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ISO 1100-1

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Measurement of liquid flow in open channels —

Part 1:
Establishment and operation of a gauging station

Mesurage de débit des liquides dans les canaux découverts —
Partie 1: Établissement et exploitation d'une station hydrométrique

Reference number
ISO 1100-1:1996(E)

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 1100-1 was prepared by Technical Committee ISO/TC 113, *Hydrometric determinations*, Subcommittee SC 1, *Velocity area methods*.

This second edition cancels and replaces the first edition (ISO 1100-1:1981), which has been technically revised.

ISO 1100 consists of the following parts, under the general title *Measurement of liquid flow in open channels*:

— *Part 1: Establishment and operation of a gauging station*

— *Part 2: Determination of the stage-discharge relation*

Annex A of this part of ISO 1100 is for information only.

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Measurement of liquid flow in open channels —

Part 1:
Establishment and operation of a gauging station

1 Scope

1.1 This part of ISO 1100 deals with the establishment and operation of a gauging station for the measurement of stage or discharge, or both, of a lake, reservoir, river or artificial open channel.

1.2 Requirements are specified for stage and for stage-discharge stations in natural channels and stations with artificial structures, for direct discharge measurement and for measurement under ice conditions.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 1100. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 1100 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 31:1992, *Quantities and units*, all parts.

ISO 748:—[1], *Measurement of liquid flow in open channels — Velocity-area methods.*

ISO 772:—[2], *Measurement of liquid flow in open channels — Vocabulary and symbols.*

ISO 1000:1992, *SI units and recommendations for the use of their multiples and of certain other units.*

ISO 1070:1992, *Liquid flow measurement in open channels — Slope-area method.*

ISO 1100-2:1982, *Liquid flow measurement in open channels — Part 2: Determination of the stage-discharge relation.*

ISO 3454:1983, *Liquid flow measurement in open channels — Direct depth sounding and suspension equipment.*

ISO 3846:1989, *Liquid flow measurement in open channels by weirs and flumes — Rectangular broad-crested weirs.*

ISO 3847:1977, *Liquid flow measurement in open channels by weirs and flumes — End-depth method for estimation of flow in rectangular channels with a free overfall.*

ISO 4359:1983, *Liquid flow measurement in open channels — Rectangular, trapezoidal and U-shaped flumes.*

ISO 4360:1984, *Liquid flow measurement in open channels by weirs and flumes — Triangular profile weirs.*

ISO 4369:1979, *Measurement of liquid flow in open channels — Moving-boat method.*

1) To be published. (Revision of ISO 748:1979)

2) To be published. (Revision of ISO 772:1988)

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

ISO 4375:1979, *Measurement of liquid flow in open channels — Cableway system for stream gauging.*

ISO 4377:1990, *Liquid flow measurement in open channels — Flat-V weirs.*

ISO 6416:1992, *Measurement of liquid flow in open channels — Measurement of discharge by the ultrasonic (acoustic) method.*

ISO 8368:1985, *Liquid flow measurement in open channels — Guidelines for the selection of flow gauging structures.*

ISO/TR 9123:1986, *Liquid flow measurements in open channels — Stage-fall-discharge relations.*

ISO 9196:1992, *Liquid flow measurement in open channels — Flow measurements under ice conditions.*

ISO 9213:1992, *Measurement of total discharge in open channels — Electromagnetic method using a full-channel-width coil.*

ISO 9555-1:1994, *Measurement of liquid flow in open channels — Tracer dilution methods for the measurement of steady flow — Part 1: General.*

ISO 9555-2:1992, *Measurement of liquid flow in open channels — Tracer dilution methods for the measurement of steady flow — Part 2: Radioactive tracers.*

ISO 9555-3:1992, *Measurement of liquid flow in open channels — Tracer dilution methods for the measurement of steady flow — Part 3: Chemical tracers.*

ISO 9555-4:1992, *Measurement of liquid flow in open channels — Tracer dilution methods for the measurement of steady flow — Part 4: Fluorescent tracers.*

3 Definitions

For the purposes of this part of ISO 1100, the definitions and symbols given in ISO 772 apply.

4 Units of measurement

The units of measurement used in this part of ISO 1100 are SI units in accordance with the appropriate parts of ISO 31 and ISO 1000.

5 Stage-discharge gauging stations (natural channels)

5.1 Principle

Water levels (stages) of rivers, lakes or reservoirs are used in delineating flood hazard areas, and in the design of structures in or near rivers, lakes or reservoirs.

The stage or water level of a stream or lake is the height of the water surface above an established datum plane.

Water-level records are obtained by systematic observations of a reference gauge, or from a water-level sensor.

When records of water level in streams are to be used as a basis for computation of discharge, the relation between stage and discharge should be determined.

In a stable channel with appropriate control of the downstream water level, a single relation may exist between stage and discharge. In this case, the relation shall be determined from discharge measurements at selected stages throughout the range of stage experienced at the station.

Discharges can be determined using either velocity-area methods according to ISO 748, tracer dilution methods according to ISO 9555-1, ISO 9555-2, ISO 9555-3 or ISO 9555-4, or ultrasonic methods using a temporary installation (see ISO 6416).

In the case where no single relation exists between stage and discharge, a relation may exist between the surface slope or fall, stage and discharge which may require the establishment of a second stage (slope) gauge. Relations shall then be established on the basis of these three factors, and discharge shall be determined from measurements of surface slope and stage (see ISO 1070 or ISO/TR 9123 as appropriate).

5.2 Main elements of a gauging station

The main elements required for establishing the historical records of discharge in a stream from water-level records are as follows:

— choice of control section or reach (see 5.2.1);

— stage-measuring device (see 5.2.2);

— stage-sensing and -recording device (see 5.2.3 and 5.2.5);

— discharge-measuring section (or reach) (see 5.2.6).

For a stage-measuring station, the aim of which is to establish stage records only, see 5.2.2 to 5.2.4.

5.2.1 Control section (or reach)

A control section or control reach of a channel is a natural or artificial section or reach whose physical characteristics are measured and used to determine the relation between stage (or stage and slope) and discharge.

A control section is one in which any change in the downstream stage does not affect the upstream stage. Whatever the discharge in the control section, a critical stage can always be recorded. In a control reach no critical stage can be recorded. A control section may be natural (e.g. a rock outcrop or sandbar) or artificial (e.g. a weir, flume or culvert).

The sensitivity of a control section or reach shall be such that any significant change in discharge shall result in either

— a measurable change in stage (for control sections), or

— a measurable change in stage at one extremity of the control reach, and a measurable change in surface slope between the two extremities.

In order to establish a stable stage-discharge relation, the control section or reach shall be stable, i.e. no change shall occur over time in its physical characteristics.

