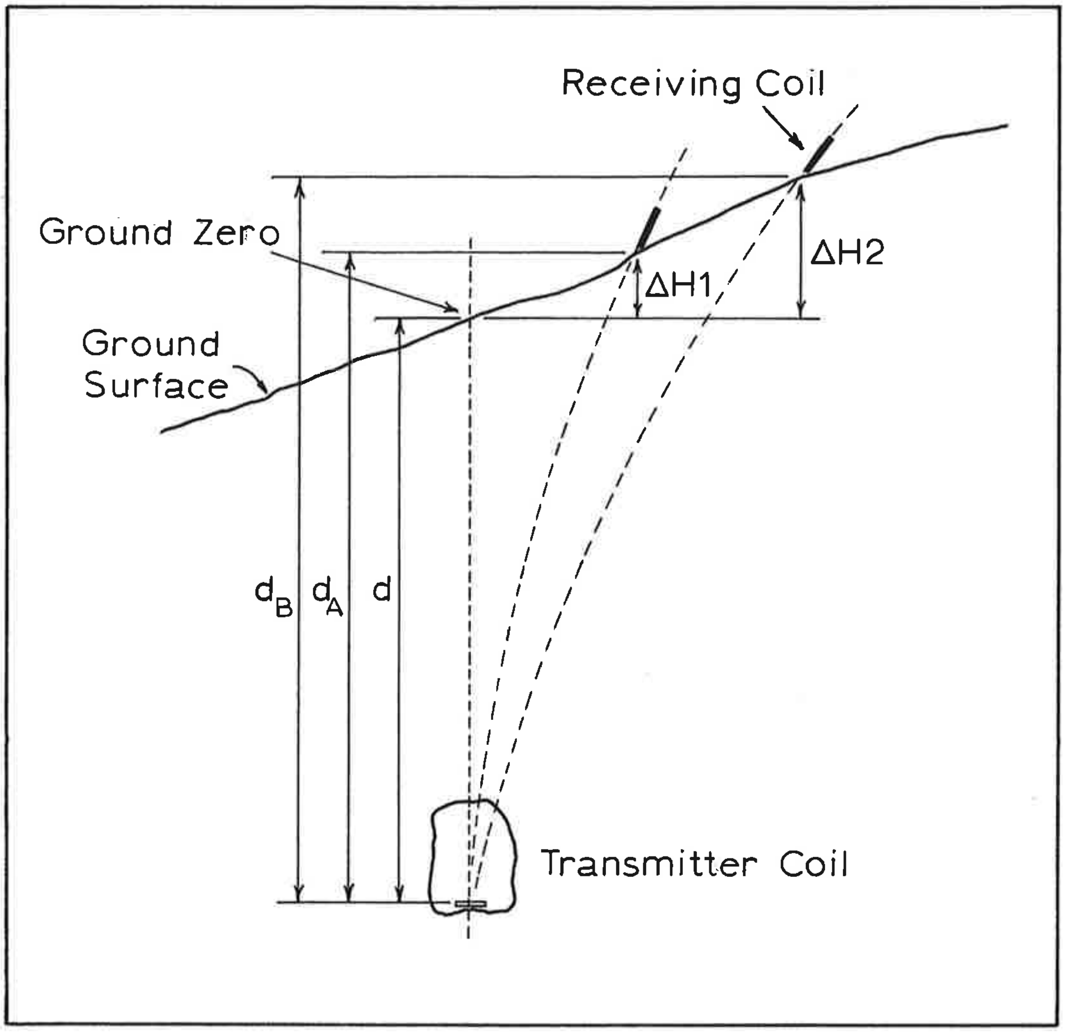


Figure 12. Relationship between calculated values d_A and d_B and actual value for depth, d. Δ H values are subtracted from d_A and d_B to obtain d.

Location Point	Operator	Error (ft.)	Direction of Error	Distance Difference
1	F.S.R.	0.41	S87.03E	-0.01
2	F.S.R.	0.32	S37.57W	0.13
3	F.S.R.	0.18	N 8.46W	-0.12
4	F.S.R.	0.02	N18.15W	-0.12
5	F.S.R.	0.16	S62.50W	-0.04
6	F.S.R.	0.24	S83.13W	0.14
7	F.S.R.	0.19	N57.80E	-0.10
8	F.S.R.	0.08	S58.95E	-0.05
9	F.S.R.	1.18	N68.00E	-0.76
10	C.S.B.	0.32	N67.99E	-0.03
11	C.S.B.	0.30	N69.58E	-0.03
12	F.S.R.	0.47	S63.49E	0.15
13	F.S.R.	0.38	N18.09E	-0.08
14	C.S.B.	0.58	N68.00E	0.08
15	C.S.B.	0.48	N88.20E	0.00
16	F.S.R.	0.52	S83.11W	-0.44
17	F.S.R.	0.33	S65.39E	-0.10
18	F.S.R.	0.28	S15.37W	-0.28
19	F.S.R.	0.09	S41.40E	-0.07
20	C.H.B.	0.17	S43.29E	0.04

Table 2. Summary of horizontal position data for work performed at Blue Springs Cave, Indiana. Depth for locations was 74 feet (compiled from reduced data in Appendix A).

Location Point	Operator	Error (ft.)	Direction of Error	Distance Difference
1	F.S.R.	7.58	N86.12E	1.37
2	F.S.R.	8.69	N82.72E	0.56
3	F.S.R.	29.27	S89.50E	18.86
4	F.S.R.	9.23	N73.26E	1.22
5	C.S.B.	9.13	N80.58E	0.53
6	F.S.R.	9.61	N84.86E	0.53
7	C.S.B.	8.91	N82.31E	0.17
8	C.S.B.	8.33	N79.92E	-0.42

Table 3. Summary of horizontal position data for work performed at Wright's Rotunda, Mammoth Cave, Kentucky. Depth for locations was 198 feet (compiled from reduced data in Appendix A).

Location Point	Operator	Error (ft.)	Direction of Error	Distance Difference
1	F.S.R.	4.76	N32.30W	-2.17
2	F.S.R.	8.30	N78.17W	-0.22
3	F.S.R.	0.49	N47.90E	6.55
4	F.S.R.	2.01	N 4.62E	5.48
5	F.S.R.	7.63	S84.45W	-1.09
6	F.S.R.	5.30	N40.33W	-1.70
7	C.S.B.	13.77	N43.44W	-1.27
8	F.S.R.	86.15	N43.77W	-31.90
9	F.S.R.	40.88	S77.48E	-0.52
10	C.S.B.	6.21	N50.56W	-1.16
11	C.S.B.	8.38	N79.83W	-0.35
12	F.S.R.	11.54	N63.75W	1.75

Table 4. Summary of horizontal position data for work performed at Rocky Mountain, Mammoth Cave, Kentucky. Depth for locations was 210 feet (compiled from reduced data in Appendix A).

Location Point	Operator	Error (ft.)	Direction of Error	Distance Difference
1	C.S.B.	47.57	N 4.20E	-5.07 0.70
2	C.S.B.	38.66	N 0.03W	-2.13 -5.91
3	C.S.B.	41.81	N11.91E	0.13 3.88
4	C.H.B.	50.21	N25.02E	-0.92 28.79
5	C.S.B.	51.28	N27.00E	-1.98 30.99
10	C.S.B.	36.00	N34.82E	-2.12 18.50
11	F.S.R.	48.72	N18.52E	2.36 11.06
12	F.S.R.	49.87	N16.84E	1.05 11.34
13	C.S.B.	46.77	N11.45E	-2.54 7.27
14	F.S.R.	51.02	N13.16E	5.92 26.81
15	F.S.R.	38.92	N13.78E	1.66 14.46
21	F.S.R.	42.42	N 9.08E	2.83 14.06
6	C.H.B.	24.11	N18.25E	6.72 3.43
7	C.S.B.	26.14	N 7.09E	13.62 -0.34
8	C.S.B.	25.36	N30.38E	3.25 3.36
9	C.H.B.	24.37	N14.15E	13.15 0.63
16	C.S.B.	19.22	N20.08E	9.02 1.03
17	C.S.B.	19.59	N 5.34W	16.99 6.65
18	F.S.R.	13.60	N 6.69E	21.69 3.41
19	C.S.B.	13.26	N 0.83E	20.05 3.83
20	F.S.R.	12.84	N21.39E	17.04 3.53

Table 5. Summary of horizontal position data for work performed at Silliman Avenue, Mammoth Cave, Kentucky. Depth for locations was 298 feet (compiled from reduced data in Appendix A).

error with respect to the other values. With the 1.18' value excluded the range of values becomes 0.02' to 0.58', with an average of 0.29'. The direction of the errors is very nearly a random distribution. Distance differences have a magnitude on the same order as the error values. The average value for all the distance differences excluding the value for location number 9 is -0.05'. An evaluation of the data would be that the pattern of location points was very nearly reproduced exactly on the surface directly above the underground point.

Table 3 contains the data for the work done at Wright's Rotunda in Mammoth Cave. In reviewing the data it can easily be noted that location point 3 is obviously in error with respect to the values for error of the other points. The range of values for error, excluding location point 3, is 7.58' to 9.61', with an average value of 8.78'. Direction of errors is not random but is consistant in one direction, being approximately N80E for all location points. Also of interest is the fact that the distance differences are small compared to the errors: average distance difference is only 0.57'. These values, error, direction and distance difference, indicate that the pattern of location points was reproduced relatively accurately on the surface, but the position of the points was shifted an average of 8.78' to the east of the underground points. The maximum error which could be expected in the position of location points would be the closure error for the traverse, which was 1.55' before the traverse was adjusted.

Table 4 contains the data for the work performed at Rocky Mountain in Mammoth Cave. On reviewing the data it can easily be seen that the values of error for location points 8 and 9 are significantly greater than those for the other points. The range of values for error, excluding points 8 and 9, is 0.49' to 13.77', with an average value of 6.84'. Direction of error was consistantly to the north-west and the average distance difference was 0.58'. Again in this situation the pattern of location points was reproduced on the surface with reasonable accuracy but was shifted to the north-west an average of 6.84'. Of possible significance is the fact that the shift in position is down hill toward the sink valley and along the strike of the cave passage in which the transmitter was located (see Figure 6).

Table 5 contains data for the work performed at Silliman Avenue in Mammoth Cave. On reviewing the table it should be noted that the location points are not arranged in numeric order. The first twelve points listed are for locations performed along the tourist trail in Silliman Avenue proper. The second set of nine were located in Valley Wayside Cut, a passage leading off the side of Silliman Avenue. In relative position, the two sets of location points are no further than 100 feet apart. For the first twelve locations the range of values for error is 36.00' to 51.28' with an average of 45.27'. The second set of nine locations has a range of error of 12.84' to 26.14', with an average value of 19.83'. Both sets of locations were consistantly in error in the same direction, to the north-northeast. Two numbers appear in the distance difference column for each location. The first number is the average distance difference to the first twelve locations and the second is to the nine locations. The average value for the difference in distance for the first twelve locations to each other is -0.07' and to the second nine is 13.44. Likewise for the second nine locations the distance difference to the first twelve is 13.55' and to other points in the second nine the value is 2.84'. The above values indicate that the pattern of the first twelve locations reproduced accurately with respect to each other but are in error by an average of 45 feet to the north. Likewise the second set reproduced relatively accurately with respect to each other but are in error by 20 feet to the north. The maximum part of the error value which could be attributed to the traverse data is around seven feet, which would be for an unadjusted traverse.

A summary of the horizontal position accuracies follows:

1. Blue Springs Cave: depth 74', average error 0.29', direction of errors random, average distance difference -0.05'.
2. Wright's Rotunda: depth 198', average error 8.78',

direction of errors N80E, average distance difference 0.57'.

3. Rocky Mountain: depth 212', average error 6.84', direction of errors N45W, average distance difference 0.58'.
4. Silliman Avenue: depth 298', average error 32.55', direction of errors N15E, average distance difference 1.39'.

Several factors which may have had a bearing on the results obtained at Silliman Avenue should be noted. The horizontal position of TT5W is very near to that of TT14W. The situation which exists is that Wright's Rotunda and its associated passages overlie some parts of Silliman Avenue exactly. Therefore the magnetic field encountered a very large void before reaching the surface. The first twelve locations are overlain by passage in Wright's Rotunda, whereas the second set of location points are not overlain by passage but are off to the side by about forty feet. To further complicate attempts to explain these errors, large metal boats which were formerly used to transport tourists across Echo River are stored in the passage near where the locations were made. There are three of these boats randomly situated in the main passage and in Valley Wayside Cut. Location points were at various distances and directions from these boats. The possible effects on the magnetic field by these boats is obvious, but resulting magnitudes and directions of errors should have been more random. There is no clear-cut explanation for the errors which resulted at Silliman Avenue.

Evaluation of Results for Depth Determination

Tables 6 through 9 contain the data for depth determinations made at each location point. Included in the tables is the actual difference in elevation between the underground transmitter and the ground zero point on the surface, along with the average value for the depth determined using the EMLD. The standard deviation for the depth determination at each location point has been calculated and included. To relate the EMLD depth to the actual depth a ratio has been taken and is expressed as a per-

Location Point	Operator	Elevation Difference	EMLD Depth	EMLD σ Std	EMLD Depth / Δ Elevation %
1	F.S.R.	74.43	--	--	--
2	F.S.R.	74.18	72.49	0.94	97.7%
3	F.S.R.	74.24	72.78	1.22	98.0%
4	F.S.R.	74.33	73.00	1.51	98.2%
5	F.S.R.	74.06	73.49	2.40	99.2%
6	F.S.R.	74.03	72.42	1.94	97.8%
7	F.S.R.	73.58	70.71	1.49	96.1%
8	F.S.R.	73.72	65.08	3.99	88.3%
9	F.S.R.	73.60	70.48	1.26	95.8%
10	C.S.B.	73.15	70.24	1.31	96.0%
11	C.S.B.	74.06	72.21	1.51	97.5%
12	F.S.R.	74.03	72.37	1.35	97.8%
13	F.S.R.	74.10	71.86	1.38	97.0%
14	C.S.B.	73.86	72.02	1.44	97.5%
15	C.S.B.	74.18	73.73	1.38	99.4%
16	F.S.R.	73.79	73.68	2.03	99.9%
17	F.S.R.	73.02	72.00	1.52	98.6%
18	F.S.R.	73.87	71.60	1.83	96.9%
19	F.S.R.	73.84	71.42	1.07	96.7%
20	C.H.B.	73.08	71.00	0.84	97.2%

Table 6. Summary of depth determination data for Blue Springs Cave, Indiana (compiled from data sheets in Appendix B).

Location Point	Operator	Elevation Difference	EMLD		$\frac{\text{EMLD Depth}}{\Delta \text{ Elevation}}$ %
			Depth	σ Std	
1	F.S.R.	198.58	188.17	4.19	94.8%
2	F.S.R.	198.71	193.24	7.00	97.2%
3	F.S.R.	193.53	193.98	4.36	100.2%
4	F.S.R.	198.22	188.97	3.73	95.3%
5	C.S.B.	197.93	187.96	3.96	95.0%
6	F.S.R.	197.86	187.42	4.04	94.7%
7	C.S.B.	197.99	187.51	7.02	94.7%
8	C.S.B.	196.44	184.05	6.28	93.7%

Table 7. Summary of depth determination data for Wright's Rotunda, Mammoth Cave, Kentucky (compiled from data sheets in Appendix B).

Location Point	Operator	Elevation Difference	EMLD		$\frac{\text{EMLD Depth}}{\Delta \text{ Elevation}}$ %
			Depth	σ Std	
1	F.S.R.	217.05	199.29	5.46	91.8%
2	F.S.R.	212.27	206.14	4.21	97.1%
3	F.S.R.	212.13	201.97	3.87	95.2%
4	F.S.R.	201.78	194.31	4.97	96.3%
5	F.S.R.	212.86	203.81	3.63	95.7%
6	F.S.R.	216.58	204.19	3.12	94.3%
7	C.S.B.	211.07	199.43	3.49	94.5%
8	F.S.R.	201.84	194.93	3.30	96.6%
9	F.S.R.	219.21	245.00	7.03	111.8%
10	C.S.B.	216.17	203.82	5.67	94.3%
11	C.S.B.	212.49	200.39	5.60	94.3%
12	F.S.R.	212.74	197.26	3.83	92.7%

Table 8. Summary of depth determination data for Rocky Mountain, Mammoth Cave, Kentucky (compiled from data sheets in Appendix B).

Location Point	Operator	Elevation Difference	EMLD Depth	EMLD σ Std	EMLD Depth / Δ Elevation %
1	C.S.B.	304.01	299.36	143.35	98.5%
2	C.S.B.	304.03	397.76	39.70	130.8%
3	C.S.B.	304.26	353.59	39.78	116.2%
4	C.H.B.	304.87	269.46	49.57	88.4%
5	C.S.B.	304.20	278.27	30.87	91.5%
6	C.H.B.	290.36	259.05	14.00	89.2%
7	C.S.B.	290.31	263.62	17.75	90.8%
8	C.S.B.	291.29	257.94	26.70	88.6%
9	C.H.B.	289.47	243.98	18.25	84.3%
10	C.S.B.	303.76	280.77	14.77	92.4%
11	F.S.R.	304.39	288.40	18.76	94.7%
12	F.S.R.	304.34	295.63	17.43	97.1%
13	C.S.B.	304.26	305.67	18.74	100.5%
14	F.S.R.	304.20	299.58	11.65	98.5%
15	F.S.R.	303.66	233.94	17.59	77.0%
16	C.S.B.	290.37	259.18	12.76	89.3%
17	C.S.B.	290.58	276.07	11.53	95.0%
18	F.S.R.	290.52	289.03	11.01	99.5%
19	C.S.B.	292.55	271.60	14.71	92.8%
21	F.S.R.	303.43	297.22	8.31	98.0%

Table 9. Summary of depth determination data for Silliman Avenue, Mammoth Cave, Kentucky (compiled from data sheets in Appendix B).

centage for each location point.

Table 6 contains the data for the work performed at Blue Springs Cave in Indiana. The first significant point to note in the table is that all values for the ratio are less than 100%. Reviewing the range of values for the ratio it can be seen that the value for point 8 is significantly lower than the others, being 88.3%. The range of values for the ratio, excluding the value for point 8, is 95.8% to 99.9%, with an average value of 97.6%.

Table 7 contains the data for the work performed at Wright's Rotunda in Mammoth Cave. The most notable point with regard to this set of data is that the value for the ratio at location point 3 exceeds 100%. Based on the work at Blue Springs this should not be the case and the value is assumed to be in error. Location point 3 also happened to be in error with regard to horizontal position. Excluding this point, the range of values for the ratio is 97.3% to 97.2%, with an average value of 95.1%.

Table 8 contains the data for the work performed at Rocky Mountain in Mammoth Cave. Again on reviewing the data it can be seen that one point is obviously in error with the ratio exceeding 100%. Excluding location point 9 as being in error, the range of values for the ratio is 91.8%, with an average value of 94.8%.

Table 9 contains the data for the work performed at Silliman Avenue in Mammoth Cave. Here again three values for the ratio exceed 100%. Excluding these values the range of values is 77.0% to 99.5% with an average of 92.1%. This low value may reflect the error in horizontal position.

A summary of the results for depth determinations is as follows:

1. Blue Springs Cave: depth 74', average ratio of EMLD depth to actual depth 97.6%.
2. Wright's Rotunda: depth 198', average ratio of EMLD depth to actual depth 95.1%.
3. Rocky Mountain: depth 212', average ratio of EMLD depth to actual depth 94.8%.
4. Silliman Avenue: depth 298', average ratio of EMLD

depth to actual depth 92.1%.

The first conclusion which could be drawn on reviewing this data is that a nearly linear relationship exists between the percent of actual depth determined, and the actual depth. This could be stated as follows: with increasing actual depth the determined depth using the EMLD is linearly decreasing. On application of the theories of error propagation to the formula for depth determination use, it was found that the error in the determined depth was directly related to the error in the ground zero position. A rough approximation of how the error propagated is that for a one-foot error in ground zero, a $1\frac{1}{2}$ or $2\frac{1}{2}$-foot error will result in the determined depth. All the differences between the actual depths and the determined depths can be accounted for in this manner.

The other measured quantity in the depth determination formula is θ, the angle of the magnetic field. Effects of errors in this variable are less noticable since they are more random, being associated with several independent measurements. Errors in the ground zero position have a constant effect on the determined depth.

It appears that the determined value for depth will consistantly be on the lower side of the actual value, and that the error in the ground zero position has a very significant effect on the determined value for depth.

