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Chapter 10: Mapping Lakes with Echo Sounders

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Chapter 10: Mapping Lakes with Echo Sounders

B. V. Hughes and C. M. Taube

[Editor's note: New equipment for lake mapping is being developed and may be ready for use in summer 2000. This new equipment consists of an electronic depth sounder, a real-time global positioning (GPS) instrument, and a lap-top computer. While transects of the lake are run, pairs of depth and position readings will be automatically taken and stored in the computer. Later, the data will be downloaded into specialized software that produces contour maps. The discussion below refers to instruments of the recording type that were common in the 1970s; however, the same basic concepts still apply.]

Echo sounders measure the interval of time required for a sound wave emitted by a transducer to strike the bottom of a lake and return to the transducer as an echo. Length of time depends on the depth of the water and the speed of sound through water, which is about 4,800 feet per second.

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Briefly, the chain of events in depth sounding are as follows. The electronic unit of the sounding instrument produces electrical impulses that are converted into sound waves by the transducer. These waves are projected downward from the surface of the water. Upon striking the bottom, the sound waves are reflected back to the transducer as echoes. The echo triggers an electronic signal that is displayed or recorded. A rapid succession of echoes results in a continuous line of recordings.

Echo sounders are of two general types: one type momentarily flashes the readings on a dial or screen; a second type records readings graphically on a paper chart. The latter instrument is the more practical for mapping lakes. Two distinct advantages of the chart recorder are that (1) it produces permanent recordings that can be easily checked for accuracy, and (2) depth recordings can be transcribed at a convenient time by virtue of their permanent character.

10.1 Equipment

The structure of graph-type echo sounders described here is based on the Bendix D R-10 Depth Recorder and the Raytheon Fathometer, Model D E-119. The recording unit is composed of an electronic section and a mechanical section. The components of the electronic section produce the electrical impulses and amplify the returning echoes to a voltage sufficient to mark the recording paper. A converter changes electrical current from a 6-volt storage battery to suitable voltages.

The recording unit of the sounder may be mounted on a board clamped to the gunnels near mid-ship. In mounting the transducer, it is important to avoid wakes and turbulence which create air bubbles that reflect sound waves and interfere with echo reception. To reduce turbulence, the transducer may have to be mounted in a small, streamlined wooden hull ("fish"). (Some newer model transducers are sufficiently streamlined.) The transducer can be installed several different ways. It may be mounted on the side of the boat, externally on the bottom of the boat, or internally inside the hull. Mounting on the side is recommended for mapping. Presently, the transducer unit is mounted on the side of the boat by means of a wood lever with spring tension.

Other equipment for mapping includes: boat; motor; battery charger; tracing of the shore outline of the lake prepared from an aerial photo; mounting board for the tracing; notebook for sounding-run records and other data; compass; cable for horizontal measurements; sounding cable equipped with a bottom sampler; pole (preferably bamboo) for shallow-water soundings; and either a dumpy level and stadia rod, or a chalk line and line level, for establishment of bench marks. A hammer and spikes are needed for setting up bench mark monuments.

10.2 Mapping procedure

The field crew consists of two people – one to navigate the boat and another to operate the sounder. In selecting sites for sounding transects, distinctive landmarks should be chosen which are recognizable both on the lake and on the work chart (i.e., an outline map of the lake prepared in advance from an aerial photo). These landmarks will be used to define the ends of transects. The procedure for starting a run depends on the type of sounder used. With an instrument of the Bendix D R-10 type, runs are started and ended at the 5-foot contour because this instrument does not give discernible readings in shallower depths. (The graph paper used with this instrument is calibrated in fathoms.) The starting point for each run on the 5-foot contour is located with the sounding pole, and the distance from shore is measured and recorded. Then the outboard motor and the echo sounder are started and a ***straight*** transect run is made at ***uniform speed*** toward the landmark on the opposite shore. At the opposite shore, the 5-foot contour is located again and its distance from shore is recorded. It is essential that boat speed be kept uniform so that, later, water depths can be transcribed accurately from sounder graph recordings to the work chart. This uniformity is required to make the length of the graph recording proportional to the actual distance of the run, and also to the distance on the work chart (the graph revolves at a uniform speed, therefore boat speed must also be uniform). Note that although boat speed during a transect run must be uniform, different (but uniform) speeds for other transect runs are permissible.

