# Flood Discharge Measurement in Japan

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An Independent Administrative Institution

# Reorganization of PWRI in 2001

1) PWRI, Ministry of Construction ( - Jan.5, 2001)

↓

2) PWRI, Ministry of Land, Infrastructure and Transport (MLIT) (Jan.6 – Mar.31, 2001)

↓

3a) **National Institute for Land and Infrastructure Management (NILIM), MLIT** (April 1, 2001 -)

&

3b) **PWRI, An Independent Administrative Institution** (April 1, 2001 -)

# Study Task Sharing on hydrology

(Just started recently! Just my view!)

1. National Institute for Land and Infrastructure Management (NILIM), MLIT

   River and watershed management policy, integrated flood disaster prevention, river hydraulic engineering and water resources development

2. Public Works Research Institute (PWRI)

   Technology and methodology for hydrologic engineering such as observation, instrumentation, modeling, forecasting, tool development for analysis & decision support, etc.

# Contents

1. Overview of River Discharge Observation in Japan, especially at MLIT
2. Flood Discharge Measurement Using Floats in Japan
3. Overview of Study on Non-Contact Surface Velocity Measurement in Japan

# River Discharge Measurement in Japan (1)

Number of Water level Stations:

- MOC (MLIT) 2555 (1998)
- MITI 717 (1996)
- MAFF 87 (1996)
- Local Governments 3252 (1995)

Number of Water-Level & Discharge Stations:

- MOC (MLIT) 1557 { 61% of WL Sta. }

# River Discharge Measurement in Japan (2)

- About 90% of WL Stations are with auto-recording device
- About 60% of WL Stations are with telemetry system

(ground-based microwave network of MLIT)

# Objective of River Discharge Measurement for River Managers (MLIT & local governments)

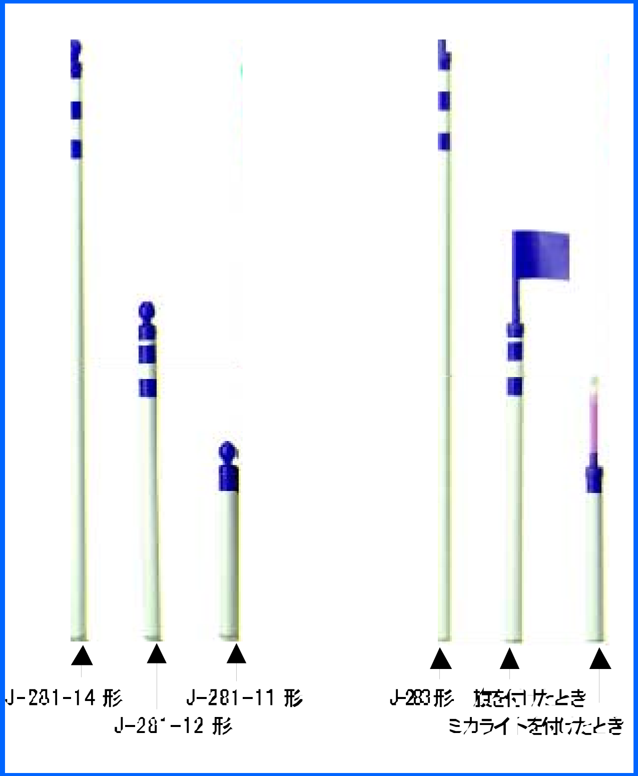
1) Master planning and improvement works for comprehensive river & basin management
2) Daily integrated river and dam management in case of flood, drought, etc.
3) River administrations such as permissions of water rights, etc.
4) Basic geoscientific data for land management

# River Discharge Measurement at MLIT

1) Low flow
   - Portable conventional current meters
     - price-type, electromagnetic-type, etc.
   - Supersonic current meter
   - ADCP
2) Flood flow (high flow)
   - Floats (rods)
   - Microwave doppler current meter