Conclusions

The capabilities and limitations of EMLD equipment and procedures were evaluated to some extent by this project. Accuracy of horizontal positions obtained using this equipment is the point of principal interest. Accuracy of horizontal position appears to be directly related to depth. This statement seems to be consistant both for the work performed on this project and for the work done by others previously. Reasons for this decrease in accuracy can be directly related to the decrease in signal strength and increasing diameter of the null with increasing distance from the transmitter. These factors limit the capabilities of the equipment.

At depths of less than one hundred feet very accurate results were obtained. The magnitude of the error in position was usually less than 0.5 feet. This corresponds reasonably well with the work performed by the French (12) and other published values for shallow depths. For the depth range between 100 and 500 feet, less accurate results will be obtained. Errors in position on the order of 5 feet or greater may result, with maximum values of 50 feet possible. Over 500 feet in depth there have been so few locations made that a speculation on accuracy is all that could be made. Results of the work which has been performed indicate that it is feasible to make locations at depths of 500 to 1000 feet or more. Depending on the intended use for locations the errors may or may not be in an acceptable range.

As an attempt to relate the error in horizontal position to some determined quantity associated with the location and depth determination procedures a plot of error in position vs. standard deviation of the depth determination for each location point was made (see Figure 13). It can be seen on the plot that in only a few cases was the error in position less than the standard deviation. The principal exception to this was the data from Blue Springs, in which the error was less in all cases. A generalization could be made from the plot that the standard deviation approximately represents the lower bound for the error in position.

Several things can also effect the accuracy of the horizontal position determination. Most important is the accuracy with which the transmitting coil can be leveled. At large depths a small error in leveling will produce a shift in the location of the ground zero null point. The axis of the coil no longer passes through the point on the surface directly above the transmitting coil. Another thing which could effect results is large metallic objects in the immediate area of either the trasnmitting or receiving antenna. These objects could distort the magnetic field in the area immediately around them.

With regard to the depth determination, the theory and

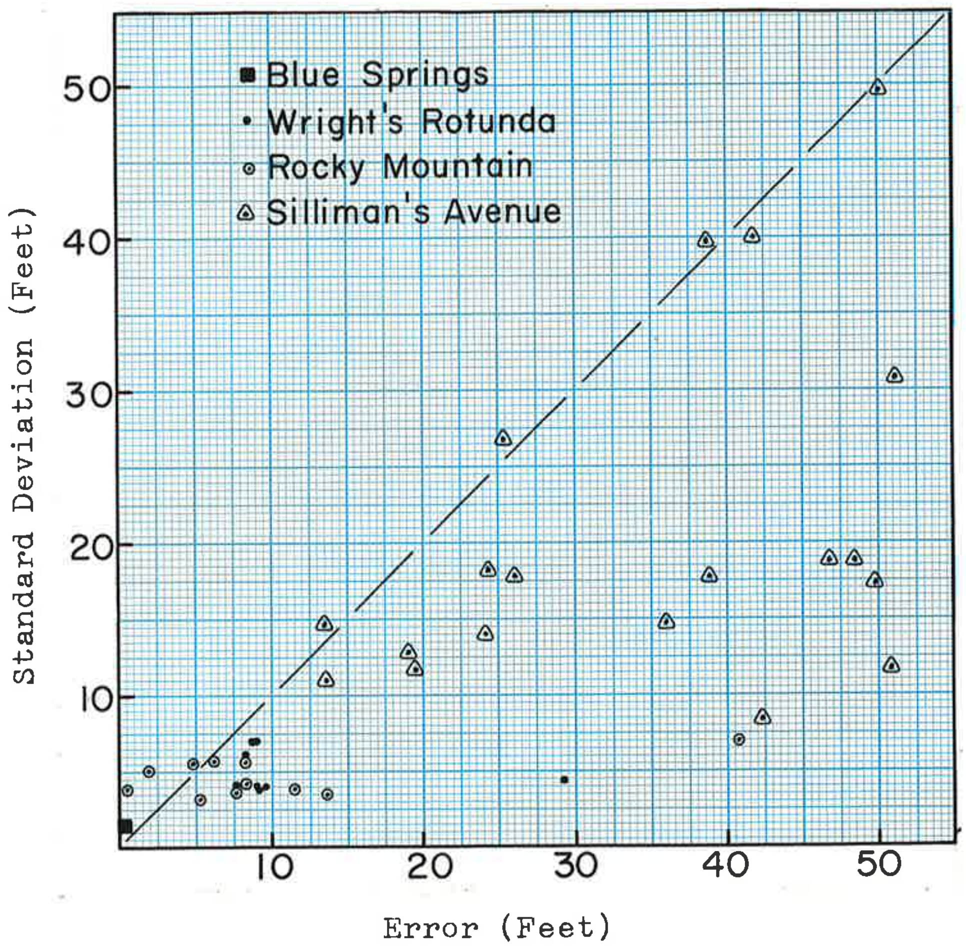


Figure 13. Plot of standard deviation of calculated depth values vs. error in horizontal position.

procedures appear to be correct and accurate. The factor having a major effect on results is the error in the horizontal position of the point on the surface. Effects of error in the field angle measurements are more random and thus do not effect the final results significantly. The accuracy of depth determination is directly related to the accuracy of the horizontal position.

The possible effects of different levels of skill by operators of the receiving unit were also evaluated. Results indicated that no significant difference in the accuracy of results for position and depth occurred. Therefore if an operator has a basic knowledge of the procedure good results should be obtained.

Use of EMLD equipment to determine the position and depth of underground points has been limited. This project and others have shown that the equipment does give reasonably accurate results within certain limitations. If more efforts are directed toward development of equipment and procedures the existing limitations may be overcome. At the present time EMLD's could be used in many situations to obtain data that would otherwise require considerable time and expense to acquire.

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APPENDIX A
REDUCED DATA FOR HORIZONTAL POSITIONS

BLUE SPRINGS CAVE , INDIANA , DEPTH 75 FOOT

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LOCATION POINT	UNDERGROUND X COOR.	UNDERGROUND Y COOR.	SURFACE X COOR.	SURFACE Y COOR.
1	1042.772	1957.086	1043.177	1957.065
2	1038.533	1956.811	1038.336	1956.555
3	1042.980	1952.764	1042.953	1952.946
4	1046.979	1957.198	1046.974	1957.213
5	1042.507	1961.226	1042.365	1961.152
6	1038.114	1956.275	1037.875	1956.246
7	1030.089	1950.916	1030.248	1951.016
8	1063.919	1973.508	1063.987	1973.467
9	1030.022	1950.872	1031.116	1951.314
10	1024.276	1947.034	1024.573	1947.154
11	1038.533	1956.811	1038.815	1956.916
12	1042.980	1952.764	1043.399	1952.555
13	1046.979	1957.198	1047.096	1957.556
14	1042.507	1961.226	1043.049	1961.445
15	1042.772	1957.086	1043.254	1957.101
16	1055.653	1967.987	1055.140	1967.925
17	1021.989	1945.507	1022.286	1945.371
18	1047.278	1962.395	1047.204	1962.126
19	1056.908	1968.826	1056.966	1968.760
20	1023.926	1946.801	1024.041	1946.679

****

LOCATION POINT	ERROR IN LOCATION	DIRECTION OF ERROR
1	0.41	S87.03E
2	0.32	S37.57W
3	0.18	N 8.46W
4	0.02	N18.15W
5	0.16	S62.50W
6	0.24	S83.13W
7	0.19	N57.80E
8	0.08	S58.95E
9	1.18	N68.00E
10	0.32	N67.99E
11	0.30	N69.58E
12	0.47	S63.49E
13	0.38	N18.09E
14	0.58	N68.00E
15	0.48	N88.20E
16	0.52	S83.11W
17	0.33	S65.39E
18	0.28	S15.37W
19	0.09	S41.40E
20	0.17	S43.29E

****

LOCATION POINT		LOCATION POINT	UNDERGROUND DISTANCE	SURFACE DISTANCE	DIFFERENCE IN DISTANCE
1	TO	2	4.25	4.87	0.62
1	TO	3	4.33	4.12	-0.20
1	TO	4	4.21	3.80	-0.41
1	TO	5	4.15	4.17	0.02
1	TO	6	4.73	5.36	0.64
1	TO	7	14.10	14.27	0.17
1	TO	8	26.77	26.50	-0.28
1	TO	9	14.18	13.36	-0.82

1	TO	10	21.05	21.08	0.03
1	TO	11	4.25	4.36	0.12
1	TO	12	4.33	4.52	0.19
1	TO	13	4.21	3.95	-0.26
1	TO	14	4.15	4.38	0.23
1	TO	15	0.00	0.08	0.08
1	TO	16	16.87	16.16	-0.72
1	TO	17	23.79	23.94	0.15
1	TO	18	6.96	6.47	-0.50
1	TO	19	18.38	18.08	-0.29
1	TO	20	21.47	21.77	0.30
2	TO	1	4.25	4.87	0.62
2	TO	3	6.01	5.86	-0.15
2	TO	4	8.45	8.66	0.21
2	TO	5	5.94	6.11	0.17
2	TO	6	0.68	0.55	-0.13
2	TO	7	10.30	9.80	-0.50
2	TO	8	30.38	30.72	0.34
2	TO	9	10.38	8.92	-1.46
2	TO	10	17.29	16.67	-0.62
2	TO	11	0.00	0.60	0.60
2	TO	12	6.01	6.45	0.44
2	TO	13	8.45	8.82	0.36
2	TO	14	5.94	6.79	0.85
2	TO	15	4.25	4.95	0.70
2	TO	16	20.45	20.29	-0.16
2	TO	17	20.04	19.56	-0.47
2	TO	18	10.38	10.47	0.10
2	TO	19	21.95	22.27	0.32
2	TO	20	17.71	17.37	-0.33
3	TO	1	4.33	4.12	-0.20
3	TO	2	6.01	5.86	-0.15
3	TO	4	5.97	5.86	-0.11
3	TO	5	8.48	8.23	-0.25
3	TO	6	6.00	6.06	0.06
3	TO	7	13.02	12.85	-0.17
3	TO	8	29.47	29.39	-0.09
3	TO	9	13.10	11.95	-1.15
3	TO	10	19.56	19.27	-0.29
3	TO	11	6.01	5.73	-0.28
3	TO	12	0.00	0.59	0.59
3	TO	13	5.97	6.20	0.23
3	TO	14	8.48	8.50	0.02
3	TO	15	4.33	4.17	-0.16
3	TO	16	19.81	19.31	-0.50
3	TO	17	22.21	22.01	-0.20
3	TO	18	10.55	10.12	-0.43
3	TO	19	21.26	21.13	-0.13
3	TO	20	19.97	19.92	-0.04
4	TO	1	4.21	3.80	-0.41
4	TO	2	8.45	8.66	0.21
4	TO	3	5.97	5.86	-0.11
4	TO	5	6.02	6.06	0.04
4	TO	6	8.91	9.15	0.24
4	TO	7	18.02	17.84	-0.18
4	TO	8	23.52	23.53	0.01
4	TO	9	18.10	16.92	-1.18
4	TO	10	24.87	24.56	-0.32

4	TO	11	8.45	8.16	-0.29
4	TO	12	5.97	5.87	-0.10
4	TO	13	0.00	0.36	0.36
4	TO	14	6.02	5.77	-0.25
4	TO	15	4.21	3.72	-0.49
4	TO	16	13.84	13.47	-0.37
4	TO	17	27.59	27.38	-0.21
4	TO	18	5.21	4.92	-0.29
4	TO	19	15.29	15.27	-0.02
4	TO	20	25.29	25.24	-0.05
5	TO	1	4.15	4.17	0.02
5	TO	2	5.94	6.11	0.17
5	TO	3	8.48	8.23	-0.25
5	TO	4	6.02	6.06	0.04
5	TO	6	6.62	6.65	0.03
5	TO	7	16.14	15.80	-0.34
5	TO	8	24.68	24.88	0.20
5	TO	9	16.22	14.94	-1.28
5	TO	10	23.10	22.64	-0.47
5	TO	11	5.94	5.53	-0.41
5	TO	12	8.48	8.66	0.18
5	TO	13	6.02	5.94	-0.08
5	TO	14	0.00	0.74	0.74
5	TO	15	4.15	4.15	-0.00
5	TO	16	14.78	14.46	-0.32
5	TO	17	25.85	25.54	-0.31
5	TO	18	4.91	4.94	0.02
5	TO	19	16.28	16.46	0.18
5	TO	20	23.52	23.35	-0.17
6	TO	1	4.73	5.36	0.64
6	TO	2	0.68	0.55	-0.13
6	TO	3	6.00	6.06	0.06
6	TO	4	8.91	9.15	0.24
6	TO	5	6.62	6.65	0.03
6	TO	7	9.65	9.25	-0.40
6	TO	8	31.03	31.28	0.25
6	TO	9	9.73	8.37	-1.36
6	TO	10	16.64	16.11	-0.53
6	TO	11	0.68	1.15	0.47
6	TO	12	6.00	6.64	0.64
6	TO	13	8.91	9.31	0.40
6	TO	14	6.62	7.33	0.72
6	TO	15	4.73	5.45	0.72
6	TO	16	21.09	20.84	-0.25
6	TO	17	19.39	19.01	-0.38
6	TO	18	11.02	11.03	0.01
6	TO	19	22.60	22.83	0.23
6	TO	20	17.06	16.82	-0.24
7	TO	1	14.10	14.27	0.17
7	TO	2	10.30	9.80	-0.50
7	TO	3	13.02	12.85	-0.17
7	TO	4	18.02	17.84	-0.18
7	TO	5	16.14	15.80	-0.34
7	TO	6	9.65	9.25	-0.40
7	TO	8	40.68	40.53	-0.15
7	TO	9	0.08	0.92	0.84
7	TO	10	6.99	6.86	-0.13
7	TO	11	10.30	10.40	0.10

7	TO	12	13.02	13.24	0.22
7	TO	13	18.02	18.07	0.05
7	TO	14	16.14	16.51	0.37
7	TO	15	14.10	14.36	0.25
7	TO	16	30.74	30.09	-0.65
7	TO	17	9.74	9.76	0.02
7	TO	18	20.67	20.27	-0.40
7	TO	19	32.25	32.07	-0.18
7	TO	20	7.41	7.57	0.16
8	TO	1	26.77	26.50	-0.28
8	TO	2	30.38	30.72	0.34
8	TO	3	29.47	29.39	-0.09
8	TO	4	23.52	23.53	0.01
8	TO	5	24.68	24.88	0.20
8	TO	6	31.03	31.28	0.25
8	TO	7	40.68	40.53	-0.15
8	TO	9	40.76	39.64	-1.12
8	TO	10	47.67	47.39	-0.28
8	TO	11	30.38	30.13	-0.26
8	TO	12	29.47	29.35	-0.13
8	TO	13	23.52	23.21	-0.31
8	TO	14	24.68	24.14	-0.54
8	TO	15	26.77	26.41	-0.36
8	TO	16	9.94	10.44	0.50
8	TO	17	50.42	50.28	-0.14
8	TO	18	20.01	20.26	0.25
8	TO	19	8.43	8.45	0.02
8	TO	20	48.09	48.10	0.01
9	TO	1	14.18	13.36	-0.82
9	TO	2	10.38	8.92	-1.46
9	TO	3	13.10	11.95	-1.15
9	TO	4	18.10	16.92	-1.18
9	TO	5	16.22	14.94	-1.28
9	TO	6	9.73	8.37	-1.36
9	TO	7	0.08	0.92	0.84
9	TO	8	40.76	39.64	-1.12
9	TO	10	6.91	7.75	0.84
9	TO	11	10.38	9.52	-0.86
9	TO	12	13.10	12.35	-0.75
9	TO	13	18.10	17.16	-0.94
9	TO	14	16.22	15.65	-0.57
9	TO	15	14.18	13.45	-0.74
9	TO	16	30.82	29.21	-1.61
9	TO	17	9.66	10.64	0.98
9	TO	18	20.75	19.38	-1.37
9	TO	19	32.33	31.19	-1.14
9	TO	20	7.33	8.46	1.13
10	TO	1	21.05	21.08	0.03
10	TO	2	17.29	16.67	-0.62
10	TO	3	19.56	19.27	-0.29
10	TO	4	24.87	24.56	-0.32
10	TO	5	23.10	22.64	-0.47
10	TO	6	16.64	16.11	-0.53
10	TO	7	6.99	6.86	-0.13
10	TO	8	47.67	47.39	-0.28
10	TO	9	6.91	7.75	0.84
10	TO	11	17.29	17.27	-0.02
10	TO	12	19.56	19.59	0.02

10	TO	13	24.87	24.81	-0.07
10	TO	14	23.10	23.36	0.25
10	TO	15	21.05	21.16	0.11
10	TO	16	37.73	36.96	-0.77
10	TO	17	2.75	2.90	0.15
10	TO	18	27.66	27.14	-0.52
10	TO	19	39.24	38.94	-0.30
10	TO	20	0.42	0.71	0.29
11	TO	1	4.25	4.36	0.12
11	TO	2	0.00	0.60	0.60
11	TO	3	6.01	5.73	-0.28
11	TO	4	8.45	8.16	-0.29
11	TO	5	5.94	5.53	-0.41
11	TO	6	0.68	1.15	0.47
11	TO	7	10.30	10.40	0.10
11	TO	8	30.38	30.13	-0.26
11	TO	9	10.38	9.52	-0.86
11	TO	10	17.29	17.27	-0.02
11	TO	12	6.01	6.33	0.31
11	TO	13	8.45	8.31	-0.15
11	TO	14	5.94	6.20	0.26
11	TO	15	4.25	4.44	0.19
11	TO	16	20.45	19.69	-0.75
11	TO	17	20.04	20.16	0.12
11	TO	18	10.38	9.88	-0.50
11	TO	19	21.95	21.67	-0.28
11	TO	20	17.71	17.97	0.27
12	TO	1	4.33	4.52	0.19
12	TO	2	6.01	6.45	0.44
12	TO	3	0.00	0.59	0.59
12	TO	4	5.97	5.87	-0.10
12	TO	5	8.48	8.66	0.18
12	TO	6	6.00	6.64	0.64
12	TO	7	13.02	13.24	0.22
12	TO	8	29.47	29.35	-0.13
12	TO	9	13.10	12.35	-0.75
12	TO	10	19.56	19.59	0.02
12	TO	11	6.01	6.33	0.31
12	TO	13	5.97	6.22	0.25
12	TO	14	8.48	8.90	0.42
12	TO	15	4.33	4.55	0.22
12	TO	16	19.81	19.34	-0.47
12	TO	17	22.21	22.30	0.09
12	TO	18	10.55	10.30	-0.25
12	TO	19	21.26	21.13	-0.13
12	TO	20	19.97	20.23	0.26
13	TO	1	4.21	3.95	-0.26
13	TO	2	8.45	8.82	0.36
13	TO	3	5.97	6.20	0.23
13	TO	4	0.00	0.36	0.36
13	TO	5	6.02	5.94	-0.08
13	TO	6	8.91	9.31	0.40
13	TO	7	18.02	18.07	0.05
13	TO	8	23.52	23.21	-0.31
13	TO	9	18.10	17.16	-0.94
13	TO	10	24.87	24.81	-0.07
13	TO	11	8.45	8.31	-0.15
13	TO	12	5.97	6.22	0.25

