SONDAR 5000
Ultrasonic Open Channel Flow Meter
(USER’S MANUAL)

IS Technologies Co., Ltd.
SONDAR 5000
May.2004 Edition

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About SONDAR 5000

Sondar 5000 is an instrument that can be used both as ultrasonic open channel flow meter and level gauge. The ultrasonic open channel flow meter measures the water level and calculates and displays accurate flow rate and total flow rate in a manner to measure the flow rate according to a flow/level calculation method, based on the principle that water level is specifically related to flow rate in the standardized open channel.

The ultrasonic flow meter employing non-contact measurement method can be applicable to various fluids, including corrosive fluid, and has semi-permanent life.

Data Logger function is built in this product, enabling long-term storage of various data, such as level, flow rate, and total flow rate. These data can be saved for up to 6 months.

This product can be applicable to the following open channels.

1. Parshall Flumes
2. Suppressed Rectangular Weirs
3. Contracted Rectangular Weirs
4. V-Notch [Triangular] Weirs. [22.5°, 30°, 45°, 60°, 90°, 120°]
5. Cipolletti Weirs
6. Leopold Lagco Flumes
7. Palmer Bowlus Flumes

In addition, 10 point DIY CURVE and flow equation \((Q=K*H(PWR))\) are used to measure the flow rate in various open channels.
Features of SONAR 5000

- Non-contact flow measurement - applicable to various fluids, semi-permanent life
- Applicable to various kinds of channels
- 10 point DIY CURVE function able to conduct flow measurement, regardless of the types of channels
- Digital measurement and display (0.01 m3/h)
- Current output in proportion to flow measurement (4mA ~ 20mA)
- Flow rate setting at 4mA ~ 20mA
- Flow-based pulse output (able to set unit flow rate) - applicable to mechanical flow meter
- 2 programmable SPDT relays
- 5 buttons for convenient and easy operation
- LCD to display operational conditions - convenient setting
- Built-in temperature sensor and temperature compensation function
- Ultrasonic output adjustment and algorithm selection assuring consistent flow measurement
- Automatic detection of bottom distance
- Storage of various data, including water level, flow rate, and total flow rate, for up to 6 months.
- Flow Switch input function able to measure the flow rate at Zero flow [Option]
- Operation with free voltage power, low power consumption
Product Specification

**Physical**
- Controller: 240(width) X 185(height) mm
- Sensor: Ø 67(dia) X 160(height) mm
- Mounting: 3/4" NPT
- Weight: around 3.0kg (sensor, controller)
- Sensor Material: Polypropylene

**Environmental**
- IP Rating (electronics housing): IP65(Controller)
- Max. & Min. temperature (electronics): -20 ºC to +60 ºC(Controller), -20 to +70ºC(Sensor)
- RTX cable length: 10m (Standard)

**Performance**
- Resolution: 1mm
- Range(Flow rate): 0.00m³/h ~ 200,000.00 m³/h
- Range(Total flow): 999999999.99 m³/h
- Range(level): 250 ~ 8000mm
- Beam Angle: 8° at -3dB
- Response Time: 500ms
- Displayed Value: Flow rate, Total flow, Level, graphic LCD (128X68 dot)
- Temperature Compensation: Fully compensated via integral temperature sensor over entire operational span

**Outputs**
- Analogue Output: 4-20mA into Max 600Ω (user adjustable)
- Fault condition Alarm: 3.8mA /Hold/21mA,
- Setpoint Relay: 3 SPDT Relays
- Relay capacity: 5A, AC250V
- Communication Port: 1 point RS-232C/RS485
- Pulse output: 1 point, open collector or line drive

**Programming**
- On-board programming: via 5 tactile push button buttons

**Supply**
- Power supply: AC90 ~ 260V, Less than 15VA(50Hz ~ 60Hz),

**Applicable Channel**
- 15 kinds of Parshall Flumes
- Suppressed Rectangular Weirs
- Contracted Rectangular Weirs
- V-Notch[Triangular] Weirs.[22.5°, 30°, 45°, 60°, 90°, 120°]
- 10 kinds of Cipolletti Weirs
- 10 kinds of Leopold Lagco Flumes
- 10 kinds of Palmer Bowlus Flumes

**Special function**
- 10 Point DIY CURVE
- Flow equation(Q=K*H(PWR))
Sondar 5000 is composed of a controller unit and one sensor

Power Supply Requirements

The Sondar 5000 operates from a AC supply of 90 ~260V.

