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Hydrometric determinations — Measurement of suspended sediment transport in tidal channels

Déterminations hydrométriques — Mesurage du transport solide dans les canaux à marée

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Foreword

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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.

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Introduction

Estuaries and creeks have become regions of major developments pertaining to port and harbour facilities, navigation, reclamation and effluent disposal. Human interference with water bodies, for example, providing navigational channels, installing major or minor structures and reclaiming land, need thorough examination of their impact on morphological changes, stability of banks and channels, the consequences of capital and maintenance dredging, and the selection of disposal grounds. For these purposes, it is necessary to estimate the suspended sediment transport rates in tidal channels, which can be based on data on morphological characteristics of the channel, flowrates and the corresponding suspended sediment concentration.

In comparison to the situation in unidirectional flow, the flow as well as sediment concentration at different locations along tidal channels are much more complex. The salt water flow from the sea at one end and the fresh water flow from the river at the other end are responsible for spatial and temporal variations in water and sediment movement in tidal channels. When measuring the flowrate and suspended sediment concentrations for estimating sediment transport rates, these factors need to be considered.

Hydrometric determinations — Measurement of suspended sediment transport in tidal channels

1 Scope

This International Standard deals with the method and techniques for the sampling of suspended sediment and estimation of sediment transport rates in natural and man-made channels influences by tidal action.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative documents referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

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

ISO 2425, *Methods for hydrometric measurements under tidal conditions.*

3 Terms and definitions

For the purposes of this International Standard, the terms and definitions given in ISO 772 and the following apply.

3.1
mixed tides
tides which have two markedly unequal successive high waters, or two markedly unequal successive low waters, or both, during most of each month

3.2
divergence
deviation of the angle between the flood and ebb axes from 180°

NOTE In a straight reach, the flood and ebb flow directions are ideally expected to lie on the same axis but in the opposite direction, i.e. the change in flow direction is 180°. However, in most situations the directions of flood and ebb flows are not along the same axis, due to prevailing approach conditions from either side.

3.3
flood [ebb] predominance
net flow, either in the flood or in the ebb direction, resulting when the flood and ebb velocity-time curves are such that the net flow integrated over a tidal period, either at a point or over a vertical, is not zero

NOTE In a typical situation, one part of a tidal channel may have flood predominance whereas the other may have ebb predominance.

3.4
creek
inlet or arm of a river or a small stream joining the coast

4 Salient features of sediment transport in tidal channels

Measurement of discharge and estimation of corresponding suspended sediment concentration by analysis of water samples are essential to estimating the rate of sediment transport through a channel section. The following aspects shall be taken into account when planning the collection of data and estimation of sediment transport.

a) Flow is two-way in tidal channels as a result of tidal fluctuation in the sea. During the flood phase, the water level rises and the flow is from the sea toward the upstream, whereas during the ebb phase, the water level falls and the flow is seaward.

b) The extent of tidal excursion, magnitude and direction of tidal current, and flood and ebb periods (at any cross-section) differ from tide to tide depending on the tidal range and freshwater discharge.

c) The variation in water level from section to section in a tidal channel depends on the freshwater discharge, tidal range in the sea, the channel bed slope and frictional resistance at the bed and banks of the channel.

d) All the above aspects result in temporal and spatial variation in the sediment transport at all points in a tidal channel.

e) The quantity and type of sediment which enters a tidal channel depends on the freshwater discharge, the wave climate and tides in the sea. As a result, there can be a large variation in the amount of suspended load in tidal channels.

f) The variation in the strength of the current from spring to neap or from neap to spring results in significant changes in the bed configuration along the channel. Variation in the freshwater discharge also causes such changes.

g) The directions of flood and ebb currents in a cross-section do not necessarily differ by 180°, (i.e. complete reversal), as the flow is governed by the bed and bank configurations upstream of flow. Furthermore, the flood flow may dominate one part of the cross-section whereas the ebb flow dominates the other part.

h) The time of reversal and the direction of transport are commonly different across the cross-section and at different depths on a vertical.

i) In a wide channel near the mouth, the time of reversal from flood to ebb or from ebb to flood differs appreciably from one part to another in the section, resulting in a large circulation.

j) The difference in densities of sea water and river water affects the mixing characteristics of tidal and freshwater flows, depending on their relatives magnitudes. The flow in the channel can be well-mixed, partially mixed or stratified.

k) Water level is affected by atmospheric pressure fluctuations and wind drag.

l) Biological effects can determine the erosivity within an estuary, which can affect the suspended sediment concentrations in time and space.

m) Variations in temperature change water viscosity and also affect the settling velocity of different sediments, thus affecting the suspended sediment load throughout the year.

n) Human activities, such as dredging, disposal and trawling, will also influence the amount of suspended sediment within the water column.