13	TO	14	6.02	5.61	-0.41
13	TO	15	4.21	3.87	-0.34
13	TO	16	13.84	13.12	-0.72
13	TO	17	27.59	27.64	0.05
13	TO	18	5.21	4.57	-0.63
13	TO	19	15.29	14.93	-0.36
13	TO	20	25.29	25.49	0.20
14	TO	1	4.15	4.38	0.23
14	TO	2	5.94	6.79	0.85
14	TO	3	8.48	8.50	0.02
14	TO	4	6.02	5.77	-0.25
14	TO	5	0.00	0.74	0.74
14	TO	6	6.62	7.33	0.72
14	TO	7	16.14	16.51	0.37
14	TO	8	24.68	24.14	-0.54
14	TO	9	16.22	15.65	-0.57
14	TO	10	23.10	23.36	0.25
14	TO	11	5.94	6.20	0.26
14	TO	12	8.48	8.90	0.42
14	TO	13	6.02	5.61	-0.41
14	TO	15	4.15	4.35	0.20
14	TO	16	14.78	13.72	-1.06
14	TO	17	25.85	26.26	0.41
14	TO	18	4.91	4.21	-0.70
14	TO	19	16.28	15.72	-0.56
14	TO	20	23.52	24.07	0.55
15	TO	1	0.00	0.08	0.08
15	TO	2	4.25	4.95	0.70
15	TO	3	4.33	4.17	-0.16
15	TO	4	4.21	3.72	-0.49
15	TO	5	4.15	4.15	-0.00
15	TO	6	4.73	5.45	0.72
15	TO	7	14.10	14.36	0.25
15	TO	8	26.77	26.41	-0.36
15	TO	9	14.18	13.45	-0.74
15	TO	10	21.05	21.16	0.11
15	TO	11	4.25	4.44	0.19
15	TO	12	4.33	4.55	0.22
15	TO	13	4.21	3.87	-0.34
15	TO	14	4.15	4.35	0.20
15	TO	16	16.87	16.08	-0.80
15	TO	17	23.79	24.03	0.24
15	TO	18	6.96	6.39	-0.57
15	TO	19	18.38	18.00	-0.38
15	TO	20	21.47	21.86	0.39
16	TO	1	16.87	16.16	-0.72
16	TO	2	20.45	20.29	-0.16
16	TO	3	19.81	19.31	-0.50
16	TO	4	13.84	13.47	-0.37
16	TO	5	14.78	14.46	-0.32
16	TO	6	21.09	20.84	-0.25
16	TO	7	30.74	30.09	-0.65
16	TO	8	9.94	10.44	0.50
16	TO	9	30.82	29.21	-1.61
16	TO	10	37.73	36.96	-0.77
16	TO	11	20.45	19.69	-0.75
16	TO	12	19.81	19.34	-0.47
16	TO	13	13.84	13.12	-0.72

16	TO	14	14.78	13.72	-1.06
16	TO	15	16.87	16.08	-0.80
16	TO	17	40.48	39.85	-0.63
16	TO	18	10.07	9.83	-0.24
16	TO	19	1.51	2.01	0.50
16	TO	20	38.15	37.66	-0.49
17	TO	1	23.79	23.94	0.15
17	TO	2	20.04	19.56	-0.47
17	TO	3	22.21	22.01	-0.20
17	TO	4	27.59	27.38	-0.21
17	TO	5	25.85	25.54	-0.31
17	TO	6	19.39	19.01	-0.38
17	TO	7	9.74	9.76	0.02
17	TO	8	50.42	50.28	-0.14
17	TO	9	9.66	10.64	0.98
17	TO	10	2.75	2.90	0.15
17	TO	11	20.04	20.16	0.12
17	TO	12	22.21	22.30	0.09
17	TO	13	27.59	27.64	0.05
17	TO	14	25.85	26.26	0.41
17	TO	15	23.79	24.03	0.24
17	TO	16	40.48	39.85	-0.63
17	TO	18	30.41	30.03	-0.38
17	TO	19	41.99	41.83	-0.16
17	TO	20	2.33	2.19	-0.14
18	TO	1	6.96	6.47	-0.50
18	TO	2	10.38	10.47	0.10
18	TO	3	10.55	10.12	-0.43
18	TO	4	5.21	4.92	-0.29
18	TO	5	4.91	4.94	0.02
18	TO	6	11.02	11.03	0.01
18	TO	7	20.67	20.27	-0.40
18	TO	8	20.01	20.26	0.25
18	TO	9	20.75	19.38	-1.37
18	TO	10	27.66	27.14	-0.52
18	TO	11	10.38	9.88	-0.50
18	TO	12	10.55	10.30	-0.25
18	TO	13	5.21	4.57	-0.63
18	TO	14	4.91	4.21	-0.70
18	TO	15	6.96	6.39	-0.57
18	TO	16	10.07	9.83	-0.24
18	TO	17	30.41	30.03	-0.38
18	TO	19	11.58	11.80	0.22
18	TO	20	28.08	27.84	-0.24
19	TO	1	18.38	18.08	-0.29
19	TO	2	21.95	22.27	0.32
19	TO	3	21.26	21.13	-0.13
19	TO	4	15.29	15.27	-0.02
19	TO	5	16.28	16.46	0.18
19	TO	6	22.60	22.83	0.23
19	TO	7	32.25	32.07	-0.18
19	TO	8	8.43	8.45	0.02
19	TO	9	32.33	31.19	-1.14
19	TO	10	39.24	38.94	-0.30
19	TO	11	21.95	21.67	-0.28
19	TO	12	21.26	21.13	-0.13
19	TO	13	15.29	14.93	-0.36
19	TO	14	16.28	15.72	-0.56

19	TO	15	18.38	18.00	-0.38
19	TO	16	1.51	2.01	0.50
19	TO	17	41.99	41.83	-0.16
19	TO	18	11.58	11.80	0.22
19	TO	20	39.66	39.64	-0.02
20	TO	1	21.47	21.77	0.30
20	TO	2	17.71	17.37	-0.33
20	TO	3	19.97	19.92	-0.04
20	TO	4	25.29	25.24	-0.05
20	TO	5	23.52	23.35	-0.17
20	TO	6	17.06	16.82	-0.24
20	TO	7	7.41	7.57	0.16
20	TO	8	48.09	48.10	0.01
20	TO	9	7.33	8.46	1.13
20	TO	10	0.42	0.71	0.29
20	TO	11	17.71	17.97	0.27
20	TO	12	19.97	20.23	0.26
20	TO	13	25.29	25.49	0.20
20	TO	14	23.52	24.07	0.55
20	TO	15	21.47	21.86	0.39
20	TO	16	38.15	37.66	-0.49
20	TO	17	2.33	2.19	-0.14
20	TO	18	28.08	27.84	-0.24
20	TO	19	39.66	39.64	-0.02

WRIGHT'S ROTUNDA , MAMMOTH CAVE KENTUCKY , DEPTH 200 FOOT

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LOCATION POINT	UNDERGROUND X COOR.	UNDERGROUND Y COOR.	SURFACE X COOR.	SURFACE Y COOR.
1	688.295	670.787	695.859	671.300
2	688.218	683.957	696.838	685.058
3	755.176	648.335	784.443	648.080
4	688.060	697.063	696.903	699.723
5	698.847	689.474	707.856	690.969
6	709.130	681.522	718.697	682.382
7	716.414	676.477	725.244	677.670
8	730.330	666.270	738.530	667.728

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LOCATION POINT	ERROR IN LOCATION	DIRECTION OF ERROR
1	7.58	N86.12E
2	8.69	N82.72E
3	29.27	S89.50E
4	9.23	N73.26E
5	9.13	N80.58E
6	9.61	N84.86E
7	8.91	N82.31E
8	8.33	N79.92E

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LOCATION POINT		LOCATION POINT	UNDERGROUND DISTANCE	SURFACE DISTANCE	DIFFERENCE IN DISTANCE
1	TO	2	13.17	13.79	0.62
1	TO	3	70.55	91.58	21.03
1	TO	4	26.28	28.44	2.17
1	TO	5	21.46	23.04	1.58
1	TO	6	23.44	25.38	1.95
1	TO	7	28.69	30.07	1.38
1	TO	8	42.28	42.82	0.54
2	TO	1	13.17	13.79	0.62
2	TO	3	75.84	95.09	19.25
2	TO	4	13.11	14.66	1.56
2	TO	5	11.98	12.50	0.53
2	TO	6	21.05	22.02	0.97
2	TO	7	29.17	29.35	0.18
2	TO	8	45.68	45.15	-0.53
3	TO	1	70.55	91.58	21.03
3	TO	2	75.84	95.09	19.25
3	TO	4	82.94	101.64	18.70
3	TO	5	69.75	87.78	18.03
3	TO	6	56.76	74.16	17.40
3	TO	7	47.90	66.18	18.28
3	TO	8	30.64	49.94	19.30
4	TO	1	26.28	28.44	2.17
4	TO	2	13.11	14.66	1.56
4	TO	3	82.94	101.64	18.70
4	TO	5	13.19	14.02	0.83
4	TO	6	26.18	27.85	1.67
4	TO	7	35.04	35.91	0.87
4	TO	8	52.30	52.50	0.21

5	TO	1	21.46	23.04	1.58
5	TO	2	11.98	12.50	0.53
5	TO	3	69.75	87.78	18.03
5	TO	4	13.19	14.02	0.83
5	TO	6	13.00	13.83	0.83
5	TO	7	21.85	21.89	0.04
5	TO	8	39.11	38.48	-0.63
6	TO	1	23.44	25.38	1.95
6	TO	2	21.05	22.02	0.97
6	TO	3	56.76	74.16	17.40
6	TO	4	26.18	27.85	1.67
6	TO	5	13.00	13.83	0.83
6	TO	7	8.86	8.07	-0.79
6	TO	8	26.12	24.66	-1.46
7	TO	1	28.69	30.07	1.38
7	TO	2	29.17	29.35	0.18
7	TO	3	47.90	66.18	18.28
7	TO	4	35.04	35.91	0.87
7	TO	5	21.85	21.89	0.04
7	TO	6	8.86	8.07	-0.79
7	TO	8	17.26	16.59	-0.66
8	TO	1	42.28	42.82	0.54
8	TO	2	45.68	45.15	-0.53
8	TO	3	30.64	49.94	19.30
8	TO	4	52.30	52.50	0.21
8	TO	5	39.11	38.48	-0.63
8	TO	6	26.12	24.66	-1.46
8	TO	7	17.26	16.59	-0.66

ROCKY MOUNTAIN , MAMMOTH CAVE KENTUCKY , DEPTH 210 FEET

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LOCATION POINT	UNDERGROUND X COOR.	UNDERGROUND Y COOR.	SURFACE X COOR.	SURFACE Y COOR.
1	737.375	820.474	734.829	824.501
2	752.423	841.375	744.301	843.076
3	785.139	817.496	785.506	817.828
4	806.969	787.928	807.131	789.934
5	752.423	841.375	744.824	840.636
6	737.375	820.474	733.948	824.511
7	785.139	817.496	775.671	827.493
8	806.969	787.928	747.367	850.136
9	733.679	839.000	773.583	830.139
10	740.900	825.655	736.104	829.600
11	752.423	841.375	744.177	842.854
12	749.190	836.991	738.844	842.094

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LOCATION POINT	ERROR IN LOCATION	DIRECTION OF ERROR
1	4.76	N32.30W
2	8.30	N78.17W
3	0.49	N47.90E
4	2.01	N 4.62E
5	7.63	S84.45W
6	5.30	N40.33W
7	13.77	N43.44W
8	86.15	N43.77W
9	40.88	S77.48E
10	6.21	N50.56W
11	8.38	N79.83W
12	11.54	N63.75W

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LOCATION POINT		LOCATION POINT	UNDERGROUND DISTANCE	SURFACE DISTANCE	DIFFERENCE IN DISTANCE
1	TO	2	25.75	20.85	-4.90
1	TO	3	47.86	51.11	3.26
1	TO	4	76.83	80.14	3.31
1	TO	5	25.75	18.98	-6.77
1	TO	6	0.00	0.88	0.88
1	TO	7	47.86	40.95	-6.91
1	TO	8	76.83	28.54	-48.29
1	TO	9	18.89	39.16	20.27
1	TO	10	6.27	5.26	-1.01
1	TO	11	25.75	20.60	-5.16
1	TO	12	20.31	18.05	-2.26
2	TO	1	25.75	20.85	-4.90
2	TO	3	40.50	48.33	7.82
2	TO	4	76.37	82.29	5.92
2	TO	5	0.00	2.50	2.50
2	TO	6	25.75	21.26	-4.50
2	TO	7	40.50	35.03	-5.48
2	TO	8	76.37	7.70	-68.67
2	TO	9	18.89	32.01	13.12
2	TO	10	19.49	15.77	-3.72
2	TO	11	0.00	0.25	0.25
2	TO	12	5.45	5.54	0.10

3	TO	1	47.86	51.11	3.26
3	TO	2	40.50	48.33	7.82
3	TO	4	36.75	35.29	-1.46
3	TO	5	40.50	46.64	6.14
3	TO	6	47.86	51.99	4.13
3	TO	7	0.00	13.79	13.79
3	TO	8	36.75	49.98	13.23
3	TO	9	55.77	17.14	-38.63
3	TO	10	44.99	50.79	5.80
3	TO	11	40.50	48.32	7.81
3	TO	12	40.89	52.59	11.70
4	TO	1	76.83	80.14	3.31
4	TO	2	76.37	82.29	5.92
4	TO	3	36.75	35.29	-1.46
4	TO	5	76.37	80.33	3.96
4	TO	6	76.83	80.94	4.11
4	TO	7	36.75	48.99	12.24
4	TO	8	0.00	84.83	84.83
4	TO	9	89.33	52.36	-36.97
4	TO	10	76.08	81.35	5.27
4	TO	11	76.37	82.24	5.88
4	TO	12	75.80	85.93	10.13
5	TO	1	25.75	18.98	-6.77
5	TO	2	0.00	2.50	2.50
5	TO	3	40.50	46.64	6.14
5	TO	4	76.37	80.33	3.96
5	TO	6	25.75	19.45	-6.30
5	TO	7	40.50	33.53	-6.97
5	TO	8	76.37	9.83	-66.53
5	TO	9	18.89	30.61	11.72
5	TO	10	19.49	14.07	-5.43
5	TO	11	0.00	2.31	2.31
5	TO	12	5.45	6.16	0.71
6	TO	1	0.00	0.88	0.88
6	TO	2	25.75	21.26	-4.50
6	TO	3	47.86	51.99	4.13
6	TO	4	76.83	80.94	4.11
6	TO	5	25.75	19.45	-6.30
6	TO	7	47.86	41.83	-6.03
6	TO	8	76.83	28.93	-47.90
6	TO	9	18.89	40.03	21.14
6	TO	10	6.27	5.53	-0.74
6	TO	11	25.75	21.00	-4.75
6	TO	12	20.31	18.25	-2.06
7	TO	1	47.86	40.95	-6.91
7	TO	2	40.50	35.03	-5.48
7	TO	3	0.00	13.79	13.79
7	TO	4	36.75	48.99	12.24
7	TO	5	40.50	33.53	-6.97
7	TO	6	47.86	41.83	-6.03
7	TO	8	36.75	36.25	-0.51
7	TO	9	55.77	3.37	-52.40
7	TO	10	44.99	39.62	-5.36
7	TO	11	40.50	35.04	-5.46
7	TO	12	40.89	39.62	-1.28
8	TO	1	76.83	28.54	-48.29

8	TO	2	76.37	7.70	-68.67
8	TO	3	36.75	49.98	13.23
8	TO	4	0.00	84.83	84.83
8	TO	5	76.37	9.83	-66.53
8	TO	6	76.83	28.93	-47.90
8	TO	7	36.75	36.25	-0.51
8	TO	9	89.33	32.97	-56.36
8	TO	10	76.08	23.42	-52.66
8	TO	11	76.37	7.95	-68.42
8	TO	12	75.80	11.72	-64.08
9	TO	1	18.89	39.16	20.27
9	TO	2	18.89	32.01	13.12
9	TO	3	55.77	17.14	-38.63
9	TO	4	89.33	52.36	-36.97
9	TO	5	18.89	30.61	11.72
9	TO	6	18.89	40.03	21.14
9	TO	7	55.77	3.37	-52.40
9	TO	8	89.33	32.97	-56.36
9	TO	10	15.17	37.48	22.31
9	TO	11	18.89	32.04	13.14
9	TO	12	15.64	36.74	21.10
10	TO	1	6.27	5.26	-1.01
10	TO	2	19.49	15.77	-3.72
10	TO	3	44.99	50.79	5.80
10	TO	4	76.08	81.35	5.27
10	TO	5	19.49	14.07	-5.43
10	TO	6	6.27	5.53	-0.74
10	TO	7	44.99	39.62	-5.36
10	TO	8	76.08	23.42	-52.66
10	TO	9	15.17	37.48	22.31
10	TO	11	19.49	15.52	-3.97
10	TO	12	14.04	12.79	-1.25
11	TO	1	25.75	20.60	-5.16
11	TO	2	0.00	0.25	0.25
11	TO	3	40.50	48.32	7.81
11	TO	4	76.37	82.24	5.88
11	TO	5	0.00	2.31	2.31
11	TO	6	25.75	21.00	-4.75
11	TO	7	40.50	35.04	-5.46
11	TO	8	76.37	7.95	-68.42
11	TO	9	18.89	32.04	13.14
11	TO	10	19.49	15.52	-3.97
11	TO	12	5.45	5.39	-0.06
12	TO	1	20.31	18.05	-2.26
12	TO	2	5.45	5.54	0.10
12	TO	3	40.89	52.59	11.70
12	TO	4	75.80	85.93	10.13
12	TO	5	5.45	6.16	0.71
12	TO	6	20.31	18.25	-2.06
12	TO	7	40.89	39.62	-1.28
12	TO	8	75.80	11.72	-64.08
12	TO	9	15.64	36.74	21.10
12	TO	10	14.04	12.79	-1.25
12	TO	11	5.45	5.39	-0.06

SILLIMAN AVENUE , MAMMOTH CAVE KENTUCKY , DEPTH 300 FEET

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LOCATION POINT	UNDERGROUND X COOR.	UNDERGROUND Y COOR.	SURFACE X COOR.	SURFACE Y COOR.
1	658.346	779.569	661.831	827.016
2	664.682	774.936	664.662	813.597
3	659.993	778.365	668.617	819.271
4	623.500	805.052	644.736	850.546
5	620.715	807.089	644.000	852.779
10	629.061	800.985	649.617	830.537
11	661.279	777.244	676.752	823.444
12	658.378	779.546	672.829	827.278
13	654.221	782.586	663.502	828.427
14	620.715	807.089	632.331	856.770
15	625.404	803.659	634.674	841.459
21	628.795	801.180	635.489	843.069
6	589.222	797.890	596.771	820.789
7	605.357	783.652	608.585	809.589
8	591.895	795.421	604.720	817.296
9	607.543	781.611	613.502	805.244
16	589.222	797.890	595.822	815.943
17	591.126	795.992	589.304	815.502
18	605.454	783.566	607.039	797.075
19	597.859	790.268	598.051	803.524
20	597.859	790.268	602.541	802.223

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LOCATION POINT	ERROR IN LOCATION	DIRECTION OF ERROR
1	47.57	N 4.20E
2	38.66	N 0.03W
3	41.81	N11.91E
4	50.21	N25.02E
5	51.28	N27.00E
10	36.00	N34.82E
11	48.72	N18.52E
12	49.87	N16.84E
13	46.77	N11.45E
14	51.02	N13.16E
15	38.92	N13.78E
21	42.42	N 9.08E
6	24.11	N18.25E
7	26.14	N 7.09E
8	25.36	N30.38E
9	24.37	N14.15E
16	19.22	N20.08E
17	19.59	N 5.34W
18	13.60	N 6.69E
19	13.26	N 0.83E
20	12.84	N21.39E

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LOCATION POINT		LOCATION POINT	UNDERGROUND DISTANCE	SURFACE DISTANCE	DIFFERENCE IN DISTANCE
1	TO	2	7.85	13.71	5.87
1	TO	3	2.04	10.30	8.26
1	TO	4	43.17	29.08	-14.09
1	TO	5	46.62	31.33	-15.29
1	TO	10	36.28	12.71	-23.57
1	TO	11	3.74	15.34	11.60