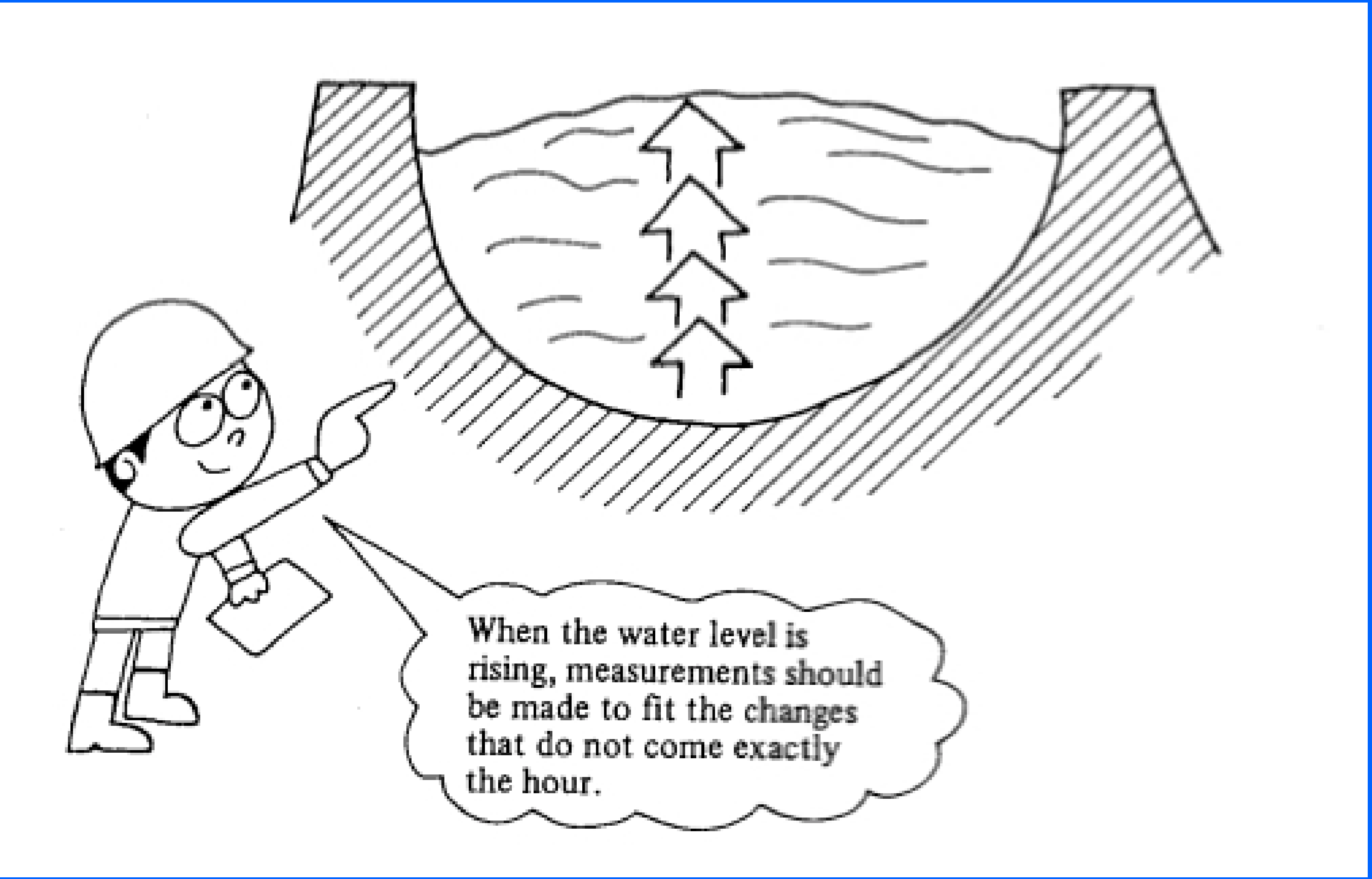
→ Making the H-Q (rating) curve

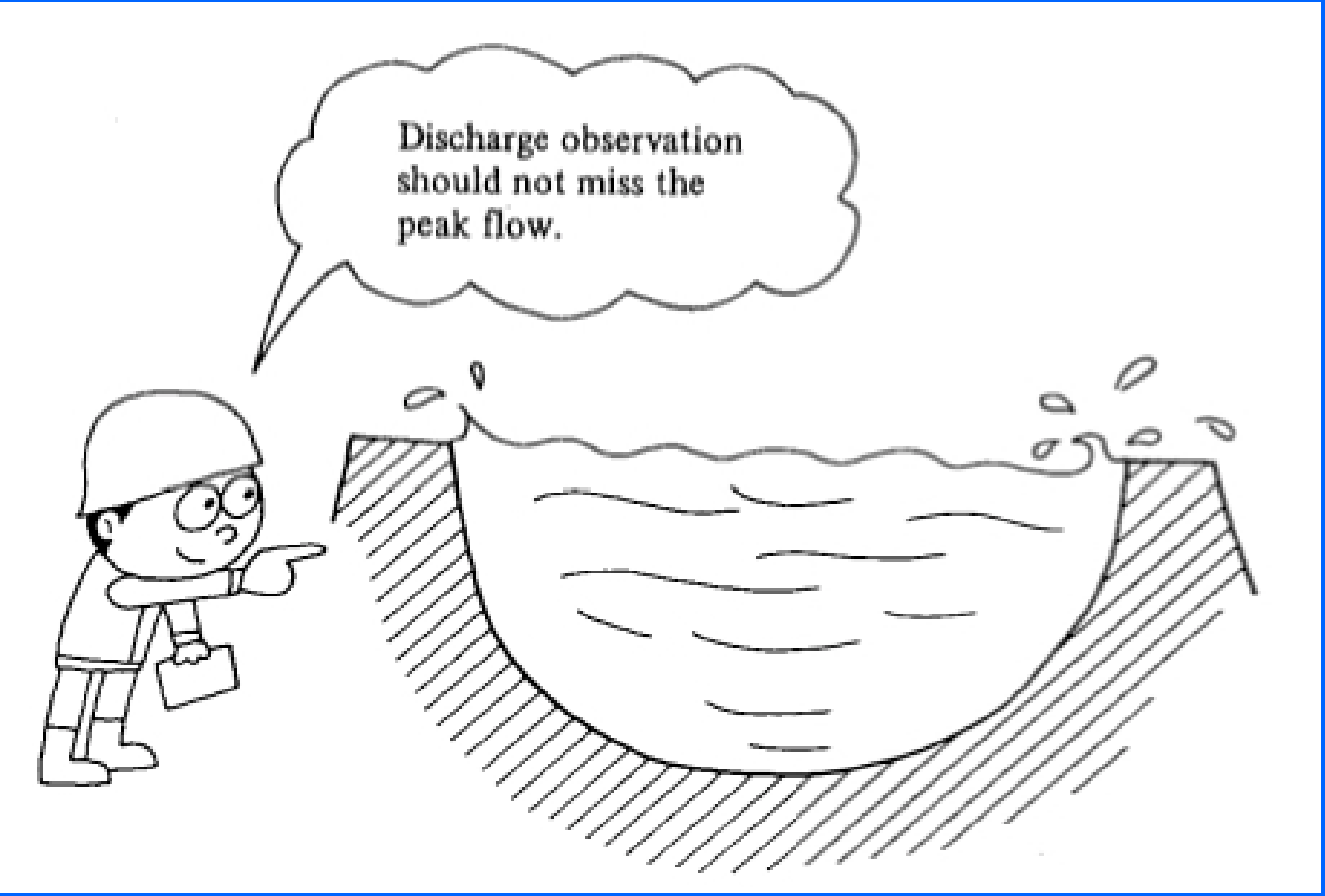
# Float Rods used in Japan

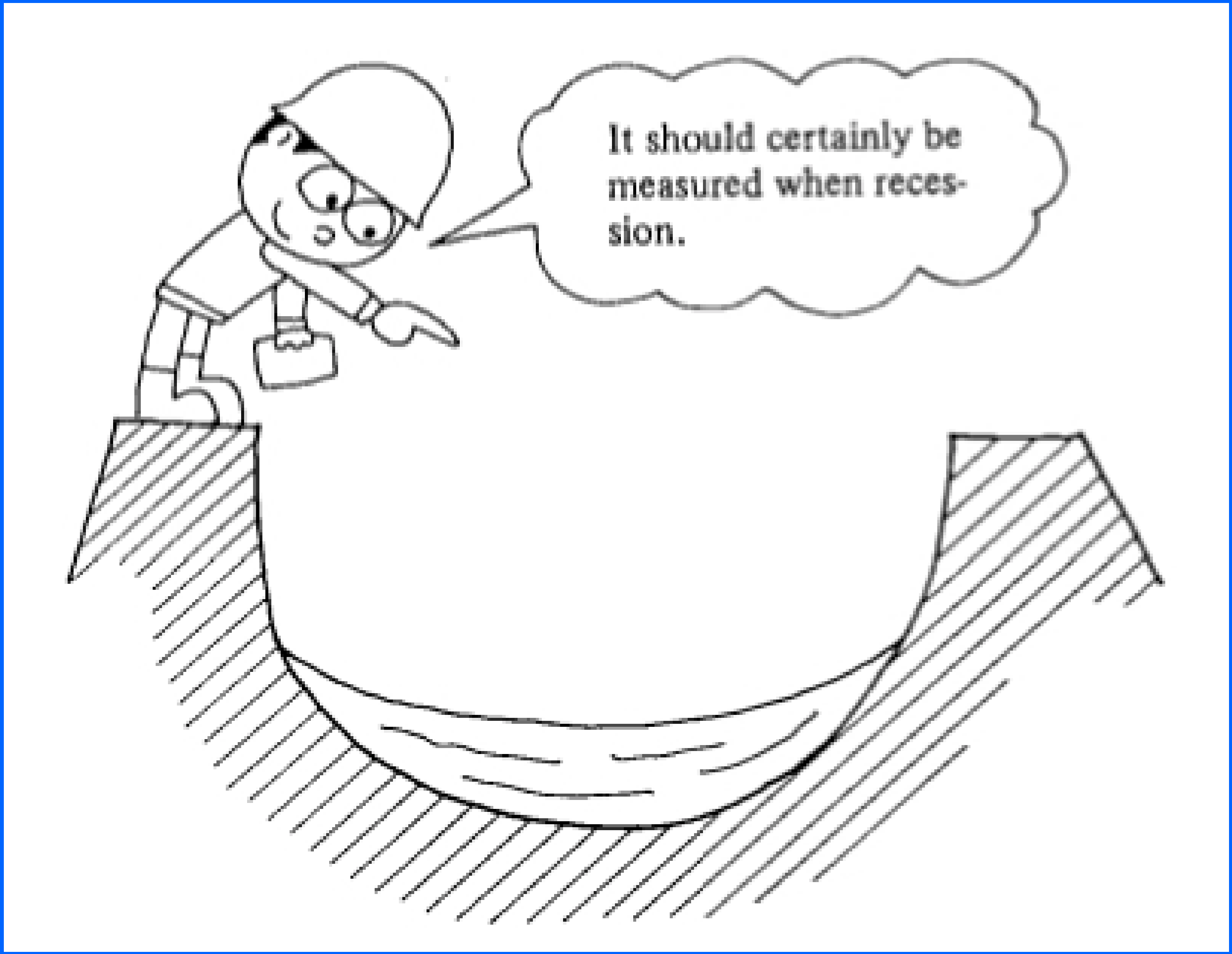


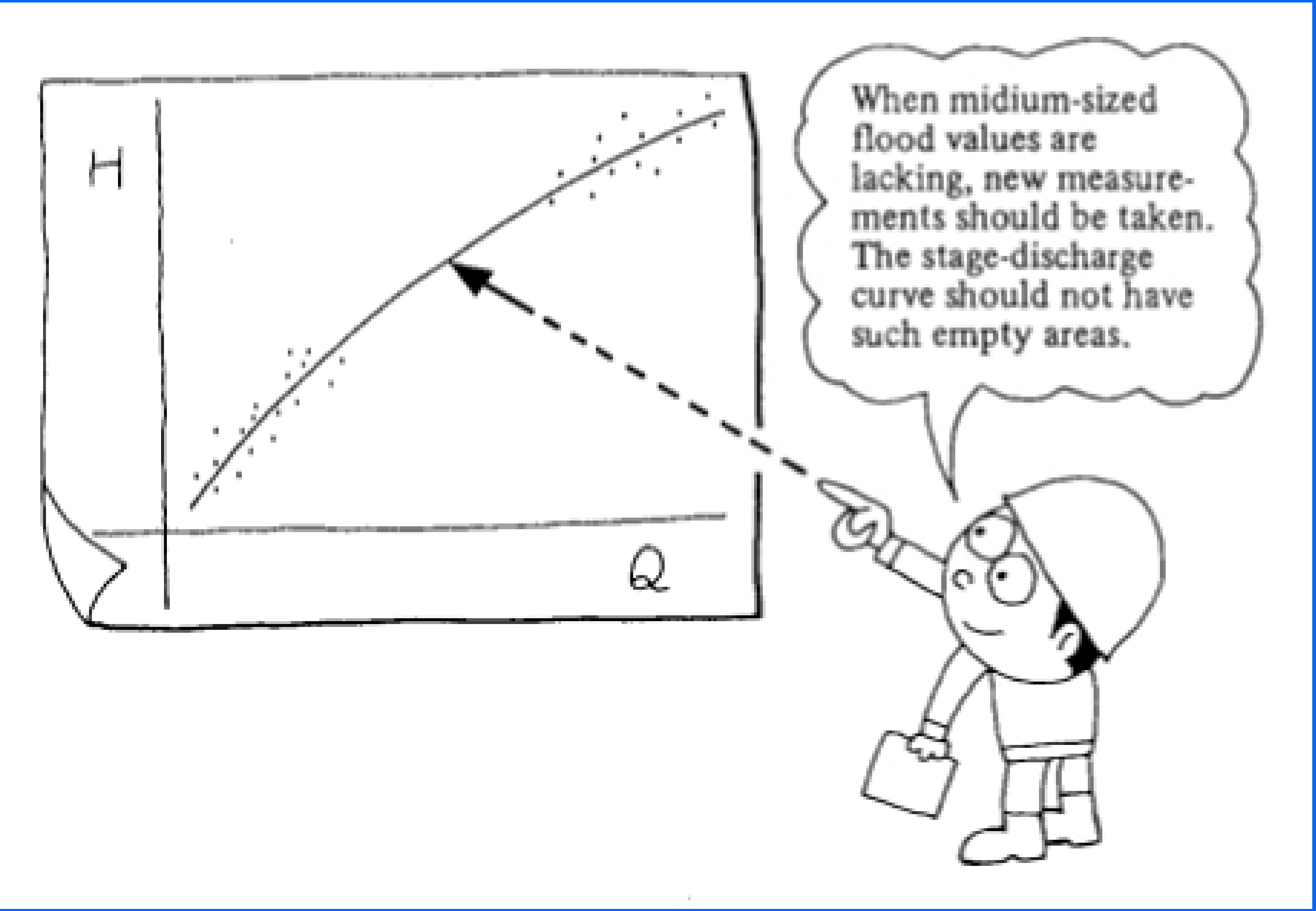

1) Rods are made of paper
2) Weight control by sand

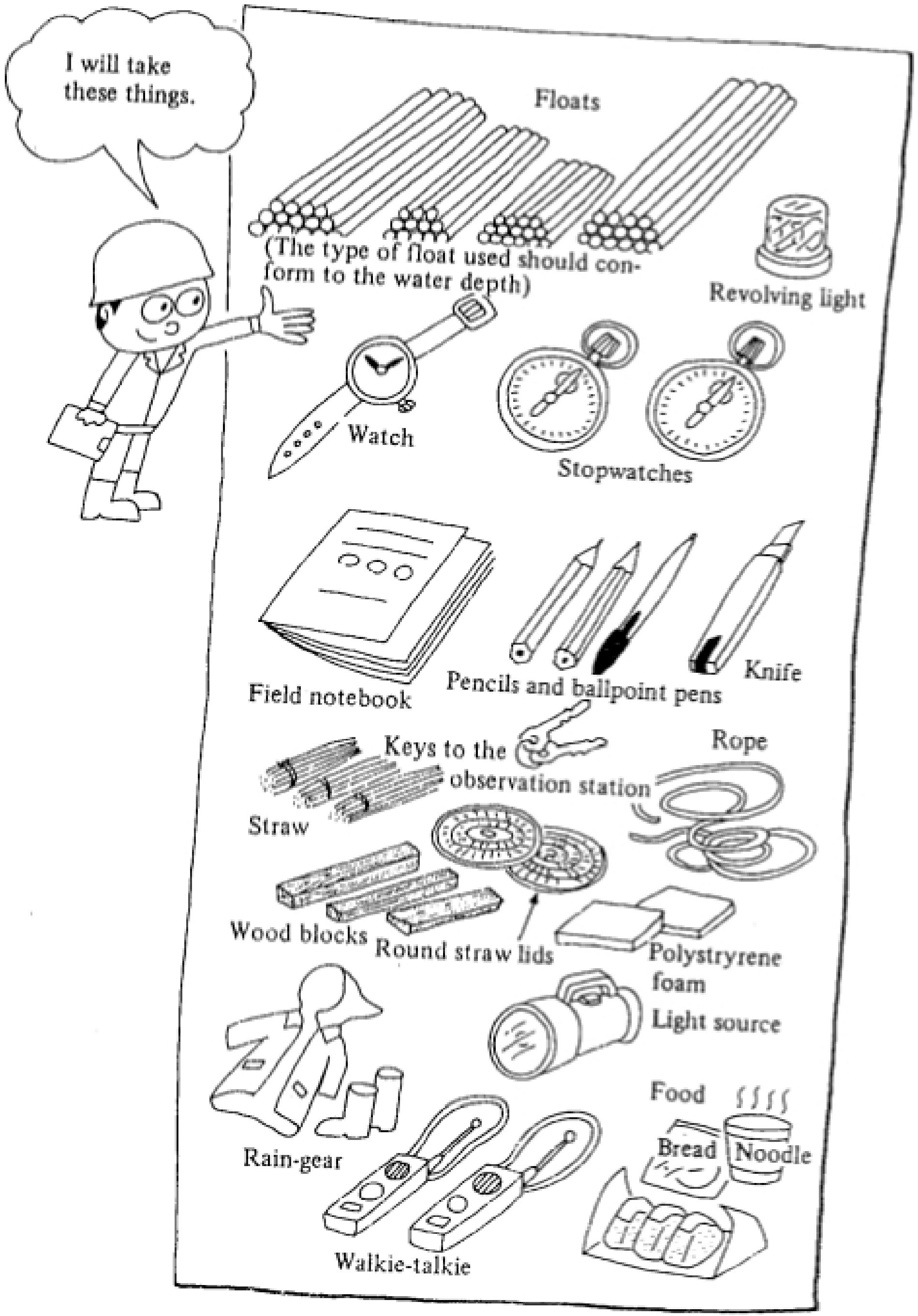
→ Enrironment-friendly

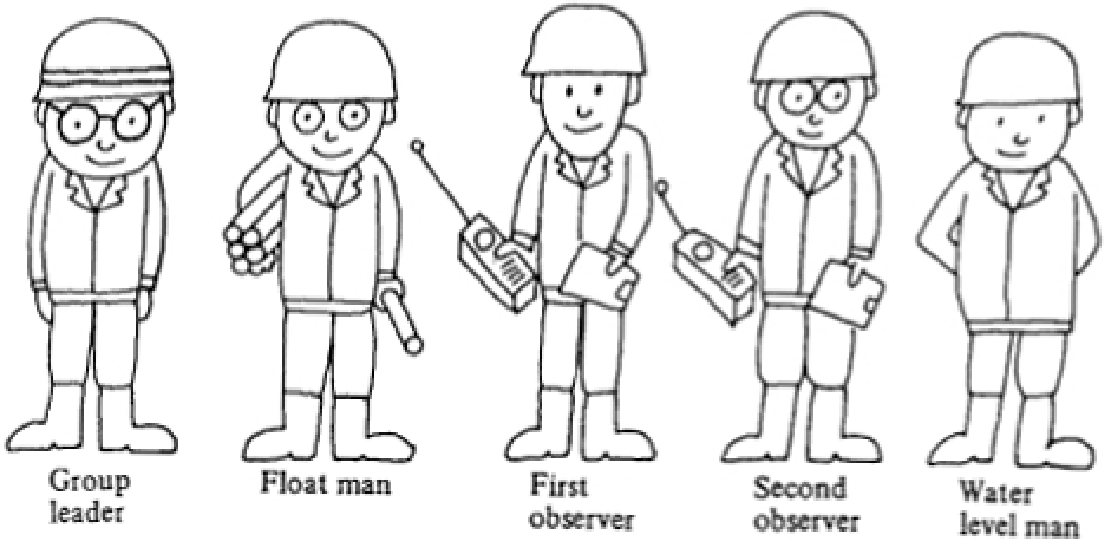

When the water level is
rising, measurements should
be made to fit the changes
that do not come exactly
the hour.


Discharge observation
should not miss the
peak flow.


It should certainly be measured when recession.


H
Q
When midium-sized flood values are lacking, new measurements should be taken. The stage-discharge curve should not have such empty areas.


I will take these things.
Floats
(The type of float used should conform to the water depth)
Revolving light
Watch
Stopwatches
Field notebook
Pencils and ballpoint pens
Knife
Keys to the observation station
Rope
Straw
Wood blocks
Round straw lids
Polystryrene foam
Light source
Rain-gear
Food
Bread
Noodle
Walkie-talkie




## Allocation of duties

**Group leader**

Directs general affairs concerning the measurement, makes contact with the office and determines the observation time; He is responsible for safety.

**Float man**

Lowers floats into water at prescribed places; observers flowing condition.

**First observer**

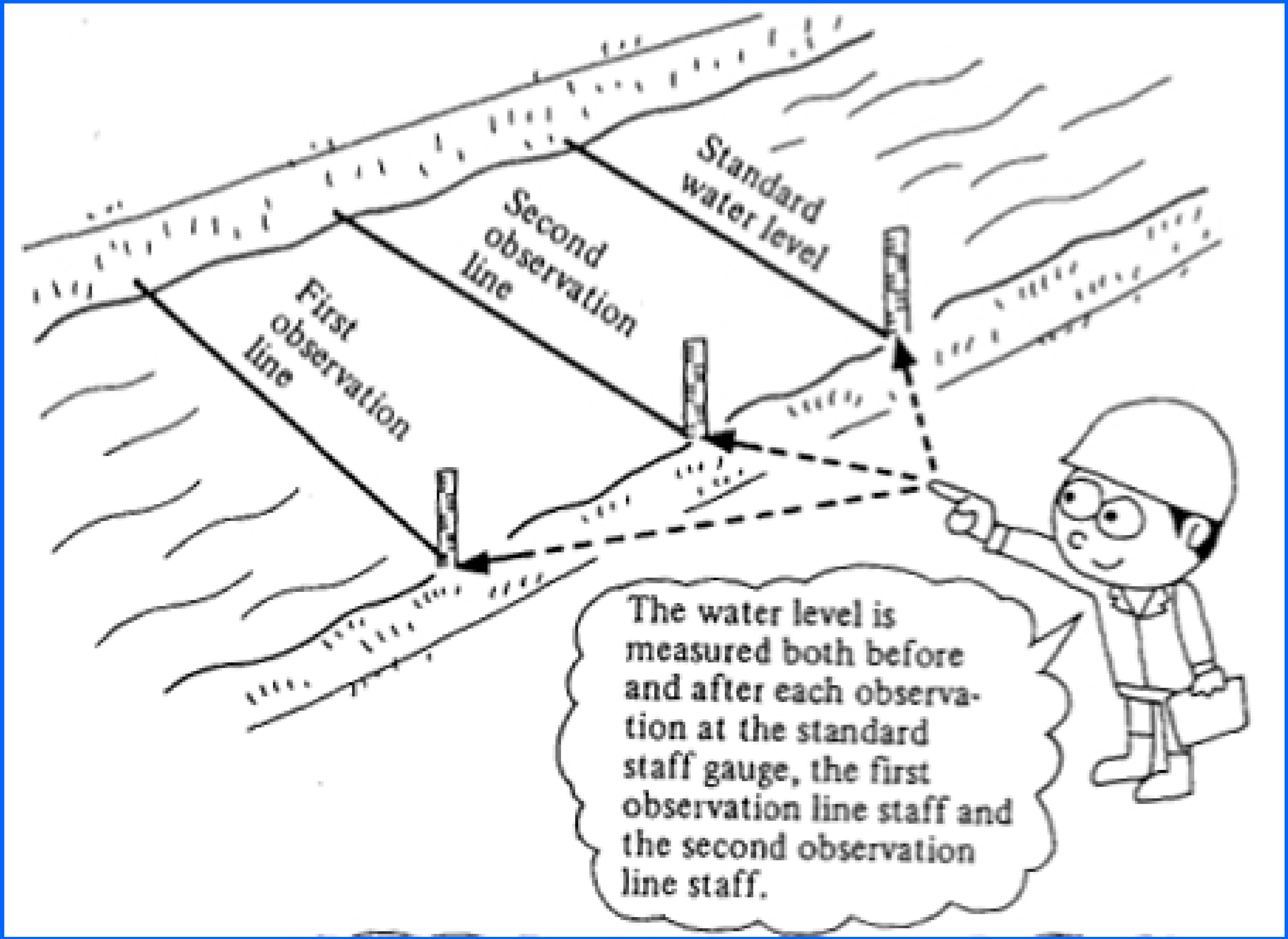
Signals to the second observer when the floats pass the first observation line.