Several control sections may be considered for discharge measurement for one gauging station.

Under given discharge conditions, the presence of a downstream weir may create a water level which submerges an upstream weir used as a control section. This downstream weir may then be considered as the new control section.

5.2.2 Stage-measuring devices

Stage-sensing and -measuring devices are the basic elements of the equipment for measuring and recording stage. They shall be stable.

A vertical or inclined staff gauge shall be located near the stage sensor, to act as the reference gauge.

The water level indicated by the stage sensor should follow the water level indicated by the reference gauge.

5.2.2.1 Vertical and inclined staff gauges

Vertical and inclined staff gauges shall meet the functional requirements described in ISO 4373, which may be briefly summarized as follows.

a) The graduations of a staff gauge shall be clearly, accurately and permanently marked directly on a smooth surface. The numerals shall be distinct and placed so that an ambiguous reading is not likely.

b) The gauges shall be durable and easy to maintain. The material shall have a low coefficient of expansion, and shall be resistant to alternating wet and dry conditions and to wear or fading of the markings.

c) The gauges shall be placed near the bank, in an easily accessible position, so that water level can be read from the shortest possible distance.

d) The gauges shall be simple to install and use.

e) The gauges shall be placed in a calm area, as close as possible to, and preferably in the same cross-section as, the stage sensor, without however affecting stage at this level. When the amplitude of variation of stage can exceed the capacity of a staff gauge, other additional elements may be installed in the same cross-sectional area, normal to the direction of flow.

5.2.2.2 Other devices

In some cases, a reference-point gauge with a device for locating the water level with respect to the reference may be substituted for a vertical or inclined gauge.

Needle gauges may be used when level variation is small (1 m max.) and when the water surface is stable.

When it is not possible to install vertical or inclined gauges, wire-weight gauges may be used if a structure exists permitting their installation over the water.

The functional requirements and conditions of installation of these gauges are specified in ISO 4373.

5.2.2.3 Gauge-zero elevation (see ISO 4373)

The establishment of the gauge zero shall be chosen so as to avoid negative readings. To ensure that the gauge zero remains the same over the duration of the station operation, care shall be taken to ensure that it is fixed low enough, especially for sites where scour is severe.

The zero of the gauge shall be correlated with a national datum through a station benchmark. The gauge zero and the other gauge divisions should be checked annually with respect to this benchmark.

This procedure allows replacement of the gauge in case of destruction and maintenance of the same stage-discharge relation provided the control section is not modified. At least two independent station benchmarks should be established so that the gauge zero can be conveniently recovered if one of the benchmarks is lost or destroyed.

5.2.3 Stage-sensing devices

When variations in stage are small, stage records may be established by direct readings of the reference gauge by an observer. However, when stage varies rapidly, the station should preferably be equipped with a sensor and recorder (see also 5.4.5).

The stage sensor converts a change in stage into a proportional quantity of shaft rotation or electrical signal, which is then recorded. The stage sensor may be a mechanical, pressure, electronic or acoustic device. The recorder associated with a stage sensor may be a graphic (analog), digital, magnetic tape or electronic device.

5.2.3.1 Float system

The typical float system consists of a float operating in a stilling well, a graduated steel tape or wire, a counterweight, a pulley and a pointer. The stage fluctuations are sensed by the float and converted into an angular moment of the pulley-bearing shaft.

The dimensions of the float and counterweight determine the sensor sensitivity and the driving torque on the output shaft. The functional requirements of stilling wells are given in ISO 4373 and are summarized as follows:

— to provide, within the well, an accurate representation of the water level in the channel;

— to damp out oscillations of the water surface;

— to accommodate the recording instrument and protect the float system.

5.2.3.2 Pneumatic pressure sensor

This type of stage-sensing device is frequently used where the installation of a stilling well would be too expensive or impractical. The principle of the sensor consists of discharging a small flow of compressed gas into a tube, the free end (orifice) of which has been placed in the water and fixed at an elevation below the level to be measured. The sensor at the opposite end of the tube detects the pressure of the gas, which is proportional to the head of water above the orifice. Servomanometer and servo beam balance devices are some of the mechanisms employed in which pressure is detected, and a strip chart recording or electrical signal is obtained through a servometer. Pressure transducers of appropriate range and accuracy based on a piezoresistive principle, quartz crystal or other type may also be used to produce an electrical signal proportional to the water head. The functional requirements and conditions of installation of these devices are described in ISO 4373.

5.2.3.3 Diaphragm pressure sensor

This is a differential pressure transducer which senses the difference between hydrostatic and atmospheric pressures. The body of the sensor is fixed in the channel at an elevation below the lowest stage to be measured. It is fitted with a diaphragm, one face of which is in contact with the water and the other face is subjected to atmospheric pressure through a capillary tube which is vented to the atmosphere above water level.

The deformation of the diaphragm under hydrostatic pressure is converted into an electrical signal which is proportional to the head of water above the sensor.

The use of such sensors is generally limited to restricted measuring ranges because of the difficulty in meeting the accuracy requirements defined in 5.2.4 over extended measuring ranges. The installation requirements for these sensors are similar to those for pneumatic sensors.

5.2.3.4 Downward-looking ultrasonic device

This device is located above the water surface, away from the influence of the banks. The time is measured for pulses of ultrasound to travel from the device to the water surface and back. The speed of sound in air is assessed either from a measurement of air temperature, or by direct measurement using a target placed at a fixed distance between the device and the water surface.

The manufacturer's recommendations for minimum distances between the device and the banks and water surface should be followed. In the presence of waves on the water surface, the device tends to determine the elevation of the wave crests. The range of these devices (meeting the accuracy requirements of 5.2.4) is limited to about 2 m.

5.2.3.5 Upward-looking ultrasonic device

A transducer is located below the water surface away from the banks, and connected to an electronic unit. The time is measured for pulses of ultrasound to travel from the transducer to the water surface and back. The speed of sound in water is assessed either by direct measurement, using a target placed at a fixed distance above the transducer, or from data derived from an ultrasonic flowmeter (see ISO 6416) of which the level sensor is an integral part.

The manufacturer's recommendations for the minimum distances between the transducer and the banks and water surface should be followed. In the presence of waves on the water surface, the device tends to determine the elevation of the wave troughs.

A common configuration consists of a vertical tube extending above the water surface, with the transducer and target at the lower end.

5.2.3.6 Other stage sensors

Other types of sensors exist which operate according to mechanical principles (buoyancy), electrical principles (capacitance or resistance sensors), or optical principles.

However, they are not covered in this part of ISO 1100.

