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Determination of volume of water and water level in lakes and reservoirs

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National foreword

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TECHNICAL REPORT

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Determination of volume of water and water level in lakes and reservoirs

Détermination du volume et du niveau d'eaux dans les lacs et réservoirs

Reference number
ISO/TR 11330:1997(E)

Foreword

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The main task of technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

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Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 11330, which is a Technical Report of type 2, was prepared by Technical Committee ISO/TC 113, *Hydrometric determinations,* Subcommittee SC 1, *Velocity-area methods.*

This document is being issued in the Technical Report (type 2) series of publications (according to subclause G.3.2.2 of part 1 of the ISO/IEC Directives, 1995) as a "prospective standard for provisional application" in the field of hydrometric determinations because there is an urgent need for guidance on how standards in this field should be used to meet an identified need.

This document is not to be regarded as an "International Standard". It is proposed for provisional application so that information and experience of its use in practice may be gathered. Comments on the content of this document should be sent to the ISO Central Secretariat.

A review of this Technical Report (type 2) will be carried out not later than three years after its publication with the options of: extension for another three years; conversion into an International Standard; or withdrawal.

Annexes A and B of this Technical Report are for information only.

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Determination of volume of water and water level in lakes and reservoirs

1 Scope

This Technical Report deals with the survey of the topography of lakes and reservoirs for the determination of volume of line storage and the determination of water level, the objective being to establish a relation between water level and volume. Both conventional surveying methods and electronic distance measurement (EDM) and Global Positioning System (GPS) total station methods are included.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Technical Report. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Technical Report are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 772:1996, *Hydrometric determinations — Vocabulary and symbols.*

ISO 4366:1979, *Echo sounders for water depth measurements.*

ISO 4373:1995, *Measurement of liquid flow in open channels — Water-level measuring devices.*

ISO 6420:1984, *Liquid flow measurement in open channels — Position fixing equipment for hydrometric boats.*

3 Definitions and symbols

For the purpose of this Technical Report, the definitions and symbols given in ISO 772 and the following definitions apply.

3.1 live storage: Storage which can be drawn off from the reservoir to downstream users.

3.2 total storage: Storage between the lowest bed level and top water level.

3.3 flood storage: Volume held above top water level during a flood event.

NOTE — Flood storage is not retained in the reservoir but is discharged until the normal top water level is reached.

4 Topography survey and analysis

4.1 Procedure

The procedure adopted requires:

a) three-dimensional coordinates of points on the bed of the reservoir;

b) contoured bathymetric plans and topographic survey above top water level;

c) water level : volume curves or tables or both.

5 Volume determination by conventional surveying methods

5.1 Survey below water level

The survey of that part of the lake or reservoir below the water surface requires a launch equipped with an echo sounder. The position of the launch is fixed during echo sounder runs by means of a sextant or theodolite. Targets are located at both ends of each section line in accordance with ISO 4366.

5.2 Choice of cross-sections

The chosen cross-sections should take into account the size and shape of the water body and should generally be close enough for accurate calculation but not greater than 1 km apart. In general, the rule is to select range locations such that the volumes computed by the average end-area method (the average cross-sectional area at both ends of each lake reach multiplied by the length of the reach) reasonably represents the volume of the valley between ranges.

5.3 Location of ranges

Ranges should be located such that the area of the polygon enclosed by the range end-points accurately reproduces the area of the water body between adjacent ranges. This rule neglects errors arising from irregular channel bottoms, but in most topography, the lake or reservoir bottom irregularity is frequently correlated with shore irregularity. Where possible, cross-sections should be located near the mouths and heads of tributary arms.

5.4 Plotting contours

Contours should be plotted using all measured levels on the cross-sections, both below and above the water surface. The scale of the plot will depend on the size of the water body, but a scale of 1:200 or 1:20 000 should be appropriate in most cases, with a vertical scale of 20 cm to 30 cm.

5.5 Calculation of volume

The plan area enclosed by each contiguous contour should be calculated with a constant vertical interval between each contour. The total volume can then be determined by a prismoidal end-area or other suitable method.

5.6 Water level during survey

When the survey is in progress, the opportunity should be taken to read the reference staff gauge(s) if available.