All electronic products are susceptible to electrostatic shock, so follow proper grounding procedures during installation.

When choosing a location to mount the sensor, bear in mind the following:

- For easy access to the LCD display and programming buttons mount it where it is easily accessible.
- The ultrasonic signal path should be free of falling material and obstructions such as pipes, beams etc.
- The sensor should be mounted at least 30cm above the maximum level of the material and be perpendicular to the surface.
- The mounting surface should be vibration-free.
- The ambient temperature of the sensor is between -20ºC and 70ºC.
- There should be no high voltage cables or electrical inverters close by.

Dimensions

Sensor
Controller

There are 23 terminals for controller and 3 terminals for power board as follows:

Input & Output Terminal

<table>
<thead>
<tr>
<th>Terminal</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>V+</td>
<td>Power Supply</td>
</tr>
<tr>
<td>SEN-</td>
<td>Signal Input</td>
</tr>
<tr>
<td>SEN+</td>
<td>Signal Input</td>
</tr>
<tr>
<td>TX-CLK</td>
<td>Communication</td>
</tr>
<tr>
<td>RX</td>
<td>Communication</td>
</tr>
<tr>
<td>GND</td>
<td>Ground</td>
</tr>
<tr>
<td>VIN</td>
<td>Power Supply</td>
</tr>
<tr>
<td>LN</td>
<td>Power Supply</td>
</tr>
<tr>
<td>TX_CLK</td>
<td>Communication</td>
</tr>
<tr>
<td>PULSE</td>
<td>Communication</td>
</tr>
<tr>
<td>RTN</td>
<td>Communication</td>
</tr>
<tr>
<td>A1_COM</td>
<td>Analog Output</td>
</tr>
<tr>
<td>A2_COM</td>
<td>Analog Output</td>
</tr>
<tr>
<td>ER_COM</td>
<td>Analog Output</td>
</tr>
<tr>
<td>A1_NO A1_NC</td>
<td>Additional Outputs</td>
</tr>
<tr>
<td>A2_NO A2_NC</td>
<td>Additional Outputs</td>
</tr>
<tr>
<td>ER_NO ER_NC</td>
<td>Additional Outputs</td>
</tr>
<tr>
<td>Terminal</td>
<td>Function</td>
</tr>
<tr>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>V+</td>
<td>DC +12V output</td>
</tr>
<tr>
<td>SEN-</td>
<td>Connect to shield cable of sensor of RTX</td>
</tr>
<tr>
<td>SEN+</td>
<td>Connect to +cable of sensor of RTX</td>
</tr>
<tr>
<td>TX CLK</td>
<td>Output of sensor’s transmitting signals in pulse form</td>
</tr>
<tr>
<td>RTH</td>
<td>Connect to outer temperature sensor</td>
</tr>
<tr>
<td>VIN</td>
<td>External Input[FOLW SWITCH]</td>
</tr>
<tr>
<td>RTN</td>
<td>External input GND</td>
</tr>
<tr>
<td>TX</td>
<td>When using RS232C interface, connection to RS232C’s transmitter. When using RS485, connection to Y.</td>
</tr>
<tr>
<td>RX</td>
<td>When using RS232C interface, connection to RS232C’s receiver. When using RS485, connection to Z.</td>
</tr>
<tr>
<td>GND</td>
<td>Digital communication GND</td>
</tr>
<tr>
<td>IOUT</td>
<td>Current output (+): Output of 4 mA ~ 20 mA in proportion to flow rate</td>
</tr>
<tr>
<td>IRTN</td>
<td>Current output (-)</td>
</tr>
<tr>
<td>PULSE OC</td>
<td>Pulse output (+): at the set intervals</td>
</tr>
<tr>
<td>PULSE RTN</td>
<td>Pulse output (-)</td>
</tr>
<tr>
<td>A1_NO</td>
<td>ALARM_1 NO contact point. On operation of ALARM_1, disconnection from A1_COM</td>
</tr>
<tr>
<td>A1_COM</td>
<td>ALARM_1 COM contact point. On operation of ALARM_1, disconnection from A1_NO &amp; on its stop, disconnection from A1_NC</td>
</tr>
<tr>
<td>A1_NC</td>
<td>ALARM_1 NC contact point. When ALARM_1 is not in operation, disconnection from A1_COM</td>
</tr>
<tr>
<td>A2_NO</td>
<td>ALARM_2 NO contact point. On operation of ALARM_2, disconnection from A2_COM</td>
</tr>
<tr>
<td>A2_COM</td>
<td>ALARM_2 COM contact point. On operation of ALARM_2, disconnection from A2_COM &amp; on its stop, disconnection from A2_NC</td>
</tr>
<tr>
<td>A2_NC</td>
<td>ALARM_2 NC contact point. When ALARM_2 is not in operation, disconnection from A2_COM</td>
</tr>
<tr>
<td>ER_NO</td>
<td>ERROR_NO contact point. On operation in ERROR situation, disconnection from ER_COM</td>
</tr>
<tr>
<td>ER_COM</td>
<td>ERROR_COM contact point. On operation in ERROR situation, disconnection from ER_NO &amp; on its stop, disconnection from ER_NC</td>
</tr>
<tr>
<td>ER_NC</td>
<td>ERROR_NC contact point. When not operated even in ERROR situation, disconnection from ER_COM</td>
</tr>
<tr>
<td>L</td>
<td>AC power connection</td>
</tr>
<tr>
<td>N</td>
<td>AC power connection</td>
</tr>
</tbody>
</table>