5.2.3.7 Maximum-stage gauge

A maximum-stage gauge may be used to obtain a record of the peak level reached during a flood when other methods of recording levels cannot be used. Peak discharges may be calculated from the water levels at two gauges installed some distance apart in a stretch of channel, provided that the time lag between measurements is negligible (see ISO 1070). These gauges do not meet the accuracy requirements of 5.2.4.

Maximum-stage gauges are locally made to different designs. Basically they may consist of a vertically installed tube of approximately 50 mm internal diameter, down the centre of which runs a rod. The tube is perforated to permit rising water to enter, the perforations being located to prevent drawdown or velocity head from affecting the static water level. The top of the tube shall be closed to prevent the entry of rain, but it should have an air vent to permit water to rise up the tube without significant delay. Powdered cork in the bottom of the tube floats on the surface of the flood water, and is deposited on the centre rod as the water recedes, thus indicating the maximum stage. Alternatively, the centre rod may be coated with a paint whose colour is permanently affected by water.

5.2.4 Accuracy of stage measurements

For the measurement of stage, in certain installations an uncertainty of ± 10 mm may be satisfactory; in others, an uncertainty of ± 3 mm or better may be required; however, in no case should the uncertainty be greater than ± 10 mm, or ± 0,1 % of the range of the measuring device, whichever is greater (see ISO 4373).

5.2.5 Water-level recorders

5.2.5.1 Analog recorders

Analog recorders produce a continuous graphic record on a paper chart of the rise and fall of the stream with respect to time, as measured by the stage sensor.

Graphic recorders may be mechanical, with a shaft rotation as input signal delivered directly by the level sensor, or electronic (e.g. potentiometric recorders).

Regardless of their type, graphic recorders shall meet the requirements of ISO 4373.

5.2.5.2 Digital paper tape recorders

Digital paper tape recorders punch or inscribe coded instantaneous or discrete values on paper tape at preselected time intervals.

5.2.5.3 Magnetic tape recorders

Magnetic type recorders record coded values of a variable on a magnetic tape at preselected time intervals. Coding may be incremental, i.e. only level variations between two measurements are recorded over the time interval, or discrete values may be recorded. In the latter case, the integer value is generally recorded in binary form. These recorders are coupled to stage sensors via encoders, such as a rotational shaft movement or an electronic encoder delivering electrical signals.

5.2.5.4 Electronic memory (solid state) recorders

These recorders store coded values in an electronic memory. Like magnetic tape recorders, they are coupled to stage sensors via digital coders suited to the signal delivered. Stored values may be retrieved on-site or remotely consulted, using an appropriate device.

5.2.6 Discharge-measuring section or reach (gauging section)

The establishment of the stage-discharge relation at a gauging station is carried out by direct measurement of discharge using the methods described in the appropriate International Standard.

In a permanent gauging station, the measurement section should be clearly identified and suitably equipped to provide satisfactory performance.

Regardless of the measuring method, the discharge through the discharge-measuring section or reach shall be the same as the discharge normal to the reference-stage gauge, over the entire range of discharge rates.

At a gauging station, different measuring sections or different methods may be used to cover the discharge range.

The various methods which can be used for calibrating a gauging station are:

— the velocity-area method using a current-meter (see ISO 748), the moving boat method (see ISO 4369) or floats (see ISO 748);

— the dilution method using a tracer (see ISO 9555-1, ISO 9555-2, ISO 9555-3 and ISO 9555-4);

— the ultrasonic method using a temporary installation in a self-calibrating mode (ISO 6416).

5.2.7 Discharge measurement by the velocity-area method

The principle of the method is to measure the mean velocity and the area of cross-section of flow, the product of which is the discharge.

The physical and hydraulic characteristics of the discharge measuring section shall meet the requirements of ISO 748 for the method to be implemented.

Where the site does not offer the main requirements for a gauging according to the specifications, conditions shall be improved as described below.

a) Minor irregularities in the bank or bed causing local eddies shall be eliminated by trimming the bank to a regular line and a stable slope, and by removing from the bed any large stones or boulders.

b) Trees obstructing the clear view of the measuring section or measuring reach shall be trimmed or removed. The field of view of a measuring section shall extend sufficiently upstream to enable floating debris, which might damage a measuring instrument, to be seen in sufficient time to permit the removal of the instrument from the stream.

c) Suitable access to the site shall be constructed where possible, to provide safe passage at all stages of flow and in all weather for personnel and for any vehicles used for the conveyance of instruments and equipment.

5.2.8 Discharge measurement by the dilution method

This method consists of injecting a tracer solution of known concentration into the stream and sampling the tracer concentration at a point further downstream, where turbulence has mixed the tracer uniformly throughout the cross-section.

The stream discharge is computed from a comparison between the concentrations of the injected solution and of the samples taken downstream.

The physical and hydraulic characteristics of the discharge measuring reach shall meet the requirements of the appropriate part of ISO 9555. The method relies on there being good mixing of the water and tracer throughout the entire cross-section. Adequate length of channel shall be used between the injection and sampling points.

5.3 Preliminary survey and selection criteria

The site selected for observation of stage should be determined by the purpose for which the records are collected, the accessibility of the site, and the availability of an observer if the gauge is nonrecording. Gauges on lakes and reservoirs are normally located near the outlet, but upstream from the zone where an increase in velocity causes a drawdown in water level. Gauges on large bodies of water should also be located so as to reduce the fetch of strong winds, which may cause damage or misleading data. Hydraulic conditions are an important factor in site selection on channels, particularly where water levels are used to compute discharge records.

5.3.1 Preliminary survey

Detailed examination of a large-scale map is required in the first instance. A low-altitude aerial survey (using a plane or helicopter) may be made if the basin is large and not readily accessible by road vehicles. This procedure gives a better view than ground surveys. Aerial views can be used as a basis for selecting potential sites, which can then be evaluated and studied more precisely by ground reconnaissance. Ground reconnaissance will include a detailed visual examination of the site and enquiry among competent services to determine whether hydraulic work projects exist which could modify the stream bed regime. This enquiry should include an investigation of past flow history, low water, high water, overflow areas, floods and bed instability.

5.3.2 Selection criteria

A list of surveyed sites shall be established with their advantages and drawbacks as to the establishment of a gauging station. Selection shall then be made according to the following criteria.

5.3.2.1 Measurement range

The site selected shall be such that it is possible to measure the entire range and all types of flow which may be encountered or which are required to be measured.

The entire range of measurement may be referred to one reference gauge, or certain ranges of discharge may be referred to different gauges. Different methods of calibration may be employed for separate parts of the range, the particular conditions relative to each of the methods of calibration being specified in the relevant International Standard (see clause 2 and annex A).