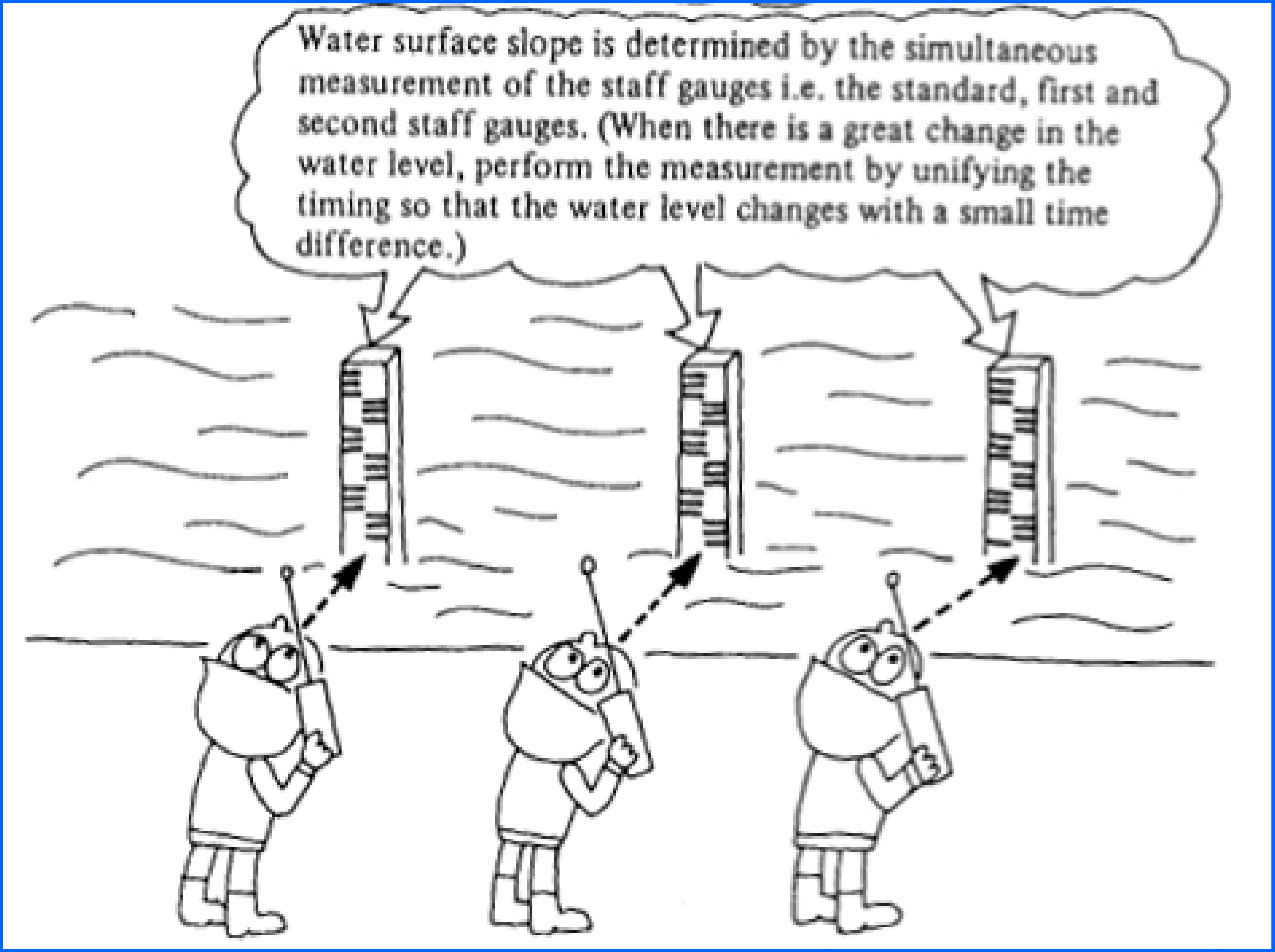
**Second observer**

Measures the time it takes for the floats to pass from the first observation line to the second observation line.

**Water level man**

Measures the water level at the standard staff gauge and the first and second observation line staff gauge during measurement periods and on a regular basis.


Standard water level
Second observation line
First observation line
The water level is measured both before and after each observation at the standard staff gauge, the first observation line staff and the second observation line staff.

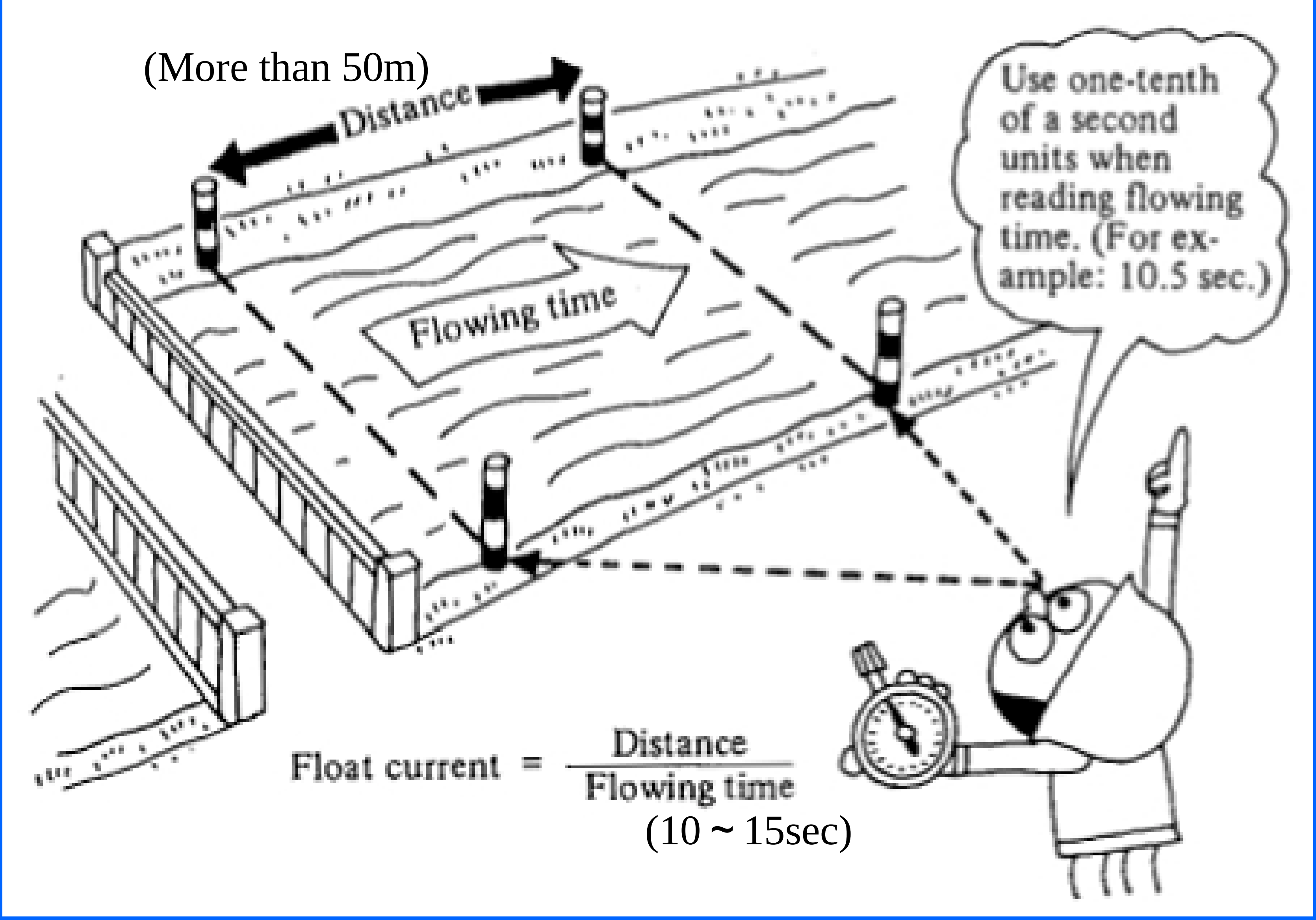

Water surface slope is determined by the simultaneous measurement of the staff gauges i.e. the standard, first and second staff gauges. (When there is a great change in the water level, perform the measurement by unifying the timing so that the water level changes with a small time difference.)

The current measurement line is set up along the current of the first cross section. For the first cross section, as a rule, the standard proportion of water surface width to the distance of the float current measurement line.

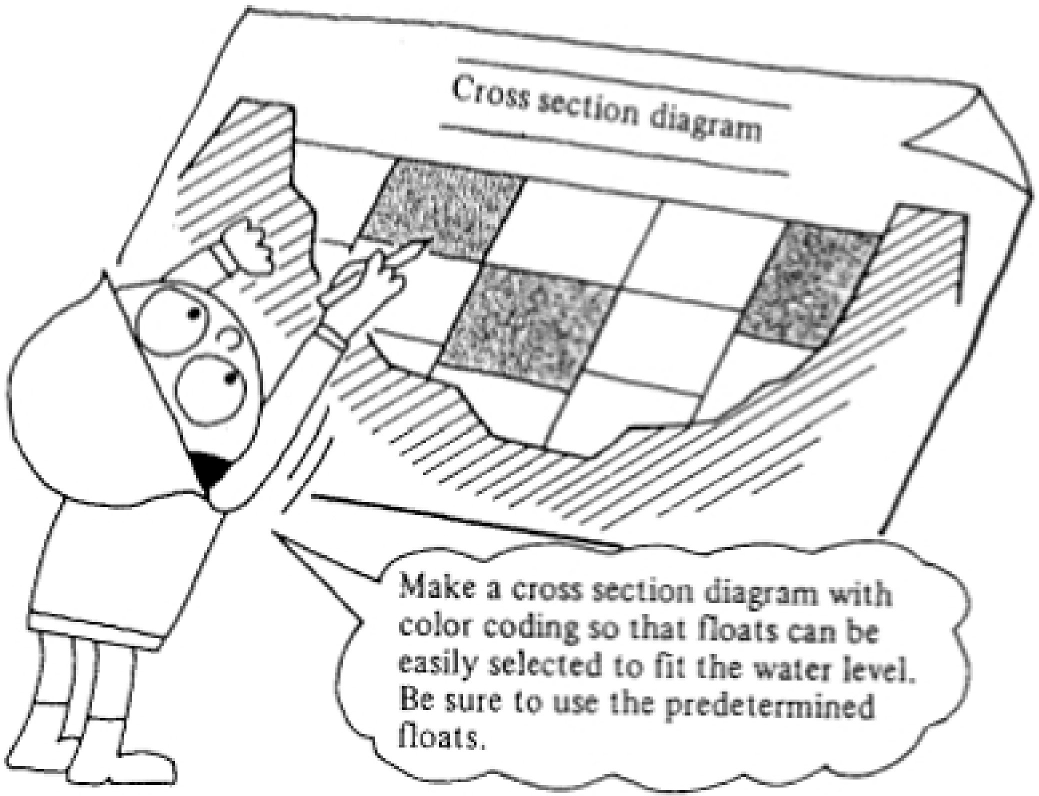
| Water surface width | 20m Less than | 20～100m | 100～200m | 200m More than |
|---|---|---|---|---|
| Number of float current measurement line | 5 | 10 | 15 | 20 |

During flood periods, etc. when measurement of flow amount is urgent, use the following table.

| Water surface width | 50m Less than | 50～100m | 100～200m | 200～400m | 400～800m | 800m More than |
|---|---|---|---|---|---|---|
| Number of float current measurement line | 3 | 4 | 5 | 6 | 7 | 8 |