* The below points are useful when test the Sondar5000 in field.

| THR       | Output of standard voltage that determines the volume of the ultrasonic signal. Users can check the most suitable installation location. | Test Point |
| DET       | Output voltage of the detected ultrasonic signal | Test Point |
| TVG       | Output of amplified voltage of the ultrasonic signal. Trigger source of DET signal | Test Point |
In order to prevent malfunctions and assure accurate measurement, installation should be conducted under consideration of the following points.

1) There should be no disturbing objects within the range of 10° beam angle where the ultrasonic pulse moves.
2) It should be installed at right angles to the water surface. (The sensor should be vertical to the floor.)
3) Input accurate bottom distance (04. BOTTOM DISTANCE).

The sensor should be installed at a position of above maximum water level of the channel to be measured (more than 30 cm).
In the rectangular, triangular, and Cipolletti channels, the sensor should be installed at the top of the channel (Max. height x 4 ~ 5 times recommended).

In the Parshall Flume, the sensor should be installed at a 2/3 position of the whole converging section length.

In the Leopold Lagco Flume, the sensor should be installed at the Measurement Point.
In the Leopold-Largco Flume, the sensor should be installed at a position distant from Converging Section (corresponding to the distance of measurement point according to Flumes size)

Flickering of "DT" at the bottom of the screen at Operation Mode means detection of water level. Therefore, such flickering should be confirmed in the course of installation.

Installation should not be done at places exposed to direct sunlight or strong wind.

After installation, operational conditions should be checked again (Power On/Off and display of measurement level).

※ Note: If not correctly installed, this product may not desirably work in the winter when temperature difference between the sensor and the water surface is high.