5.3.2.2 Stability

The operation of a gauging station is based on the assumption of a relation between stage and discharge.

It is therefore desirable that this relation is stable at the selected site. This condition is met if the control section or reach is stable and not subject to variable backwater.

Sites where weed growth is prevalent shall be avoided, if possible.

There shall be no vortices, dead water or other abnormalities in flow. Sites where difficult ice conditions are prevalent shall be avoided, if possible.

5.3.2.3 Sensitivity

The site shall be sensitive, such that a significant change in discharge, even for the lowest discharges, shall be accompanied by a significant change in stage. Small errors in stage readings during calibration at a nonsensitive station can result in large errors in the discharges indicated by the stage-discharge relation.

A comparison shall be made between the change in discharge and the corresponding minimum change in stage to ensure that the sensitivity of the station is sufficient for the purpose for which the measurements are required.

5.3.2.4 Scale readability

It is essential that the reference gauge is easily readable and accurate at all values of discharge, because stage readings are the basis of discharge measurements.

The water surface shall be calm to ensure that readings shall correspond to the indication of the stage sensor. The gauge and the sensor shall therefore be installed close to each other in a low-velocity area.

5.3.2.5 Accessibility

Ideally the station should be accessible, or made accessible, at all seasons regardless of the discharge conditions.

5.3.2.6 Silting

When the stream carries a high sediment load, silting of the gauge may occur, especially in low-velocity protected areas. Access to any stilling well should therefore be provided to permit quick and easy cleaning.

5.3.2.7 Flood protection

Site inspection shall be carried out under low-water and high-water conditions to study currents and eddies. The sensor shall be placed out of reach of any floating debris to avoid accidental damage, and the recorder should be set at an elevation to avoid being flooded under high-water conditions.

Public records shall be consulted, the vegetation shall be observed and the population questioned to this end.

5.3.2.8 Discharge measurements

During preliminary surveys, the possibility of using one method of discharge measurement for the whole discharge range shall be considered. It is preferable, but not essential, that the discharge measuring section, or reach, is situated at the gauging station, but it is satisfactory to use a measuring section at a different location from the gauge if the same discharge is recorded at both places. Exploratory measurements should be carried out to check this requirement.

5.3.2.9 Possible site improvements

When the main requirements for a measuring site according to the specifications cannot all be satisfied, improvements such as those described below can be contemplated at the surveying stage.

a) The loss of water from the main channel by spillage can often be avoided by constructing flood banks to confine the flow in a defined flood channel.

b) Minor irregularities in the bank or bed causing local eddies may be eliminated by trimming the bank to a regular line and a stable slope, and by removing from the bed any large stones or boulders.

c) Unstable banks should be protected wherever possible. Such protections shall extend upstream and downstream of a measuring section for a distance equal to at least one quarter of the bankfull width of the channel in each direction. In the case of float gauging, the whole of the measuring reach shall be protected.

d) Instability of the bed may sometimes be corrected by introducing an artificial control which may also serve to improve the stage-discharge relation (sensitivity) or to create conditions in the measuring section for instruments to be effectively used. Occasionally, it may be possible to eliminate variable backwater effects by introducing an artificial control. Artificial controls are, however, not practicable in large alluvial rivers.

e) Installation of cableways, walkways or footbridges as necessary.

5.4 Establishment of stage-discharge relation gauging station

5.4.1 General

The history of stage data shall be traced either by periodic observations of a reference gauge for streams having small variations in stage, or by continuous stage recording at intervals as necessary to define the hydrograph adequately.

The availability of a control section or reach establishing a stable relation between stage and discharge can convert stage records into discharge records.

However, a stage-discharge relation cannot always be established for alluvial rivers. In this case, the stage-discharge relation is only applicable for the interval of time for which it has been verified by discharge measurements.

5.4.2 Preparatory work

After the preliminary survey, a topographical survey shall be made when selecting a permanent site for a suitable measuring section. This shall include a plan of the site indicating the width of the water surface at a specified stage, the edges of the natural banks of the channel(s), the line of any definite discontinuity of the slope of these banks and the toe and crest of any artificial flood bank.

At sites where a permanent measuring section is warranted, the following preparatory work shall be carried out.

a) All obstructions in the channel or floodway shall be indicated.

b) A longitudinal section of the channel shall be drawn from a point downstream of a control, where this exists, to the upstream limit of the reach showing the level of the deepest part of the bed and water surface gradients at low and high stages.

c) The reach containing the measuring section shall be checked to ensure that it contains no discontinuities that may affect the measurement results. At least five cross-sections shall be surveyed in the measuring reach: two cross-sections upstream from the measuring section and two downstream, at distances upstream and downstream of not less than one bankfull width of the channel.

d) The control shall be defined by one or more cross-sections or by a close grid of levels over the area.

e) The detailed survey of the reach shall be extended to an elevation well above the highest anticipated flood level.

f) The spacing of levels or soundings should be close enough to reveal any abrupt change in the contour of the channel.

g) The bed of the reach shall be examined for the presence of rocks or boulders, particularly in the vicinity of the measuring section.

h) All key points at the site shall be permanently marked on the ground by markers sunk to such a depth below the surface as will secure them against movement. Cross-section markers should be on the line of the cross-section to facilitate the repetition of levels or soundings when the section is checked.

i) Where the main requirements necessary for a suitable gauging site, as specified, are not present, conditions may be improved as described in 5.3.2.9.

5.4.3 Stage measurement and recording

A recorder shall be installed so as to produce a continuous record of stage at intervals as necessary to define the hydrograph adequately (but see 5.4.5.1). It may be desirable to establish gauges at both banks particularly when there is any risk of differential level.

A station benchmark shall be established to conform to 5.2.2.3.

If a section control regulates the stage at low and/or medium discharges at the gauging station, the gauge shall be situated upstream from the control and sufficiently remote from it to avoid any distortion of flow which might occur in that vicinity. It shall be close enough to ensure that a variable stage-discharge relation will not be introduced through the effect of wind or weed growth in the channel. Higher discharges are most often controlled by the general characteristics of the channel for a considerable distance downstream.

The reference gauge and water-level recorder shall be located as close as possible to the measuring reach unless floats are used to measure the velocities, in which case the reference gauge and water-level recorder shall be located near the midpoint of the measuring reach.

The reference gauge shall comply with 5.2.2 and ISO 4373.

5.4.4 Discharge measurement

The stage-discharge relation shall be established by measuring the discharges corresponding to respective stage values.

5.4.4.1 When the station is to be calibrated using current meters to measure velocities, exploratory measurements of velocities shall be made in the proposed measuring section and in the cross-sections immediately upstream and downstream. When possible, the method of velocity distribution described in ISO 748 shall be used for these measurements to determine the feasibility of using reduced-point methods (see 5.3.2.8 and 5.2.6).