1	TO	12	0.04	11.00	10.96
1	TO	13	5.11	2.19	-2.92
1	TO	14	46.62	41.90	-4.72
1	TO	15	40.81	30.76	-10.05
1	TO	21	36.61	30.85	-5.76
1	TO	6	71.51	65.36	-6.15
1	TO	7	53.15	56.03	2.88
1	TO	8	68.32	57.93	-10.38
1	TO	9	50.84	53.01	2.16
1	TO	16	71.51	66.93	-4.58
1	TO	17	69.20	73.44	4.24
1	TO	18	53.04	62.44	9.40
1	TO	19	61.43	67.97	6.54
1	TO	20	61.43	64.27	2.84
2	TO	1	7.85	13.71	5.87
2	TO	3	5.81	6.92	1.11
2	TO	4	51.02	41.98	-9.04
2	TO	5	54.47	44.30	-10.17
2	TO	10	44.13	22.66	-21.47
2	TO	11	4.11	15.59	11.48
2	TO	12	7.81	15.93	8.12
2	TO	13	12.96	14.88	1.92
2	TO	14	54.47	53.94	-0.53
2	TO	15	48.66	40.93	-7.73
2	TO	21	44.46	41.47	-2.99
2	TO	6	78.87	68.27	-10.60
2	TO	7	59.96	56.22	-3.74
2	TO	8	75.61	60.06	-15.56
2	TO	9	57.53	51.84	-5.69
2	TO	16	78.87	68.88	-9.99
2	TO	17	76.51	75.38	-1.13
2	TO	18	59.85	59.94	0.09
2	TO	19	68.56	67.37	-1.19
2	TO	20	68.56	63.15	-5.41
3	TO	1	2.04	10.30	8.26
3	TO	2	5.81	6.92	1.11
3	TO	4	45.21	39.35	-5.86
3	TO	5	48.66	41.58	-7.08
3	TO	10	38.32	22.09	-16.23
3	TO	11	1.71	9.14	7.44
3	TO	12	2.00	9.05	7.05
3	TO	13	7.15	10.49	3.34
3	TO	14	48.66	52.18	3.52
3	TO	15	42.85	40.55	-2.30
3	TO	21	38.65	40.79	2.14
3	TO	6	73.41	71.86	-1.55
3	TO	7	54.89	60.81	5.92
3	TO	8	70.20	63.93	-6.27
3	TO	9	52.55	56.87	4.32
3	TO	16	73.41	72.87	-0.54
3	TO	17	71.09	79.40	8.32
3	TO	18	54.79	65.46	10.67
3	TO	19	63.26	72.30	9.04
3	TO	20	63.26	68.24	4.98
4	TO	1	43.17	29.08	-14.09
4	TO	2	51.02	41.98	-9.04
4	TO	3	45.21	39.35	-5.86
4	TO	5	3.45	2.35	-1.10

4	TO	10	6.89	20.60	13.71
4	TO	11	46.91	41.95	-4.96
4	TO	12	43.21	36.48	-6.73
4	TO	13	38.06	29.01	-9.05
4	TO	14	3.45	13.88	10.43
4	TO	15	2.36	13.56	11.20
4	TO	21	6.56	11.89	5.33
4	TO	6	35.02	56.45	21.43
4	TO	7	28.06	54.63	26.57
4	TO	8	33.04	52.03	18.99
4	TO	9	28.36	55.03	26.67
4	TO	16	35.02	59.92	24.90
4	TO	17	33.62	65.58	31.96
4	TO	18	28.06	65.42	37.36
4	TO	19	29.60	66.26	36.66
4	TO	20	29.60	64.15	34.55
5	TO	1	46.62	31.33	-15.29
5	TO	2	54.47	44.30	-10.17
5	TO	3	48.66	41.58	-7.08
5	TO	4	3.45	2.35	-1.10
5	TO	10	10.34	22.94	12.60
5	TO	11	50.36	43.97	-6.39
5	TO	12	46.66	38.49	-8.17
5	TO	13	41.51	31.20	-10.31
5	TO	14	0.00	12.33	12.33
5	TO	15	5.81	14.67	8.86
5	TO	21	10.01	12.91	2.90
5	TO	6	32.81	57.04	24.23
5	TO	7	28.02	55.85	27.83
5	TO	8	31.09	52.93	21.84
5	TO	9	28.68	56.48	27.80
5	TO	16	32.81	60.65	27.84
5	TO	17	31.60	66.19	34.59
5	TO	18	28.04	66.85	38.81
5	TO	19	28.38	67.36	38.98
5	TO	20	28.38	65.38	37.00
10	TO	1	36.28	12.71	-23.57
10	TO	2	44.13	22.66	-21.47
10	TO	3	38.32	22.09	-16.23
10	TO	4	6.89	20.60	13.71
10	TO	5	10.34	22.94	12.60
10	TO	11	40.02	28.05	-11.97
10	TO	12	36.32	23.44	-12.88
10	TO	13	31.17	14.04	-17.13
10	TO	14	10.34	31.42	21.08
10	TO	15	4.53	18.51	13.98
10	TO	21	0.33	18.89	18.56
10	TO	6	39.96	53.74	13.78
10	TO	7	29.37	46.07	16.70
10	TO	8	37.58	46.81	9.23
10	TO	9	28.95	44.09	15.14
10	TO	16	39.96	55.74	15.78
10	TO	17	38.26	62.16	23.90
10	TO	18	29.34	54.15	24.82
10	TO	19	32.99	58.21	25.22
10	TO	20	32.99	54.93	21.94
11	TO	1	3.74	15.34	11.60
11	TO	2	4.11	15.59	11.48

11	TO	3	1.71	9.14	7.44
11	TO	4	46.91	41.95	-4.96
11	TO	5	50.36	43.97	-6.39
11	TO	10	40.02	28.05	-11.97
11	TO	12	3.70	5.49	1.78
11	TO	13	8.85	14.16	5.30
11	TO	14	50.36	55.53	5.17
11	TO	15	44.55	45.77	1.22
11	TO	21	40.35	45.69	5.34
11	TO	6	74.96	80.02	5.07
11	TO	7	56.29	69.56	13.27
11	TO	8	71.73	72.29	0.57
11	TO	9	53.91	65.82	11.90
11	TO	16	74.96	81.28	6.32
11	TO	17	72.62	87.81	15.19
11	TO	18	56.18	74.53	18.35
11	TO	19	64.74	81.18	16.44
11	TO	20	64.74	77.19	12.44
12	TO	1	0.04	11.00	10.96
12	TO	2	7.81	15.93	8.12
12	TO	3	2.00	9.05	7.05
12	TO	4	43.21	36.48	-6.73
12	TO	5	46.66	38.49	-8.17
12	TO	10	36.32	23.44	-12.88
12	TO	11	3.70	5.49	1.78
12	TO	13	5.15	9.40	4.25
12	TO	14	46.66	50.10	3.44
12	TO	15	40.85	40.71	-0.14
12	TO	21	36.65	40.54	3.89
12	TO	6	71.55	76.33	4.79
12	TO	7	53.18	66.63	13.46
12	TO	8	68.35	68.84	0.48
12	TO	9	50.88	63.29	12.41
12	TO	16	71.55	77.84	6.29
12	TO	17	69.23	84.35	15.12
12	TO	18	53.08	72.39	19.32
12	TO	19	61.46	78.46	17.00
12	TO	20	61.46	74.62	13.16
13	TO	1	5.11	2.19	-2.92
13	TO	2	12.96	14.88	1.92
13	TO	3	7.15	10.49	3.34
13	TO	4	38.06	29.01	-9.05
13	TO	5	41.51	31.20	-10.31
13	TO	10	31.17	14.04	-17.13
13	TO	11	8.85	14.16	5.30
13	TO	12	5.15	9.40	4.25
13	TO	14	41.51	42.13	0.62
13	TO	15	35.70	31.64	-4.06
13	TO	21	31.50	31.61	0.11
13	TO	6	66.78	67.17	0.39
13	TO	7	48.88	58.06	9.18
13	TO	8	63.63	59.83	-3.81
13	TO	9	46.69	55.11	8.42
13	TO	16	66.78	68.82	2.05
13	TO	17	64.50	75.32	10.81
13	TO	18	48.78	64.58	15.81
13	TO	19	56.88	70.03	13.15
13	TO	20	56.88	66.35	9.47

14	TO	1	46.62	41.90	-4.72
14	TO	2	54.47	53.94	-0.53
14	TO	3	48.66	52.18	3.52
14	TO	4	3.45	13.88	10.43
14	TO	5	0.00	12.33	12.33
14	TO	10	10.34	31.42	21.08
14	TO	11	50.36	55.53	5.17
14	TO	12	46.66	50.10	3.44
14	TO	13	41.51	42.13	0.62
14	TO	15	5.81	15.49	9.68
14	TO	21	10.01	14.06	4.05
14	TO	6	32.81	50.59	17.78
14	TO	7	28.02	52.82	24.80
14	TO	8	31.09	48.17	17.08
14	TO	9	28.68	54.86	26.18
14	TO	16	32.81	54.77	21.96
14	TO	17	31.60	59.62	28.02
14	TO	18	28.04	64.83	36.79
14	TO	19	28.38	63.33	34.95
14	TO	20	28.38	62.15	33.77
15	TO	1	40.81	30.76	-10.05
15	TO	2	48.66	40.93	-7.73
15	TO	3	42.85	40.55	-2.30
15	TO	4	2.36	13.56	11.20
15	TO	5	5.81	14.67	8.86
15	TO	10	4.53	18.51	13.98
15	TO	11	44.55	45.77	1.22
15	TO	12	40.85	40.71	-0.14
15	TO	13	35.70	31.64	-4.06
15	TO	14	5.81	15.49	9.68
15	TO	21	4.20	1.80	-2.40
15	TO	6	36.64	43.17	6.53
15	TO	7	28.32	41.19	12.86
15	TO	8	34.51	38.49	3.98
15	TO	9	28.37	41.95	13.58
15	TO	16	36.64	46.48	9.84
15	TO	17	35.13	52.27	17.15
15	TO	18	28.31	52.28	23.97
15	TO	19	30.63	52.73	22.10
15	TO	20	30.63	50.71	20.09
21	TO	1	36.61	30.85	-5.76
21	TO	2	44.46	41.47	-2.99
21	TO	3	38.65	40.79	2.14
21	TO	4	6.56	11.89	5.33
21	TO	5	10.01	12.91	2.90
21	TO	10	0.33	18.89	18.56
21	TO	11	40.35	45.69	5.34
21	TO	12	36.65	40.54	3.89
21	TO	13	31.50	31.61	0.11
21	TO	14	10.01	14.06	4.05
21	TO	15	4.20	1.80	-2.40
21	TO	6	39.71	44.67	4.96
21	TO	7	29.27	42.95	13.68
21	TO	8	37.35	40.14	2.79
21	TO	9	28.89	43.75	14.86
21	TO	16	39.71	48.06	8.35
21	TO	17	38.02	53.79	15.76
21	TO	18	29.24	54.08	24.84
21	TO	19	32.80	54.46	21.65

21	TO	20	32.80	52.48	19.67
6	TO	1	71.51	65.36	-6.15
6	TO	2	78.87	68.27	-10.60
6	TO	3	73.41	71.86	-1.55
6	TO	4	35.02	56.45	21.43
6	TO	5	32.81	57.04	24.23
6	TO	10	39.96	53.74	13.78
6	TO	11	74.96	80.02	5.07
6	TO	12	71.55	76.33	4.79
6	TO	13	66.78	67.17	0.39
6	TO	14	32.81	50.59	17.78
6	TO	15	36.64	43.17	6.53
6	TO	21	39.71	44.67	4.96
6	TO	7	21.52	16.28	-5.24
6	TO	8	3.64	8.68	5.04
6	TO	9	24.51	22.84	-1.67
6	TO	16	0.00	4.94	4.94
6	TO	17	2.69	9.15	6.46
6	TO	18	21.65	25.84	4.19
6	TO	19	11.52	17.31	5.79
6	TO	20	11.52	19.44	7.92
7	TO	1	53.15	56.03	2.88
7	TO	2	59.96	56.22	-3.74
7	TO	3	54.89	60.81	5.92
7	TO	4	28.06	54.63	26.57
7	TO	5	28.02	55.85	27.83
7	TO	10	29.37	46.07	16.70
7	TO	11	56.29	69.56	13.27
7	TO	12	53.18	66.63	13.46
7	TO	13	48.88	58.06	9.18
7	TO	14	28.02	52.82	24.80
7	TO	15	28.32	41.19	12.86
7	TO	21	29.27	42.95	13.68
7	TO	6	21.52	16.28	-5.24
7	TO	8	17.88	8.62	-9.26
7	TO	9	2.99	6.56	3.57
7	TO	16	21.52	14.26	-7.26
7	TO	17	18.84	20.17	1.33
7	TO	18	0.13	12.61	12.48
7	TO	19	10.00	12.16	2.16
7	TO	20	10.00	9.53	-0.47
8	TO	1	68.32	57.93	-10.38
8	TO	2	75.61	60.06	-15.56
8	TO	3	70.20	63.93	-6.27
8	TO	4	33.04	52.03	18.99
8	TO	5	31.09	52.93	21.84
8	TO	10	37.58	46.81	9.23
8	TO	11	71.73	72.29	0.57
8	TO	12	68.35	68.84	0.48
8	TO	13	63.63	59.83	-3.81
8	TO	14	31.09	48.17	17.08
8	TO	15	34.51	38.49	3.98
8	TO	21	37.35	40.14	2.79
8	TO	6	3.64	8.68	5.04
8	TO	7	17.88	8.62	-9.26
8	TO	9	20.87	14.91	-5.96
8	TO	16	3.64	9.00	5.36
8	TO	17	0.96	15.52	14.56

8	TO	18	18.01	20.35	2.34
8	TO	19	7.88	15.30	7.42
8	TO	20	7.88	15.23	7.35
9	TO	1	50.84	53.01	2.16
9	TO	2	57.53	51.84	-5.69
9	TO	3	52.55	56.87	4.32
9	TO	4	28.36	55.03	26.67
9	TO	5	28.68	56.48	27.80
9	TO	10	28.95	44.09	15.14
9	TO	11	53.91	65.82	11.90
9	TO	12	50.88	63.29	12.41
9	TO	13	46.69	55.11	8.42
9	TO	14	28.68	54.86	26.18
9	TO	15	28.37	41.95	13.58
9	TO	21	28.89	43.75	14.86
9	TO	6	24.51	22.84	-1.67
9	TO	7	2.99	6.56	3.57
9	TO	8	20.87	14.91	-5.96
9	TO	16	24.51	20.67	-3.84
9	TO	17	21.82	26.28	4.46
9	TO	18	2.86	10.42	7.56
9	TO	19	12.99	15.55	2.56
9	TO	20	12.99	11.37	-1.62
16	TO	1	71.51	66.93	-4.58
16	TO	2	78.87	68.88	-9.99
16	TO	3	73.41	72.87	-0.54
16	TO	4	35.02	59.92	24.90
16	TO	5	32.81	60.65	27.84
16	TO	10	39.96	55.74	15.78
16	TO	11	74.96	81.28	6.32
16	TO	12	71.55	77.84	6.29
16	TO	13	66.78	68.82	2.05
16	TO	14	32.81	54.77	21.96
16	TO	15	36.64	46.48	9.84
16	TO	21	39.71	48.06	8.35
16	TO	6	0.00	4.94	4.94
16	TO	7	21.52	14.26	-7.26
16	TO	8	3.64	9.00	5.36
16	TO	9	24.51	20.67	-3.84
16	TO	17	2.69	6.53	3.84
16	TO	18	21.65	21.95	0.30
16	TO	19	11.52	12.62	1.10
16	TO	20	11.52	15.28	3.76
17	TO	1	69.20	73.44	4.24
17	TO	2	76.51	75.38	-1.13
17	TO	3	71.09	79.40	8.32
17	TO	4	33.62	65.58	31.96
17	TO	5	31.60	66.19	34.59
17	TO	10	38.26	62.16	23.90
17	TO	11	72.62	87.81	15.19
17	TO	12	69.23	84.35	15.12
17	TO	13	64.50	75.32	10.81
17	TO	14	31.60	59.62	28.02
17	TO	15	35.13	52.27	17.15
17	TO	21	38.02	53.79	15.76
17	TO	6	2.69	9.15	6.46
17	TO	7	18.84	20.17	1.33
17	TO	8	0.96	15.52	14.56

17	TO	9	21.82	26.28	4.46
17	TO	16	2.69	6.53	3.84
17	TO	18	18.97	25.58	6.61
17	TO	19	8.84	14.83	5.99
17	TO	20	8.84	18.75	9.91
18	TO	1	53.04	62.44	9.40
18	TO	2	59.85	59.94	0.09
18	TO	3	54.79	65.46	10.67
18	TO	4	28.06	65.42	37.36
18	TO	5	28.04	66.85	38.81
18	TO	10	29.34	54.15	24.82
18	TO	11	56.18	74.53	18.35
18	TO	12	53.08	72.39	19.32
18	TO	13	48.78	64.58	15.81
18	TO	14	28.04	64.83	36.79
18	TO	15	28.31	52.28	23.97
18	TO	21	29.24	54.08	24.84
18	TO	6	21.65	25.84	4.19
18	TO	7	0.13	12.61	12.48
18	TO	8	18.01	20.35	2.34
18	TO	9	2.86	10.42	7.56
18	TO	16	21.65	21.95	0.30
18	TO	17	18.97	25.58	6.61
18	TO	19	10.13	11.06	0.93
18	TO	20	10.13	6.84	-3.29
19	TO	1	61.43	67.97	6.54
19	TO	2	68.56	67.37	-1.19
19	TO	3	63.26	72.30	9.04
19	TO	4	29.60	66.26	36.66
19	TO	5	28.38	67.36	38.98
19	TO	10	32.99	58.21	25.22
19	TO	11	64.74	81.18	16.44
19	TO	12	61.46	78.46	17.00
19	TO	13	56.88	70.03	13.15
19	TO	14	28.38	63.33	34.95
19	TO	15	30.63	52.73	22.10
19	TO	21	32.80	54.46	21.65
19	TO	6	11.52	17.31	5.79
19	TO	7	10.00	12.16	2.16
19	TO	8	7.88	15.30	7.42
19	TO	9	12.99	15.55	2.56
19	TO	16	11.52	12.62	1.10
19	TO	17	8.84	14.83	5.99
19	TO	18	10.13	11.06	0.93
19	TO	20	0.00	4.67	4.67
20	TO	1	61.43	64.27	2.84
20	TO	2	68.56	63.15	-5.41
20	TO	3	63.26	68.24	4.98
20	TO	4	29.60	64.15	34.55
20	TO	5	28.38	65.38	37.00
20	TO	10	32.99	54.93	21.94
20	TO	11	64.74	77.19	12.44
20	TO	12	61.46	74.62	13.16
20	TO	13	56.88	66.35	9.47
20	TO	14	28.38	62.15	33.77
20	TO	15	30.63	50.71	20.09
20	TO	21	32.80	52.48	19.67
20	TO	6	11.52	19.44	7.92

20	TO	7	10.00	9.53	-0.47
20	TO	8	7.88	15.23	7.35
20	TO	9	12.99	11.37	-1.62
20	TO	16	11.52	15.28	3.76
20	TO	17	8.84	18.75	9.91
20	TO	18	10.13	6.84	-3.29
20	TO	19	0.00	4.67	4.67

```
CORE USAGE          OBJECT CODE=    3736 BYTES,ARRAY AREA=    1720 BYTES,TOTAL ARE

DIAGNOSTICS          NUMBER OF ERRORS=        0, NUMBER OF WARNINGS=        0, NUMB

COMPILE TIME=     0.13 SEC,EXECUTION TIME=     0.44 SEC,  WATFIV - JUL 1973 V1L
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$JOB               ,TIME=1
      REAL CX(50),CY(50),SX(50),SY(50),DX,DY,D(50),ANGLE,CL,SL,DL(50)
      INTEGER NL,NS,EW,P(50),J,K,L,TITLE(80),NU,A
      INTEGER N/'N'/,S/'S'/,E/'E'/,W/'W'/
      READ, NU
      DO 25 A=1,NU,1
      READ (5,1) TITLE
    1 FORMAT (80A1)
      WRITE (6,2) TITLE
    2 FORMAT ('1',6X,80A1)
      WRITE (6,3)
    3 FORMAT ('0',6X,'**************************************************
     1********')
      WRITE (6,4)
    4 FORMAT (' ',6X,'LOCATION',8X,'UNDERGROUND',14X,'SURFACE')
      WRITE (6,5)
    5 FORMAT (' ',6X,' POINT  ',4X,'X COOR.',5X,'Y COOR.',4X,'X COOR.',5
     1X,'Y COOR.')
      READ, NL
      DO 6 J=1,NL,1
      READ, P(J),CX(J),CY(J),SX(J),SY(J)
    6 WRITE (6,7) P(J),CX(J),CY(J),SX(J),SY(J)
    7 FORMAT (' ',9X,I2,7X,F8.3,3X,F8.3,4X,F8.3,3X,F8.3)
      WRITE (6,8)
    8 FORMAT ('0',6X,'**************************************************
     1********')
      WRITE (6,9)
    9 FORMAT (' ',6X,'LOCATION',4X,'ERROR IN',4X,'DIRECTION')
      WRITE (6,10)
   10 FORMAT (' ',7X,'POINT ',5X,'LOCATION',4X,'OF ERROR')
      K=0
   11 K=K+1
      DX=SX(K)-CX(K)
      DY=SY(K)-CY(K)
      D(K)=SQRT((DX**2)+(DY**2))
      IF (DY.GT.0) GO TO 12
      NS=S
      GO TO 13
   12 NS=N
   13 IF (DX.GT.0) GO TO 14
      EW=W
      GO TO 15
   14 EW=E
   15 ANGLE=ATAN(ABS(DX/DY))*(180.00/3.14159)
      WRITE (6,16) P(K),D(K),NS,ANGLE,EW
   16 FORMAT (' ',8X,I2,9X,F5.2,7X,A1,F5.2,A1)
      IF (K.NE.NL) GO TO 11
      WRITE (6,17)
   17 FORMAT ('0',6X,'**************************************************
     1********')
      WRITE (6,18)
   18 FORMAT (' ',6X,'LOCATION  LOCATION  UNDERGROUND  SURFACE   DIFFERE
     1NCE')
      WRITE (6,19)
   19 FORMAT (' ',6X,' POINT     POINT     DISTANCE    DISTANCE  IN DIST
     1ANCE')
      K=0
   20 K=K+1
      L=0
   21 L=L+1
      IF (L.EQ.K) GO TO 21
```

```
      IF (L.EQ.(NL+1)) GO TO 23
      CL=SQRT(((CX(K)-CX(L))**2)+((CY(K)-CY(L))**2))
      SL=SQRT(((SX(K)-SX(L))**2)+((SY(K)-SY(L))**2))
      DL(L)=SL-CL
      WRITE (6,22) P(K),P(L),CL,SL,DL(L)
   22 FORMAT (' ',8X,I2,3X,'TO',3X,I2,8X,F6.2,6X,F6.2,6X,F6.2)
      IF (L.EQ.NL) GO TO 23
      GO TO 21
   23 WRITE (6,24)
   24 FORMAT (' ','                                                   ')
      IF (K.EQ.NL) GO TO 25
      GO TO 20
   25 CONTINUE
      RETURN
      END

 $ENTRY
```