5.7 Use of conventional surveying

The conventional surveying method is now seldom used for volume determination of lakes or reservoirs whose surface areas are greater than 500 km^2 and whose smallest linear dimension at top water level exceeds 10 km.

6 Volume determination by modern surveying methods

6.1 General

The advent of electromagnetic distance measurement (EDM) and computer software facilities in surveying, together with the Global Positioning System (GPS), has virtually revolutionized land surveying.

6.2 The EDM Total Station method

A fully integrated survey system, consisting of a combination of theodolite, EDM equipment, data processor and dedicated software gives x, y and z coordinates directly and encompasses everything from field observations to the production of the final plans. This integrated system is known as the Total Station.

6.2.1 Water depth : volume curves

All survey data are transferred from the total station to an electronic notepad which allows input in the form of three-dimensional coordinates. All data from topographic and sonar surveys are inserted into a computer with a dedicated software package to produce contour plans and water depth : volume curves.

6.2.2 Range of EDM Total Station

The major advantage of EDM, apart from speed and accuracy, is that greater distances can be surveyed, irrespective of ground conditions. The maximum range of an EDM Total Station is about 8 km. This enables the largest water bodies to be surveyed. The EDM system is based on measuring the transit time of an electromagnetic beam emitted from a transmitter-receiver to a reflecting target or prism and back again. A combination of EDM and theodolite causes the electromagnetic beam to pass through the telescope optical system. Care is therefore exercised in positioning the prisms around the lake or reservoir with respect to the EDM Total Station and the launch position. Though modern techniques no longer require working along cross-sections, they still need to concentrate on irregular areas.

6.3 The GPS receiver

Twenty-four GPS satellites orbit the earth twice per day at an altitude of 20 200 km. GPS receivers on the ground calculate their positions by making distance measurements to four or more satellites. The satellites function as known reference points that broadcast (free) satellite identity, position and time information via codes on two carrier frequencies — 1575,42 MHz and 1227,6 MHz. Measurements of distance to each individual satellite are made by analysing the time it takes for a signal to travel from a satellite to a GPS receiver. Trilateration is then used to establish the GPS receiver's position. Since latitude and longitude and height of each point are displayed, distances between points are also displayed.

6.3.1 GPS system of surveying

A receiver is installed in the launch whose position can be displayed and recorded along with sonar data from an echo sounder. The GPS Total Station can be used in the travelling mode such that the survey launch can troll the waters of reservoirs and lakes without the need for pre-defined range locations. In the GPS system of contouring, one base station set-up can serve many roving units (outstations equipped with receivers and data links) within a 10 km radius. There is therefore no practical limit to the size of water body to be surveyed; it will depend on the number of base stations and rovers which can be set up.

6.3.2 GPS Total Station determination of volume

The GPS Total Station can be mounted on vehicles to extend the survey and provide contour and topographic surveying data. For small water bodies (see 5.7) a combination of vehicles and individual surveyors with back-pack and hand-held survey controllers can be employed. Each GPS receiver, whether it be tripod-mounted, vehicle-mounted, rover or backpack, accepts and processes raw distance signals from multiple GPS satellites.

The rover unit merges carrier-phase data broadcast from the base station with incoming satellite signals to establish three-dimensional coordinates of the survey points with 10 mm accuracy. The coordinates are displayed after a few seconds of point occupation and, to extend the system's range, radio repeaters can be used to re-broadcast GPS carrier-phase data over and around hilly obstructions. All GPS data and sonar data are transferred directly from hand-held survey controllers and converted via dedicated commercially available software packages into the necessary output of contour plans, lake or reservoir configuration, three-dimensional drawings and water depth: volume curves.

The GPS Total Station surveying method for the determination of volume of lakes and reservoirs employing rover vehicles and hand-held roving units is now becoming a fast and accurate method of land surveying. For each application of the system, description of a suitable software for navigation, data acquisition, analysis and plotting should be provided (see annex A).

6.3.3 Radio position-fixing system

A radio position-fixing system should be provided. Proprietary standard radio position-fixing systems can be used for surveying most sizes of open water surface with a usual accuracy within 1 m to 3 m. Positions of the stationary or moving target which contain the radio receiver are fixed electronically by an intersection method with reference to the two or three fixed reference stations installed for this purpose at known locations.