<table>
<thead>
<tr>
<th>Flume Size</th>
<th>Measurement Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>inches</td>
</tr>
<tr>
<td>100 ~</td>
<td>4~12</td>
</tr>
<tr>
<td>380</td>
<td>15</td>
</tr>
<tr>
<td>455</td>
<td>18</td>
</tr>
<tr>
<td>530</td>
<td>21</td>
</tr>
<tr>
<td>610</td>
<td>24</td>
</tr>
<tr>
<td>760</td>
<td>30</td>
</tr>
</tbody>
</table>
Chapter 3  How To Use SONDAR 5000

Operating the controller

Operation Mode I

- Push SET button at Operation Mode I and Operation Mode II will be displayed. Operation Mode II can be toggled to Operation Mode I by SET button.
- To see MGD(millions gallons per day)unit information, you can simply press UP button at Operation Mode I
- You can choose Operation Mode I or II as you want.

Operation Mode II
● Description of abbreviations displayed
1) FR : Flow rate measured in m3/h.
2) TF : Total flow from the set time.
3) TH : Total hours from the set time.
4) LE : Measured level from the bottom to the surface in mm.
4) T : Ambient temperature.
5) Bar graph: Ratio of measured flow rate to max. flow rate.

● Description of characters displayed
SONDAR 5000 shows its operational conditions on its LCD.
1) A1 : RELAY1 is ON.
2) A2 : RELAY2 is ON.
3) SYSTEM OK : System is normal.
4) FAIL: Failure to measure the flow rate.
5) DT: Flickered on normal measurement of water level.
   (meaning normal detection of reflected waves)
6) D: Echo detection is okay
7) S: Searching Echo
8) LE: On failure to detect the reflected waves.

Button Functions

1) MODE Button
   ● To convert Operation Mode to Program Mode.
   ● Push MODE button at Operation Mode and PASSWORD CHECK, the first menu of Program
     Mode, will be displayed.
   ● Push SET button and Program Mode will be immediately shown.
   ● At Program Mode, push Up or Down button to move to other menu option.
   ● Use MODE button to return to menu option after device selection (02. DEVICE SELECTION)

2) UP [↑] and DOWN [↓] Button
   ● Use this button to change the value of an option selected.
   ● One push of these buttons leads to increase by one. Continuous push of these buttons results
     in continuous increase one by one. Further push of this button results in change of the number
     at tenth or hundredth figures.
   ● If a specific menu is not selected, this button can be used to change menu options. One push of
     this button results in return to the previous menu.

3) SET Button
   ● Use this button to save the values of an option and then, go to the next option selection.

4) RUN Button
   ● Use this button to return to Operation Mode from Program Mode.
Application Menu Option

**Password Check**

- Push MODE button at Operation Mode and PASSWORD CHECK, the initial menu of Program Mode, will be displayed. This is a function to prevent change of set values by unauthorized persons.

- If the password is wrong, "PASSWORD ERROR!" and "RETURN MEASURE MODE" will be displayed at the same time and it will return to Operation Mode.

- If the password is confirmed, "PASSWORD OK!" will be displayed and it will go to Program Mode.

- The password can be changed at PASSWORD CHANGE. The password numbers can be selected within the range of 0~1000.

- Use ↑ or ↓ to move to a specific menu. Place the cursor (*) at a specific menu and push SET button. Then, you can change the value of the menu.

- If you don't want to change the value, push SET button and then, select another menu option.

- If you want to change the value, push ↑ or ↓ to change it. After change, push SET button to save the set value and then, select another menu.

- If you push RUN in the course of selecting an option, Program Mode is converted into Operation Mode.
Password Change

Factory Set = 0

*01. PASSWORD CHANGE
  ▲ ▼
02. DEVICE SELECTION
03. AUTO ZERO
04. BOTTOM DISTANCE

- This is an option for change of password. Push ↑ or ↓ to change the password.
- Push SET button and the changed password will be saved.
- The initial value is 0. (Setting range: 0~1000, Unit: 1)

※Note: If the password is wrong, you cannot go to Program Mode from Operation Mode. Therefore, careful attention should be paid to password change. When you forget the password, please contact the local distributor.

