|  |  |  |
| --- | --- | --- |
| WEATHER CLIMATE WATER | **World Meteorological Organization****COMMISSION FOR OBSERVATION, INFRASTRUCTURE AND INFORMATION SYSTEMS****Third Session**15 to 19 April 2024, Geneva | **INFCOM-3/Doc. 8.2(4)** |
| Submitted by:Chair SC-MINT 26.II.2024**DRAFT 1** |

**AGENDA ITEM 8: TECHNICAL DECISIONS**

**AGENDA ITEM 8.2:** **WMO Integrated Global Observing System – measurements**

# Update of the Guide to Hydrological Practices, Volume I (WMO-No. 168)

|  |
| --- |
| **Summary** |
| **Document presented by:** Chair, Standing Committee on Measurements, Instrumentation and Traceability (SC-MINT) **Strategic objective 2024–2027:** 2.1 Optimize the acquisition of Earth system observation data through the WMO Integrated Global Observing System (WIGOS) **Financial and administrative implications:** Strategic and Operating Plans 2024–2027.**Key implementers:** Secretariat **Time frame:** 2024**Action expected:** Review and approve the proposed draft resolution |

# GENERAL CONSIDERATIONS

**Introduction**

The last revision of the [*Guide to Hydrological Practices*](https://library.wmo.int/records/item/35804-guide-to-hydrological-practices-volume-i?offset=2) (WMO-No. 168) was published in 2008, and taking into account the advances in the technology and practices, its review and update has now become a priority (see [draft Decision 6.1/1 (INFCOM-3)](https://meetings.wmo.int/INFCOM-3/English/Forms/AllItems.aspx?RootFolder=%2FINFCOM%2D3%2FEnglish%2F1%2E%20DRAFTS%20FOR%20DISCUSSION&FolderCTID=0x0120004D58D6EBC5C7054898FF36E91D58C193&View=%7B84F6CC21%2D2DD6%2D403B%2DB16A%2D97A4B833DE2B%7D) A preliminary review of the most urgent topics to review, update and add has been conducted by the Joint Expert Team on Hydrological Monitoring (JET-HYDMON) and the Standing Committee on Hydrological Services (SC-HYD), with support from the Secretariat. Among the gaps, the absence of any reference to the image-based methods for discharge measurement was identified. Experts from HydroHub Think Tank, in collaboration with members of JET-HYDMON and the Management Committee of the Project on the Assessment of Flow Measurement Instruments and Techniques (Project X) prepared a draft text that has been reviewed also by SC-MINT Editorial Board and their feedback incorporated in the proposed draft text.

**Expected action**

Based on the above, the INFCOM may wish to adopt the draft resolution to include in the [*Guide to Hydrological Practices*](https://library.wmo.int/records/item/35804-guide-to-hydrological-practices-volume-i?offset=2) (WMO-No. 168), the proposed new section 5.3.7.6 – Image-based methods for discharge measurement.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

# DRAFT resolution

## Draft Resolution 8.2(4)/1 (INFCOM-3)

### Update of the Guide to Hydrological Practices, Volume I (WMO-No. 168)

THE COMMISSION FOR OBSERVATION, INFRASTRUCTURE AND INFORMATION SYSTEMS,

**Recalling** that the [*Guide to Hydrological Practices, Volume I, Hydrology – From Measurement to Hydrological Information*](https://library.wmo.int/records/item/35804-guide-to-hydrological-practices-volume-i?offset=2) (WMO-No. 168), (hereinafter referred to as “the *Guide*”) provides an overall view of the current operational hydrological practices, procedures and instrumentation (from stream gauging to forecasting and management) that can be used by Members’ National Hydrological Service to implement the provision contained in the [*Technical Regulation*s, Volume III – Hydrology](https://library.wmo.int/records/item/35631-technical-regulations?offset=4) (WMO-No. 49),

**Having considered** that the last revision of the *Guide* was published in 2008, and therefore the most recent advances in technology and practices in hydrology are not adequately reflected in the text,

**Noting** that a preliminary review of the most urgent topics to review, update and add has been conducted by the Joint Expert Team on Hydrological Monitoring (JET-HYDMON) and the Standing Committee on Hydrological Services (SC-HYD) of the Commission for Weather, Climate, Hydrological, Marine and Related Environmental Services and Applications (SERCOM), with support from the Secretariat, underlying the absence, among others, of any reference to the image-based methods for discharge measurement,