APPENDIX B

DATA SHEETS FOR DEPTH DETERMINATIONS

PROJECT Radio locator accuracy evaluation DATE 8-23-75

UNDERGROUND LOCATION #2, Blue Springs Cave, Indiana

SURFACE LOCATION #2

UNDERGROUND PARTY MEMBERS:

OPERATOR C.S. Bishop

C.H. Bishop

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.S. Bishop

TRANSMITTING SCHEDULE Continuous

RECEIVING CONDITIONS Excellent

INITIAL DISTANCE FROM GROUND ZERO 100' ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
0	--	--	0.00	--
10	6.55	72.55	+0.38	72.17
15	9.50	74.64	+0.51	74.03
20	12.75	73.57	+0.79	72.78
25	16.00	72.52	+0.94	71.58
30	18.70	73.68	+1.11	72.57
35	21.10	75.37	+1.19	74.18
40	24.60	72.55	+1.21	71.34
45	26.80	73.96	+1.29	72.67
50	29.40	73.65	+1.41	72.24
55	32.00	73.06	+1.57	71.49
60	33.50	72.25	+1.74	73.51
65	36.30	73.50	+1.75	71.75
70	38.30	73.68	+1.69	71.99
				Avg=72.49
				Std=0.94

SHEET___ OF___

PROJECT Radio locator accuracy evaluation **DATE** 8-23-75

UNDERGROUND LOCATION #3, Blue Springs Cave, Indiana

SURFACE LOCATION #3

UNDERGROUND PARTY MEMBERS:

OPERATOR C.S. Bishop

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.H. Bishop

TRANSMITTING SCHEDULE Continuous

RECEIVING CONDITIONS Excellent

INITIAL DISTANCE FROM GROUND ZERO ____ **ANGLE UNITS** 2θ=grads **DISTANCES** Feet

L	θ	D	ΔH	D − ΔH
0	--	--	0.00	--
10	6.5	73.12	+0.49	72.63
15	10.0	70.84	+0.40	70.44
20	12.8	73.27	+0.17	73.10
25	15.8	73.49	-0.20	73.69
30	19.1	72.02	-0.66	72.68
35	22.0	71.97	-1.19	73.16
40	25.2	70.58	-1.02	71.60
45	27.4	72.07	-0.96	73.03
50	30.7	69.89	-1.03	70.92
55	32.1	72.78	-1.24	74.02
60	34.7	71.95	-1.24	73.66
65	32.7	84.04	-2.62	86.66
70	38.9	72.14	-2.25	74.39
				Avg=72.78
				Std=1.22

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 8-23-75

UNDERGROUND LOCATION #4, Blue Springs Cave, Indiana

SURFACE LOCATION #4

UNDERGROUND PARTY MEMBERS:

OPERATOR C.S. Bishop

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.H. Bishop

TRANSMITTING SCHEDULE Continuous

RECEIVING CONDITIONS Excellent

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
0	--	--	0.00	--
10	6.4	74.27	+0.57	73.70
15	9.7	73.07	+0.61	72.46
20	12.7	73.87	+0.48	73.39
25	15.75	73.74	+0.20	73.54
30	18.6	74.11	+0.05	74.06
35	21.7	73.08	+0.17	72.91
40	23.7	75.68	+0.25	75.43
45	27.4	72.07	+0.49	71.58
50	29.2	74.26	+0.67	73.59
55	31.2	75.38	+0.69	74.69
60	34.2	73.30	+0.63	72.67
65	36.9	71.93	+0.61	71.32
70	39.6	70.39	+0.68	69.71
				Avg=73.00
				Std=1.51

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 8-23-75

UNDERGROUND LOCATION #5, Blue Springs Cave, Indiana

SURFACE LOCATION #5

UNDERGROUND PARTY MEMBERS:

OPERATOR C.S. Bishop

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.H. Bishop

TRANSMITTING SCHEDULE Continuous

RECEIVING CONDITIONS Excellent

INITIAL DISTANCE FROM GROUND ZERO ____ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
0	--	--	0.00	--
10	6.9	68.84	+0.65	68.19
15	9.4	75.45	+1.04	74.41
20	12.75	73.57	+1.40	72.17
25	15.5	74.99	+1.80	73.19
30	18.2	75.87	+2.14	73.73
35	19.75	81.03	+2.48	78.55
40	23.4	76.78	+2.83	73.95
45	26.7	74.28	+3.20	71.08
50	28.5	76.44	+3.55	72.89
55	30.7	76.88	+3.94	72.94
60	32.05	79.55	+4.16	75.39
65	34.2	79.41	+4.34	75.07
70	36.6	78.30	+4.45	73.85
				Avg=73.49
				Std=2.40

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 9-13-75

UNDERGROUND LOCATION #6, Blue Springs Cave, Indiana

SURFACE LOCATION #6

UNDERGROUND PARTY MEMBERS:

OPERATOR C.S. Bishop, K. Hoskins, D. Kelley, D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.H. Bishop, C.S. Bishop, K., Hoskins

TRANSMITTING SCHEDULE Irregular

RECEIVING CONDITIONS Good. Wet Ground.

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
0	--	--	0.00	--
10	6.9	68.84	+0.38	68.46
15	9.8	72.31	+0.62	71.69
20	13.0	72.10	+0.82	71.28
25	16.1	72.05	+1.00	71.05
30	19.1	72.02	+1.18	70.84
35	21.35	74.40	+1.28	73.12
40	24.2	73.92	+1.37	72.55
45	26.8	73.96	+1.48	72.48
50	29.1	74.56	+1.67	72.89
55	30.9	76.28	+1.78	74.50
60	33.9	74.13	+2.05	72.08
65	34.6	78.23	+2.05	76.18
70	37.3	76.35	+1.97	74.38
				Avg=72.42
				Std=1.94

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation **DATE** 9-13-75

UNDERGROUND LOCATION #7, Blue Springs Cave, Indiana

SURFACE LOCATION #7

UNDERGROUND PARTY MEMBERS:

OPERATOR C.S. Bishop, K. Hoskins, D. Kelley, D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.H. Bishop, K. Hoskins

TRANSMITTING SCHEDULE Irregular

RECEIVING CONDITIONS Good. Wet ground, clear, breeze, temperature 60's.

INITIAL DISTANCE FROM GROUND ZERO ____ **ANGLE UNITS** 2Θ=grads **DISTANCES** Feet

L	Θ	D	ΔH	D − ΔH
0	--	--	0.00	--
10	6.8	69.86	+0.82	69.04
15	10.0	70.84	+1.18	69.66
20	12.5	75.09	+1.59	73.50
25	16.0	72.52	+1.82	70.70
30	18.8	73.26	+1.89	71.37
35	21.2	74.98	+1.89	73.09
40	24.7	72.22	+1.70	70.62
45	27.15	72.85	+1.60	71.25
50	30.4	70.74	+1.74	69.00
55	31.8	73.63	+2.01	71.62
60	35.0	71.15	+2.32	68.83
65	36.85	72.06	+2.51	69.55
70	38.3	73.68	+2.71	70.97
				Avg=70.71
				Std=1.49

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 9-13-75

UNDERGROUND LOCATION #8, Blue Springs Cave, Indiana

SURFACE LOCATION #8

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.H. Bishop

C.S. Bishop, K. Hoskins

TRANSMITTING SCHEDULE Irregular

RECEIVING CONDITIONS Good, wet ground.

INITIAL DISTANCE FROM GROUND ZERO ____ ANGLE UNITS 2θ=grads DISTANCES Feet

L	Θ	D	ΔH	D − ΔH
0	--	--	0.00	--
10	6.5	73.12	+0.02	73.10
15	9.95	71.20	+0.05	71.15
20	13.25	70.69	+0.33	70.36
25	16.6	62.32	+0.60	61.72
30	18.5	66.49	+0.83	65.66
35	21.8	64.61	+1.05	63.56
40	23.8	66.77	+1.32	65.45
45	27.05	64.55	+1.56	62.99
50	29.05	65.71	+1.68	64.03
55	32.7	62.12	+1.75	60.37
60	34.0	64.34	+1.90	62.44
65	36.2	63.96	+2.05	61.91
70	37.5	65.52	+2.26	63.26
				Avg=65.08
				Std=3.99

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 9-13-75

UNDERGROUND LOCATION #9, Blue Springs Cave, Indiana

SURFACE LOCATION #9

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins, D. Kelley, D. Pollock, F. Reid

SURFACE PARTY MEMBERS:

OPERATOR C.S. Bishop

NOTES C.H. Bishop, K. Hoskins

TRANSMITTING SCHEDULE Irregular

RECEIVING CONDITIONS Good, wet ground

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
0	--	--	0.00	--
10	6.8	69.86	+0.71	69.15
15	10.0	70.84	+1.07	69.77
20	13.5	69.33	+1.37	67.96
25	16.4	70.65	+1.70	68.95
30	18.7	73.68	+2.00	71.68
35	21.5	73.83	+2.33	71.50
40	24.3	73.57	+2.55	71.02
45	26.9	73.64	+2.82	70.82
50	29.3	73.95	+3.12	70.83
55	30.9	76.28	+3.54	72.74
60	33.7	74.69	+3.89	70.80
65	35.8	74.85	+4.24	70.61
70	37.8	75.00	+4.55	70.45
				Avg=70.48
				Std=1.26

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 9-13-75

UNDERGROUND LOCATION #10, Blue Spring Cave, Indiana

SURFACE LOCATION #10

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins, D. Kelley, D. Pollock, F. Reid

SURFACE PARTY MEMBERS:

OPERATOR C.S. Bishop

NOTES C.H. Bishop, F. Reid

TRANSMITTING SCHEDULE Irregular

RECEIVING CONDITIONS Good, wet ground.

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
0	--	--	0.00	--
10	6.9	68.84	-0.57	69.41
15	10.3	68.73	-0.74	69.47
20	13.4	69.87	-0.89	70.76
25	16.9	68.43	-1.09	69.52
30	19.8	69.26	-1.36	70.62
35	22.8	69.16	-1.62	70.78
40	25.5	69.63	-1.95	71.58
45	28.0	70.25	-2.19	72.44
50	30.9	69.34	-2.45	71.79
55	34.3	66.94	-2.86	69.80
60	37.7	64.52	-3.19	67.71
65	39.0	66.75	-3.78	70.53
70	42.1	64.56	-4.20	68.76
				Avg=70.24
				Std=1.31

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 9-13-75

UNDERGROUND LOCATION #11, Blue Springs Cave, Indiana

SURFACE LOCATION #11

UNDERGROUND PARTY MEMBERS:

OPERATOR D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR C. S. Bishop

NOTES C. H. Bishop

K. Hoskins, F. Reid

TRANSMITTING SCHEDULE Irregular

RECEIVING CONDITIONS Good, wet ground.

INITIAL DISTANCE FROM GROUND ZERO ANGLE UNITS 20=grads DISTANCES Feet

L	Θ	D	ΔH	D − ΔH
0	--	--	0.00	--
10	6.8	69.86	+0.01	69.85
15	9.6	73.85	+0.10	73.75
20	13.2	70.97	0.00	70.97
25	16.5	70.20	-0.37	70.57
30	18.8	73.26	-0.60	73.86
35	22.1	71.61	-1.17	72.78
40	25.0	71.23	-1.79	73.02
45	27.7	71.15	-2.65	73.80
50	31.4	67.99	-3.71	71.70
55	33.8	68.21	-4.96	73.17
60	37.3	65.45	-6.01	71.46
65	38.8	67.22	-6.59	73.81
70	42.8	63.03	-7.02	70.05
				Avg=72.21
				Std=1.51

SHEET___ OF___

PROJECT Radio locator accuracy evaluation DATE 9-13-75

UNDERGROUND LOCATION #12, Blue Springs Cave, Indiana

SURFACE LOCATION #12

UNDERGROUND PARTY MEMBERS:

OPERATOR C.S. Bishop, K. Hoskins, D. Kelley, D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.H. Bishop

K. Hoskins

TRANSMITTING SCHEDULE Irregular

RECEIVING CONDITIONS Good, wet ground.

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
0	--	--	0.00	--
10	6.7	70.91	-0.15	71.06
15	10.0	70.84	-0.37	71.21
20	13.1	71.53	-0.71	72.24
25	16.5	70.20	-1.02	71.22
30	19.65	69.84	-1.49	71.33
35	22.4	70.54	-1.96	72.50
40	25.4	69.95	-2.63	72.58
45	28.5	68.80	-3.50	72.30
50	32.05	66.29	-4.70	70.99
55	33.1	70.04	-5.70	75.74
60	36.6	67.12	-6.63	73.75
65	39.25	66.17	-7.31	73.48
70	42.1	64.56	-7.90	72.46
				Avg=72.37
				Std=1.35

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 9-13-75

UNDERGROUND LOCATION #13, Blue Springs Cave, Indiana

SURFACE LOCATION #13

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.H. Bishop

C.S. Bishop, K. Hoskins, D. Kelley

TRANSMITTING SCHEDULE Irregular

RECEIVING CONDITIONS Good

INITIAL DISTANCE FROM GROUND ZERO ____ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
0	--	--	0.00	--
10	6.65	71.45	+0.36	71.09
15	9.9	71.57	+0.54	71.03
20	13.0	72.10	+0.74	71.36
25	16.0	72.52	+0.94	71.58
30	18.9	72.84	+1.02	71.82
35	21.5	73.83	+1.13	72.70
40	23.7	75.68	+1.31	74.37
45	27.0	73.32	+1.42	71.90
50	29.15	74.41	+1.56	72.85
55	33.0	70.30	+1.74	68.56
60	34.2	73.30	+1.84	71.46
65	35.7	75.13	+1.82	73.31
70	38.2	73.94	+1.80	72.14
				Avg=71.86
				Std=1.38

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 9-13-75

UNDERGROUND LOCATION #14, Blue Springs Cave, Indiana

SURFACE LOCATION #14

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR C.S. Bishop

NOTES C.H. Bishop

K. Hoskins, D. Kelley, F. Reid

TRANSMITTING SCHEDULE Irregular

RECEIVING CONDITIONS Good

INITIAL DISTANCE FROM GROUND ZERO ____ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
0	--	--	0.00	--
10	6.6	72.00	+0.84	71.16
15	9.9	71.57	+1.19	70.38
20	13.0	72.10	+1.56	70.54
25	16.0	72.52	+1.93	70.59
30	18.4	74.98	+2.25	72.73
35	20.8	76.57	+2.60	73.97
40	23.7	75.68	+2.88	72.80
45	26.0	76.60	+3.15	73.45
50	29.0	74.87	+3.46	71.41
55	30.6	77.19	+3.77	73.42
60	33.0	76.70	+4.11	72.59
65	34.7	77.94	+4.39	73.55
70	38.0	74.47	+4.77	69.70
				Avg=72.02
				Std=1.44

SHEET___ OF___

PROJECT Radio locator accuracy evaluation DATE 9-13-75

UNDERGROUND LOCATION #15, Blue Springs Cave, Indiana

SURFACE LOCATION #15

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR C.S. Bishop

NOTES C.H. Bishop

K. Hoskins, D. Kelley, F. Reid

TRANSMITTING SCHEDULE Irregular

RECEIVING CONDITIONS Good

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
0	--	--	0.00	--
10	6.5	73.12	-0.63	73.75
15	9.4	75.45	-0.90	76.35
20	12.9	72.68	-1.21	73.89
25	16.1	72.05	-1.60	73.65
30	19.0	72.43	-1.90	74.33
35	22.2	71.25	-2.18	73.43
40	25.3	70.27	-2.53	72.80
45	27.8	70.85	-2.90	73.75
50	29.8	72.46	-3.16	75.62
55	33.8	68.21	-3.53	71.74
60	36.1	68.34	-3.82	72.16
65	37.3	70.90	-4.12	75.02
70	40.8	67.51	-4.49	72.00
				Avg=73.73
				Std=1.38

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 9-13-75

UNDERGROUND LOCATION #16, Blue Spring Cave, Indiana

SURFACE LOCATION #16

UNDERGROUND PARTY MEMBERS:

OPERATOR C.S. Bishop, K. Hoskins, D. Kelley, D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.H. Bishop

C.S. Bishop, K. Hoskins, D. Kelley

TRANSMITTING SCHEDULE Irregular

RECEIVING CONDITIONS Good (receiver dropped before this location)

INITIAL DISTANCE FROM GROUND ZERO ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
0	--	--	0.00	--
10	6.65	71.45	-0.50	71.95
15	9.8	72.31	-0.80	73.11
20	12.25	76.67	-1.03	77.70
25	16.7	69.30	-1.40	70.70
30	19.2	71.61	-1.83	73.44
35	22.7	69.51	-2.22	71.73
40	25.2	70.58	-2.53	73.11
45	27.7	71.15	-2.96	74.11
50	30.0	71.88	-3.37	75.25
55	34.15	67.32	-3.91	71.23
60	35.4	70.11	-4.46	74.57
65	37.2	71.16	-5.12	76.28
70	40.3	68.69	-5.90	74.59
				Avg=73.68
				Std=2.03

SHEET___ OF___

PROJECT Radio locator accuracy evaluation DATE 9-13-75

UNDERGROUND LOCATION #17, Blue Springs Cave, Indiana

SURFACE LOCATION #17

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.H. Bishop

C.S. Bishop, K. Hoskins, D. Kelley

TRANSMITTING SCHEDULE Irregular

RECEIVING CONDITIONS Good

INITIAL DISTANCE FROM GROUND ZERO ____ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
0	--	--	0.00	--
10	6.7	70.91	+0.60	70.31
15	10.1	70.12	+1.02	69.10
20	13.0	72.10	+1.24	70.86
25	15.5	74.99	+0.41	74.58
30	18.5	74.54	+1.69	72.85
35	21.5	73.83	+1.93	71.90
40	24.1	74.26	+2.00	76.26
45	26.6	74.61	+2.01	72.60
50	29.45	73.50	+2.06	71.44
55	31.3	75.08	+2.13	72.95
60	34.3	73.03	+2.27	70.76
65	35.2	76.52	+2.39	74.13
70	37.0	74.74	+2.53	72.21
	Possible 0.9			
	error in			Avg=72.00
	all angles			Std=1.52

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 9-14-75

UNDERGROUND LOCATION #18, Blue Springs Cave, Indiana

SURFACE LOCATION #18

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.H. Bishop

C.S. Bishop, K. Hoskins, D. Kelley

TRANSMITTING SCHEDULE Irregular

RECEIVING CONDITIONS Good

INITIAL DISTANCE FROM GROUND ZERO ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
0	--	--	0.00	--
10	6.4	74.27	+0.42	73.85
15	10.2	69.42	+0.72	68.70
20	12.8	73.27	+0.93	72.34
25	16.3	71.11	+1.07	70.04
30	18.05	76.54	+1.23	75.31
35	22.3	70.90	+1.46	69.44
40	24.7	72.22	+1.75	70.47
45	27.2	72.69	+1.69	70.73
50	29.6	73.05	+2.21	70.84
55	31.6	74.20	+2.36	71.84
60	33.8	74.41	+2.46	71.95
65	35.7	75.13	+2.51	72.62
70	37.7	75.27	+2.55	72.72
				Avg=71.60
				Std=1.83

SHEET___ OF___

PROJECT Radio locator accuracy evaluation DATE 9-14-75

UNDERGROUND LOCATION #19, Blue Springs Cave, Indiana

SURFACE LOCATION #19

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.H. Bishop

C.S. Bishop, K. Hoskins, D. Kelley

TRANSMITTING SCHEDULE Irregular

RECEIVING CONDITIONS Good

INITIAL DISTANCE FROM GROUND ZERO ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
0	--	--	0.00	--
10	6.6	72.00	-0.12	72.12
15	10.0	70.84	-0.13	70.97
20	13.3	70.41	-0.26	70.67
25	16.6	69.75	-0.34	70.09
30	19.1	72.02	-0.41	72.43
35	22.5	70.20	-0.55	70.75
40	25.6	69.32	-0.61	69.93
45	27.8	70.85	-0.68	71.53
50	30.5	70.45	-0.86	71.31
55	32.6	71.39	-1.06	72.45
60	34.8	71.68	-1.25	72.93
65	37.1	71.41	-1.56	72.97
70	40.4	68.45	-1.89	70.34
				Avg=71.42
				Std=1.07

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 9-14-75

UNDERGROUND LOCATION #20, Blue Spring Cave, Indiana

SURFACE LOCATION #20

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR C.H. Bishop

NOTES C.S. Bishop

K. Hoskins, D. Kelley

TRANSMITTING SCHEDULE Irregular

RECEIVING CONDITIONS Good

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
0	--	--	0.00	--
10	6.6	72.00	-0.35	72.35
15	10.1	70.12	-0.48	70.60
20	13.3	70.41	-0.59	71.00
25	16.3	71.11	-0.77	71.88
30	19.4	70.81	-1.08	71.89
35	22.7	69.51	-1.28	70.79
40	25.8	68.70	-1.58	70.28
45	28.2	69.66	-2.07	71.73
50	31.7	67.20	-2.56	69.76
55	34.4	66.69	-3.20	69.89
60	36.3	67.85	-3.76	71.61
65	39.1	66.52	-4.59	71.11
70	42.0	64.78	-5.37	70.15
				Avg=71.00
				Std=0.84

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 3-29-75

UNDERGROUND LOCATION #1, Wright's Rotunda, Mammoth Cave, Kentucky

SURFACE LOCATION #1

UNDERGROUND PARTY MEMBERS:

OPERATOR C.S. Bishop

R. Hosley

K. Hoskins, J. Kearns

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES D. Kelley

TRANSMITTING SCHEDULE Transmit for one hour

RECEIVING CONDITIONS Poor. Slight power line and atmospheric noise.