Device Selection

Factory Set = 1

01. PASSWORD CHANGE
*02. DEVICE SELECTION
03. AUTO ZERO
04. BOTTOM

- This is an option for channel selection and detailed parameter setting. Select the channel first and then, set parameters for the channel.
- Place the cursor at this menu. Push SET button and the following screen I will be displayed. The initial value is 1. (Setting range: 1~8, Unit: 1)

*** DEVICE : 1) - 6

*1. Parshall Flumes
  2. Rect. Suppressed
  3. Rect. Contracted
  4. V-Notch Weirs

< 2. DEVICE SELECTION Screen I >

*** DEVICE : 1) - 6

5. Cipoletti Weirs
  6. Leoplod Lagco Flume
  7. Palmer Bowlus Flume
  8. DIY Curve/Special

< 2. DEVICE SELECTION Screen II >
At Program Mode, push ↑ or ↓ to place the cursor (*) at a specific menu and push SET button to go to the mode for change of the relevant device.

Push ↓ at No. 4 and Screen II showing No. 5 to 8 will be displayed. Also, push↑ at No. 1 and the cursor will go to No. 8.

Push MODE button to return to upper-level menu option.

On selection of 2. DEVICE SELECTION menu, the channel and max. flow rate value able to measure in the channel with the relevant device will be automatically set.

When the type of channel is changed during measurement, the previously set values will be lost and values for menus (No. 7, 8, 9, 11, 14) will be initialized as those for the changed channel.

**Pharshall Flumes**

Factory Set = 1

<table>
<thead>
<tr>
<th><strong>1. Parshall Flumes</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flume Selection:</strong></td>
</tr>
<tr>
<td>1: 1in.</td>
</tr>
<tr>
<td>2: 2in.</td>
</tr>
<tr>
<td>3: 3in.</td>
</tr>
<tr>
<td>4: 6in.</td>
</tr>
<tr>
<td>5: 9in.</td>
</tr>
</tbody>
</table>

Select Parshall Flumes and push SET button. Then, the menu for flume selection will be displayed as shown in the above figure.

Use ↑ or ↓ to select the relevant Parshall Flume and push SET button to save the set value and return to main menu. (Setting range: 1~15, Unit: 1)

Measurable maximum height is automatically set.

<table>
<thead>
<tr>
<th>Parshall Flume</th>
<th>Max. Height [mm]</th>
<th>Parshall Flume</th>
<th>Max. Height [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&quot;</td>
<td>180</td>
<td>9&quot;</td>
<td>600</td>
</tr>
<tr>
<td>2&quot;</td>
<td>180</td>
<td>1~8 ft</td>
<td>760</td>
</tr>
<tr>
<td>3&quot;</td>
<td>450</td>
<td>10 ft</td>
<td>1060</td>
</tr>
<tr>
<td>6&quot;</td>
<td>450</td>
<td>12 ft</td>
<td>1370</td>
</tr>
</tbody>
</table>

**Rect. Suppressed**

Factory Set B = 1
Factory Set D = 1
Factory Set H = 1m

<table>
<thead>
<tr>
<th><strong>2. Rect. Suppressed</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Crest Length:</strong></td>
</tr>
<tr>
<td>1: 1ft.</td>
</tr>
<tr>
<td>4: 2.5ft.</td>
</tr>
<tr>
<td>7: 5ft.</td>
</tr>
<tr>
<td>10: 10ft.</td>
</tr>
</tbody>
</table>
Select Rect. Suppressed and push SET button. Then, the menu for selection of the rectangular weir will be displayed as shown in the above figure.

Use ↑ or ↓ to select the relevant Rect. Suppressed and push SET button to save the set values and return to main menu option. (Setting range: 1~10, Unit: 1)

Measurable maximum height is automatically set.