With a sounder of the Raytheon Fathometer D E-119 type, sounding may be done in depths as shallow as 2 or 3 feet. (The graph paper used with this instrument is calibrated in feet.) Distances to shore from the beginning and from the end of a run with the sounder are measured and recorded as with the Bendix D R-10.

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Numerous transects are run from shore to shore and each is numbered on the base map as well as on the sounder graph paper. Many runs may be recorded successively on one sheet of graph paper. If the curvature of the shoreline is fairly uniform, most (if not all) of the transects may be made parallel to each other. Changes in direction of transects may be necessary if the shoreline is marked with bays or other distinctive irregularities. The number of transect runs required for a given lake must be determined largely by the operator's judgment; basins that have numerous depressions or irregular bottoms require more soundings than basins with uniform declivity. Ordinarily, lakes with a surface area of approximately 100 acres require 20 to 30 transects. The operator should be sure to identify the lake by name and location on the graph paper. When the recordings for a given lake have been completed, remove that section of graph paper from the roll. Now and then it may be necessary to sound with a hand line to verify echo sounder readings. Take hand soundings when recordings are fuzzy due to dense vegetation or equipment malfunction.

Another use of the hand line is to determine bottom soil types. A sample of the bottom is retained in a cup at the base of the sounder weight. The number of samples required depends on extent of variation of soil types.

If corrections need to be made on the work outline (because changes have occurred in lake shape since the aerial photo was taken), make them while at the lake. At that time add shore features such as slopes, wooded areas, marsh, prominent buildings, etc. Establishment of a bench mark completes the field work.

Later, at a work table, transcribe depths from sounder graph recordings to the work chart. Simple proportion is used for locating sounding stations and plotting corresponding depths. Equal divisions are marked off on both the sounder chart recordings and the transect lines of the work chart. The depth at each division mark on the recording is determined and then transcribed to the corresponding mark on the transect line. The number of equal divisions may range from three to seven or more – the number depending on length of the transect and amount of depth data required for accurate contours.

After a sufficient number of depths have been recorded on all transect lines, depth contours can be drawn by eye.

10.2.1 Sounder operation instructions

Refer to the instrument's manual for detailed instructions on operation. The following comments are merely precautions and hints that will aid in operation, and apply specifically to the Bendix D R-10 Depth Recorder and the Raytheon D E-119 Fathometer. These suggestions may or may not apply to other sounders.

Adjustment of the power output regulates the uniformity and density of the recording trace. A strong vibration is required to register the surface of flocculent bottom in deep water. However, excess volume (sensitivity) may result in secondary reflections that are recorded on the graph at twice the actual depth. Also, excess power will burn the stylus point. The sensitivity (volume) control is adjusted at various depths so that there will be adequate power to produce a legible recording. If the stylus point has been burned, the stylus will need to be readjusted. A spare stylus, an additional vibrator, and a complete extra set of tubes should be carried in the spare parts kit.

A fully charged storage battery will supply sufficient power to operate the sounder for about 8 hours. It is advisable to carry an extra battery for use while the other one is being recharged.

Dense vegetation is apt to cause false readings. When such difficulty occurs, hand line or sounding pole will have to be employed. Where extensive areas are involved, mapping of the lake may need to be postponed until late fall or early spring when density of aquatic vegetation is minimal.

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10.3 Preparation of the work chart and tracing

Prior to taking soundings at the lake, the work chart is prepared from an aerial photo that shows the outline of the lake. Scales of aerial photos presently available are too small for lake mapping work; consequently, the work chart consists of an enlargement of the photo, made with plastic grid cards and map paper.