5 Guidelines for measurement and estimation of suspended sediment transport

a) Long-term measurements of flow and simultaneous water sampling are required for estimating sediment transport in tidal channels. For regular semidiurnal tides, data should be collected for a minimum of 13 h. However, in case of diurnal tides or where there is a strong diurnal component (mixed tides), an observation period of 25 h is recommended. The time interval between the observations shall also be kept as small as possible (no more than 0,5 h) due to the unsteady nature of tidal flow.

b) The period of data collection may need to cover various ranges of tide, from neap to spring, to account for the variation in velocity and suspended sediment concentration if morphological changes are to be estimated.

c) During the preliminary survey, the mixing characteristics of the tidal channel shall be identified by taking simultaneous observations at surface and at bed. If flow is stratified, it may be necessary to extend the observation period to cover a period from neap to spring tides.

d) As the presence of freshwater discharge affects the flow field and sediment transport, collection of data is necessary to cover both dry and freshet seasons.

e) Items a) through d) emphasize the need for long-term observations. Depending on the hydraulic conditions, a decision should be taken on the required period and time of observations to serve the purpose for which the investigation is undertaken. It may also be possible to limit the field observations if suitable numerical models are available to simulate the range of prevailing hydraulic conditions.

f) The scatter in data for suspended sediment concentration is more than for unidirectional flow in tidal channels, due to the variable nature of the flow. Repeated observations for the same tidal conditions are therefore necessary to arrive at a reliable estimation of sediment transport.

g) The sampling points on a vertical need to be changed with variation in flow depth in a tidal cycle. The sampling points should be selected on the basis of depth of stratification for stratified flow,

h) The level of the sampling point with respect to the water surface is easily measured. However, the elevation of water surface itself changes with time. This change shall be taken into account while analysing and interpreting the data in absolute terms. The simultaneous measurement of water level with respect to a known datum is necessary.

i) Simultaneous observations are desirable at all the verticals in a section, as well as at a number of sections, depending on the reach to be covered. This requires more resources in respect of boats, equipment and personnel in order to determine the effects of variations in flows.

j) Point sampling is better than depth-integrated sediment sampling in tidal channels.

k) During the collection of data over long observation periods (even covering one tidal cycle), problems may arise due to ships in the navigation channel and dredging activity. Considering these problems, as well as the limitation of resources in carrying out simultaneous observations at a number of locations, it may be necessary to utilize data collected from different tides of the same range to cover the different locations, keeping at least one common observation station for reference.

l) Though the values of suspended sediment flux during the flood and ebb phases can be very large, the value of the net flux (algebraic sum of flood and ebb fluxes) can be very small. Errors in the estimation of flood and ebb sediment fluxes may therefore result in a significant error in the magnitude and perhaps even in the direction of the net flux. Great care therefore shall be taken to minimize errors in the basic measurements.

6 Selection of site

6.1 Choice of cross-section

It is desirable to carry out a preliminary survey to choose a suitable site satisfying the conditions given below, in addition to those conforming to ISO 2425.

a) The banks of the cross-section should not be too flat, in order to avoid large intertidal variation in water-surface width.

b) There should not be appreciable divergence between predominant flood and ebb flow directions. Sections involving multiple channels should be avoided.

c) There should not be abrupt variation in bed levels across the cross-section.

d) The minimum depth of water at the lowest low water in the section should be sufficient for submergence of the equipment, viz. currentmeter and sediment sampler. A minimum depth of 2 m is desirable.

These conditions are broadly specified and are intended to serve as a guideline. Site-specific conditions, as well as the requirement for estimation of transport in a specific reach of interest, may not permit strict adherence to all these conditions.

6.2 Choice of verticals

The section should be divided into as many equally spaced segments as possible. Ideally, the spacing between the verticals in a cross-section should be:

a) 0,25 W, 0,5 W, 0,75 W

or

b) 0,2 W, 0,4 W, 0,6 W, 0,8 W

where W is the total width of the channel.

However, actual spacing should be determined by the flow distribution across the section, especially if site conditions given in 6.1 are not satisfied.