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
20	5.0	190.46	+0.08	190.38
25	6.5	182.79	+0.13	182.66
30	7.7	184.82	+0.18	184.64
35	8.8	188.29	+0.03	188.26
40	10.2	185.11	-0.12	185.23
45	11.0	192.74	-0.32	193.06
50	12.0	195.81	-0.52	196.33
55	12.9	199.87	-0.57	200.44
60	15.1	185.00	-0.62	185.62
65	16.3	184.89	-0.72	185.61
70	17.4	185.75	-0.82	186.57
75	18.9	182.11	-1.12	183.23
80	18.9	183.68	-1.42	185.10
85	20.8	185.95	-1.62	187.57
90	21.1	193.81	-1.82	195.63
95	22.7	188.66	-1.92	190.58
100	23.8	188.31	-2.02	190.33
				Avg=188.90
				Std=5.03

NOTE: Took 30 min. to locate ground zero because signal acquired on back side of magnetic field. Nearby power line caused problems in initial search for ground zero, but not too bad at actual location.

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 3-29-75

UNDERGROUND LOCATION #2, Wright's Rotunda, Mammoth Cave, Kentucky

SURFACE LOCATION #2

UNDERGROUND PARTY MEMBERS:

OPERATOR C.S. Bishop

R. Hosley

K. Hoskins, J. Kearns

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES D. Kelley

TRANSMITTING SCHEDULE Transmit for one hour

RECEIVING CONDITIONS Poor. Slight power line and atmospheric noise.

INITIAL DISTANCE FROM GROUND ZERO ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
20	5.0	190.46	-0.22	190.68
25	5.9	201.54	-0.27	201.81
30	7.3	195.07	-0.32	195.39
35	9.2	179.96	-0.32	180.28
40	10.4	181.47	-0.32	181.79
45	11.5	184.13	-0.47	184.60
50	12.7	184.67	-0.62	185.29
55	13.2	195.16	-0.67	195.83
60	14.7	190.29	-0.72	191.01
65	15.8	191.08	-0.67	191.75
70	16.8	192.82	-0.62	193.44
75	17.2	201.49	-0.67	202.16
80	18.9	194.25	-0.72	194.97
85	19.8	196.24	-0.72	196.96
90	20.3	202.21	-0.72	202.93
95	21.4	201.42	-0.72	202.93
100	23.7	189.21	-0.72	189.93
NOTE:	Game called due to rain.			Avg=193.24
				Std=7.00

SHEET___ OF___

PROJECT Radio locator accuracy evaluation DATE 3-30-75

UNDERGROUND LOCATION #3, Wright's Rotunda, Mammoth Cave, Kentucky

SURFACE LOCATION #3

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.S. Bishop

TRANSMITTING SCHEDULE Transmit for one hour

RECEIVING CONDITIONS Poor. Slight power line and atmospheric noise.

INITIAL DISTANCE FROM GROUND ZERO ANGLE UNITS 2θ=grads DISTANCES Meters

L	θ	D (feet)	ΔH	D − ΔH (feet)
6	4.8	195.32	-0.30	195.62
8	6.5	191.91	-0.38	192.29
10	8.1	192.00	-0.45	192.45
12	9.4	198.04	-0.40	198.39
14	11.5	187.94	-0.35	188.29
16	12.6	195.47	-0.53	196.00
18	14.9	184.66	-0.70	185.36
20	15.6	195.50	-0.88	196.38
22	16.9	197.59	-1.05	198.62
24	18.4	196.80	-1.10	197.90
26	20.15	193.21	-1.15	194.36
28	21.95	189.38	-1.20	190.58
30	23.15	191.21	-1.25	192.41
				Avg=193.98
				Std=4.36

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation **DATE** 11-15-75

UNDERGROUND LOCATION #4, Wright's Rotunda, Mammoth Cave, Kentucky

SURFACE LOCATION #4

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.H. Bishop

C.S. Bishop

TRANSMITTING SCHEDULE Transmit 40 minutes, off 10 minutes.

RECEIVING CONDITIONS Clear, frosty; small amount of power line noise, no atmospheric noise.

INITIAL DISTANCE FROM GROUND ZERO ______ **ANGLE UNITS** 2θ=grads **DISTANCES** Feet

L	θ	D	ΔH	D − ΔH
50	12.4	189.29	-0.24	189.53
55	13.8	186.34	-0.23	186.57
60	15.2	183.72	-0.32	184.04
65	16.1	187.32	-0.22	187.54
70	17.3	186.90	-0.38	187.28
75	18.7	184.21	-0.25	184.46
80	19.6	186.74	-0.22	186.96
85	20.7	186.94	-0.26	187.20
90	21.55	189.35	-0.23	189.58
95	23.0	185.91	-0.09	186.00
100	23.6	190.11	-0.10	190.21
105	24.5	191.34	+0.02	191.32
110	26.0	187.25	+0.12	187.13
115	26.9	188.20	+0.12	188.06
120	27.85	188.53	+0.21	188.32
125	28.3	192.70	+0.38	192.32
130	29.1	193.87	+0.44	193.43
135	29.5	198.05	+1.02	197.03
140	30.3	198.85	+0.73	198.12
145	32.9	186.06	+0.75	185.31
150	33.4	188.85	+0.80	188.05
				Avg=188.05
				Std=3.73

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation **DATE** 11-15-75

UNDERGROUND LOCATION #5, Wright's Rotunda, Mammoth Cave, Kentucky

SURFACE LOCATION #5

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR C.S. Bishop

NOTES C.H. Bishop

F. Reid

TRANSMITTING SCHEDULE Transmit 40 minutes, off 10 minutes.

RECEIVING CONDITIONS Little power line noise, no atmospheric noise.

INITIAL DISTANCE FROM GROUND ZERO ______ **ANGLE UNITS** 2Θ=grads **DISTANCES** Feet

L	Θ	D	ΔH	D − ΔH
50	12.9	181.70	-0.19	181.89
55	14.0	183.56	-0.18	183.74
60	15.3	182.42	-0.28	182.70
65	16.0	188.56	-0.24	188.80
70	17.0	190.41	-0.24	190.65
75	18.0	191.93	-0.16	192.09
80	20.0	182.68	-0.12	182.80
85	20.9	184.97	-0.05	185.02
90	22.0	185.07	-0.22	185.29
95	22.5	190.53	-0.26	190.79
100	23.7	189.21	-0.10	189.31
105	24.9	187.84	-0.06	187.90
110	25.8	188.93	+0.07	188.86
115	26.3	193.18	+0.06	193.12
120	27.1	194.67	+0.08	194.59
125	28.0	195.15	+0.17	194.98
130	30.0	186.89	+0.14	186.75
135	30.3	191.75	+0.25	191.50
140	32.0	185.97	+0.29	185.68
145	33.0	185.35	+0.30	185.05
150	33.8	186.02	+0.43	185.59
				Avg=187.96
				Std=3.96

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 11-15-75

UNDERGROUND LOCATION #6, Wright's Rotunda, Mammoth Cave, Kentucky

SURFACE LOCATION #6

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.H. Bishop

C.S. Bishop

TRANSMITTING SCHEDULE Transmit 40 minutes, off 10 minutes.

RECEIVING CONDITIONS Little power line noise, no atmospheric noise.

INITIAL DISTANCE FROM GROUND ZERO ____ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
50	12.8	183.17	-0.05	183.22
55	14.4	178.24	-0.01	178.25
60	14.9	187.61	-0.09	187.70
65	15.9	189.81	+0.02	189.79
70	17.0	190.41	+0.04	190.37
75	17.9	193.08	+0.03	193.05
80	20.0	182.68	+0.04	182.64
85	20.6	187.93	+0.07	187.86
90	21.0	194.83	+0.06	194.77
95	22.7	188.66	+0.15	188.51
100	23.6	190.11	+0.25	189.86
105	24.8	188.70	+0.19	188.51
110	25.55	191.06	+0.26	190.80
115	25.55	199.74	+0.33	199.41
120	28.0	187.34	+0.38	186.96
125	28.6	190.30	+0.59	189.71
130	29.8	188.41	+0.39	188.02
135	31.2	185.02	+0.57	184.45
140	32.3	183.82	+0.67	183.15
145	33.2	183.94	+0.65	183.29
150	34.1	183.94	+0.68	183.26
				Avg=187.42
				Std=4.04

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 11-15-75

UNDERGROUND LOCATION #7, Wright's Rotunda, Mammoth Cave, Kentucky

SURFACE LOCATION #7

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR C.S. Bishop

NOTES C.H. Bishop

F. Reid

TRANSMITTING SCHEDULE Transmit 40 minutes, off 10 minutes.

RECEIVING CONDITIONS Small amount power line noise, no atmospheric noise. Clear null.

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
50	12.4	189.29	+0.18	189.11
55	13.7	187.75	+0.18	187.57
60	14.9	187.61	+0.17	187.44
65	15.8	191.08	+0.11	190.97
70	17.8	181.29	+0.14	181.15
75	18.9	182.11	+0.18	181.93
80	19.2	190.97	+0.27	190.70
85	20.0	194.10	+0.29	193.81
90	21.5	189.84	+0.41	189.43
95	22.7	188.66	+0.55	188.11
100	24.3	183.93	+0.60	183.33
105	25.3	184.45	+0.71	183.74
110	26.1	186.43	+0.90	185.53
115	26.9	188.18	+0.95	187.23
120	27.5	191.36	+0.94	190.42
125	28.8	188.73	+1.16	187.57
130	29.6	189.94	+1.46	188.48
135	30.1	193.30	+1.45	191.85
140	31.0	193.39	+1.63	191.76
145	33.0	185.35	+1.86	183.49
150	33.5	188.14	+2.02	186.12
				Avg=187.51
				Std=7.02

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 11-15-75

UNDERGROUND LOCATION #8, Wright's Rotunda, Mammoth Cave, Kentucky

SURFACE LOCATION #8

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR C.S. Bishop

NOTES C.H. Bishop

F. Reid

TRANSMITTING SCHEDULE Transmit 40 minutes, off 10 minutes.

RECEIVING CONDITIONS Small amount of power line noise, no atmospheric noise, added continuous noise.

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
50	12.3	190.88	+0.27	190.61
55	13.6	189.19	+0.26	188.93
60	16.2	171.78	+0.25	171.53
65	16.3	184.89	+0.27	184.62
70	17.5	184.62	+0.35	184.27
75	18.3	188.55	+0.33	188.22
80	19.2	190.97	+0.31	190.66
85	19.9	195.16	+0.31	194.85
90	21.0	194.83	+0.30	194.53
95	22.5	190.53	+0.33	190.20
100	24.8	179.72	+0.21	179.51
105	26.0	178.74	+0.27	178.47
110	26.6	182.37	+0.33	182.04
115	27.1	186.56	+0.31	186.25
120	29.0	179.69	+0.30	179.39
125	29.4	184.13	+0.28	183.85
130	30.7	181.72	+0.24	181.48
136	31.5	184.21	+0.35	183.86
140	33.0	178.96	+0.14	178.82
145	34.0	178.47	+0.12	178.35
150	35.5	174.64	+0.09	174.55
				Avg=184.05
				Std=6.28

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 3-1-75

UNDERGROUND LOCATION #1, Rocky Mountain, Mammoth Cave, Kentucky

SURFACE LOCATION #1

UNDERGROUND PARTY MEMBERS:

OPERATOR C.S. Bishop

R. Hosley

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES W. Eidson

C.H. Bishop

TRANSMITTING SCHEDULE Transmit until notified from surface

RECEIVING CONDITIONS Excellent

INITIAL DISTANCE FROM GROUND ZERO ____ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
0	--	--	0.000	--
10	2.65	180.037	+0.250	179.787
15	3.8	188.175	+0.552	187.623
20	4.9	194.371	+0.099	194.272
25	6.15	193.287	+0.040	193.247
30	6.9	206.511	-0.165	206.676
35	8.1	204.830	-0.078	204.908
40	9.6	196.937	+0.480	196.457
45	10.7	198.288	-0.518	198.806
50	11.9	197.510	-0.859	198.369
55	12.8	201.488	-1.016	202.504
60	14.2	197.304	-1.116	198.420
65	14.7	206.145	-1.273	207.418
70	16.1	201.726	-1.435	203.161
75	17.6	196.601	-1.309	197.910
80	18.5	198.781	-1.556	200.337
				Avg=199.293
				Std=5.464

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 3-1-75

UNDERGROUND LOCATION #2, Rocky Mountain, Mammoth Cave, Kentucky

SURFACE LOCATION #2

UNDERGROUND PARTY MEMBERS:

OPERATOR C.S. Bishop

R. Hosley

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES W. Eidson

C.H. Bishop

TRANSMITTING SCHEDULE Transmit until notified from surface

RECEIVING CONDITIONS Excellent

INITIAL DISTANCE FROM GROUND ZERO ____ ANGLE UNITS 2θ=grads DISTANCES Feet

L	Θ	D	ΔH	D − ΔH
0	--	--	0.000	--
10	2.4	198.818	-0.118	198.936
15	3.4	210.379	-0.046	210.425
20	4.55	209.398	+0.254	209.144
25	5.7	208.669	-0.626	209.295
30	6.7	212.739	-0.856	213.595
35	8.0	207.427	-1.196	208.623
40	9.35	202.309	-1.442	203.731
45	10.6	200.206	-1.675	201.881
50	11.4	206.438	-1.856	208.294
55	12.9	199.869	-1.813	201.682
60	13.6	206.391	-2.001	208.392
65	14.8	204.685	-2.184	206.869
70	16.4	197.821	-2.114	199.935
75	17.1	202.743	-1.496	204.239
80	18.0	204.721	-2.363	207.084
				Avg=206.142
				Std=4.209

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 3-1-75

UNDERGROUND LOCATION #3, Rocky Mountain, Mammoth Cave, Kentucky

SURFACE LOCATION #3

UNDERGROUND PARTY MEMBERS:

OPERATOR C.S. Bishop

R. Hosley

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES W. Eidson

C.H. Bishop

TRANSMITTING SCHEDULE Transmit until notified from surface

RECEIVING CONDITIONS Excellent

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
0	--	--	0.000	--
10	2.6	183.504	-0.006	183.510
15	3.55	201.467	+0.032	201.435
20	4.6	207.112	-0.189	207.301
25	5.9	201.544	-0.281	201.825
30	7.1	200.632	-0.411	201.043
35	8.1	204.830	-0.487	205.317
40	9.6	196.937	-0.611	197.548
45	10.5	202.160	-0.572	202.732
50	11.4	206.438	-0.483	206.921
55	12.6	204.801	-0.673	205.474
60	14.2	197.304	-0.761	198.065
65	15.35	196.987	-0.745	197.732
70	16.1	201.726	-0.971	202.697
75	17.5	197.802	-0.989	198.791
80	18.0	204.721	-0.914	205.635
NOTE:	Two sets of measurements made for depth determination. They were taken in opposite directions from ground zero. See following sheet.			Avg=202.323 Std=3.433

SHEET 1 OF 2

PROJECT Radio locator accuracy evaluation DATE 3-1-75

UNDERGROUND LOCATION #3, Rocky Mountain, Mammoth Cave, Kentucky

SURFACE LOCATION #3

UNDERGROUND PARTY MEMBERS:

OPERATOR C.S. Bidhop

R. Hosley

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES W. Eidson

C.H. Bishop

TRANSMITTING SCHEDULE Transmit until notified from surface

RECEIVING CONDITIONS Excellent

INITIAL DISTANCE FROM GROUND ZERO ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
0	--	--	0.000	--
10	2.1	227.254	-0.123	227.377
15	4.0	178.735	-0.217	178.952
20	5.0	190.463	-0.159	190.622
25	6.0	198.159	-0.213	198.372
30	6.9	206.511	-0.238	206.749
35	8.2	202.295	-0.266	202.561
40	9.6	196.937	-0.496	197.406
45	10.5	202.160	-0.622	202.782
50	11.7	200.991	-0.804	201.795
55	12.5	206.497	-0.897	207.394
60	14.5	193.037	-1.136	194.173
65	15.7	206.145	-1.286	207.431
70	16.6	195.293	-1.490	196.783
75	18.9	182.107	-1.680	183.787
80	18.4	199.944	-1.307	201.251
				Avg=201.518
				Std=4.504
			Combined	Avg=201.969
			Combined	Std=3.873

PROJECT Radio locator accuracy evaluation DATE 3-1-75

UNDERGROUND LOCATION #4, Rocky Mountain, Mammoth Cave, Kentucky

SURFACE LOCATION #4

UNDERGROUND PARTY MEMBERS:

OPERATOR C.S. Bishop

R. Hosley

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES W. Eidson

C.H. Bishop

TRANSMITTING SCHEDULE Transmit until notified from surface

RECEIVING CONDITIONS Excellent

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
0	--	--	0.000	--
10	2.7	176.697	+0.801	175.887
15	3.9	183.334	+1.126	182.208
20	5.0	190.463	+1.425	189.038
25	5.9	201.544	+1.691	199.853
30	6.5	219.348	+1.945	217.403
35	8.6	192.744	+2.397	190.347
40	9.7	194.865	+2.351	192.514
45	11.1	190.959	+2.593	188.366
50	12.5	187.725	+2.955	184.770
55	13.6	189.192	+3.149	186.043
60	14.45	193.737	+3.331	190.406
65	15.8	191.078	+3.454	187.624
70	16.3	199.107	+3.604	195.503
75	17.0	204.013	+3.944	200.069
80	19.0	193.143	+4.114	189.029
NOTE:	Two sets of measurements made for depth			Avg=191.130
	determination. They were taken in			Std=4.984
	opposite directions from ground zero.			
	See following sheet.			