For stations calibrated with current-meters, a standard profile on the measuring cross-section shall be drawn, indicating the position of the cross-section markers. On this drawing, the positions selected for the measuring verticals may be recorded (see ISO 748). The bed levels of the cross-section shall be frequently checked and the profile revised, if necessary.

The velocity measurements described above shall be repeated at more than one stage to ensure that any abnormality of flow is detected.

If the site allows it, the discharge-measuring section may be equipped with a device for improving the measuring equipment to be used. Bridges and current-meter wading rods, cableways and current-meter suspension equipment shall conform to ISO 4375 and ISO 3454.

5.4.4.2 When floats are to be used for velocity measurements, trial runs of floats shall be closely spaced across the width of the channel.

For stations calibrated with floats, a standard plan shall be prepared on which the lines of the selected floats, runs and the release points for floats shall be indicated. A copy of this plan shall be kept in the instrument house at all times (see ISO 748).

5.4.4.3 When dilution techniques are to be used to calibrate the station, trial measurements should be made to check the efficiency of mixing (see ISO 9555-1).

5.4.5 Operation of a stage-discharge relation gauging station

5.4.5.1 The production of a satisfactory record depends on the station being maintained in full operating order at all times. This requires efficient attention to the recorder and proper maintenance of the station, its equipment and its calibration. Where a station is fitted only with a reference gauge or reference gauges (vertical, inclined, wire-weight or hook) and no water-level recorder, the local observers shall be required to furnish readings at specified intervals of all the gauges in their care. Preferably the readings shall be made at fixed hours. The intervals between the readings shall be determined by the rate at which the water level at the site changes, but arrangements shall be made to have additional readings when the water level is changing more rapidly than usual.

It is essential that the local observer records the exact time and correct date of each gauge observation.

5.4.5.2 When a recorder is provided, visits by the observer should be made throughout the period to verify that the recorder is operating satisfactorily. The observer shall be required to record readings of stage from the reference gauge with the exact time of recording for comparison with the recorder reading. To relate the readings to a chart trace, the observer may mark the chart. At all stations, the observer shall record any obstruction of the channel, for example by weeds or ice, and shall note any casual obstruction of the channel, inlet pipe(s), measuring structure or transducer mountings caused by flood debris or any other cause. The site and equipment shall be kept generally clean and tidy, particular attention being paid to legibility of the reference gauge. The observer may be required to despatch all records, tapes or charts to the record office for processing immediately after they have been completed, together with any relevant notes or observations.

5.4.5.3 Every gauging station shall be inspected whenever any incident which might affect its accuracy is reported by the observer.

5.4.5.4 All mechanical recorders and recorder clocks shall be cleaned and lubricated in accordance with the manufacturer's instructions or as indicated by experience under prevailing operating conditions.

5.4.5.5 The elevation of all key points (including particularly the zero of the reference gauge) shall be surveyed when the station is established and shall be checked by reference to the station benchmark at least annually or following any flood when equipment might have been damaged by debris or by ice. At the same time, any vertical staff gauge shall be tested for verticality. Where feasible, correlation of the station benchmark with a National Survey datum shall be checked at intervals of not greater than five years.

5.4.5.6 Bed profiles shall be checked after a flood.

5.4.6 Stage-discharge gauging stations with artificial controls (notches, weirs and flumes)

5.4.6.1 Principle

When physical and hydraulic conditions permit, an artificial control consisting of a fixed, undeformable structure may be installed. The stage-discharge relation shall then depend on the geometrical characteristics of the artificial control and shall be defined either by

— the application of the relevant International Standard (see clause 2), or

— by a previous calibration using other methods.

5.4.6.2 Survey and selection of site

A preliminary survey shall be made of the physical and hydraulic features of the proposed site to check that it conforms (or may be constructed or modified so as to conform) to the requirements necessary for measurement of discharge by the structure as specified in the relevant International Standard given in clause 2.

Particular attention shall be paid to the following features in selecting the site.

a) adequacy of the length of channel relative to the regular cross-section;

b) uniformity of the existing velocity distribution;

c) avoidance of a steep channel (Froude number shall not exceed approximately 0,5);

d) effects of any increased upstream water levels due to the measuring structure;

e) conditions downstream of the control structure (including tides, confluences with other controlling features, seasonal weed growth);

f) impermeability of the ground on which the structure is to be founded and the necessity for piling, grouting or other means of controlling seepage;

g) necessity for flood banks, to confine the maximum discharge to the channel;

h) stability of the banks, and the necessity for trimming and/or revetment;

i) uniformity of section of the approach channel.

If the site does not possess the characteristics necessary for satisfactory measurements, or if an inspection of the stream shows that the velocity distribution in the approach channel deviates appreciably from uniformity, the site may have to be rejected unless suitable improvements are practicable. Alternatively, the performance of the installation shall be checked by independent flow measurement.

The flow conditions downstream of the structure are important in that they control the tail-water level which may influence its operation. The structure shall be so designed that it cannot become drowned under the operating conditions specified in the relevant

International Standard. Construction of a measuring structure in a river or stream may alter conditions and cause scouring downstream of the structure, hence appropriate bank and bed protection should be included in the design.

If the flow in the approach channel is disturbed by irregularities in the boundary, for example large boulders or rock outcrops, or by a bend, sluice gate or other feature which causes asymmetry of discharge across the channel, the accuracy of gauging may be affected. The flow in the approach channel should have a symmetrical velocity distribution; this can most readily be ensured by providing a long straight approach channel of uniform cross-section.

The cross-section of the approach shall be uniform for a length of approximately 10 times the width, in order to produce a regular (uniform) velocity distribution (see the International Standards on weirs and flumes listed in clause 2).

Conditions in the approach channel can be verified by inspection or measurement. Several methods are available, such as floats, velocity rods, or concentrations of dye, the latter being useful in checking conditions at the bottom of the channel. A complete and quantitative assessment of velocity distribution may be made by means of a current-meter.

5.4.6.3 Types of measuring structure

5.4.6.3.1 Standardized measuring structures

The calibration equations of standardized measuring structures which are the subject of International Standards shall be strictly complied with (see clause 2):

a) thin-plate weirs

- full-width
- with side contraction
- notches

b) broad-crested weirs

- rectangular, with sharp edges
- rectangular, with rounded edges
- triangular profile

c) standing-wave flumes

- with side contraction
- with hump

5.4.6.3.2 Nonstandardized measuring structures

A combination of different standardized measuring structures is also permissible using standard calibration equations for each structure (compound gauging structures). Nonstandardized measuring structures require a field or laboratory calibration over the entire range of discharge to be measured.

