HYDROLOGY PROJECT
Technical Assistance

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Training module # SWDP - 34

How to compute discharge data

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with
HALCROW, TAHAL, CES, ORG & JPS

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1. Module context

While designing a training course, the relationship between this module and the others, would be maintained by keeping them close together in the syllabus and place them in a logical sequence. The actual selection of the topics and the depth of training would, of course, depend on the training needs of the participants, i.e. their knowledge level and skills performance upon the start of the course.

2. Module profile

Title	:	How to compute discharge data
Target group	:	Assistant Hydrologists, Hydrologists, Data Processing Centre Managers
Duration	:	One session of 45 minutes
Objectives	:	After the training the participants will be able to: • Transform stage into discharge data
Key concepts	:	• Stage record • Stage-discharge relationship • Transformation of stages into discharges
Training methods	:	Lecture, software
Training tools required	:	Board, OHS, Computer
Handouts	:	As provided in this module
Further reading and references	:	

3. Session plan

No	Activities	Time	Tools
1	***General*** Overhead – Computation of discharge data (text)		OHS 1
2	***Station review*** Overhead – Station review (text)		
3.	***Transformation of stage into discharge data*** Overhead - Single channel rating curve Overhead - Single channel rating equation Overhead - Compound channel rating curve Overhead - Rating curve with unsteady flow correction Overhead – Rating curve with constant fall backwater correction Overhead - Rating curve with normal fall backwater correction		

4. Overhead/flipchart master

5. Handout

Add copy of Main text in chapter 8, for all participants.

6. Additional handout

These handouts are distributed during delivery and contain test questions, answers to questions, special worksheets, optional information, and other matters you would not like to be seen in the regular handouts.

It is a good practice to pre-punch these additional handouts, so the participants can easily insert them in the main handout folder.

7. Main text

Contents

How to compute discharge data

1. General

- **With limited exceptions, discharge cannot be measured both directly and continuously. Instead measurements of stage (or level) are made continuously or at specified intervals at a gauging station and these are converted to discharge by the use of stage discharge relationships.**

- **Computation of discharge normally be carried out monthly on the stage data from the previous month but will always be reviewed annually before transferring to the archive.**

- **Computation of discharge will be carried out at Divisional offices and reviewed at the State Data Management Centre.**

2. Station Review

Before computing discharge, it is essential to have available a summary of all the relevant information for the station, including:

- **the stage record - to ensure that it is complete and without abrupt discontinuities.**

- **a listing of stage discharge relationships to check that periods of application do not overlap or have gaps between ratings.**

- **Ancillary information based on field records (Field Record Book) or on information from validation of stage or stage discharge relationships**. In particular field information on datum changes, scour and deposition, blockage and backwater effects should be assembled along with any adjustments or corrections applied during validation.

3. Transformation of stage to discharge

The procedure used to transform stage to discharge depends on physical conditions at the station and in the river reach downstream The following alternatives are considered:

- single channel rating curve
- compound channel rating curve
- rating curves with unsteady flow correction
- rating curves with constant fall backwater correction
- rating curves with normal fall backwater correction

3.1 Single channel rating curve

When unsteady flow and backwater effects are negligibly small the stage discharge data are fitted by a single channel relationship, valid for a given time period and water level range. Rating equations will have previously been derived either as parabolic or power law equations; it is assumed that in the vast majority of cases the recommended power law relationship will have been applied. Equations for standard and non-standard gauging structures may also be re-computed in this form with little loss of accuracy.

The basic equations are as follows:

(a) For the power type equation used for curve fitting.

$$Q_t \quad = \quad c_{1,i}\ (h_t + a_{1,i})^{b_{1,i}} \qquad (1)$$

(b) For the parabolic type of equation used for curve fitting

$$Q \quad = \quad a_{2,i} \quad + \quad b_{2,i}\ h_t \quad + \quad c_{2,t}\ h_t^2 \qquad (2)$$

Where:

Q_t	=	discharge at time t (m^3/sec)
h_t	=	measured water level at time t(m)
a_1,b_1,c_1	=	parameters of the power equation
a_2,b_2,c_2	=	parameters of the parabolic equation
i	=	index for water level interval for which the parameters are valid ($1 \le i \le 4$)

The parabolic form of rating equation is however not recommended for use while establishing the rating curves.