6.3.4 GPS Total Station power requirements

The power requirements for sensors and controller units are generally of the following order:

Sensor:	maximum 9 W
Sensor and controller:	12 W
Supply voltage:	12 V d·c
Recommended battery:	12 V, 7 A·h NiCd for up to about 6 h continuous operation at 20 °C.

6.3.5 GPS Total Station display

A typical display, nominally 8 lines of 40 characters, gives the following information:

Satellite status/satellite health;

satellite-tracking information;

azimuth, elevation, signal-to-noise ratio, etc.;

data-logging information;

receiver information;

point numbers;

attributes and codes;

loss of lock information;

STOP and GO information;

real-time navigation position;

latitude, longitude, ellipsoidal, height in WGS84;

grid coordinates in local system;

GDOP/PDOP;

local time/GPS time/time zone;

real-time navigation;

way points, course, bearing, distance, speed.

7 Water level measurement

7.1 Recording of water level

The water level of a lake or reservoir should be measured according to ISO 4373 and recorded by one of the methods outlined therein. If continuous recording of the water level is not required, the reference or staff gauge should be read daily. Suitable access to the gauge should be ensured.

7.2 Established and location of water level measuring stations

The number of water level measuring stations depends on the size and shape of the reservoir, but should be a function of the accuracy of surface elevation. The main objective should be that the measured values should be sufficient to establish the mean horizontal water level and hence the volume of live, total or flood storage.

7.3 Wind set-up, surface curvature, outlets and inflows, seiches, long-wavelength waves

The number of water level measuring stations should be increased for any of the above conditions in order to determine the mean water level. This can be performed after a detailed study of the water body and from knowledge of the specific climatic conditions.

Wave height can be estimated from wind speed or wind duration from annex B.

The following table is given as a guide.

Surface area km^2	10 000	5 000	1 000	500	< 500
Number of water level measuring stations	6-8	4-6	2-4	2	1

In the case of small reservoirs (< 500 km^2 see 5.7), location of a staff gauge at the draw-off tower is common practice, although this method may not always provide a record of the mean level of the reservoir. It may however be related to the mean water level of the reservoir determined over a sufficiently long period of time.

Annex A
(informative)

Bathymetric maps

For example, a bathymetric map can be generated by appropriate software in conjunction with EDM or GPS equipment. See figures A.1 and A.2 and table A.1.