5.4.6.4 Choice of measuring structure

A guide for the selection of weirs and flumes is given in ISO 8368, to which reference shall be made.

The parameters involved in selecting a structure are:

- expected difference in water level (afflux) after construction;
- measuring accuracy;
- dimensions and shape of channel;
- conditions of flow in the approach channel;
- presence of floating or suspended debris;
- magnitude and range of discharge to be measured.

5.4.6.5 Construction and installation

The gauging station shall consist of an approach channel, a measuring structure (including its associated upstream gauges), a downstream channel and a reference gauge. Normally a water-level recorder is installed to provide a continuous record of head.

The measuring structure shall be rigid and watertight, and capable of withstanding flood-flow conditions without damage from flow around the ends or from downstream erosion. The axis shall be in line with the direction of flow of the upstream channel, and the geometry shall conform to the dimensions given in the relevant International Standard (see clause 2).

The surface of a flume may be constructed in concrete with a smooth cement finish or surfaced with a smooth noncorrodible material. The weir crest shall be constructed using precision tooling.

Precautionary measures shall be taken to avoid scouring, particularly downstream.

Appropriate devices shall, if necessary, be placed upstream to straighten flow in the approach channel. These devices may be in the form of baffles in order to avoid asymmetric flow and to obtain an acceptable velocity distribution in the vertical and horizontal planes.

5.4.6.6 Checking of dimensions

In order to obtain an acceptable uncertainty in the discharge, the tolerances in construction, which are given in the relevant International Standards, shall be followed. The structure shall therefore be measured on completion and average values of relevant dimensions and their standard deviations at 95 % confidence limits computed. The former shall be used for computation of discharge and the latter shall be used to obtain the overall uncertainty in the determination of discharge.

5.4.6.7 Stage measurement

The position of the stage (head)-measuring section with respect to measuring structures is dealt with in the relevant International Standard. If a flow straightener or baffle is used upstream, the distance between the stage-measuring section and this device shall not be less than 10 times the maximum head.

As the size of the structure and the head reduce, small discrepancies in construction, in the zero setting and reading of the stage-measuring device become of greater relative importance.

The accurate initial setting of the zero of the stage-measuring device with reference to the level of the weir crest or the invert of the throat, and regular checking of this setting thereafter, are essential if overall accuracy is to be maintained.

An accurate means of checking the zero shall be provided. The instrument zero shall be obtained by a direct reference to the crest level or throat invert, and a datum plate shall be set on the wall of the approach channel and in the stilling well accurately levelled with reference to the crest or throat.

The reference gauge and recorder shall conform to ISO 4373.

5.5 Establishment and operation of a stage-fall-discharge relation gauging station (two gauges)

5.5.1 General

In a stable channel with variable downstream control of water level, when there is no unique relation between stage and discharge, there may be a relation between water-surface slope (or fall), stage and discharge. In such channels, two gauges are used to measure water level at two locations sufficiently far apart to compute water-surface slope (or fall). A relation between slope (or fall), stage and discharge can be developed according to the procedure given in ISO/TR 9123. The site should be sensitive, such that even for the lowest discharge, there should be measurable fall between the two gauges. Small errors in stage readings during calibration at a nonsensitive station can result in large errors in the discharge indicated by the stage-fall-discharge relation.

5.5.2 Preparatory work

A preliminary survey should be made to ensure that a length of reach is adequate to provide sufficient fall for acceptable accuracy. Two suitable gauging sites should be available, one at each end of the reach, for the purpose of measuring water level. There should be no significant tributary inflow to or outflow from the reach between the two gauging sites.

5.5.3 Stage measurement and recording

5.5.3.1 Composition of gauging station

The gauging station shall consist of two water-level gauges, one of which is the reference gauge. Water-level recorders may be installed to produce a continuous or intermittent record of stage. The reference gauge should be located as close as possible to the discharge measurement site.

5.5.3.2 Benchmarks

Gauging-station benchmarks shall be established to maintain the datum of the gauge zero. Benchmarks should conform to 5.2.2.3.

5.5.3.3 Stage (reference) gauges

The stage-measuring gauges and recorders shall conform in all respects to the requirements of stage gauges specified in 5.2.3 and ISO 4373.

5.5.4 Discharge measurement

The stage-fall-discharge relation shall be calibrated by measuring the discharge corresponding to different stage and fall values. Discharge measurement shall be made in accordance with ISO 748 or ISO 4369.

5.5.5 Operation of the station

The operation of the station shall conform to the specifications in 5.5 for the two gauges and stage recorders. As the slope or fall is determined by a difference between stage reading at two gauges, careful attention should be given to stage and time adjustments for the two recorders.

6 Direct discharge-gauging stations

For these types of station, control sections or control reaches are not necessary. Instantaneous measurement by appropriate means of the cross-sectional area and mean velocity can be used for the determination of discharge.

6.1 Ultrasonic gauging stations

6.1.1 Principle

The principle of the ultrasonic (acoustic) method is to measure the velocity of flow at a certain depth in the channel by transmitting acoustic pulses in both directions through the water from transducers located in the bank on each side of the river. The transducers may be designed to transmit and receive pulses. They are staggered so that the angle between the acoustic path and the direction of flow is usually between 30° and 60°.

The difference between the time of travel of the pulses crossing the river in an upstream direction and those travelling downstream is directly related to the average velocity of the water at the depth of the transducers. This velocity can then be related to the average velocity of flow of the whole cross-section and, if desired, by incorporating an area factor in the electronic processor the system will provide an output (readout) of discharge.

The requirements for the selection of site, design, construction and operation of an ultrasonic gauging station are dealt with in ISO 6416. A summary of the main requirements and specifications is given in the following sections.

6.1.2 Selection of site

A preliminary survey shall be made to ensure that the physical and hydraulic features of the proposed site conform to the requirements for the application of the method.

The site selected shall be such that it is feasible to measure the entire range and all types of flow which may be encountered or which are required to be measured. The following factors should be considered.

a) Abrupt bends in the channel shall be avoided. In the reach between the two cross-sections containing the transducers, the velocity distribution shall be uniform.

b) Cause of distortion or interruption of the acoustic signal, e.g. weed growth, suspended materials, entrained air bubbles, etc., shall be avoided. To avoid refraction of the acoustic signal, minimum depth requirements as a function of the acoustic path length and signal frequency shall be complied with. Refraction may also be caused by temperature gradients.

c) Adequate electrical power shall be available or made possible.