SHEET 1 OF 2

PROJECT Radio locator accuracy evaluation DATE 3-1-75

UNDERGROUND LOCATION #4, Rocky Mountain, Mammoth Cave, Kentucky

SURFACE LOCATION #4

UNDERGROUND PARTY MEMBERS:

OPERATOR C.S. Bishop

R. Hosley

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES W. Eidson

C.H. Bishop

TRANSMITTING SCHEDULE Transmit until notified from surface

RECEIVING CONDITIONS Excellent

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
0	--	--	0.000	--
10	3.11	153.859	-0.425	154.284
15	3.6	198.661	-0.598	199.259
20	4.3	221.627	-0.922	222.549
25	5.9	201.544	-1.172	202.716
30	7.3	195.073	-1.419	196.492
35	8.5	195.048	-1.855	196.903
40	9.8	192.835	-1.945	194.780
45	10.8	196.406	-2.252	198.658
50	12.1	194.142	-2.551	196.693
55	13.5	190.651	-2.850	193.501
60	14.2	197.304	-3.230	200.534
65	15.6	193.304	-3.230	200.534
70	17.55	184.053	-3.798	187.851
75	18.0	191.926	-4.132	196.049
80	19.5	187.784	-4.490	192.274
85	19.8	196.237	-4.776	201.013
90	21.17	187.908	-5.207	193.115
95	22.6	189.590	-5.696	195.285
100	23.3	192.868	-6.169	199.037
		Combined Avg=	194.305	Avg=196.545
		Combined Std=	4.971	Std=3.642

SHEET 2 OF 2

PROJECT Radio locator accuracy evaluation DATE 11-16-75

UNDERGROUND LOCATION #5, Rocky Mountain, Mammoth Cave, Kentucky

SURFACE LOCATION #5

UNDERGROUND PARTY MEMBERS:

OPERATOR C.S. Bishop

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.H. Bishop

K. Hoskins

TRANSMITTING SCHEDULE Transmit until notified from surface

RECEIVING CONDITIONS Good

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
50	11.4	206.44	+0.77	205.67
55	12.3	209.97	+0.84	209.13
60	13.9	201.75	+0.86	200.89
65	14.5	209.12	+0.96	208.16
70	16.1	201.73	+0.98	200.75
75	17.2	201.49	+1.01	200.48
80	17.8	207.19	+1.26	205.93
85	19.2	202.90	+1.49	201.41
90	20.2	203.30	+1.79	201.51
95	21.0	205.65	+1.96	203.69
100	22.15	204.09	+2.19	201.90
105	23.95	196.33	+2.69	193.64
110	24.2	203.27	+2.62	200.65
115	24.8	206.68	+2.80	203.88
120	25.3	210.80	+3.04	207.76
125	26.6	207.24	+3.23	204.01
130	27.2	209.99	+3.73	206.26
135	27.8	212.55	+4.17	208.38
140	29.1	208.78	+4.33	204.45
145	29.8	210.15	+4.71	205.44
150	30.5	211.36	+5.26	206.10
				Avg=203.81
				Std=3.63

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 11-16-75

UNDERGROUND LOCATION #6, Rocky Mountain, Mammoth Cave, Kentucky

SURFACE LOCATION #6

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.H. Bishop

TRANSMITTING SCHEDULE Transmit until notified from surface

RECEIVING CONDITIONS Good

INITIAL DISTANCE FROM GROUND ZERO ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
50	11.2	201.23	+2.36	207.87
55	12.5	206.50	+2.49	204.01
60	13.6	206.39	+2.61	203.78
65	14.7	206.14	+2.79	203.35
70	15.7	207.16	+2.93	204.23
75	16.8	206.60	+3.11	203.49
80	17.8	207.19	+3.49	203.70
85	18.7	208.77	+3.68	205.09
90	20.2	203.30	+3.66	199.64
95	20.5	211.16	+3.85	207.31
100	21.0	216.48	+4.07	212.41
105	22.9	206.48	+4.37	202.11
110	23.2	213.18	+4.57	208.61
115	24.7	207.63	+4.67	202.87
120	26.0	204.28	+5.19	199.09
125	26.6	207.24	+5.24	202.00
130	27.3	209.09	+5.65	203.44
135	27.8	212.55	+5.77	206.78
140	29.3	207.07	+5.93	201.14
145	30.1	207.62	+5.86	201.76
150	30.5	211.36	+6.05	205.31
				Avg=204.19
				Std=3.12

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 11-16-75

UNDERGROUND LOCATION #7, Rocky Mountain, Mammoth Cave, Kentucky

SURFACE LOCATION #7

UNDERGROUND PARTY MEMBERS:

OPERATOR D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR C.S. Bishop

NOTES C.H. Bishop

K. Hoskins, F. Reid

TRANSMITTING SCHEDULE Transmit until notified from surface

RECEIVING CONDITIONS Good

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
50	12.1	194.14	-0.02	194.16
55	13.0	198.27	-0.26	198.53
60	14.2	197.30	-0.52	197.82
65	15.2	199.03	-0.45	199.48
70	16.4	197.82	-0.55	198.37
75	17.3	200.24	-0.29	200.53
80	18.3	201.12	-0.52	201.64
85	19.7	197.32	-0.42	197.74
90	20.5	200.05	-0.63	200.68
95	21.5	200.39	-0.54	200.93
100	23.2	193.80	-0.41	194.21
105	23.0	205.48	-0.31	205.79
110	24.0	205.19	-0.44	205.63
115	25.9	196.64	-0.61	197.25
120	26.4	200.70	-0.71	201.41
125	27.5	199.33	-0.57	199.90
130	27.7	205.55	-0.41	205.96
135	29.3	199.68	-0.04	199.72
140	30.8	194.93	+0.11	194.82
145	31.2	198.72	+0.31	198.41
150	32.5	195.44	+0.39	195.05
				Avg=199.43
				Std=3.49

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 11-16-75

UNDERGROUND LOCATION #8, Rocky Mountain, Mammoth Cave, Kentucky

SURFACE LOCATION #8

UNDERGROUND PARTY MEMBERS:

OPERATOR D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.H. Bishop

K. Hoskins

TRANSMITTING SCHEDULE Transmit until notified from surface

RECEIVING CONDITIONS Good

INITIAL DISTANCE FROM GROUND ZERO ____ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
50	12.1	194.14	+0.20	193.94
55	13.2	195.16	+0.12	195.04
60	14.5	193.04	+0.02	193.02
65	15.6	193.66	-0.12	193.78
70	16.5	196.55	-0.15	196.70
75	17.9	193.08	-0.30	193.38
80	19.0	193.14	-0.29	193.43
85	20.1	193.05	-0.36	193.41
90	21.4	190.82	-0.36	191.18
95	22.0	195.35	-0.34	195.69
100	23.5	191.02	-0.34	191.36
105	24.05	195.40	-0.24	195.64
110	24.8	197.69	-0.20	197.89
115	26.15	194.47	-0.02	194.49
120	27.3	193.01	-0.21	193.22
125	28.6	190.30	+0.02	190.28
130	29.1	193.87	+0.09	193.78
135	29.5	198.05	+0.21	197.84
140	30.7	195.70	+0.16	195.54
145	31.25	198.33	+0.36	197.97
150	31.1	206.39	+0.45	205.94
				Avg=194.93
				Std=3.30

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 11-16-75

UNDERGROUND LOCATION #9, Rocky Mountain, Mammoth Cave, Kentucky

SURFACE LOCATION #9

UNDERGROUND PARTY MEMBERS:

OPERATOR D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.H. Bishop

K. Hoskins

TRANSMITTING SCHEDULE Transmit until notified from surface

RECEIVING CONDITIONS Good

INITIAL DISTANCE FROM GROUND ZERO ANGLE UNITS 2Θ=grads DISTANCES Feet

L	Θ	D	ΔH	D − ΔH
50	9.75	242.31	-1.63	243.94
55	10.5	247.08	-1.72	248.80
60	11.0	256.99	-2.06	259.05
65	13.1	232.47	-2.31	234.78
70	14.2	230.19	-2.25	232.44
75	14.5	241.30	-2.41	243.71
80	15.7	236.75	-2.29	239.04
85	16.2	243.35	-2.41	245.76
90	17.3	240.29	-2.45	242.74
95	18.4	237.43	-2.65	240.08
100	19.1	240.06	-2.75	242.81
105	19.3	237.37	-2.80	240.17
110	19.7	255.36	-2.63	257.99
115	21.7	240.10	-2.72	242.82
120	22.6	239.48	-2.69	242.17
125	23.5	238.78	-2.71	241.49
130	23.9	243.65	-2.23	245.88
135	23.7	255.43	-2.26	257.69
141	25.8	242.17	-1.25	243.42
145	26.1	245.74	-2.32	248.06
150	26.5	249.77	-2.40	252.17
				Avg=245.00
				Std=7.03

SHEET___ OF___

PROJECT Radio locator accuracy evaluation DATE 11-16-75

UNDERGROUND LOCATION #10, Rocky Mountain, Mammoth Cave, Kentucky

SURFACE LOCATION #10

UNDERGROUND PARTY MEMBERS:

OPERATOR D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR C.S. Bishop

NOTES C.H. Bishop

F. Reid

TRANSMITTING SCHEDULE Transmit until notified from surface

RECEIVING CONDITIONS Good

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
50	11.6	202.78	+0.79	201.99
55	12.6	204.80	+0.91	203.89
60	14.2	197.30	+0.92	196.38
65	15.1	200.42	+0.99	199.43
70	15.9	204.41	+1.05	203.36
75	17.0	204.01	+0.98	203.03
80	18.0	204.72	+1.04	203.68
85	20.0	194.10	+1.07	193.03
90	20.8	196.89	+1.12	195.77
95	21.2	203.52	+1.24	202.28
100	22.5	200.56	+1.59	198.97
105	23.2	203.49	+1.82	201.67
110	23.1	214.22	+1.93	212.29
115	24.4	210.54	+2.48	208.06
120	25.6	207.96	+2.78	205.18
125	26.4	209.06	+2.65	206.41
130	26.5	216.47	+2.90	213.57
135	27.5	215.28	+3.16	212.12
140	28.2	216.73	+3.45	213.28
145	30.2	206.78	+3.93	202.85
150	31.0	207.20	+4.27	202.93
				Avg=203.82
				Std=5.67

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 11-16-75

UNDERGROUND LOCATION #11, Rocky Mountain, Mammoth Cave, Kentucky

SURFACE LOCATION #11

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR C.S. Bishop

NOTES C.H. Bishop

F. Reid

TRANSMITTING SCHEDULE Transmit until notified from surface

RECEIVING CONDITIONS Good

INITIAL DISTANCE FROM GROUND ZERO ____ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
50	11.9	197.51	+1.03	196.48
55	13.0	198.27	+1.30	196.97
60	13.2	212.90	+1.16	211.74
65	15.4	196.31	+1.39	194.92
70	16.2	200.41	+1.42	198.99
75	17.0	204.01	+1.55	202.46
80	18.5	198.78	+1.84	196.94
85	19.2	202.90	+2.11	200.79
90	19.4	212.44	+2.41	210.03
95	20.5	211.16	+2.65	208.51
100	21.8	207.73	+2.91	204.82
105	22.9	206.48	+3.07	203.41
110	25.2	194.11	+3.05	191.06
115	25.3	202.01	+3.24	198.77
120	25.9	205.19	+3.47	201.72
125	26.6	207.24	+3.75	203.49
130	27.8	204.68	+4.16	200.52
135	28.9	202.99	+4.60	198.39
140	29.8	202.90	+4.64	198.26
145	30.3	205.95	+5.17	200.78
150	32.6	194.69	+5.56	189.13
				Avg=200.39
				Std=5.60

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation **DATE** 11-16-75

UNDERGROUND LOCATION #12, Rocky Mountain, Mammoth Cave, Kentucky

SURFACE LOCATION #12

UNDERGROUND PARTY MEMBERS:

OPERATOR D. Kelley

D..Pollock

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.H. Bishop

C.S. Bishop

TRANSMITTING SCHEDULE Transmit until notified from surface

RECEIVING CONDITIONS Good

INITIAL DISTANCE FROM GROUND ZERO ______ **ANGLE UNITS** 2θ=grads **DISTANCES** Feet

L	θ	D	ΔH	D − ΔH
50	12.2	192.50	+0.04	192.46
55	12.9	199.87	+0.14	199.73
60	14.1	198.77	+0.36	198.41
65	15.1	200.42	+0.24	200.18
70	16.1	201.73	+0.51	201.22
75	18.0	191.93	+0.64	191.29
80	18.8	191.29	+0.60	190.69
85	19.8	196.24	+0.83	195.41
90	20.8	196.89	+1.00	195.89
95	22.1	195.89	+1.19	194.70
100	22.3	202.56	+1.11	201.45
105	23.35	202.02	+1.60	200.42
110	24.0	205.19	+1.49	203.70
115	25.6	199.30	+1.76	197.54
120	25.9	205.19	+1.85	203.34
125	28.9	186.95	+2.50	185.45
130	28.5	198.74	+2.55	196.19
135	29.8	195.65	+2.83	192.82
140	30.4	198.06	+2.87	195.19
145	31.1	199.51	+3.07	196.44
150	31.7	201.59	+3.39	198.20
				Avg=197.26
				Std=3.83

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 10-11-75

UNDERGROUND LOCATION #1, Silliman Avenue, Mammoth Cave, Kentucky

SURFACE LOCATION #1

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Richers

SURFACE PARTY MEMBERS:

OPERATOR C.S. Bishop

NOTES C.H. Bishop

S. Schillereff

TRANSMITTING SCHEDULE Transmit 45 minutes, off 10 minutes.

RECEIVING CONDITIONS Warm, partly cloudy. Wet ground. Electrical storm last night. Power line close. Weak signal, very wide null.

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
10	6.0	79.26	-0.20	79.46
15	6.9	103.26	-0.20	103.46
20	7.3	130.05	-0.37	130.42
25	8.0	148.16	-0.34	148.50
Line reversed				
180° due to				
power line				
proximity.				
50	4.7	506.71	+0.86	505.86
55	6.5	402.14	+0.95	401.19
60	6.6	431.99	+1.02	430.97
65	8.4	366.61	+1.30	365.31
70	9.4	352.12	+1.40	350.72
75	9.0	354.18	+1.48	352.70
80	10.5	359.40	+1.48	357.92
85	10.9	367.50	+1.67	365.83
				Avg=299.36
				Std=143.35

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 10-11-75

UNDERGROUND LOCATION #2, Silliman Avenue, Mammoth Cave, Kentucky

SURFACE LOCATION #2

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Richers

SURFACE PARTY MEMBERS:

OPERATOR C.S. Bishop

NOTES C.H. Bishop

S. Schillereff

TRANSMITTING SCHEDULE Transmit 45 minutes, off 10 minutes.

RECEIVING CONDITIONS Warm, partly cloudy; wet ground; electrical storm last night; power line close; weak signal, very wide null.

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
20	2.2	433.83	+0.25	433.58
30	4.4	324.85	+0.68	324.17
40	5.2	366.19	+0.57	365.52
50	6.9	344.18	+0.67	343.51
60	7.3	390.15	+1.11	389.04
70	7.1	468.14	+1.18	466.96
80	8.5	445.82	+1.29	444.53
90	10.3	412.36	+1.53	410.83
100	12.1	388.28	+1.80	386.48
110	12.5	412.99	+2.21	410.78
120	13.3	422.47	+2.31	420.16
130	15.4	392.63	+2.60	390.03
140	16.7	388.10	+2.91	385.19
				Avg=397.76
				Std=39.70

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 10-11-75

UNDERGROUND LOCATION #3, Silliman Avenue, Mammoth Cave, Kentucky

SURFACE LOCATION #3

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Richers

SURFACE PARTY MEMBERS:

OPERATOR C.S. Bishop

NOTES C.H. Bishop

S. Schillereff

TRANSMITTING SCHEDULE Transmit 45 minutes, off 10 minutes.

RECEIVING CONDITIONS Warm, partly cloudy; wet ground; electrical storm last night; power line close; weak signal, very wide null.

INITIAL DISTANCE FROM GROUND ZERO ____ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
20	3.0	318.00	+0.34	317.66
30	3.0	476.99	+0.43	476.56
40	5.6	339.87	+0.62	339.25
50	7.0	339.22	+1.04	338.18
60	7.8	364.83	+1.12	363.71
70	9.6	344.64	+1.28	343.36
80	10.9	345.88	+1.71	344.17
90	11.1	381.92	+1.72	380.20
100	13.8	338.79	+1.88	336.91
110	15.2	336.82	+2.17	334.65
120	16.0	348.10	+2.48	345.62
130	17.8	336.68	+2.77	333.91
140	19.8	323.21	+3.13	320.08
150	18.2	379.33	+3.33	376.00
				Avg=353.59
				Std=39.78

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 10-11-75

UNDERGROUND LOCATION #4, Silliman Avenue, Mammoth Cave, Kentucky

SURFACE LOCATION #4

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Richers

SURFACE PARTY MEMBERS:

OPERATOR C.H. Bishop

NOTES S. Schillereff

C.S. Bishop

TRANSMITTING SCHEDULE Transmit 45 minutes, off 10 minutes.

RECEIVING CONDITIONS Partly sunny; wet ground; electrical storm last night; power line close; weak signal, very wide null; 70° F.

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
20	5.6	169.94	+0.45	169.49
30	7.0	203.53	+0.58	202.95
40	7.4	256.54	+0.61	255.93
50	9.0	262.91	+0.69	262.22
60	10.9	259.41	+0.84	258.57
70	12.2	269.50	+0.95	268.55
80	11.8	318.78	+1.19	317.59
90	15.2	275.58	+1.48	274.10
100	15.2	306.20	+1.67	304.53
110	15.4	332.22	+2.30	329.92
120	17.2	322.38	+2.15	320.23
				Avg=269.46
				Std=49.57

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 10-11-75

UNDERGROUND LOCATION #5, Silliman Avenue, Mammoth Cave, Kentucky

SURFACE LOCATION #5

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Richers

SURFACE PARTY MEMBERS:

OPERATOR C.S. Bishop

NOTES C.H. Bishop

S. Schillereff

TRANSMITTING SCHEDULE Transmit 45 minutes, off 10 minutes.

RECEIVING CONDITIONS 70° F.; wet ground; electrical storm last night; power line close; weak signal, very wide null.

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
50	10.6	222.45	+0.87	221.58
60	11.5	245.51	+1.01	244.50
70	12.8	256.44	+1.33	255.11
80	14.8	251.92	+1.63	250.29
90	15.3	273.69	+1.59	272.10
100	15.7	295.94	+1.98	293.96
110	16.5	308.86	+2.39	306.47
120	17.9	308.92	+2.57	306.35
130	19.3	308.58	+2.87	305.71
140	21.2	299.92	+3.22	296.70
150	21.8	311.59	+3.42	308.17
				Avg=278.27
				Std=30.87

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 10-11-75

UNDERGROUND LOCATION #6, Silliman Avenue, Mammoth Cave, Kentucky

SURFACE LOCATION #6

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Richers

SURFACE PARTY MEMBERS:

OPERATOR C.H. Bishop

NOTES C.S. Bishop

S. Schillereff

TRANSMITTING SCHEDULE Transmit 45 minutes, off 10 minutes.

RECEIVING CONDITIONS 70° F.; wet ground; electrical storm last night; power line close; weak signal, very wide null.

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
50	9.8	241.04	+0.94	240.10
60	11.2	252.28	+1.10	251.18
70	13.4	244.53	+1.25	243.28
80	14.9	250.15	+1.39	248.76
90	16.5	252.71	+1.40	251.31
100	18.2	252.88	+1.30	251.58
110	17.9	283.18	+1.55	281.63
120	20.4	268.16	+1.64	266.52
130	22.0	267.32	+1.66	268.98
140	23.1	272.64	+1.80	270.84
150	24.2	277.19	+1.85	275.34
				Avg=259.05
				Std=14.0

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 10-11-75

UNDERGROUND LOCATION #7, Silliman Avenue, Mammoth Cave, Kentucky

SURFACE LOCATION #7

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Richers

SURFACE PARTY MEMBERS:

OPERATOR C.S. Bishop

NOTES S. Schillereff

C.H. Bishop

TRANSMITTING SCHEDULE Transmit 45 minutes, off 10 minutes.

RECEIVING CONDITIONS Electrical storm last night; power line close; weak signal, very wide null.