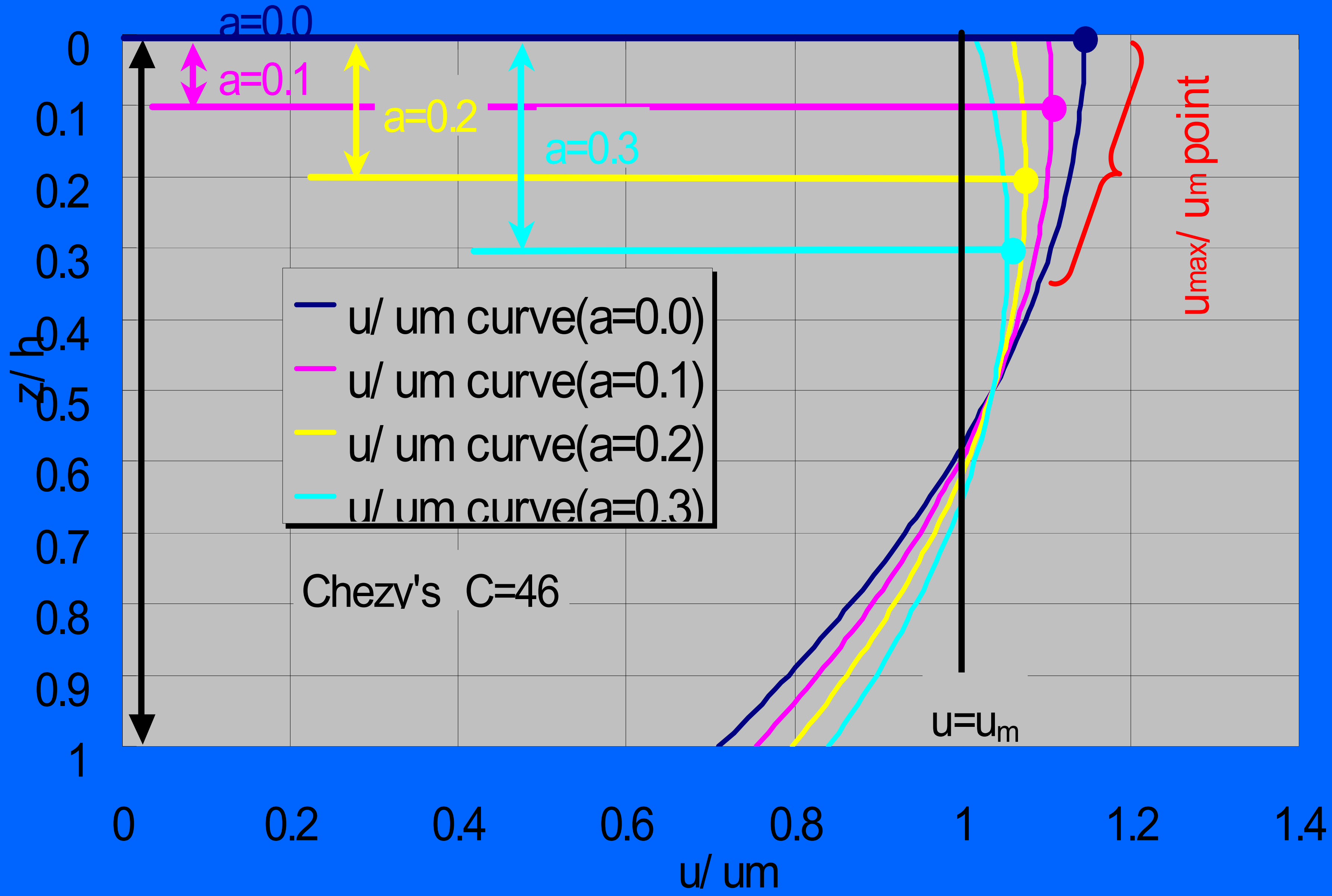

(More than 50m)
Distance
Flowing time
Use one-tenth of a second units when reading flowing time. (For example: 10.5 sec.)
Float current = Distance / Flowing time
(10 ~ 15sec)

| Float number | 1 | 2 | 3 | 4 | 5 |
| --- | --- | --- | --- | --- | --- |
| Water depth (m) | 0.7 Less than | 0.7~1.3 | 1.3~2.6 | 2.6~5.2 | 5.2 More than |
| Free board (m) | Surface float | 0.5 | 1.0 | 2.0 | 4.0 |
| Adjustment coefficient | 0.85 | 0.88 | 0.91 | 0.94 | 0.96 |



# Aki's formula (1932)

$$\frac{u}{u_m} = \frac{1}{c}\left( c + \frac{20}{3} - 20a + 40a\frac{z}{h} - 20\frac{z^2}{h^2} \right)$$



The depth of mean velocity (a) is a function of WL and river width:

| $b$(m) \ $a$(m) | 0 | 0.1 | 0.2 | 0.3 |
|---|---|---|---|---|
| 20 | $h<0.6$ | $0.6<h<1.1$ | $1.1<h<1.6$ | $1.6<h$ |
| 60 | $h<1.1$ | $1.1<h<1.6$ | $1.6<h<2.2$ | $2.2<h$ |
| 100 | $h<1.5$ | $1.5<h<2.0$ | $2.0<h<2.6$ | $2.6<h$ |

h: water level

b: river width

The above table can be re-arranged as below:

| $b$(m) \ $h$ | ~1 | 1~2 | 2~4 | 4~6 | 6~8 | 8~10 | 10~ |
|---|---|---|---|---|---|---|---|
| 20 | 0~0.1 | 0.1~0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| 60 | 0 | 0~0.2 | 0.2~0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| 100 | 0 | 0~0.1 | 0.2~0.3 | 0.3 | 0.3 | 0.3 | 0.3 |

If we assume the river width ~ 100m, then

| $h$ | ~1 | 1~2 | 2~4 | 4~6 | 6~8 | 8~10 | 10~ |
|---|---|---|---|---|---|---|---|
| $a$ | 0 | 0.1 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 |

Chezy's coefficient (C) for various combinations of hydraulic depth and Manning coeffcient is as follows:

| R(m) \ n | 0.025 | 0.030 | 0.035 | 0.040 | average |
|---|---|---|---|---|---|
| 0.5 | 35.6 | 29.7 | 25.4 | 22.3 | 29.5 |
| 1.0 | 40.0 | 33.3 | 28.6 | 25.0 | 31.7 |
| 1.5 | 42.8 | 35.6 | 30.6 | 26.8 | 33.9 |
| 2.0 | 44.8 | 37.3 | 32.0 | 28.0 | 35.5 |
| 3.0 | 48.4 | 40.1 | 34.6 | 30.2 | 38.3 |
| 4.0 | 50.4 | 42.0 | 36.0 | 31.5 | 39.9 |
| 5.0 | 52.3 | 43.6 | 37.4 | 32.7 | 41.5 |
| 6.0 | 54.0 | 44.9 | 38.5 | 33.7 | 42.7 |
| 7.0 | 55.3 | 46.1 | 39.5 | 34.6 | 43.8 |
| 8.0 | 56.6 | 47.1 | 40.4 | 35.4 | 44.8 |
| 9.0 | 57.7 | 48.0 | 41.2 | 36.1 | 45.7 |
| 10.0 | 58.6 | 48.9 | 41.9 | 36.7 | 46.5 |
| 12.0 | 60.5 | 50.4 | 43.2 | 37.8 | 47.9 |

$$C = R^{1/6} / n$$

n: Manning's Coefficient

R: hydraulic depth

Then we get the following averaged C for several water-depth range:

| h | ~1 | 1~2 | 2~4 | 4~6 | 6~8 | 8~10 | 10~ |
|---|---|---|---|---|---|---|---|
| c | 30 | 34 | 38 | 41 | 44 | 46 | 48 |

h ≒R

Draft depth

Draft depth ratio to water depth (from 0.4 up to 0.8)

Float type

a

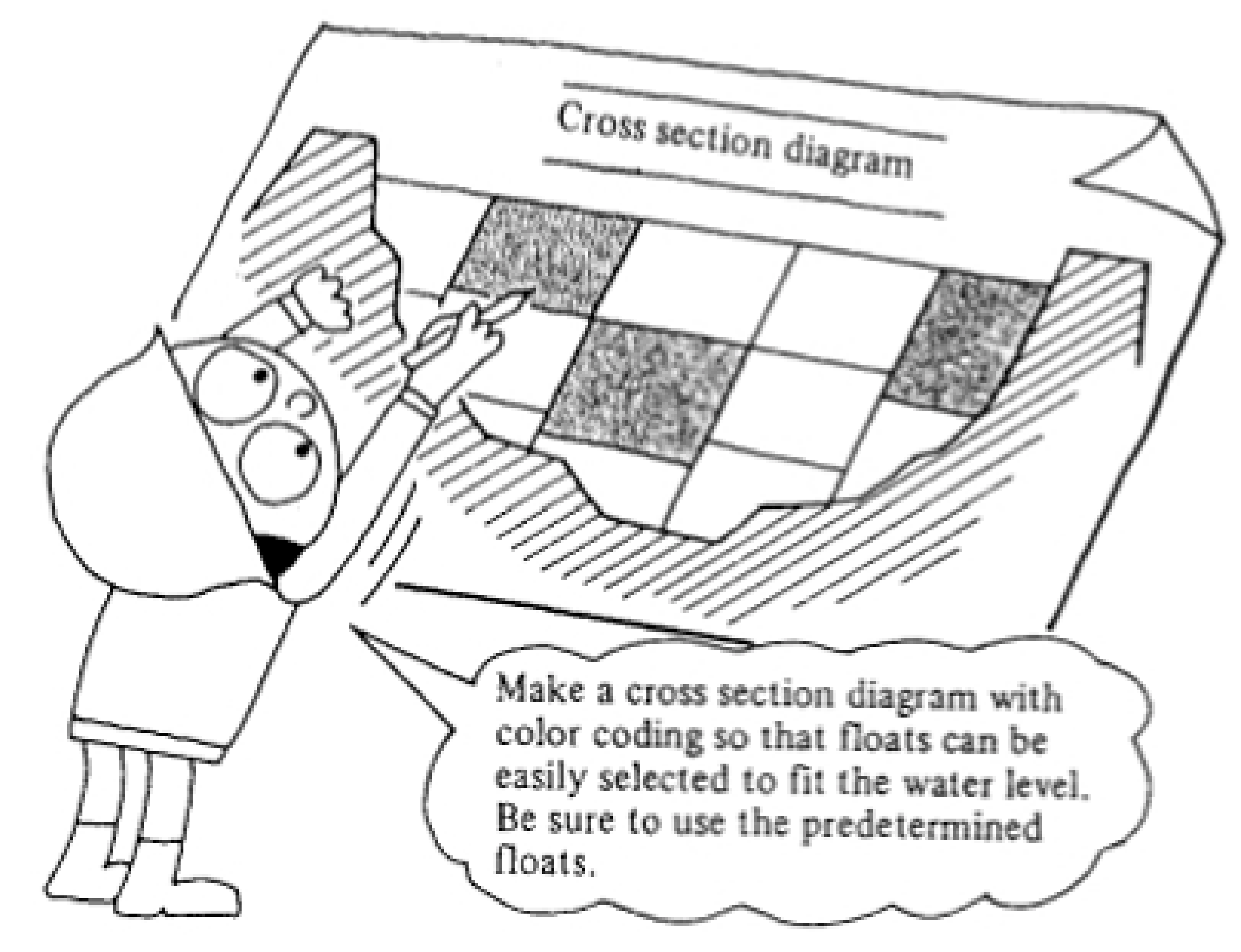
C

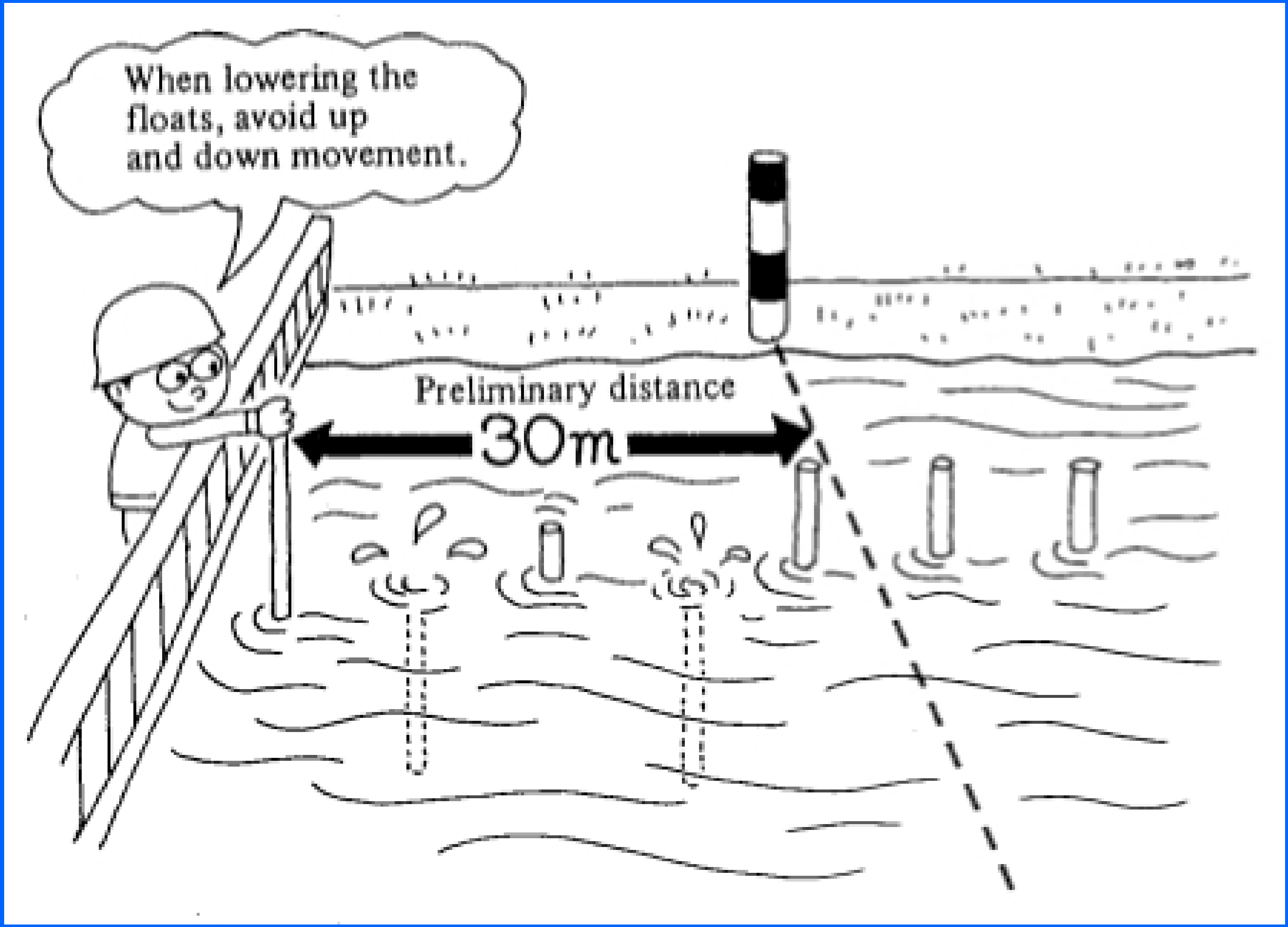
Conversion factor to obtain mean velocity