6.1.3 Design and construction

The gauging station shall consist of:

a) one or more pairs of transducers (single-path or multipath), either

   1) installed on each bank and fixed permanently in position, or

   2) installed on each bank, and having facility of movement in the vertical plane or on an incline.

b) an electronic console containing an electronic data processor and a data recorder, or an output to a telemetry system;

c) a level recorder interfaced with an electronic data processor;

d) a reference-stage gauge.

All interconnecting cables to or from transducers shall be shielded and damage-protected.

The decision to use a single-path or multipath system will depend on the intended accuracy of the desired system, the range in stage to be expected, the vertical velocity distribution at these stages and the attenuation and reflection limitations. If a satisfactory rating can be achieved from a velocity index at all stages, the single-path system may be considered in preference to a multipath system. For this method of fixed transducers, a path or index velocity is obtained, which is related to stage and area to obtain discharge. Calibration by current-meter is required in this method.

For the method whereby the transducers are designed to move on a vertical or inclined assembly, the system is self-calibrating. This is performed by establishing vertical-velocity curves by moving the transducers to the various paths and obtaining a series of path velocities in the vertical. This should be performed at different values of stage and the resulting curves analysed to determine the optimum location to fix the transducers.

In the multipath system, where several pairs of transducers are employed, the optimum positions of these shall be determined from a preliminary examination of vertical-velocity curves obtained by current-meter. The transducers should be fixed and preferably mounted on an assembly.

When the positions of the transducer mountings have been decided, the angle and path length between the mountings shall be carefully surveyed for subsequent programming into the electronic processor. A survey of the bed level between the transducer mountings along the path length shall be made, and the average bed level shall then be calculated for input into the electronic processor where discharge is being determined on-site. This survey shall be repeated periodically as an operational requirement.

The reference gauge and level sensor shall be in accordance with ISO 4373. The ultrasonic equipment shall be in accordance with ISO 6416.

6.1.4 Calibration

The calibration of an ultrasonic gauging station should be performed by the ultrasonic meter itself. If necessary a check calibration should be made by current-meter. If channel conditions change with time, it will be necessary to re-evaluate the calibration.

6.1.5 Operation of the station

The production of a satisfactory record depends on the station being maintained in full operating order at all times. This requires proper maintenance of the station, its equipment and its calibration.

In carrying out checks on the equipment, the instructions given in the manufacturer's handbook shall be followed. The operator shall arrange to have special training, and be able to attend to minor defects in the system, should they occur.

The electrical energy source shall be reliable or assisted; if not, automatic restart of the station shall be provided in case of power failure.

6.2 Electromagnetic gauging stations

6.2.1 Principle

The principle of the electromagnetic method is to measure the potential difference generated across the width of the channel when the water flows through a vertical magnetic field generated by a coil located either beneath or above the channel. The electrical current through the coil is reversed at regular intervals in order to generate an oscillating magnetic field, the potential difference measured being proportional to the spatial average of the velocity of the water in the channel. The system is described in detail in ISO/TR 9213.

6.2.2 Selection of site

A preliminary survey shall be made to ensure that the physical and hydraulic features of the proposed site are in accordance with the requirements given in ISO/TR 9213. Particular attention shall be paid to

— avoiding areas where electrical interference may occur;

— availability of power supply;

— access and working space for construction of the coil;

— possible temporary diversion of the channel to allow an insulating membrane to be installed;

— width-to-depth ratio of the channel;

— need to calibrate the gauge by an alternative method after construction;

— avoiding rapid changes in water quality.

6.2.3 Design and construction

The gauging station shall consist of

a) a field coil installed below or above the channel;

b) a pair of electrodes, one on each side of the channel;

c) an insulating membrane, where necessary;

d) an instrument unit including a coil power supply;

e) a water-level measuring device;

f) a reference-level gauge.

The station shall be constructed in accordance with ISO/TR 9213.

6.2.4 Calibration

After the station has been installed, a rating equation for the calculation of discharge, Q, should be developed of the form:

$$Q = \left(K_1 + h - K_2 h^2\right) \phi / H$$

where

K_1 and K_2 are constants;

h is the depth;

ϕ is the potential difference measured between the electrodes;

H is the magnetic field computed from the dimensions of the coil and its position relative to the water flowing in the channel.

The gauging station shall be calibrated by current-meter or other method, to ensure that the equipment performs as expected by the theoretical rating equation, over the whole range of flows and depths expected. Care shall be taken to ensure that the activity of calibration does not affect the working of the electromagnetic gauge.

6.2.5 Operation of the station

The station shall be maintained in accordance with the recommendations given for ultrasonic gauging stations in 6.1.5 . Periodic checks should be made to ensure that the level of electrical interference does not significantly increase, and that the rating equation remains valid.

7 Measurement of stage and discharge under particular conditions

7.1 Ice conditions

Weather conditions such as frost or ice may impede the operation of the stage-sensing device or recorder and the application of normal measuring methods, thus affecting the stability of the stage-discharge relation (see 8.4.1).

7.1.1 Stilling well

Any stilling well and inlet pipes shall be constructed in such a manner that the system will remain operational during extended periods of freezing temperatures. This may be achieved by the following.

a) Construct the well of nonconductive materials, or insulate to prevent frost penetration.

b) Where necessary and feasible, the lower inlet pipe shall be wrapped with electrical heating tape, or the heating tape placed inside the inlet pipe, so that it may be kept free of ice using a commercial power source or portable generator. A steaming apparatus having the necessary length of steam hose may also be used to thaw an inlet pipe.

c) Inlet pipes shall be positioned such that the lower pipe is below the bottom of the ice sheet, and the upper pipe is above the ice sheet. In this way the recorder will operate on the lower inlet during the freezing period and, should lower inlet freeze, the upper inlet will become operative during the snowmelt freshet while the lower intake thaws.

d) Stilling wells which are constructed far enough into the bank to be below the frost line may be kept free of ice through the use of a removable insulated subfloor. The subfloor shall be positioned below the frost line but above the maximum likely water level during the freezing period. Provision shall be made for free passage of the float and counterweight wires. The subfloor should be removed prior to the snowmelt freshet.

e) In certain areas, the use of the following method may be acceptable. An open-ended waterproof cylinder, of diameter larger than the float diameter, shall be placed vertically in the well and partially filled with a nonvolatile petroleum distillate. The cylinder shall be of sufficient length and installed such that the lower end will be substantially lower than the minimum anticipated water level and the upper end higher than the maximum anticipated water level for the period over which freezing temperatures occur. Care should be taken to ensure that the float will ride freely in the cylinder and the travel of the counterweight is not impeded. The cylinder and petroleum distillate should be removed before the spring freshet. If the petroleum distillate escapes from the cylinder, errors in stage record will result because of the difference in specific gravity between water and distillate.

f) Stilling wells may be heated by means of electrical or propane (bottled gas) heaters. In some instances, it may be necessary to mount the heater on a separate float system or to incorporate an electric immersion heater into the recorder float to prevent freezing of the well. The quantity of heat provided shall be the minimum required to keep the stilling well ice-free. Overheating of the well will result in production of excessive water vapour which will condense as frost in the recorder housing possibly causing jammed doors, recorder and clock malfunctions.