6.3 Choice of sampling points on a vertical

The sampling points on a vertical may be at 0,2 d, 0,4 d, 0,6 d, 0,8 d (where d is flow depth at the sampling vertical at sampling time) and near the surface and bottom, where the depth is more than 10 m. However, when there is substantial variation in flow depth, the sampling points are required to be adjusted for every set of observations. For depths of water shallower than 10 m, sampling only at near-surface, near-bed and at mid-depth should be considered.

In the case of stratified flow, the spacing between sampling points in lower layers shall be about 0,5 m (or at least less than 1 m). In order to decrease the total number of sampling points from consideration of available resources, the spacing in the upper layer may be increased.

7 Principles of measurement

For the estimation of suspended sediment transport, the following principles shall be followed.

a) Measurements of velocity and collection of water samples should be simultaneous at each point without disturbing the flow field appreciably. A 1-min period of measurement of current speed is recommended to allow for integration of pulses. To obtain a representative average a minimum of three repetitions should be made.

b) Considering rapid changes in conditions, the time interval between the collection of data at the same point on a vertical should be as small as possible (not greater than 0,5 h). The velocity measurements at various points on a vertical should be corrected to the same instant, for example the first observation, in order to obtain the correct velocity distribution over the vertical. The method for correction specified in ISO 2425 may be followed.

   It may, however, be noted that though the velocity measurements can be corrected by the method cited above, such a correction is not meaningful for suspended sediment concentration. Hence, it is recommended that no correction in sediment concentration be made and the minimum possible time interval be used.

c) Integrating-point sediment sampling is necessary.

d) For a more accurate estimation of suspended sediment concentration, the quantity of each sample should be at least 1 litre.

e) Simultaneously, measurement of the water level at, or close to, the cross-section is required during data collection. Echo-sounders shall be used to monitor the depth during observation.

f) As simultaneous observations may not be possible at all the verticals in a cross-section or at all the cross-sections of interest, the collection of data can be carried out over tides of practically equal range, keeping one common (reference) station for comparison.

g) Considering the known scatter of sediment concentration data, it is recommended that the observations be repeated for a nearly equal range of tide.

h) Data on the tidal variation at the mouth of the channel and the freshwater discharge beyond the tidal limit should be collected during the period of observations. Data for wind velocity and direction during the period of observation is also important for comparison of the estimated suspended sediment transport.

i) Measurement of salinity and temperature are also important, particularly when suspended sediment samples are taken at different times of year.

8 Estimation of suspended sediment transport

The suspended sediment transport is estimated from the data simultaneously collected (or collected for the same tidal conditions) for water level, velocity and sediment concentration by following the steps given below.

a) The corrected values of velocity for all the depths of sampling on a vertical are resolved normal to the cross-section, and the components are plotted against the depth to obtain a graph of vertical velocity distribution prevailing at the time of sampling at that vertical.

b) Sediment concentration data is also plotted against depth for examination of consistency. As the values of concentration are likely to have a wide scatter, it is advisable that some theoretical form of the profile is assumed, and the particular concentration profile may be obtained by a best fit of the observed data. This may lead to more consistent results. The fitting of a profile to the data is also necessary as there are unsampled zones near the surface and especially near the bed. Since the sediment concentration increases towards the bed, using data only from collected samples may lead to underestimation of the sediment transport.

c) The corrected velocity values (v_i) at all the sampling points resolved at right angles to the cross-section of measurement are then multiplied by the corresponding values of suspended sediment concentration (c_i). The depth-integrated value of the suspended sediment load, q_s, per unit time per unit width at the vertical is obtained by plotting the vertical distribution of the suspended sediment transport and measuring the area with a planimeter or by any numerical integration technique.

$$q_s = \int_z v_i \cdot c_i \, dz$$

d) In order to determine the quantity of the suspended sediment transported per unit time through the cross-section, the values of suspended sediment load, q_s, per unit time per unit width of all the verticals are plotted with respect to the sectional width axis. The width-integrated value (Q_s) provides the suspended sediment load transported per unit time through the cross-section at the time of sampling, i.e.:

$$Q_s = \int_y q_s \, dy$$

e) For determining the suspended sediment transported over a tidal cycle, suspended sediment transport through the cross-section per unit time computed for each instant of observation is integrated to obtain suspended sediment load, G_s, separately for the flooding period and for the ebbing period, i.e.:

$$G_{sf} = \int_t Q_{sf} \, dt$$

$$G_{se} = \int_t Q_{se} \, dt$$