Grid cards are clear plastic sheets on which squares have been scratched. Commonly used grid cards have 2, 3, 4, 5, 6, 8, or 10 lines per linear inch (4, 9, 16, 25, 36, 64, or 100 sections per square inch). Outside dimensions of the grid cards range from 3 inches to 12 inches square. The size to be employed depends on the size of the photographic outline of the lake. The grid cards are subject to shrinkage and should be checked from time to time for accuracy. Usually, they need to be replaced every few months.

For example, suppose we wish to enlarge the aerial photographic outline of a lake by 5-fold for a work chart. First, tape a grid card with 5 divisions per inch over the aerial outline. Then, transcribe (by inspection) a section of shoreline that extends between successive division lines on the grid card onto a sheet of grid map paper. The ends of the transcribed section will be 1/5-inch apart under the grid card and 1-inch apart on the work chart. If the aerial photo has a true scale of 1 inch equals 1,760 feet, and the lake outline is being enlarged 5 times, the scale of the enlarged work chart becomes 1 inch equals 352 feet (1,760 ÷ 5).

After transcription of the shore outline, islands, roads, trails, and any other prominent lake-related features that appear on the photo are added to the work chart. If shoal areas are evident on the photo, their outlines should be shown on the work chart (with broken lines, for example) to provide orientation during field work.

Nearly always the given scale for the aerial photo needs to be corrected because of primary error or photo paper shrinkage. In such cases, the correct scale must be determined before the work chart can be prepared. Correction is made by comparing measured distance between landmarks on the aerial photo to their known distance (e.g., township lines). The points of dividers (or calipers) are placed on two landmarks on the photo whose distance apart is known, then divider spread is measured with an engineer's ruler. This measurement is then multiplied by the scale given on the aerial photo and compared to the known distance. A measurement span of about 3 inches should be used for comparison. Corrections are computed on the basis of 40 parts to the inch.

If the photo lacks landmarks for checking scale accuracy and computing a correction factor, then at the lake make on-the-spot measurements between landmarks that appear on the photo and compute a correction later.

Example 10.1- The scale given on an aerial photo is 1 inch equals 1,666 feet. One mile represented on the photo is found to contain 120 1/40-inch units.

120 ÷ 40 = 3 inches
5,280 ÷ 3 = 1,760 feet

Therefore, 1 inch on the photo now actually represents 1,760 feet rather than 1,666 feet.
If the lake shown on the photo is enlarged 4x on the work chart:

1,760 ÷ 4 = 440

The scale on the work chart is 1 inch = 440 feet.

Before the lake is sounded, the accuracy of the shoreline drawn on the work chart should be checked. This may be done while circling the lake in a boat. This precaution is advised because the shoreline may have changed since the aerial photo was taken, or it may have been misinterpreted from the aerial photo. If corrections are necessary, make them before sounding commences. Shoreline corrections can be made with a common alidade, compass, and measuring cable. Positions of roads, trails, streams, etc., should be checked also. Important features not apparent from the photograph should be added to the work chart while on-site.

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Final touches to the map are made later, in the laboratory. First, carefully examine the work chart for all required information. The agency (if different from the one preparing the new map) responsible for the aerial photo is given a credit line and the date of the photo is recorded. Then the map is prepared for photographic blow-up to a standard scale. Over the past 40 years (of lake mapping and drafting) most maps have been drawn on a chart paper with dimensions of 22 inches x 34 inches. For the final blow-up, select a scale that permits maximum enlargement of the lake outline ***and*** uses one of following scales (feet of lake dimension to inch of final map): 25, 50, 75, 100, 150, 200, 300, 400, 600, 800, 1000, or 1200. At the time of the 1976 revision of these instructions, lake maps were being drafted by the Engineering Division of the MDNR.

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