**Noting** further the Secretary-General’s responsibility to publish the adopted publications included in [Resolution 47 (Cg-19)](https://library.wmo.int/viewer/67177?viewer=picture#page=520&viewer=picture&o=bookmark&n=0&q=) – WMO mandatory publications and distribution policy for the nineteenth period, including any subsequent purely editorial amendments,

**Adopts** the proposed updates to the [*Guide to Hydrological Practices, Volume I*](https://library.wmo.int/records/item/35804-guide-to-hydrological-practices-volume-i?offset=2) (WMO-No. 168) new section 5.3.7.6 - Image-based methods for discharge measurement, as provided in the [annex](#annex) to the present decision;

**Requests** its Standing Committees to periodically review the *Guide*, for the areas of their competence and mandate, and in cooperation with SERCOM, and update it as necessary.

\_\_\_\_\_\_\_\_\_\_\_\_

## Annex to draft Resolution 8.2(4)/1 (INFCOM-3)

**5.3.7.6 Image-based methods for discharge measurement**

Image-based methods can be low cost and efficient of tracers among consecutive frames which then is converted into surface velocity using the time spacing between the frames. Among the wide variety of approaches, surface image velocimetry measurement methods maybe grouped into the following categories (ISO 748, 2021):

• Particle Image Velocimetry (PIV) methods (also called Large Scale PIV when applied to river scales (Fujita et al. 1994 and Muste et al. 2008)) are based on cross correlation (pattern matching) algorithms and are well suited for flows with dense natural tracers such as turbulence patterns or foam;

• Particle Tracking Velocimetry (PTV), (Lloyd, Stans by, & Ball, 1995)) is a Lagrangian method which tracks the trajectories of solid and sparse tracers, like debris, or artificial seeding;

• Other optical flow methods use the apparent movement of brightness patterns in an image to obtain the distribution of velocities (Barron, Fleet, Beauchemin, & Burkitt, 1994);

• Space Time Image Velocimetry (STIV), (Fujita, Watanabe, & Tsubaki, 2007) measures 1D surface velocity, at multiple analysis lines set perpendicular to a transect. Velocities are calculated based on each line’s composite Space Time images which creates an angled pattern based on the surface tracer’s movement over distance and time.

PIV, PTV and other optical flow methods allow measurement of instantaneous 2D surface velocities over large areas. STIV is a robust method for velocity estimation when tracer particles are minimal and sparsely distributed. Regardless the method used, they have to perform the same processing steps:

(i) Recording of a video of a river reach;

(ii) Pre-processing of the video (stabilization, subsampling, image enhancements, images registration…);

(iii) Orthorectification of the images to correct the perspective distortion and to scale the images onto a real-world coordinate system;

(iv) Determination of surface velocity, by tracking visible patterns over time and space as described by each method (Note, steps iii) and iv) are interchangeable);

(v) Post-processing (mostly filtering and time-averaging); and

(vi) Computation of the discharge The discharge calculation requires the cross section bathymetry and water level of one or several transects as well as a valid method or assumption to convert surface velocity to depth-averaged velocity.

Videos can be recorded from fixed camera stations, handheld cameras (or smartphones cameras) and Unmanned Aerial Vehicles (UAVs, aka drones), depending on the available equipment and on the size of the river reach to survey. Videos from non-professional observers may be processed, especially as part of post-flood estimation surveys (Boursicaud et al. 2016, Le Coz et al. 2016). Visible light spectrum red-green-blue (RGB) cameras are economical, easy to obtain and offer relatively high-resolution images, but they are limited to visible light and cannot capture nighttime images without an external source of illumination. Night measurements can be made with Near Infrared (NIR) cameras (additional NIR light sources may be needed). Examples are trail cameras, or some RGB cameras with the NIR filter removed (Hutley et al., 2023). The pinnacle of surface image velocimetry is the use of high-performance thermal infrared (i.e. long wave infrared) cameras (Schweitzer & Cowen, 2021). These can be used during the daytime, or at night, and use subtle temperature differences in the surface water as tracers. While effective, these cameras are currently too expensive and delicate for routine deployment.