<table>
<thead>
<tr>
<th>Rect. Suppressed</th>
<th>Max. Height [mm]</th>
<th>Rect. Suppressed</th>
<th>Max. Height [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ft</td>
<td>150</td>
<td>4 ft</td>
<td>600</td>
</tr>
<tr>
<td>1.5 ft</td>
<td>220</td>
<td>5 ft</td>
<td>750</td>
</tr>
<tr>
<td>2 ft</td>
<td>300</td>
<td>6 ft</td>
<td>900</td>
</tr>
<tr>
<td>2.5 ft</td>
<td>370</td>
<td>8 ft</td>
<td>1200</td>
</tr>
<tr>
<td>3 ft</td>
<td>450</td>
<td>10 ft</td>
<td>1500</td>
</tr>
</tbody>
</table>

Rect. Contracted

Factory Set B = 1
Factory Set D = 1
Factory Set b = 1
Factory Set H = 1m

3. Rect. Contracted

**Crest Length:** 1

1 : 1 ft.  
2 : 1.5 ft.  
3 : 2 ft.  
4 : 2.5 ft.  
7 : 3 ft.  
6 : 4 ft.  
7 : 5 ft.  
8 : 6 ft.  
9 : 8 ft.  
10 : 10 ft.

Select Rect. Contracted and push SET button. Then, the menu for selection of the rectangular weir will be displayed as shown in the above figure.

Use ↑ or ↓ to select the relevant Rect. Contracted and push SET button to save the set values and return to main menu. (Setting range: 1~10, Unit: 1)

Measurable maximum height is automatically set.

<table>
<thead>
<tr>
<th>Rect. Suppressed</th>
<th>Max. Height [mm]</th>
<th>Rect. Suppressed</th>
<th>Max. Height [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ft</td>
<td>150</td>
<td>4 ft</td>
<td>600</td>
</tr>
<tr>
<td>1.5 ft</td>
<td>220</td>
<td>5 ft</td>
<td>750</td>
</tr>
<tr>
<td>2 ft</td>
<td>300</td>
<td>6 ft</td>
<td>900</td>
</tr>
<tr>
<td>2.5 ft</td>
<td>370</td>
<td>8 ft</td>
<td>1200</td>
</tr>
<tr>
<td>3 ft</td>
<td>450</td>
<td>10 ft</td>
<td>1500</td>
</tr>
</tbody>
</table>
V-Notch Weirs [Triangular]

Factory Set = 0.600m

4. V-Notch Weirs

** Weir Selection: 1

1 : 22.5°  2 : 30°  3 : 45°
4 : 60°  5 : 90°  6 : 120°

- Select V-Notch Weirs and push SET button. Then, the menu for selection of the triangular weir will be displayed as shown in the above figure.
- Use ↑ or ↓ to select the relevant V-Notch Weir and push SET button to save the set values and return to menu option. (Setting range: 1~6, Unit: 1)
- Measurable maximum height is automatically set at 600 mm.

Cipolletti Weirs [Trapezodial Weirs]

Factory Set = 0.600m

5. Cipolletti Weirs

** Weir Selection: 1

1 : 1ft.  2 : 1.5ft.  3 : 2ft.
4 : 2.5ft.  7 : 3ft.  6 : 4ft.
7 : 5ft.  8 : 6ft.  9 : 8ft.
10 : 10ft.

- Select Cipolletti Weirs and push SET button. Then, the menu for selection of the weir will be displayed as shown in the above figure.
- Use ↑ or ↓ to select the relevant Cipolletti Weir and push SET button to save the set values and return to menu option. (Setting range: 1~10, Unit: 1)
- Measurable maximum height is automatically set.