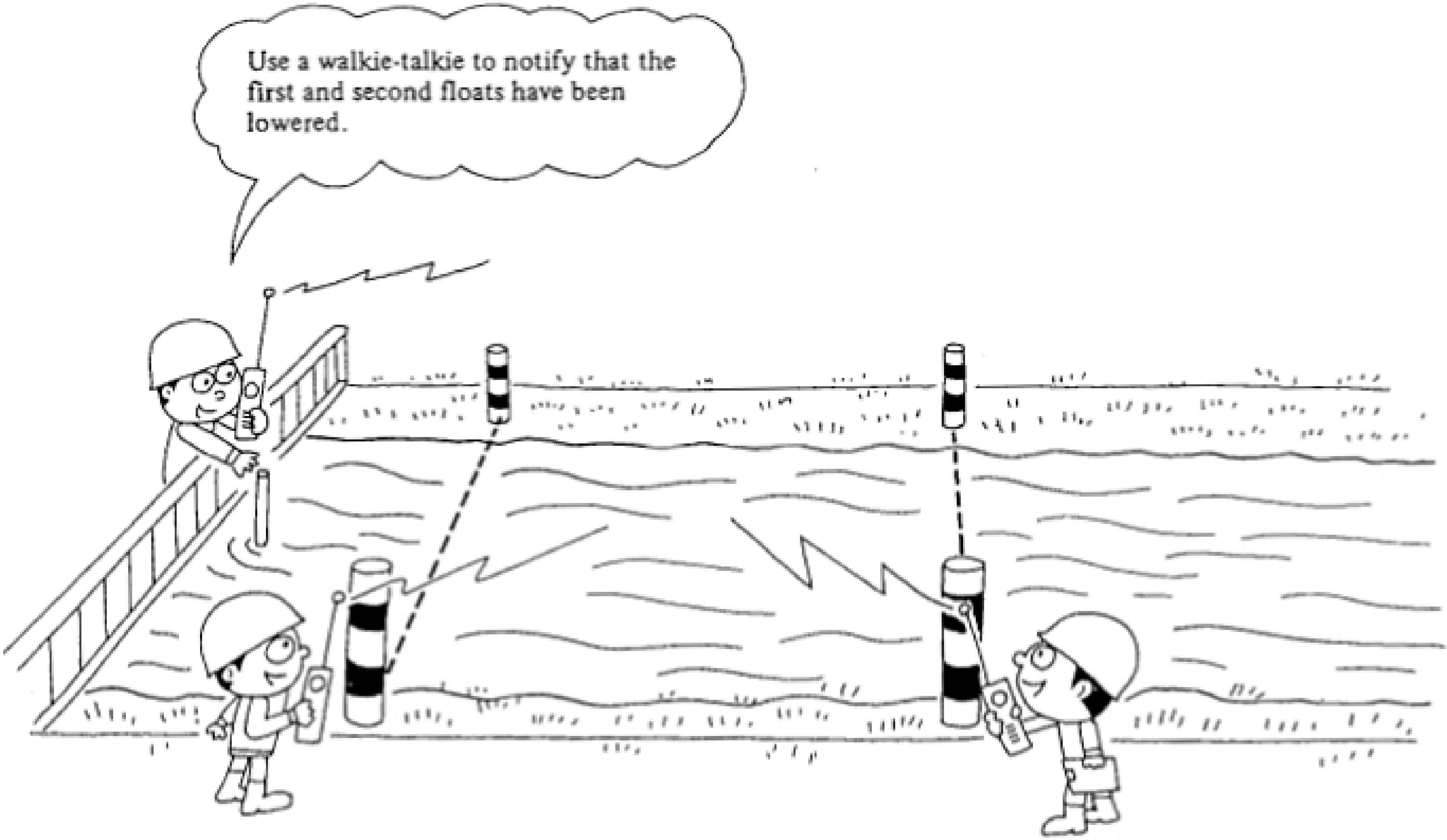
| 番号 | 浮子種類 | キッ水深 | a | c | キッ水比 | 更正係数 |
|---|---|---|---|---|---|---|
| 1 | 表面浮子① Surface | 0.15 | 0 | 30 | 0.55 | 0.91 |
| | | | 0 | 30 | 0.50 | 0.86 |
| | | | 0 | 30 | 0.38 | 0.84 |
| | | | 0 | 30 | 0.30 | 0.83 |
| | | | 0 | 30 | 0.25 | 0.83 |
| | | | 0 | 30 | 0.22 | 0.82 |
| 1 | 表面浮子③ Surface | 0.25 | 0 | 30 | 0.62 | 0.87 |
| | | | 0 | 30 | 0.50 | 0.85 |
| | | | 0 | 30 | 0.42 | 0.84 |
| | | | 0 | 30 | 0.36 | 0.83 |
| 1 | 0.5m 浮子 0.5 m | 0.50 | 0 | 30 | 0.71 | 0.90 |
| | | | 0 | 30 | 0.62 | 0.88 |
| | | | 0 | 30 | 0.56 | 0.87 |
| | | | 0 | 30 | 0.50 | 0.86 |
| | | | 0.1 | 34 | 0.54 | 0.89 |
| | | | 0.1 | 34 | 0.42 | 0.89 |
| | | | 0.1 | 34 | 0.38 | 0.88 |
| 3 | 1m 浮子 1 m | 1.00 | 0.1 | 34 | 0.77 | 0.94 |
| | | | 0.1 | 34 | 0.71 | 0.92 |
| | | | 0.1 | 34 | 0.67 | 0.92 |
| | | | 0.1 | 34 | 0.63 | 0.91 |
| | | | 0.1 | 34 | 0.59 | 0.90 |
| | | | 0.1 | 34 | 0.56 | 0.90 |
| | | | 0.1 | 34 | 0.53 | 0.90 |
| | | | 0.1 | 34 | 0.50 | 0.89 |
| | | | 0.2 | 38 | 0.48 | 0.92 |
| | | | 0.2 | 38 | 0.45 | 0.92 |
| | | | 0.2 | 38 | 0.43 | 0.92 |
| | | | 0.2 | 38 | 0.42 | 0.92 |
| | | | 0.2 | 38 | 0.40 | 0.92 |
| | | | 0.2 | 38 | 0.38 | 0.92 |
| 4 | 2m 浮子 2 m | 2.00 | 0.2 | 38 | 0.77 | 0.95 |
| | | | 0.2 | 38 | 0.74 | 0.94 |
| | 2 m | | 0.2 | 38 | 0.71 | 0.94 |
| | | | 0.2 | 38 | 0.69 | 0.94 |
| | | | 0.2 | 38 | 0.67 | 0.94 |
| | | | 0.2 | 38 | 0.65 | 0.93 |
| | | | 0.2 | 38 | 0.63 | 0.93 |
| | | | 0.2 | 38 | 0.61 | 0.93 |
| | | | 0.2 | 38 | 0.59 | 0.93 |
| | | | 0.2 | 38 | 0.57 | 0.93 |
| | | | 0.2 | 38 | 0.56 | 0.93 |
| | | | 0.2 | 38 | 0.54 | 0.93 |
| | | | 0.2 | 38 | 0.53 | 0.93 |
| | | | 0.2 | 38 | 0.51 | 0.93 |
| | | | 0.2 | 38 | 0.50 | 0.93 |
| | | | 0.3 | 41 | 0.49 | 0.95 |
| | | | 0.3 | 41 | 0.48 | 0.95 |
| | | | 0.3 | 41 | 0.47 | 0.95 |
| | | | 0.3 | 41 | 0.45 | 0.95 |
| | | | 0.3 | 41 | 0.44 | 0.95 |
| | | | 0.3 | 41 | 0.43 | 0.95 |
| | | | 0.3 | 41 | 0.43 | 0.95 |
| | | | 0.3 | 41 | 0.42 | 0.95 |
| | | | 0.3 | 41 | 0.41 | 0.95 |
| | | | 0.3 | 41 | 0.40 | 0.95 |
| | | | 0.3 | 41 | 0.39 | 0.95 |
| | | | 0.3 | 41 | 0.38 | 0.95 |
| 5 | 4m 浮子 4 m | 4.00 | 0.3 | 41 | 0.77 | 0.97 |
| | | | 0.3 | 41 | 0.67 | 0.96 |
| | | | 0.3 | 44 | 0.57 | 0.96 |
| | | | 0.3 | 44 | 0.50 | 0.96 |
| | | | 0.3 | 46 | 0.44 | 0.96 |
| | | | 0.3 | 46 | 0.40 | 0.96 |
| | | | 0.3 | 48 | 0.36 | 0.95 |
| | | | 0.3 | 48 | 0.33 | 0.95 |

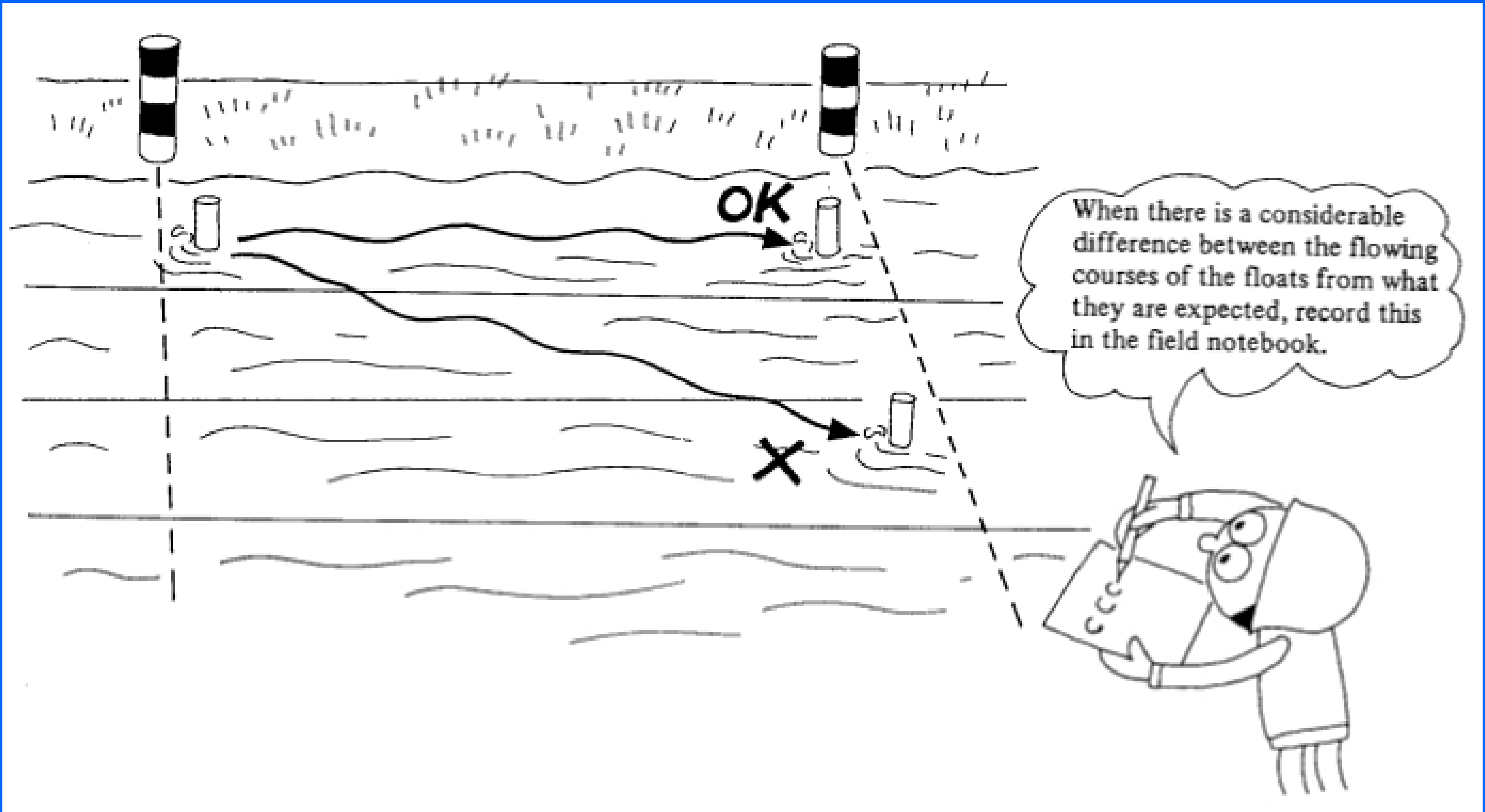
# As a result, the averaged (max.&min.) conversion factor for each type of float is as follows:

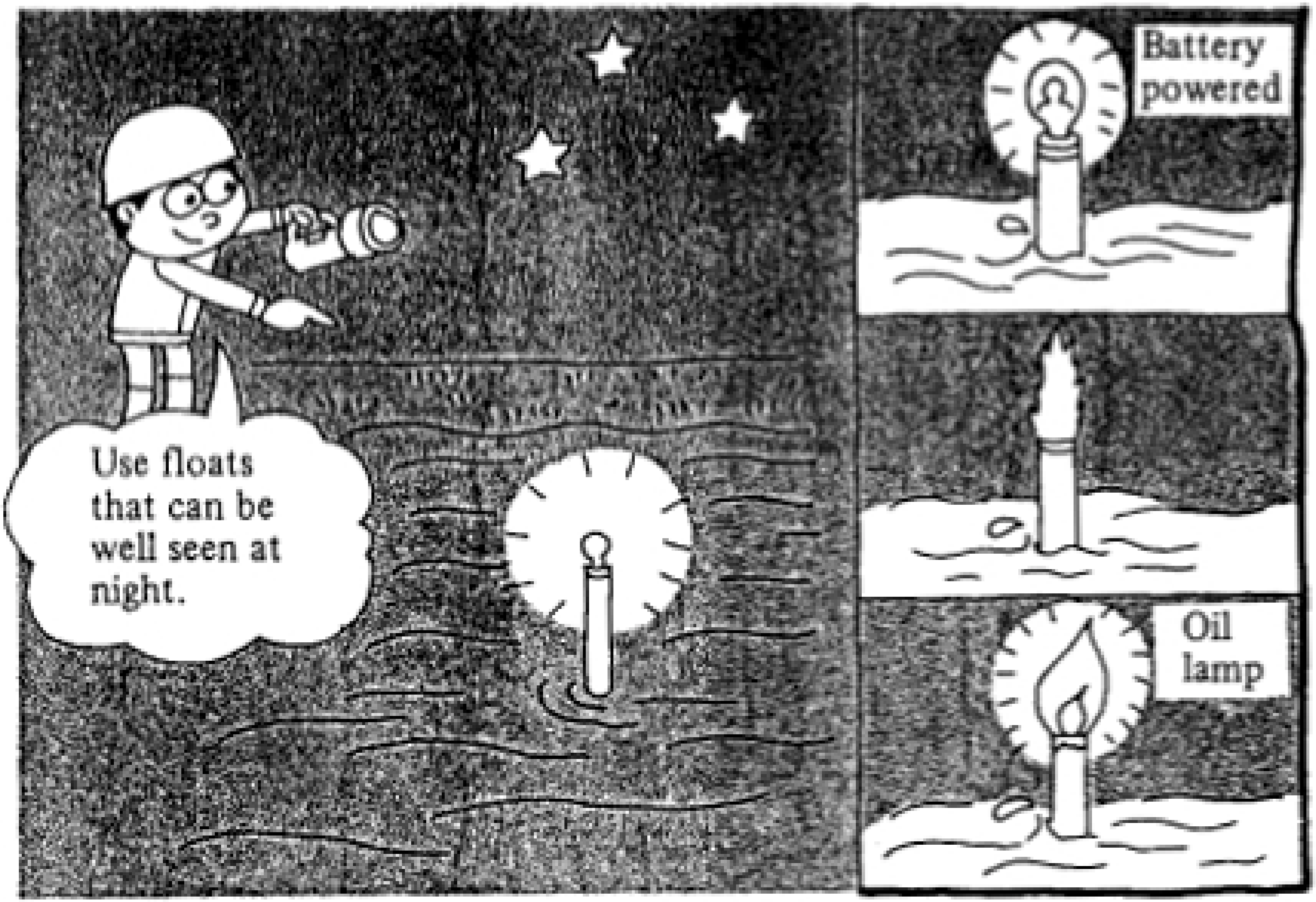
| | | |
|---|---|---|
| 1) | Surface float: | 0.85 ( valid for h ≦ 0.7m ) |
| 2) | 0.5 m float: | 0.88 ( valid for h = 0.7 ~ 1.3m ) |
| 3) | 1 m float: | 0.91 ( valid for h = 1.3 ~ 2.6m ) |
| 4) | 2 m float: | 0.94 ( valid for h = 2.6 ~ 5.2m ) |
| 5) | 4 m float: | 0.94 ( valid for h ≧ 5.2m ) |

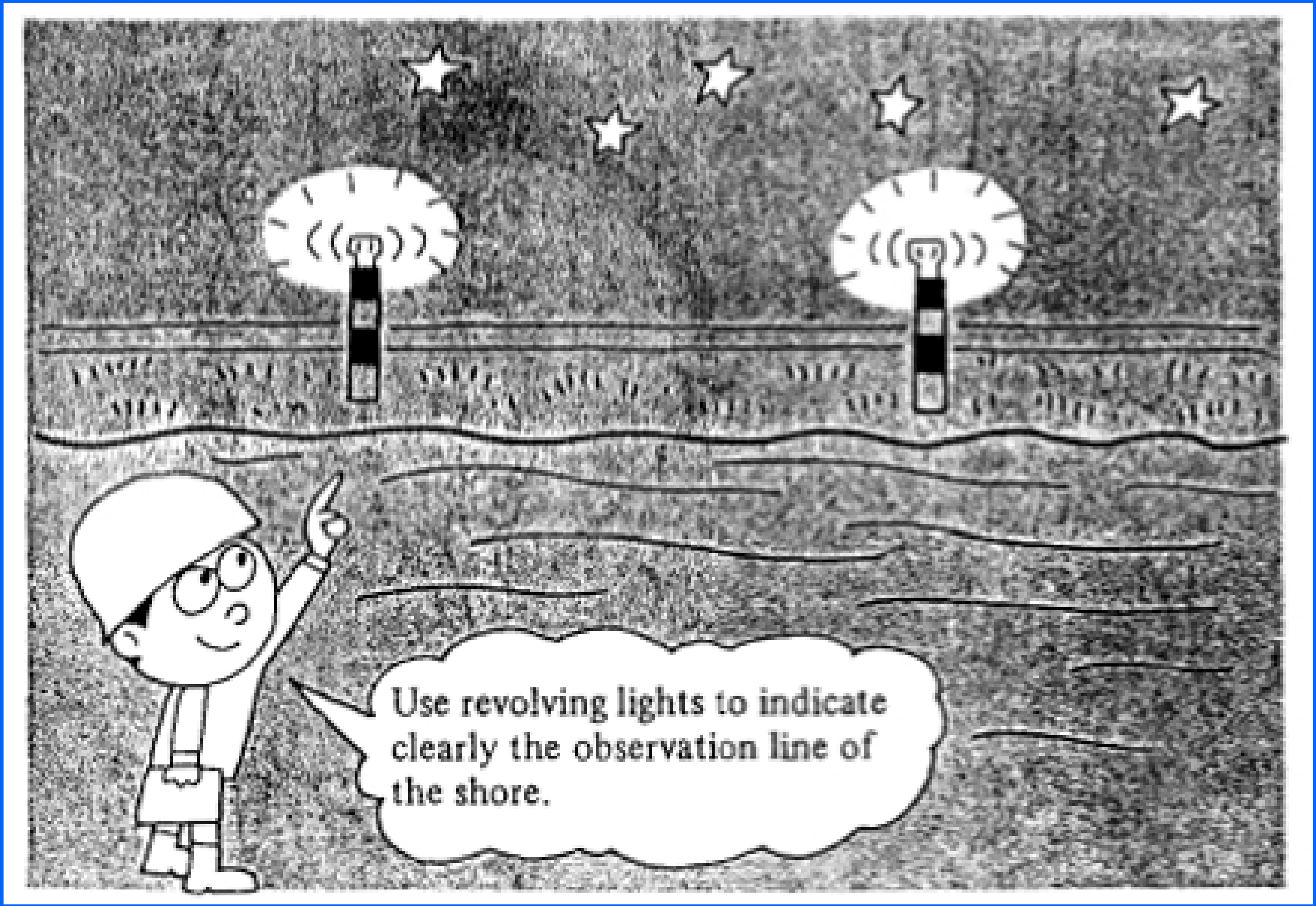

Cross section diagram
Make a cross section diagram with color coding so that floats can be easily selected to fit the water level. Be sure to use the predetermined floats.

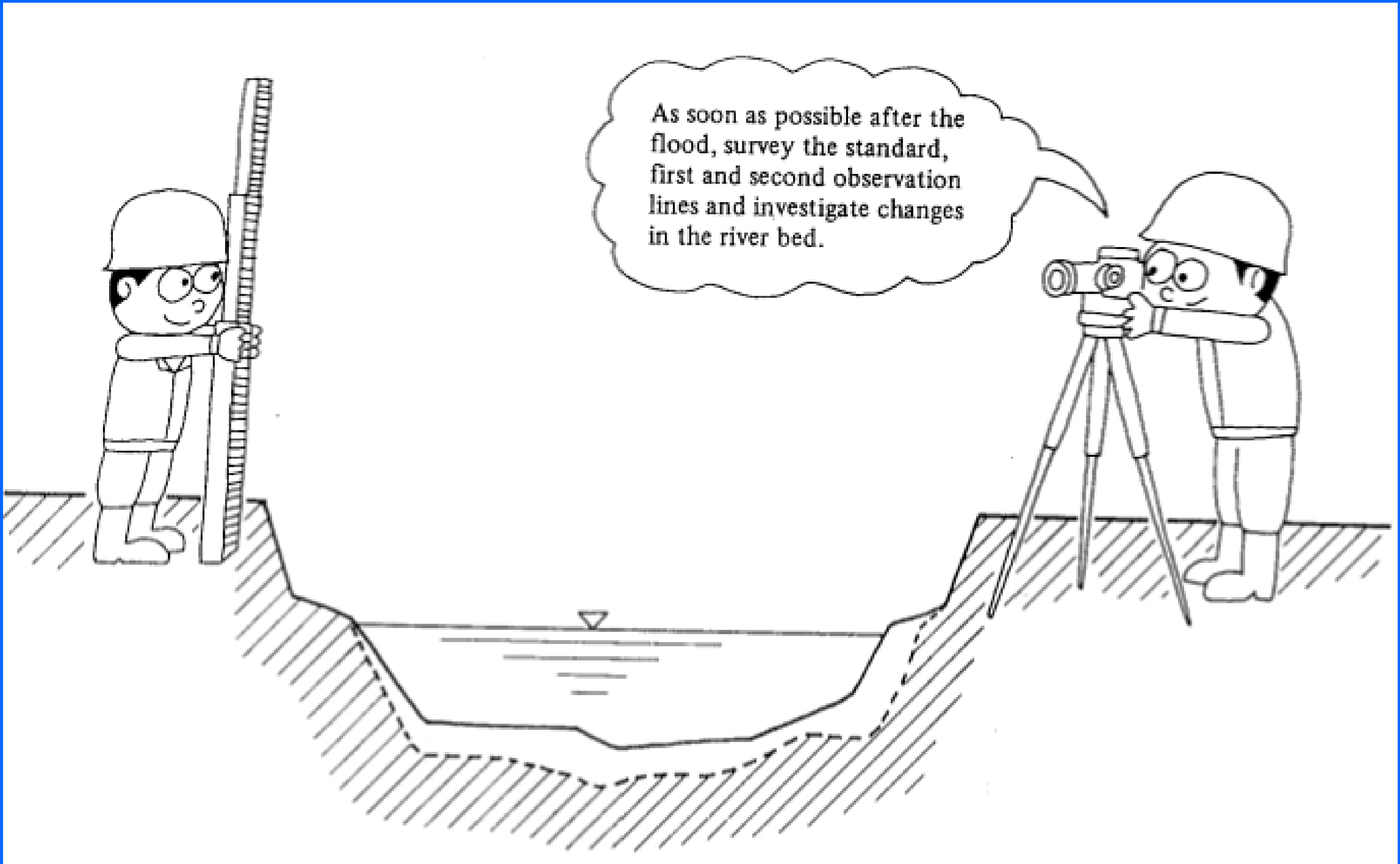

When lowering the floats, avoid up and down movement.
Preliminary distance
30m


Use a walkie-talkie to notify that the first and second floats have been lowered.


OK
When there is a considerable difference between the flowing courses of the floats from what they are expected, record this in the field notebook.


Use floats that can be well seen at night.
Battery powered
Oil lamp


Use revolving lights to indicate clearly the observation line of the shore.

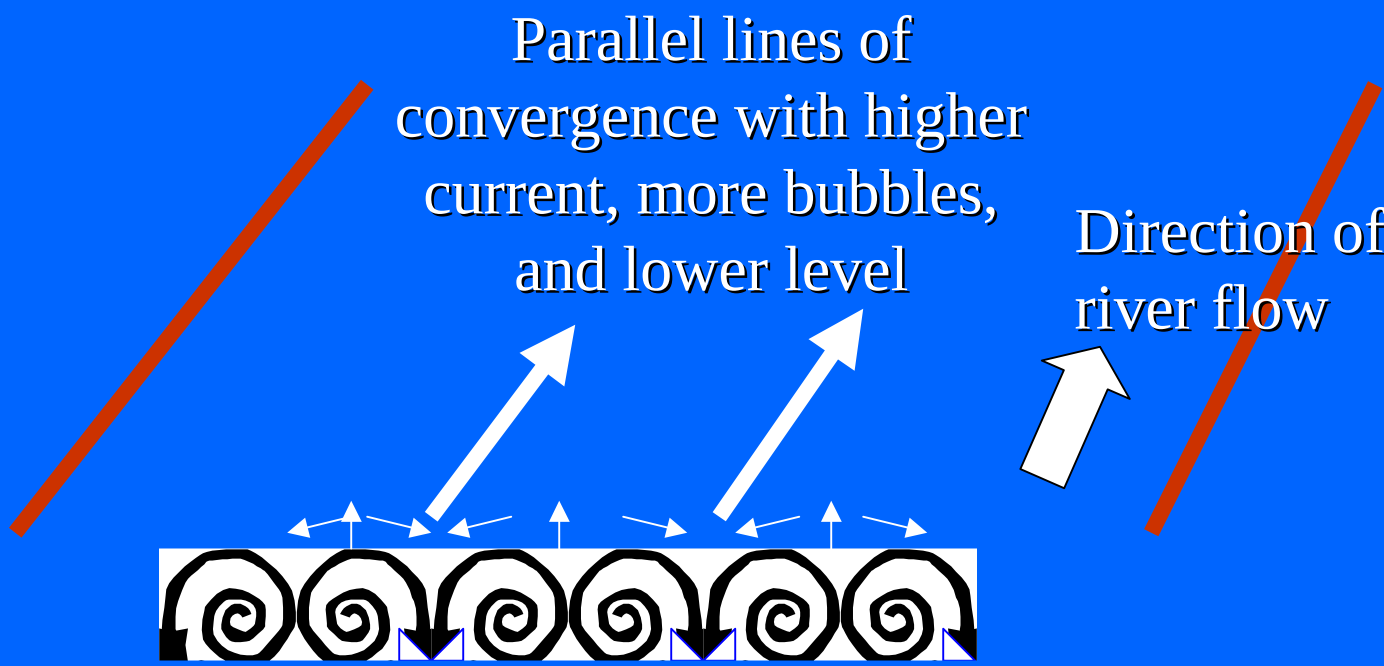

As soon as possible after the flood, survey the standard, first and second observation lines and investigate changes in the river bed.