INITIAL DISTANCE FROM GROUND ZERO ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
50	10.0	236.12	+0.89	235.23
60	11.5	245.51	+1.04	244.47
70	13.7	238.96	+1.22	237.74
80	14.3	261.15	+1.28	259.87
90	15.2	275.58	+1.40	274.18
100	17.7	260.55	+1.32	259.23
110	18.5	273.32	+1.53	271.79
120	20.1	272.54	+1.55	270.99
130	20.6	287.42	+1.77	285.65
140	22.4	282.18	+2.02	280.16
150	23.8	282.47	+2.01	280.46
				Avg=263.62
				Std=17.75

SHEET___ OF___

PROJECT Radio locator accuracy evaluation DATE 10-11-75

UNDERGROUND LOCATION #8, Silliman Avenue, Mammoth Cave, Kentucky

SURFACE LOCATION #8

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Richers

SURFACE PARTY MEMBERS:

OPERATOR C.S. Bishop

NOTES S. Schillereff

C.H. Bishop

TRANSMITTING SCHEDULE Transmit 45 minutes, off 10 minutes.

RECEIVING CONDITIONS Electrical storm last night; power line close; weak signal, very wide null.

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
50	11.0	214.16	+1.13	213.03
60	12.5	225.27	+1.18	224.09
70	14.1	231.89	+1.32	230.57
80	15.6	238.35	+1.63	236.72
90	16.6	251.09	+1.67	249.42
100	17.3	266.99	+1.69	265.30
110	19.7	255.36	+1.70	253.66
120	20.4	268.16	+1.99	266.17
130	21.8	270.04	+2.31	267.73
140	22.7	278.02	+2.39	275.63
150	24.1	278.49	+2.49	276.00
170	24.6	308.35	+3.03	305.32
190	28.3	292.21	+3.31	289.60
				Avg=257.94
				Std=26.70

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 10-11-75

UNDERGROUND LOCATION #9, Silliman Avenue, Mammoth Cave, Kentucky

SURFACE LOCATION #9

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Richers

SURFACE PARTY MEMBERS:

OPERATOR C.H. Bishop

NOTES S. Schillereff

C.S. Bishop

TRANSMITTING SCHEDULE Transmit 45 minutes, off 10 minutes

RECEIVING CONDITIONS Electrical storm last night; power line close; weak signal, very wide null.

INITIAL DISTANCE FROM GROUND ZERO ____ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
50	10.8	218.23	+0.78	217.45
60	11.7	241.19	+0.90	240.29
70	13.3	211.24	+1.00	210.24
80	15.2	244.96	+1.11	243.85
90	15.0	279.45	+1.13	278.32
100	18.4	249.93	+1.17	248.76
110	19.6	256.77	+1.29	255.48
120	21.3	255.75	+1.17	254.58
130	24.0	242.50	+1.41	241.09
140	25.2	247.05	+1.54	245.51
150	26.5	249.77	+1.59	248.18
				Avg=243.98
				Std=18.25

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation **DATE** 10-11-75

UNDERGROUND LOCATION #10, Silliman Avenue, Mammoth Cave, Kentucky

SURFACE LOCATION #10

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Richers

SURFACE PARTY MEMBERS:

OPERATOR C.S. Bishop

NOTES S. Schillereff

C.H. Bishop

TRANSMITTING SCHEDULE Transmit 45 minutes, off 10 minutes

RECEIVING CONDITIONS Wet ground; electrical storm last night; power line close; weak signal, very wide null.

INITIAL DISTANCE FROM GROUND ZERO ______ **ANGLE UNITS** 2θ=grads **DISTANCES** Feet

L	θ	D	ΔH	D − ΔH
48	8.8	268.99	+0.356	268.64
58	9.9	276.73	+0.367	276.36
68	11.8	270.96	+0.547	270.41
78	13.8	264.26	+0.383	263.88
90	13.8	304.91	+0.644	304.27
100	16.9	273.73	+0.677	273.05
110	18.2	278.17	+0.740	277.43
120	18.9	291.37	+0.898	290.47
130	19.6	303.46	+1.036	302.42
				Avg=280.77
				Std=14.77

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 11-1-75

UNDERGROUND LOCATION #11, Silliman Avenue, Mammoth Cave, Kentucky

SURFACE LOCATION #11

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.H. Bishop

C.S. Bishop, N. Eidson

TRANSMITTING SCHEDULE Transmit 50 minutes, off 10 minutes.

RECEIVING CONDITIONS Clear, dry; no noise from power line; temperature 60's.

INITIAL DISTANCE FROM GROUND ZERO ____ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
50	8.9	265.91	-0.80	266.71
60	10.9	259.41	-1.03	260.44
70	11.8	278.93	-1.05	279.98
80	13.9	269.00	-1.10	271.10
90	15.0	279.45	-1.42	280.87
100	16.0	290.09	-1.61	291.70
110	17.5	290.11	-1.82	291.93
120	18.4	299.92	-1.89	301.81
130	20.1	295.25	-1.39	296.64
140	20.3	314.54	-2.19	316.73
150	21.7	313.18	-2.27	315.45
				Avg=288.40
				Std=18.76

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 11-1-75

UNDERGROUND LOCATION #12, Silliman Avenue, Mammoth Cave, Kentucky

SURFACE LOCATION #12

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.H. Bishop

C.S. Bishop, N. Eidson

TRANSMITTING SCHEDULE Transmit 50 minutes, off 10 minutes.

RECEIVING CONDITIONS Clear, dry, temperature in 60's.

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	Θ	D	ΔH	D − ΔH
50	7.1	334.39	-0.84	335.23
55	9.6	270.79	-0.96	271.75
60	10.5	269.55	-1.16	270.71
70	12.3	267.23	-1.21	268.44
80	13.7	273.10	-1.23	274.33
90	14.8	283.41	-1.52	284.93
100	15.5	299.97	-1.70	301.67
105	16.9	287.42	-1.81	289.23
110	16.9	301.10	-1.88	302.99
115	17.5	303.30	-2.01	305.31
120	18.1	305.26	-2.01	307.27
125	18.7	307.02	-2.05	309.07
130	19.4	306.86	-2.17	309.03
135	21.0	292.24	-2.23	294.47
140	21.3	298.37	-2.26	300.63
145	21.9	299.68	-2.13	301.81
;50	22.8	296.42	-2.38	298.80
				Avg=295.63
				Std=17.43

SHEET___ OF___

PROJECT Radio locator accuracy evaluation DATE 11-1-75

UNDERGROUND LOCATION #13, Silliman Avenue, Mammoth Cave, Kentucky

SURFACE LOCATION #13

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR C.S. Bishop

NOTES C.H. Bishop

N. Eidson, F. Reid

TRANSMITTING SCHEDULE Transmit 50 minutes, off 10 minutes.

RECEIVING CONDITIONS Clear, dry, temperature in 60's.

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
50	6.5	365.58	-0.47	366.05
55	9.4	276.67	-0.40	277.07
60	10.1	280.48	-0.37	280.85
65	11.2	273.30	-0.43	273.73
70	11.4	289.01	-0.49	289.50
75	11.25	313.90	-0.50	314.40
80	10.95	344.26	-0.54	344.80
85	13.15	302.80	-0.58	303.38
90	14.2	295.96	-0.60	296.56
95	14.65	302.37	-0.60	302.97
100	15.9	292.01	-0.69	292.70
105	16.6	292.94	-0.57	293.51
110	16.75	303.97	-0.65	304.62
115	17.1	310.87	-0.82	311.69
125	17.8	323.73	-0.61	324.34
130	19.0	313.86	-0.66	314.52
135	19.8	311.67	-0.25	311.92
140	20.3	314.54	-0.80	315.34
145	20.3	325.77	-0.99	326.06
150	20.8	328.15	-0.91	329.06
				Avg=305.67
				Std=18.74

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 11-1-75

UNDERGROUND LOCATION #14, Silliman Avenue, Mammoth Cave, Kentucky

SURFACE LOCATION #14

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.H. Bishop

C.S. Bishop, N. Eidson

TRANSMITTING SCHEDULE Transmit 50 minutes, off 10 minutes.

RECEIVING CONDITIONS Clear, dry, temperature in 60's. Increased noise due to moving closer to power line.

INITIAL DISTANCE FROM GROUND ZERO ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
50	8.9	265.91	-0.75	266.66
55	9.4	276.67	-0.86	277.53
60	10.2	277.66	-0.88	278.54
65	10.5	292.01	-0.91	292.92
70	10.7	308.45	-0.95	309.40
75	11.0	321.24	-1.01	322.25
80	12.4	302.87	-1.06	303.93
85	13.2	301.61	-1.09	302.70
90	14.0	300.37	-1.12	301.49
95	14.9	297.05	-1.14	298.19
100	15.3	304.10	-1.21	305.31
105	16.0	304.59	-1.18	305.77
110	17.7	286.61	-1.13	287.34
115	18.6	284.09	-1.04	285.13
120	19.2	286.45	-1.08	287.53
125	19.3	296.71	-1.09	297.80
130	19.7	301.78	-1.03	302.81
135	20.0	308.28	-0.85	309.13
140	21.2	299.92	-0.96	300.88
145	21.4	307.43	-0.99	308.42
150	21.7	313.18	-0.90	314.08
				Avg=299.58
				Std=11.65

SHEET___ OF___

PROJECT Radio locator accuracy evaluation DATE 11-1-75

UNDERGROUND LOCATION #15, Silliman Avenue, Mammoth Cave, Kentucky

SURFACE LOCATION #15

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.H. Bishop

C.S. Bishop, N. Eidson

TRANSMITTING SCHEDULE Transmit 50 minutes, off 10 minutes.

RECEIVING CONDITIONS Clear, dry, temp. in 60's. Hum increases as receiver coil approaches horizontal; may be interference from underground transformer.

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
50	9.0	262.91	+0.87	262.04
55	10.0	259.73	+1.16	258.57
60	11.5	245.51	+1.21	244.30
65	12.7	240.06	+1.31	238.75
70	13.2	248.38	+1.51	246.87
75	14.3	244.83	+1.61	243.22
80	15.6	238.35	+1.65	236.70
85	15.6	253.25	+1.83	251.42
90	16.0	261.08	+1.91	259.17
95	17.3	253.64	+2.00	251.64
100	19.1	240.06	+2.13	237.93
105	21.6	220.35	+2.12	218.23
110	22.2	223.94	+2.19	221.75
115	24.9	205.73	+2.31	203.42
120	23.6	228.13	+2.33	225.80
125	24.4	228.84	+2.38	226.46
130	24.7	234.71	+2.39	232.32
NOTE: A second set of data was taken by a different operator. See following sheet.				Avg=238.86
				Std=16.15

SHEET___ OF___

PROJECT Radio locator accuracy evaluation DATE 11-1-75

UNDERGROUND LOCATION #15, Silliman Avenue, Mammoth Cave, Kentucky

SURFACE LOCATION #15

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR C.S. Bishop

NOTES C.H. Bishop

N. Eidson, F. Reid

TRANSMITTING SCHEDULE Transmit 50 minutes, off 10 minutes.

RECEIVING CONDITIONS Clear, dry, temp. in 60's. Hum increases as receiver coil approaches horizontal; may be interference from underground transformer.

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
50	9.7	243.58	+0.87	242.71
55	10.6	244.70	+1.16	243.54
60	12.8	219.80	+1.21	218.59
65	13.8	220.22	+1.31	218.91
70	13.0	252.35	+1.51	250.84
75	15.3	228.07	+1.61	226.46
80	17.6	209.71	+1.65	208.06
85	19.0	205.21	+1.83	203.38
90	20.0	205.52	+1.91	203.61
95	19.0	229.36	+2.00	227.36
100	18.5	248.48	+2.13	246.35
NOTE: A second set of data was taken by a different				Avg=226.35
operator. See previous sheet.				Std=17.49
			Combined Avg=	233.94
			Combined Std=	17.59

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 11-1-75

UNDERGROUND LOCATION #16, Silliman Avenue, Mammoth Cave, Kentucky

SURFACE LOCATION #16

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR C.S. Bishop

NOTES C.H. Bishop

N. Eidson,d F. Reid

TRANSMITTING SCHEDULE Transmit 50 minutes, off 10 minutes.

RECEIVING CONDITIONS Clear, dry, temperature in 70's.

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
50	10.5	224.62	+0.86	223.76
55	10.5	247.08	+0.97	246.11
60	11.4	247.73	+1.00	246.73
65	12.1	252.38	+1.13	251.25
70	13.2	248.38	+1.15	247.23
75	13.5	259.98	+1.28	258.70
80	13.7	273.10	+1.30	271.80
85	15.3	258.48	+1.36	257.12
90	15.9	262.81	+1.36	261.45
95	16.5	266.75	+1.35	265.40
100	17.1	270.32	+1.22	269.10
105	17.9	270.31	+1.25	269.06
110	18.7	271.17	+1.34	269.83
115	19.0	277.64	+1.50	276.14
120	20.5	266.73	+1.51	265.22
125	21.1	267.18	+1.51	265.67
130	22.0	267.32	+1.55	265.77
135	22.7	268.09	+1.64	266.45
140	22.7	278.02	+1.81	276.21
145	23.8	274.73	+1.68	273.05
150	24.7	270.82	+1.87	268.95
NOTE: A second set of data was taken by a different				Avg=261.72
operator. See following sheet.				Std=12.68

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 11-1-75

UNDERGROUND LOCATION #16, Silliman Avenue, Mammoth Cave, Kentucky

SURFACE LOCATION #16

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.H. Bishop

C.S. Bishop, N. Eidson

TRANSMITTING SCHEDULE Transmit 50 minutes, off 10 minutes.

RECEIVING CONDITIONS Clear, dry, temperature in 70's.

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
50	9.6	246.17	+0.86	245.31
55	10.7	242.35	+0.97	241.38
60	11.0	256.99	+1.00	255.99
65	11.7	259.01	+1.13	257.88
70	13.2	248.38	+1.15	247.23
75	14.6	239.57	+1.28	238.29
80	15.2	243.96	+1.30	243.66
85	15.2	260.27	+1.36	258.91
90	15.5	269.97	+1.36	268.61
95	16.1	273.77	+1.35	272.42
100	17.1	270.32	+1.22	269.10
NOTE: A second set of data was taken by a different				Avg=254.44
operator. See previous sheet.				Std=12.07
			Combined Avg=	259.18
			Combined Std=	12.76

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 11-1-75

UNDERGROUND LOCATION #17, Silliman Avenue, Mammoth Cave, Kentucky

SURFACE LOCATION #17

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR C.S. Bishop

NOTES C.H. Bishop

N. Eidson, F. Reid

TRANSMITTING SCHEDULE Transmit 50 minutes, off 10 minutes.

RECEIVING CONDITIONS Clear, dry, temperature in 60's.

INITIAL DISTANCE FROM GROUND ZERO ____ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
50	8.5	278.64	+1.28	277.36
55	10.5	247.08	+1.26	245.82
60	10.7	264.38	+1.23	263.15
65	11.3	270.81	+1.38	269.43
70	11.8	278.93	+1.54	177.39
75	13.4	262.00	+1.50	260.50
80	13.7	273.10	+1.65	271.45
85	14.1	281.59	+1.75	279.84
90	15.5	269.97	+1.76	268.21
95	16.0	275.58	+1.83	273.75
100	16.6	278.99	+1.80	277.19
105	16.7	291.08	+1.77	289.31
110	17.1	297.36	+1.79	295.57
115	18.2	290.82	+1.88	288.94
120	19.8	277.04	+1.96	275.08
125	20.6	276.37	+2.00	274.37
130	20.6	287.42	+2.02	285.40
135	20.9	293.78	+2.34	291.44
140	22.8	276.66	+2.30	274.36
145	23.7	274.35	+2.29	272.06
150	23.3	289.30	+2.47	286.83
				Avg=276.07
				Std=11.53

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation **DATE** 11-1-75

UNDERGROUND LOCATION #18, Silliman Avenue, Mammoth Cave, Kentucky

SURFACE LOCATION #18

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.H. Bishop

C.S. Bishop, N. Eidson

TRANSMITTING SCHEDULE Transmit 50 minutes, off 10 minutes.

RECEIVING CONDITIONS Clear, dry, added atmospheric noise with sunset.

INITIAL DISTANCE FROM GROUND ZERO ______ **ANGLE UNITS** 2θ=grads **DISTANCES** Feet

L	θ	D	ΔH	D − ΔH
50	8.6	275.35	+1.12	274.23
55	9.0	289.20	+1.14	288.06
60	10.2	277.66	+1.25	276.41
65	10.5	292.01	+1.44	290.57
70	10.7	308.45	+1.49	306.96
75	11.5	306.89	+1.38	305.51
80	12.7	295.46	+1.54	293.92
85	13.3	299.25	+1.57	297.68
90	14.0	300.37	+1.65	298.72
95	14.55	304.54	+1.63	302.91
100	16.3	284.44	+1.82	282.62
105	16.3	298.66	+1.83	296.83
110	18.6	271.74	+1.88	269.86
115	19.3	272.97	+2.03	270.94
120	19.1	288.07	+2.18	285.89
125	20.2	282.36	+2.05	280.31
130	21.0	281.42	+2.03	279.39
135	21.15	289.96	+2.06	287.90
140	21.7	292.30	+2.27	290.03
145	22.1	296.67	+2.49	294.18
150	22.6	299.35	+2.56	296.79
				Avg=289.03
				Std=11.01

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 11-1-75

UNDERGROUND LOCATION #19, Silliman Avenue, Mammoth Cave, Kentucky

SURFACE LOCATION #19

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR C.S. Bishop

NOTES C.H. Bishop

N. Eidson, F. Reid

TRANSMITTING SCHEDULE Transmit 50 minutes, off 10 minutes.

RECEIVING CONDITIONS Clear, dark. Increased atmospheric noise but not excessive. Weak signal, wide null.

INITIAL DISTANCE FROM GROUND ZERO ____ ANGLE UNITS 2θ=grads DISTANCES Feet

L	θ	D	ΔH	D − ΔH
50	8.8	268.99	+0.64	268.35
55	9.9	262.41	+0.77	261.64
60	11.5	245.51	+0.80	244.71
65	12.3	248.15	+0.82	247.33
70	12.8	256.44	+0.92	255.52
75	12.6	279.27	+1.08	278.19
80	14.2	263.07	+1.12	261.95
85	15.1	262.09	+1.14	260.95
90	15.1	277.50	+1.35	276.15
95	15.2	290.89	+1.30	289.59
100	16.8	275.46	+1.26	274.20
105	16.9	287.42	+1.49	285.93
110	18.5	273.32	+1.34	271.98
115	18.9	279.23	+1.35	277.88
120	19.6	280.12	+1.38	278.74
125	19.8	288.58	+1.44	287.14
130	19.9	271.48	+1.49	296.99
				Avg=271.60
				Std=14.71

SHEET ___ OF ___

PROJECT Radio locator accuracy evaluation DATE 11-1-75

UNDERGROUND LOCATION #21, Silliman Avenue, Mammoth Cave, Kentucky

SURFACE LOCATION #21

UNDERGROUND PARTY MEMBERS:

OPERATOR K. Hoskins

D. Kelley

D. Pollock

SURFACE PARTY MEMBERS:

OPERATOR F. Reid

NOTES C.S. Bishop

C.H. Bishop, N. Eidson

TRANSMITTING SCHEDULE Transmit 50 minutes.

RECEIVING CONDITIONS Very weak signal. Atmospheric noise has not increased since sundown.

INITIAL DISTANCE FROM GROUND ZERO ______ ANGLE UNITS 20=grads DISTANCES Feet

L	Θ	D	ΔH	D − ΔH
50	8.8	268.99	+0.69	268.30
55	9.0	289.20	+0.76	288.44
60	9.6	295.41	+0.75	294.66
65	10.5	292.01	+0.77	291.24
70	11.8	278.93	+0.97	277.96
75	12.1	291.21	+1.04	290.17
80	13.1	286.12	+1.06	285.06
85	13.1	304.00	+1.19	302.81
90	13.8	304.91	+1.34	303.57
95	15.15	291.90	+1.41	290.49
100	15.5	299.97	+1.95	298.02
105	16.2	300.61	+1.80	298.81
110	16.2	314.93	+1.65	313.28
115	17.3	307.04	+1.82	305.22
120	18.1	305.26	+2.10	303.16
125	18.9	303.51	+2.11	301.40
130	19.7	301.78	+2.17	299.61
135	20.4	301.68	+2.29	299.39
140	20.8	306.27	+2.55	303.72
145	21.7	302.74	+2.61	300.13
150	20.9	326.42	+2.67	323.75
				Avg=297.22
				Std=8.31

SHEET ___ OF ___