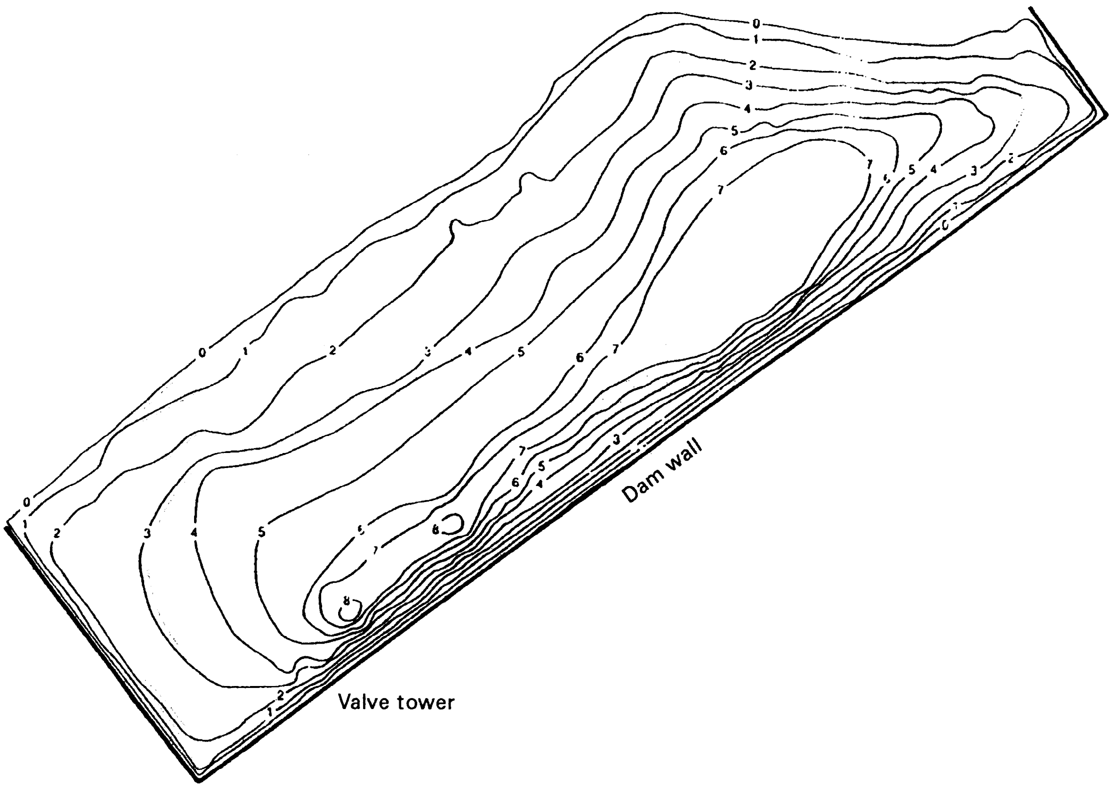
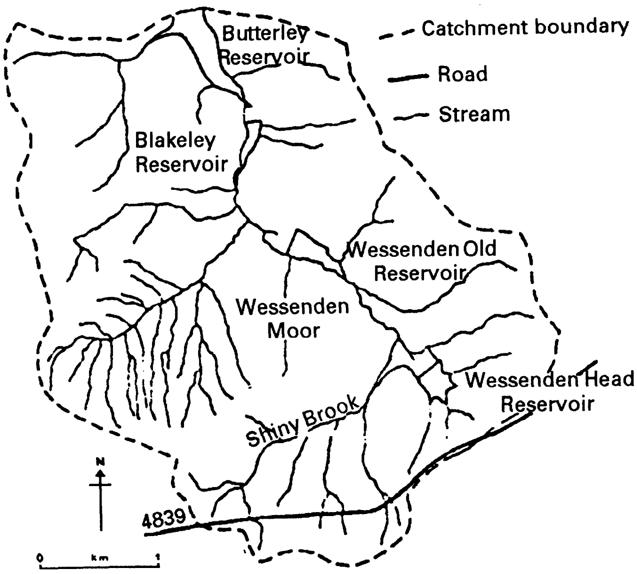


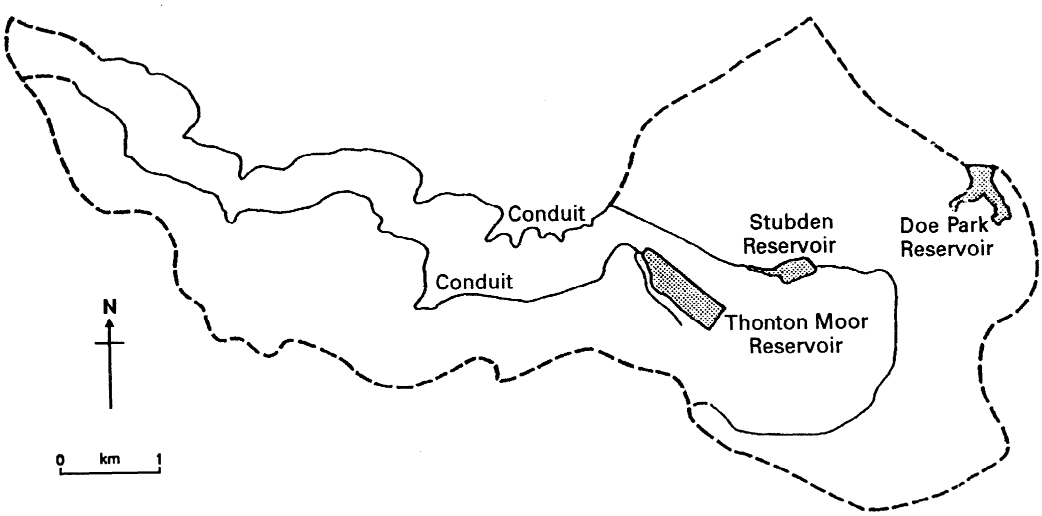
Figure A.1 — Bathymetric map of Thornton Moor Reservoir