Orthorectification is achieved using simple geometric scaling in the case of video recorded from UAV pointing at the nadir, or with more complex 2D or 3D photogrammetric equations for oblique angles. Orthorectification requires Ground Control Points (GCP: points of known world coordinates that can be seen on the images) or the knowledge of the intrinsic and extrinsic parameters of the camera. GCPs consist of identifiable features within the video that can be surveyed for the XYZ coordinates required. GCPs can be surveyed prior or post-video collection and must be visible on the image (i.e. they must be larger than the minimum pixel size at full resolution). The GCP XYZ data creates a calibration between pixel coordinates and real-world coordinates that remains valid for all videos in a fixed camera installation where camera resolution, zoom, pitch, roll and yaw remain constant. This allows videos to be processed even when GCP are no longer visible e.g. when they are submerged during high water conditions.

To calculate the discharge using Image-based methods, it is necessary to know the depth-averaged velocities, water level (depth or stage) and the cross-sectional bathymetry; which are either measured independently or estimated. Other surface velocity methods, such as floats, near-surface current meters and radars measure surface velocities at a point but can also be used to estimate discharge. Surface velocities are commonly related to depth-averaged velocities with a conversion factor often referred to as Alpha (Biggs et al. 2021). Image-based methods use a velocity area method of discharge calculation by either the mid or mean section methodology and therefore follows much of the guidance outlined in ISO 748. Primary sources of uncertainty for image-based methods include: cross section measurement (especially when in connection with flood events), Alpha, stage, orthorectification (Le Coz et al, 2021).

**References and Suggested Reading**

Fujita, Ichiro, and Saburo Komura, 1994: *Application of Video Image Analysis for Measurements of River-Surface Flows*. Proceedings of Hydraulic Engineering 38: 733–38.

Biggs, H., et al., 2021: *River discharge from surface velocity measurements-A field guide for selecting alpha*. Envirolink Advice Report. Christchurch, New Zealand.

Australian Water monitoring, N. I., 2021: Part 11: Application of surface velocity methods for velocity and open channel discharge measurements NI GL 100.11–2021. Water Monitoring Standardization Technical Committee – Bureau of Meteorology.

Barron, J., Fleet, D., Beauchemin, S., & Burkitt, T., 1994: *Performance of optical flow techniques*. International Journal of Computer Vision.

Fujita, I., Watanabe, H., & Tsubaki, R., 2007: *Development of a non-intrusive and efficient flow monitoring technique: the space-time image velocimetry* (STIV). Int. J. River Basin Manage., 5, 105-114. doi:10.1080/15715124.2007.9635310.

Hutley, N. R., Beecroft, R., Wagenaar, D., Soutar, J., Edwards, B., Deering, N., Grinham, A& Albert, S., 2023: *Adaptively monitoring streamflow using a stereo computer vision system*. Hydrology and Earth System Sciences, 27(10), 2051-2073. https://doi.org/10.5194/hess-27-2051-2023.

ISO 748:2021 Hydrometry — Measurement of liquid flow in open channels — Velocity area methods using point velocity measurements

Jérôme Le Coz, Antoine Patalano, Daniel Collins, Nicolás Federico Guillén, Carlos Marcelo García, Graeme M. Smart, Jochen Bind, Antoine Chiaverini, Raphaël Le Boursicaud, Guillaume Dramais, Isabelle Braud: *Crowdsourced data for flood hydrology: Feedback from recent citizen science projects in Argentina, France and New Zealand*. https://doi.org/10.1016/j.jhydrol.2016.07.036

Lloyd, P., Stansby, P., & Ball, D., 1995: *Unsteady surface-velocity field measurement using particle tracking velocimetry*. J. Hydraul. Res., 33, 519–534. doi:10.1080/00221689509498658

Muste, M., Fujita, I., & Hauet, A., 2008: *Large‐scale particle image velocimetry for measurements in riverine environments. Water resources research*, 44(4). doi:10.1029/2008WR006950

Raphaël Le Boursicaud, Lionel Pénard, Alexandre Hauet, Fabien Thollet, Jérôme Le Coz. Gauging extreme floods on YouTube: application of LSPIV to home movies for the post-event determination of stream discharges. https://doi.org/10.1002/hyp.10532

Schweitzer, S. A., & Cowen, E. A., 2021: *Instantaneous River-Wide Water Surface Velocity Field Measurements at Centimeter Scales Using Infrared Quantitative Image Velocimetry*. Water Resources Research, 57. doi:10.1029/2020WR029279

\_\_\_\_\_\_\_\_\_\_