# Frequent Problems for Flood Discharge Measurement & Data (1/2)

1. Float Measurement
   - Non-straight flowing ← compound cross section, vegetation, bridge base, etc.
   - Difficulty to obtain Q data during the water-level rising
   - Danger of around-peak flow measurement
   - Effect of parallel spiral flow → possibility of overestimation?
   - Validity of conversion factor →So far, we have given priority to secure the consistent-accuracy data with ease at every field.

→ Expectation to other methods,
especially, non-contact discharge measurement

# Possibility of Overestimation of high flow measurement with floats




"'Parallel spiral flow' is created in the downstream of bridge basements. Floats are apt to be concentrated in the lines. Velocity is about +10% more than the average."

According to Dr. Ryosaku KINOSHITA (1998) A discussion on the flood discharge measurement in the downstream of river, Journal of Japan Society of Hydrology & Water Resources, vol.11, No.5, pp.460-471 (in Japanese).

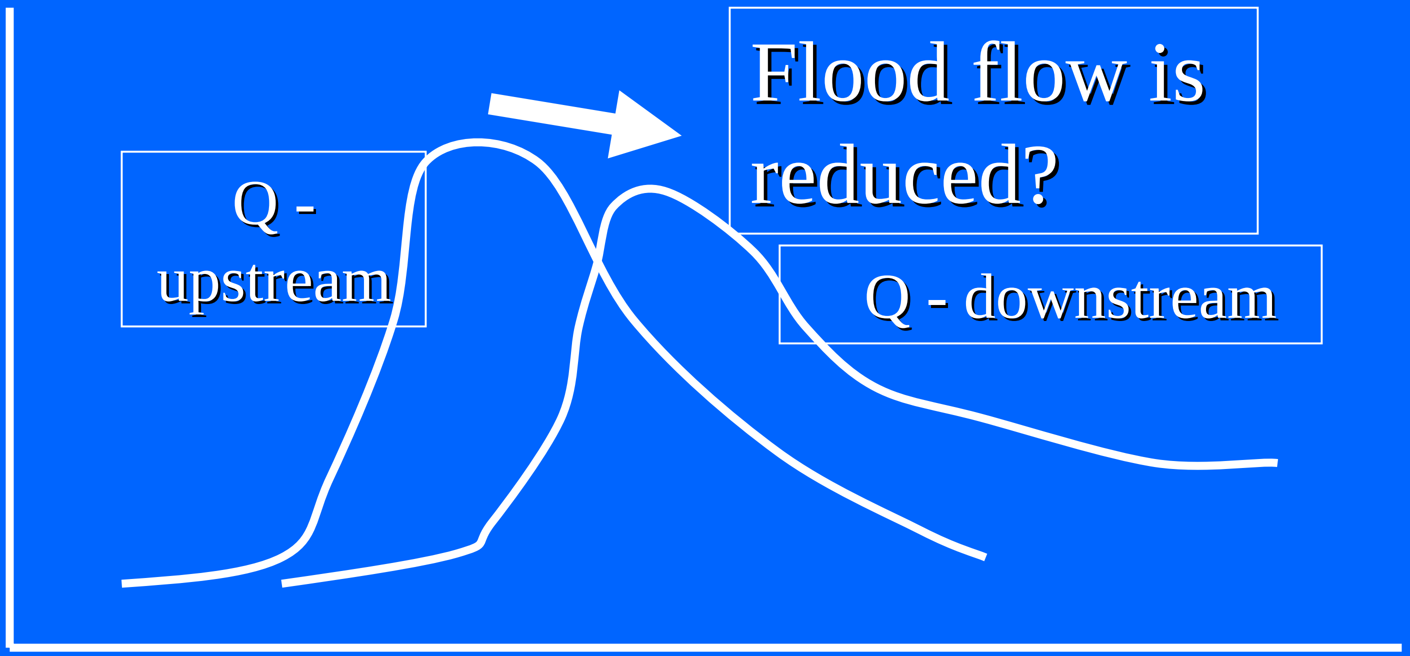
# Frequent Problems for Flood Discharge Measurement & Data (2/2)

2. H-Q Curve Estimation

- Scatter, shift and/or variation of slope of H-Q plots
  - ← Errors of flow measurement owing to no-good flow of floats, low representativeness of them, suitability of measurement lines considering their cross sections, etc.
  - ← Water-surface gradient (ascending, descending), roughness change, riverbed change, etc.
- Accurate at a glance but not precise comparing with other flow measurements in its upstream and/or downstream

# Reverse of high flow discharge?
## Storage in channel, or dispersion?

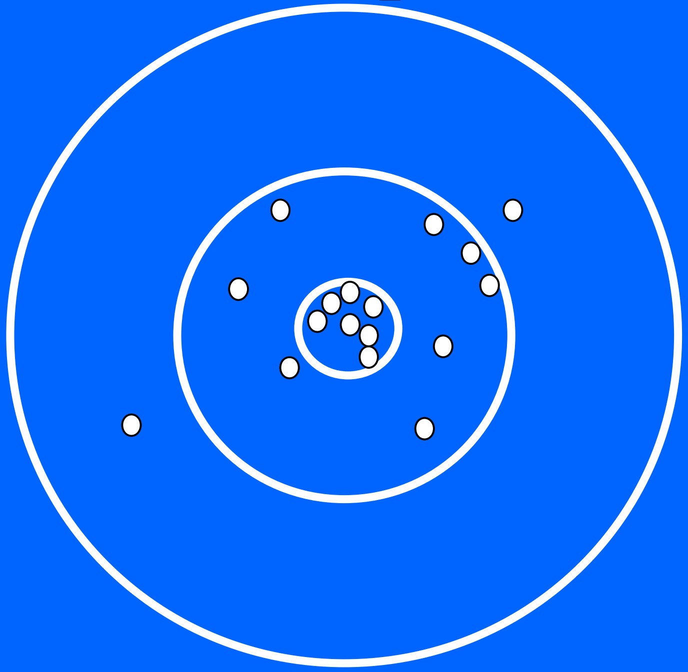
Proper data check is really needed!