HYMOS permits a maximum of 5 equations applicable over different level ranges in a single stage discharge relationship; normally three will be sufficient. One equation may require to be used for the situation where water is ponded at the gauge and a non-zero level has been measured but the flow is zero. In this case an equation may be introduced for the range from h = 0.0 to h at minimum flow, taking the power law form with c = 0.0, a = 0.0 and b = 1.0

3.2 Compound channel rating curve

The compound channel rating curve is used to avoid large values of the parameter b and very low values of the c-parameter in the power equation at levels where the river begins to spill over from its channel to the floodplain.

When a compound channel rating has been applied, the discharge for the flood plain interval will be computed by adding the discharge computed for the river section up to the maximum flood plain level using the parameters for the one but last interval, and the discharge computed for the flood plain section for the last interval. That is:

$$Q_{tot} = Q_r + Q_{fp} \qquad (3)$$

Where:

Q_{tot}	=	total discharge
Q_r	=	discharge flowing through the main river section up to the maximum water level
Q_{fp}	=	discharge flowing through the flood plain section.

3.3 Rating curve with unsteady flow correction

Where an unsteady flow correction is required, the application of the simple rating curve first yields a discharge for steady flow which must then be multiplied by the unsteady flow correction to give the discharge for the required rate of change of water level. The stage-discharge transformation used for this case is:

$$Q_t = Q_{st} \sqrt{\left(1 + \frac{1}{S_0\ c}\frac{dh_t}{dt}\right)} \qquad (4)$$

where:

Q_t = is the required discharge corresponding to the observed stage h_t and rate of change of stage (dh_t/dt)

Q_{st} = is the steady state discharge as obtained from the available steady state rating curve.

The expression ($1/S_0c$) is expressed in the form of parabolic equation as:

$$\frac{1}{S_0 c} = a_3 + b_3\ h_t + c_3 h_t^2 \qquad and \quad h_t > h_{\min} \qquad (5)$$

a_3, b_3, c_3 = parameters of the equation

h_{min} = the lowest water level below which the correction is not to be applied.

The parameters of the above parabolic equation and that of the steady state equation are available from the established rating curve.

The rate of change of stage with respect to time (dh_t/dt) at time t can be obtained from the stage time series as:

$$\frac{dh_t}{dt} = \frac{h_{t+1} - h_{t-1}}{2\Delta t} \qquad (6)$$

where:

Δt = time interval between two successive observations. If h_{t+1} or h_{t-1} does not exist, its value is replaced by h_t and the denominator by Δt.

3.4 Rating curve with constant fall backwater correction

Where the station is affected by backwater and the rating curve with constant fall type of backwater correction has been established for it then the stage-discharge transformation is carried out using the following equation:

$$Q_t = Q_{rt}\left(\frac{F_t}{F_r}\right)^p \qquad (7)$$

where:

Q_{rt} = reference discharge computed using the established rating curve with h_t replaced with h_{1t}

F_r and p= are the reference fall and exponent in the equation and are available as parameters of the established rating curve

F_t = $h_{1t} - h_{2t}$

= is the measured fall between the stages at the station under consideration (h_{1t}) and the reference station (h_{2t}). The stages used for calculating the fall have to be precisely synchronised in time.

3.5 Rating curve with normal fall backwater correction

Where the station is affected by backwater and the rating curve with normal fall type of backwater correction has been established for it, then the stage-discharge transformation is carried out using the equation:

$$Q_t = Q_{rt} \left(\frac{F_t}{F_{rt}} \right)^p \qquad (8)$$

where:

Q_{rt}	=	backwater free discharge computed using established rating curve with h_t replaced with h_{1t}
p	=	is the exponent in the above equation and is available as the parameter of the established rating curve
F_t	=	$h_{1t} - h_{2t}$
	=	is the measured fall between the stages at the station under consideration (h_{1t}) and the reference station (h_{2t}). The stages used for calculating the fall have to be precisely synchronised in time.

The reference fall, F_{rt} in this case is expressed as:

$$F_{rt} = a_4 + b_4 h_t + c_4 h_t^2 \qquad and \qquad h_t > h_{\min} \qquad (9)$$

The parameters a_4, b_4 and c_4 are available from the established rating curve and the reference fall is evaluated for any stage above the minimum stage h_{min} below which the control is not affected by the backwater.