Table A.1 — Loss of reservoir capacity

Reservoir parameter	Wessenden Head	Wessenden Old	Blakeley	Butterley	Thornton Moor	Stubden
Date of construction	1881	1835	1903	1907	1885	1868
Catchment area (km²)	◄ – – – – – 15,05 – – – – – – – – – ►				5,12	1,94
Original capacity (Ml)	373	486	364	1832	795	451
Revised capacity (Ml)	358	321	137	1724	702	406
Loss of capacity per century (%)	3,7	23	75,2	7,5	11,3	8,2
Annual loss of capacity (m³)	137	1220	2736	1365	895	318
Annual area-specific loss (m³/km²/year)	◄ – – – – – 362,66 – – – – – – – – – ►				174,87	191,58



a) Wessenden Head and Blakeley Reservoirs



b) Thornton Moor, Stubden and Doe Park Reservoirs

Figure A.2 — Location of study areas

Annex B
(informative)

WMO nomogram: Estimating wave height from wind speed and fetch

Choose the wind speed curve on the right-hand side, follow this curve to the left until you reach the orthogonal curve for the required fetch, or until you reach the vertical line for the duration, whichever is the limiting factor. The wave height may then be read off from the horizontal lines-scale on the left, and wave period by interpolating between the dashed curves.

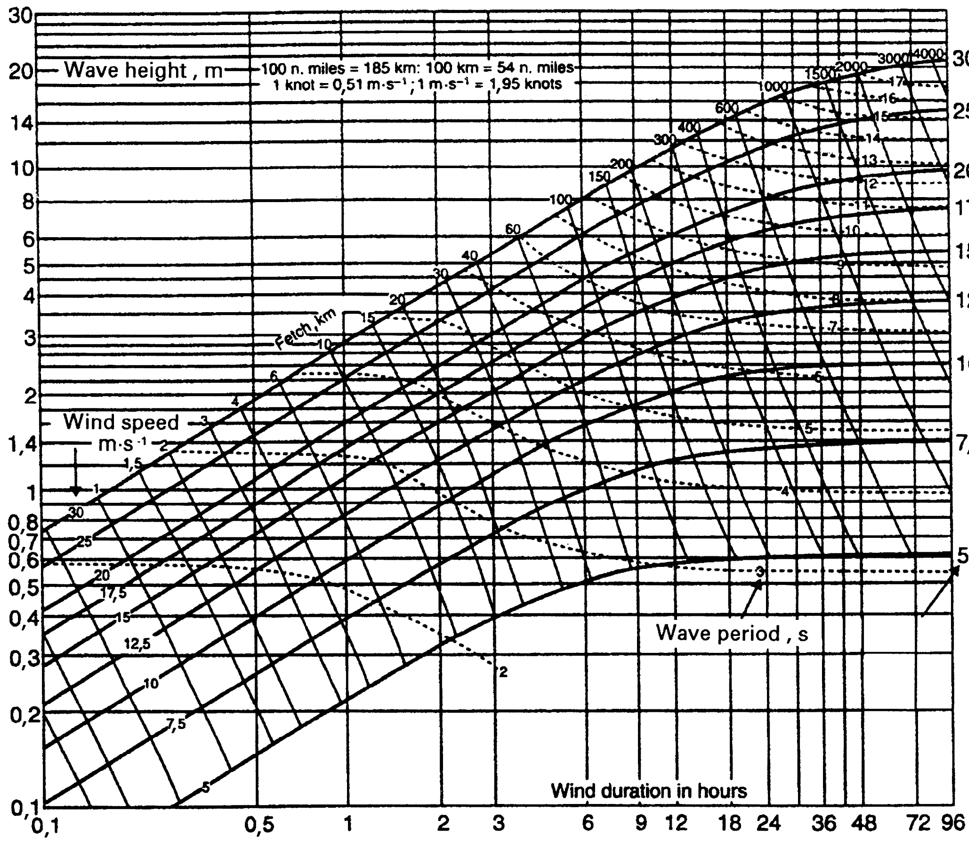


Figure B.1

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