# Precision & Accuracy

**Accurate**

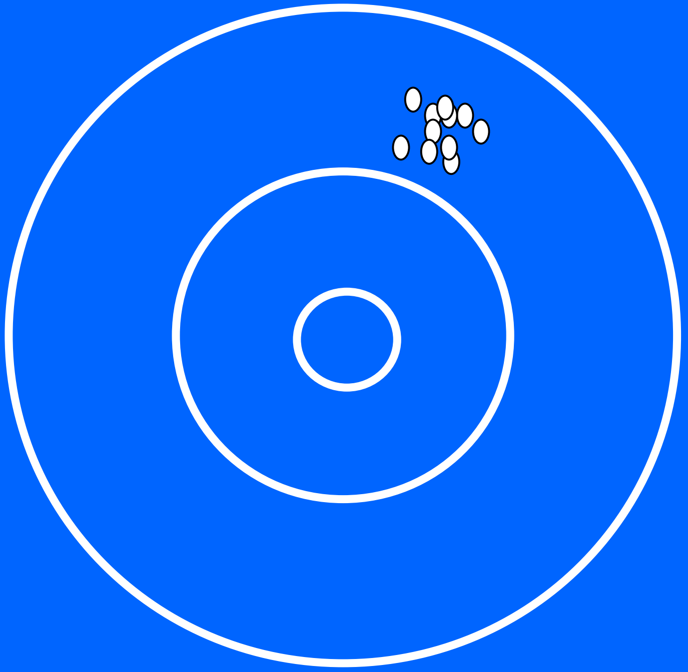
but not precise



**much scattered**

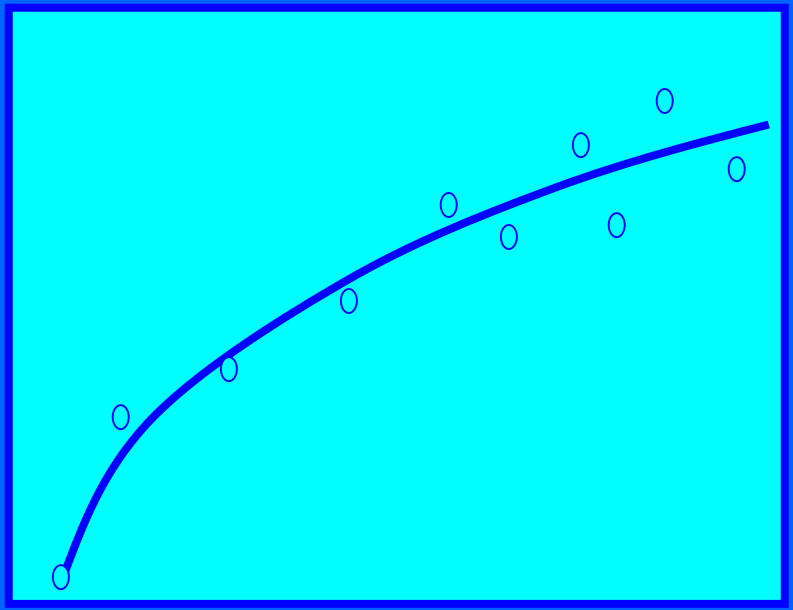
**Precise**

but inaccurate

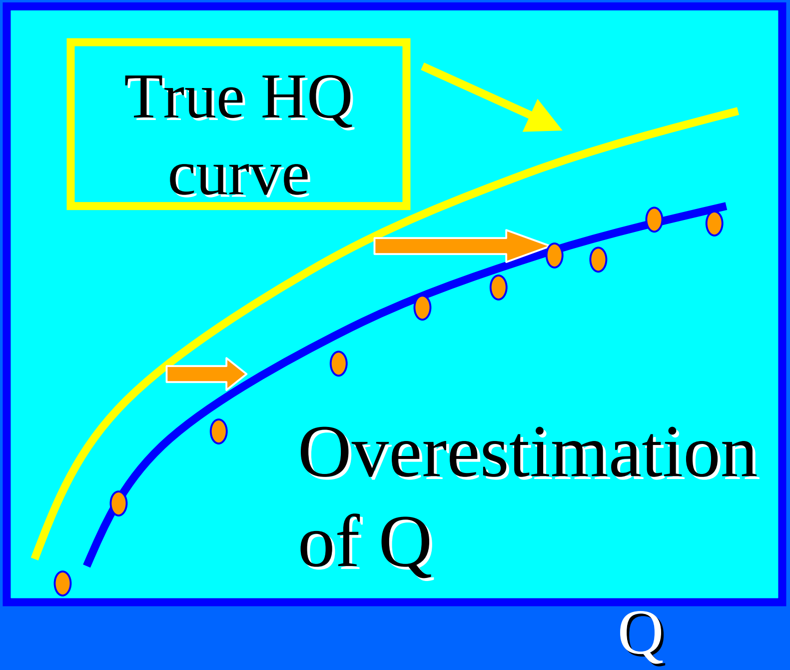


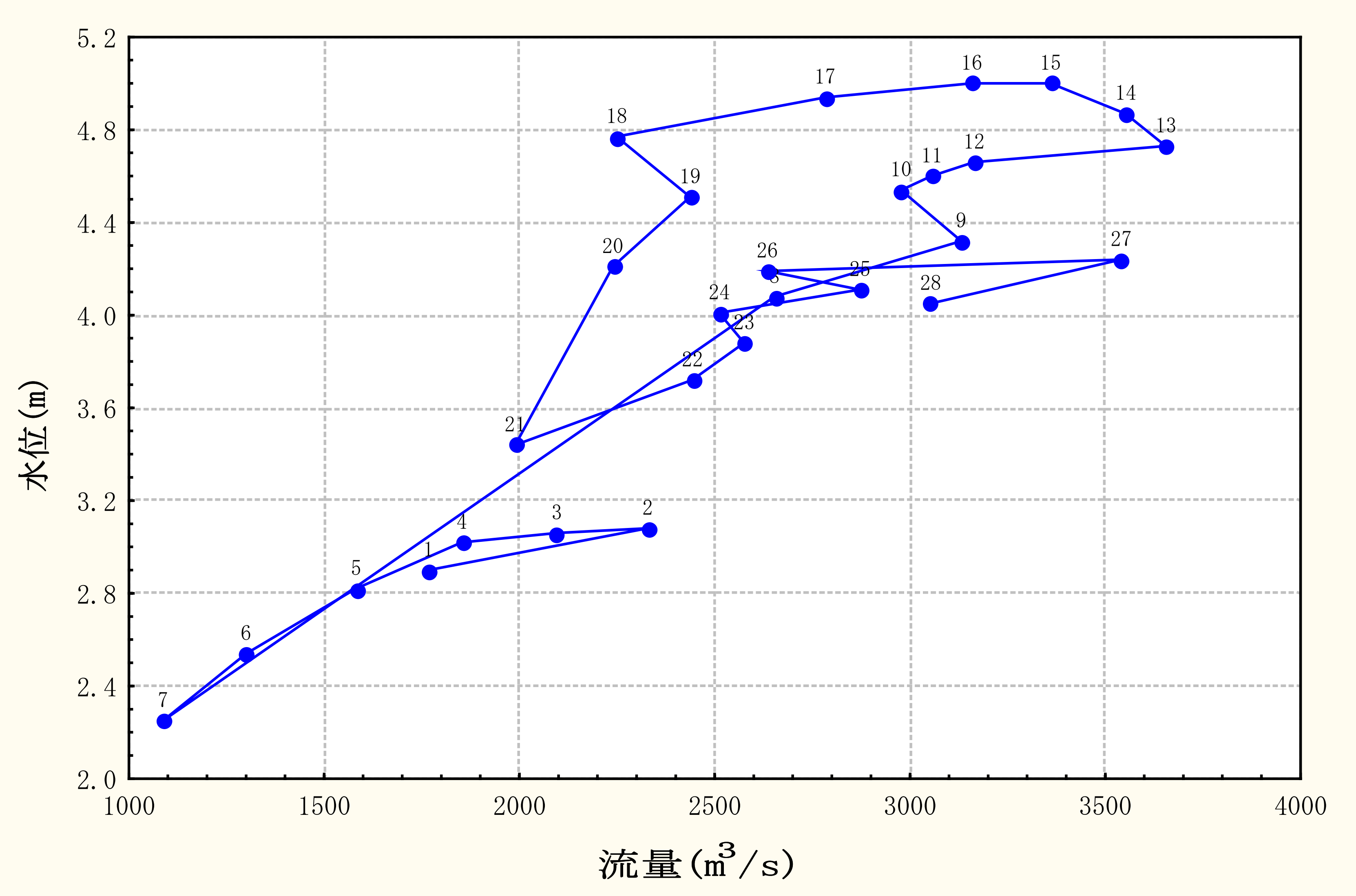
**less scattered**

# **Precise**
but inaccurate



# **Accurate**
but not precise





5.2
4.8
4.4
4.0
3.6
3.2
2.8
2.4
2.0
1000
1500
2000
2500
3000
3500
4000
水位(m)
流量(m3/s)
1
2
3
4
5
6
7
8
9
10
11
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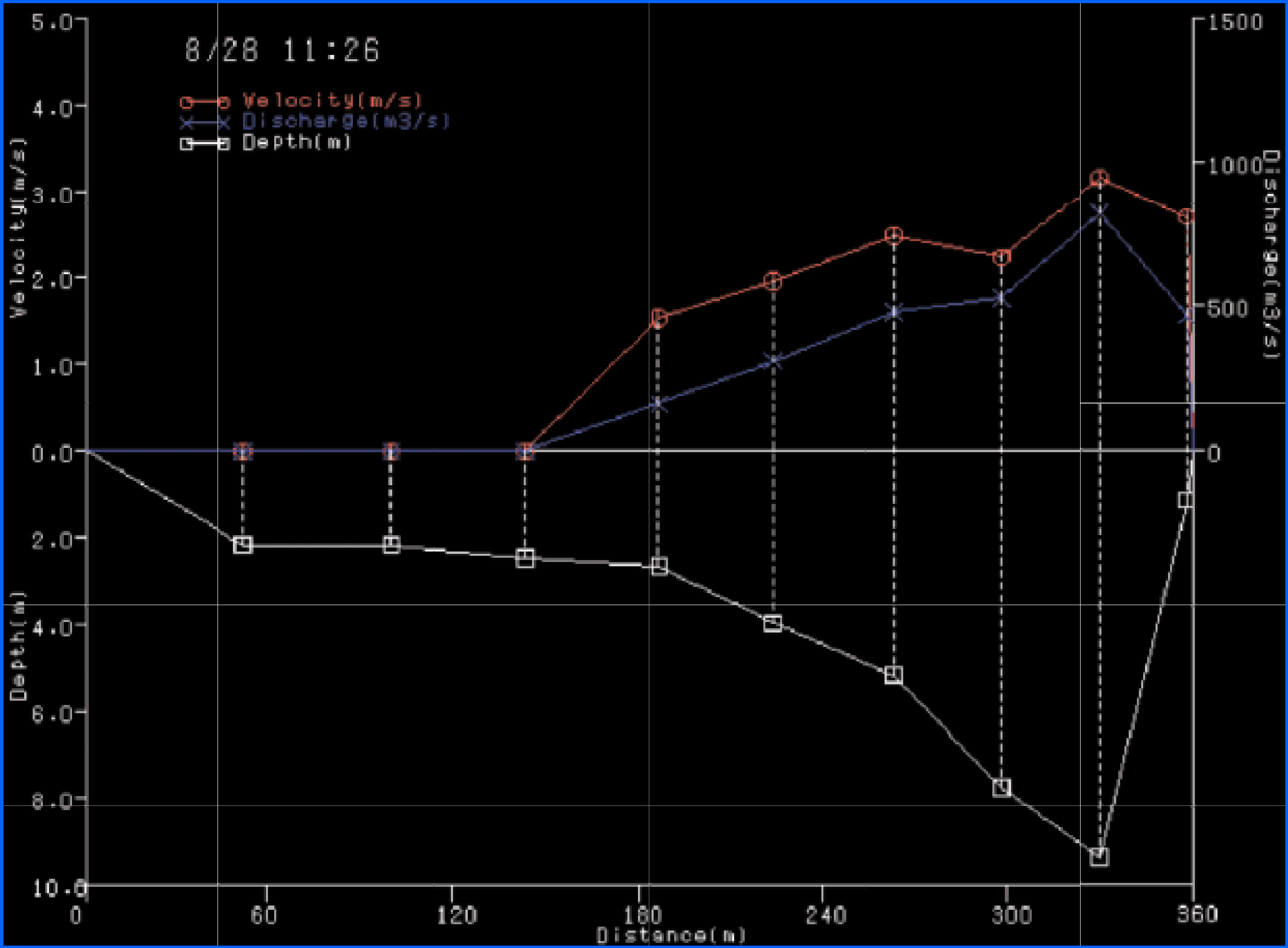
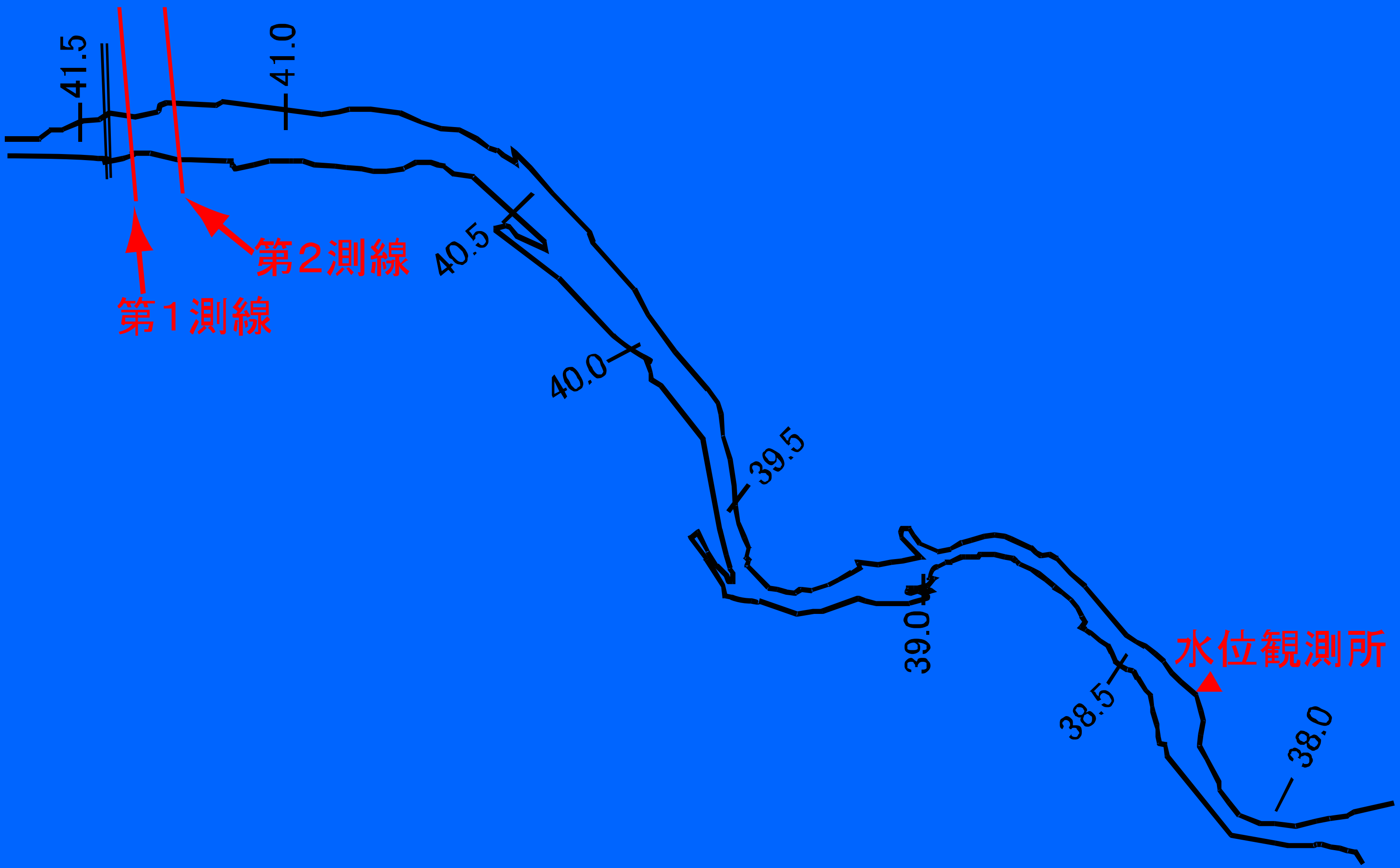
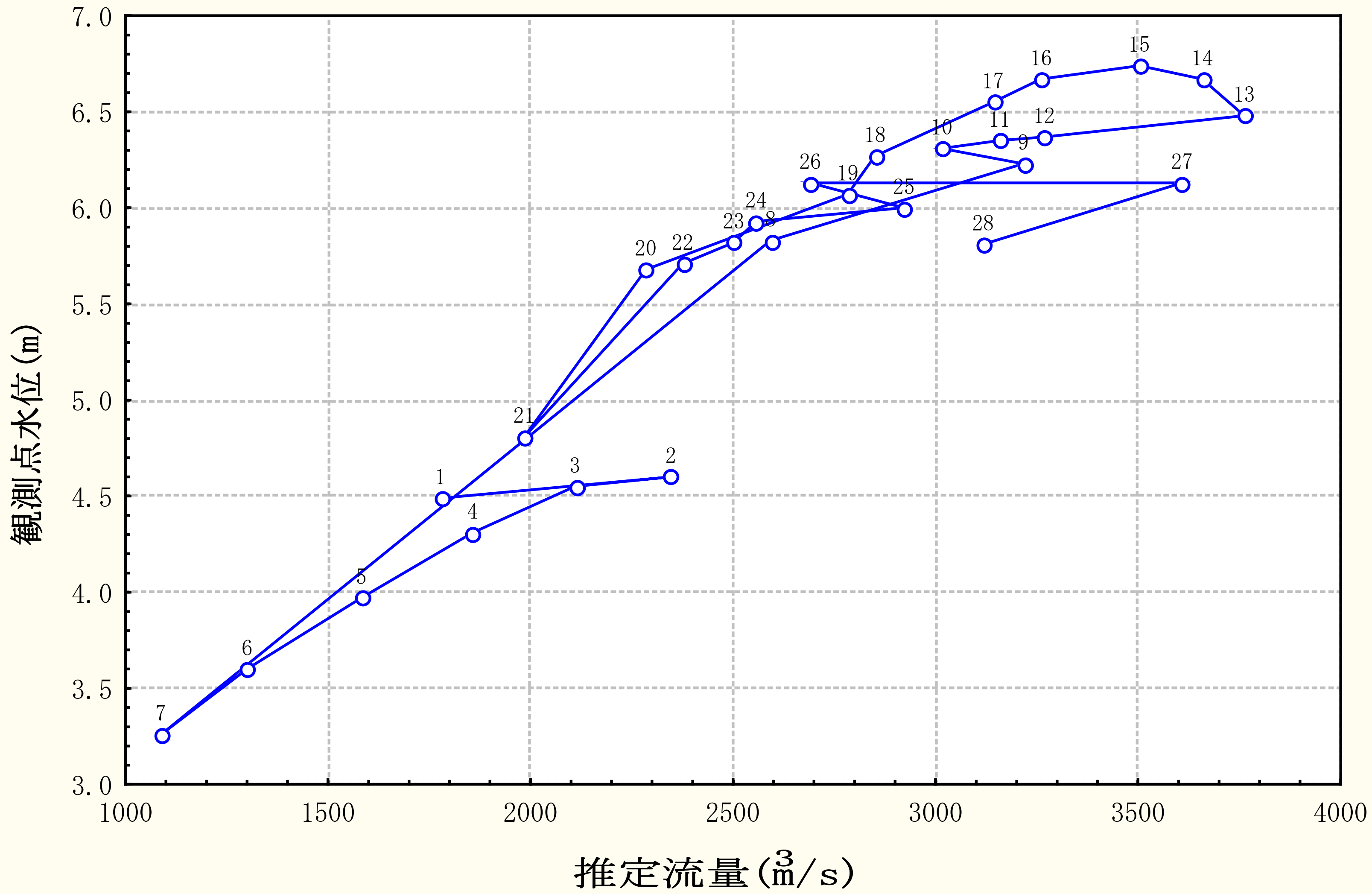

8/28 11:26
Velocity(m/s)
Discharge(m3/s)
Depth(m)
Velocity(m/s)
Depth(m)
Discharge(m3/s)
Distance(m)
5.0
4.0
3.0
2.0
1.0
0.0
2.0
4.0
6.0
8.0
10.0
1500
1000
500
0
0
60
120
180
240
300
360



41.5
41.0
40.5
40.0
39.5
39.0
38.5
38.0
第２測線
第１測線
水位観測所


観測点水位(m)
推定流量(m³/s)
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
1000
1500
2000
2500
3000
3500
4000
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
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27
28

# Future Direction ( unauthorized )

Proper flow measurement with conventional methods & new technology development for the future

- Proper check with other independent data source
- Check with hydrologic ( & hydraulic ) models

Scientific understanding of river flow structure

Hydrologic database
+
H-Q curve checking assistant system

H-Q curve optimization with feedbacks