It may be necessary to heat the water stage instrumentation to ensure continuous operation under severe temperatures, although some instruments will operate at temperatures of − 45 °C if special cold-temperature lubricants are used.

7.1.2 Pneumatic pressure sensor

The following precautions should be taken to protect a pneumatic pressure sensor under ice conditions.

a) The orifice from which the compressed gas exits into the stream shall be mounted at an elevation below that of the bottom of the ice sheet that would normally form at the gauging station.

b) The orifice shall be installed remotely from locations where anchor ice may form, such as above rapids, to prevent blockage of the orifice.

c) Where there is a possibility of the orifice becoming frozen, the gas-feed pressure shall be reduced to a value less than the pressure equivalent to the full-scale range of the instrument. This will prevent possible instrument damage in the event of the orifice becoming blocked.

d) The pipe to the orifice shall be buried in the bank to a depth sufficient to prevent damage from ice scour during a freshet.

e) The mercury used in some instruments solidifies at approximately − 40 °C, preventing collection of water-level information at colder temperatures. The instrumentation shall be heated to the minimum operating temperature stated by the manufacturer, if uninterrupted operation is required. Battery power supplies may be waterproofed and placed in the stream to obtain satisfactory performance during extremely low temperatures.

7.1.3 Diaphragm pressure sensor

The following precautions should be taken to protect a diaphragm pressure sensor under ice conditions.

a) The body of the sensor should be located at an elevation below the bottom of the ice sheet that would normally form at the gauging station.

b) The body of the sensor should be located away from locations where anchor ice or ice jams might form, such as above rapids.

c) All connections and lines leading to the sensor shall be protected from ice damage by burying them to a sufficient depth, or enclosing them in a duct.

d) The elevation of the body of the sensor shall be checked periodically by surveyors' level to maintain the established elevation and to ensure there has been no vertical movement due to ice or floating debris.

7.1.4 Notches, weirs and flumes

Where necessary and feasible, these structures shall be heated during the freezing period to ensure that the head-discharge relation is applicable during the winter. This may be accomplished by suspending an array of electric or propane radiant heaters from a hood over the structure, or by enclosing the entire structure, leaving openings for the free inflow and outflow of water. The space enclosed in this manner may then be heated.

The elevation of the structure shall be checked by surveyor's level during the ice period to ensure the structure has not heaved due to freezing of the soil.

7.2 Weed growth at gauging stations

Weed growth in the water changes the hydraulic flow conditions in the control reach, and hence the stage-discharge relation. Seasonal plant development makes it necessary to correct discharge measurements, in order to follow the variations in the stage-discharge relation. The observer shall note the dates when weeds appear and disappear, the development and density of vegetation, and the dates of weed-clearing campaigns.

To determine discharge, the following procedure shall be followed.

a) A reference stage-discharge relation shall be established in the absence of weed.

b) For each discharge measurement affected by weeds, the stage difference with respect to the reference stage-discharge relation shall be determined.

   1) Using site data, a curve of variation of these differences as a function of the days of the year shall be plotted.

2) When processing records, stage readings shall be corrected to take into account the stage differences with respect to the stage readings on the curve for the day under consideration, and shall then be converted into discharge valves using the reference stage-discharge relation.

Weed growth due to water pollution may impede proper operation of stage sensors (obstruction of tappings).

Weed growth may also be an obstacle in using ultrasonic devices for the measurement of velocities (see 6.1).

7.3 Rapid changes in discharge

The design and construction of the gauging station shall provide for failure-free operation of the station in the case of sudden floods and rapid changes in stage and discharge. If recording of stage is not continuous, the frequency of stage readings shall be such that changes are observed without undue delay.

Because flow may change rapidly, the stage-discharge relation may show a hysteresis effect. Plotting shall therefore be made in accordance with ISO 1100-2.

8 Compilation of records

8.1 General

8.1.1 Collection of field data

The collection of field data in the form of records of gauge readings, charts, tapes or solid-state modules taken from recorders and of velocity or discharge measurements is only the first step in the compilation of a station record. While it is important that field observation should be made accurately, no less importance should be attached to the work of reducing the transcribed information. Both operations shall be performed with meticulous care, as negligence in either operation can invalidate the value of the records. All field data should be examined critically and promptly with the objective of uncovering any anomalies which may exist.

8.1.2 Converting stage data to discharge data

Where recorders are installed, readings of water levels from instrument charts, tapes or solid-state modules shall be taken at such intervals as may be necessary to define the hydrograph adequately. The conversion of data from water level to discharge by the use of stage-discharge curves and station-rating tables, in the case of a velocity-area station, and the weir or flume equation in the case of a measuring structure, should be made for each water level, making all necessary corrections. The daily mean discharge should be computed independently. For the computation of daily mean discharge, the assumption is often made that changes in water level which take place between readings, whether these are observations of a gauge or readings from a recording instrument, vary linearly with time. This is not necessarily the case. Readings should therefore be taken at frequent enough intervals to ensure that the assumption of linearity is valid.

8.1.3 Extrapolation of the stage-discharge relation

A stage-discharge curve should not be applied outside the range of observations upon which it is based. If estimates of flow, however, are required, they should be so identified having regard to the range, number and quality of the observations which have been made, to the natural features of the gauging station and to the conditions of flow with respect to time. Little reliance shall be placed on extrapolation below the lowest observed value (see ISO 1100-2). Discharges determined by extrapolation shall be distinguished from those derived by interpolation. Notwithstanding, a record may be considered a standard record provided the sum of the estimated quantities does not exceed 5 % of the total run-off for the year.

8.2 Stage records

8.2.1 At constant time intervals

Stage values are normally taken off charts, tapes or solid state modules at constant intervals of time (but see 8.3.3). The specified interval should be determined as a function of the rate of change in stage. The maximum and minimum stage values for a given period of time should also be recorded. If the reference gauge is read only once a day, however, the value is converted to discharge from the rating curve (if required), and that discharge taken as the daily mean discharge.

8.2.2 Pivot-point values

Slope-change points or "pivot points" should be marked or entered on the record and, since stage varies linearly with time between two consecutive pivot points, the coordinates of these points (stage and time) should be noted. The principle of this