<table>
<thead>
<tr>
<th>Cipolletti Weirs</th>
<th>Max. Height [mm]</th>
<th>Cipolletti Weirs</th>
<th>Max. Height [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ft</td>
<td>150</td>
<td>4 ft</td>
<td>600</td>
</tr>
<tr>
<td>1.5 ft</td>
<td>220</td>
<td>5 ft</td>
<td>750</td>
</tr>
<tr>
<td>2 ft</td>
<td>300</td>
<td>6 ft</td>
<td>900</td>
</tr>
<tr>
<td>2.5 ft</td>
<td>370</td>
<td>8 ft</td>
<td>1200</td>
</tr>
<tr>
<td>3 ft</td>
<td>450</td>
<td>10 ft</td>
<td>1500</td>
</tr>
</tbody>
</table>
**6. Leopold Lagco Flumes**

**Flume Selection:** 1

1: 4in.  2: 6in.  3: 8in.  4: 10in.  5: 12in.  6: 15in.  7: 18in.  8: 21in.  9: 24in.  10: 30in.

- Select Leopold Lagco Flumes and push SET button. Then, the menu for selection of the flume will be displayed as shown in the above figure.
- Use ↑ or ↓ to select the relevant Leopold Lagco Flume and push SET button to save the setting values and return to menu option. (Setting range: 1~10, Unit: 1)
- Measurable maximum height is automatically set.

<table>
<thead>
<tr>
<th>Leopold Lagco Flumes</th>
<th>Max. Height [mm]</th>
<th>Leopold Lagco Flumes</th>
<th>Max. Height [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 inch</td>
<td>70</td>
<td>15 inch</td>
<td>270</td>
</tr>
<tr>
<td>6 inch</td>
<td>100</td>
<td>18 inch</td>
<td>320</td>
</tr>
<tr>
<td>8 inch</td>
<td>130</td>
<td>21 inch</td>
<td>380</td>
</tr>
<tr>
<td>10 inch</td>
<td>180</td>
<td>24 inch</td>
<td>420</td>
</tr>
<tr>
<td>12 inch</td>
<td>210</td>
<td>30 inch</td>
<td>530</td>
</tr>
</tbody>
</table>

**7. Palmer Bowlus Flumes**

**Flume Selection:** 1

1: 4in.  2: 6in.  3: 8in.  4: 10in.  5: 12in.  6: 15in.  7: 18in.  8: 21in.  9: 24in.  10: 27in.

<table>
<thead>
<tr>
<th>Leopold Lagco Flumes</th>
<th>Max. Height [mm]</th>
<th>Leopold Lagco Flumes</th>
<th>Max. Height [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 inch</td>
<td>76</td>
<td>15 inch</td>
<td>274</td>
</tr>
<tr>
<td>6 inch</td>
<td>107</td>
<td>18 inch</td>
<td>320</td>
</tr>
<tr>
<td>8 inch</td>
<td>152</td>
<td>21 inch</td>
<td>381</td>
</tr>
<tr>
<td>10 inch</td>
<td>183</td>
<td>24 inch</td>
<td>427</td>
</tr>
<tr>
<td>12 inch</td>
<td>213</td>
<td>27 inch</td>
<td>488</td>
</tr>
</tbody>
</table>
Select DIY Curve / Special and push SET button. Then, an option for selection of 1. DIY Curve, 2. Q=K*H(PWR), or 3. Rectangular Weir will be displayed as shown in the above figure.

This menu is used for measurement of flow rate, regardless of the type of device.
1. DIY Curve: This option equally divides the known level-based flow rate into 10 parts and measures the flow rate according to change of level.
2. Q=K*H(PWR): This option inputs constant values, K and PWR, to an exponentially changing device and measures the flow rate.
3. Rectangular Weir: This option selects Crest Length of all Rectangular Weirs in mm unit and measures the flow rate.

Use ↑ or ↓ to select the relevant special option and push SET button to save the set values and return to menu option. (Setting range: 1~3, Unit: 1)

Select 1. DIY Curve and push SET button. Then, an option to input max. height of 1. 10 Point DIY Curve will be displayed as shown in the above figure.

Use ↑ or ↓ to input measurable maximum height of the installed device and push SET button to save the value and go to an option for input of flow rate at 10% height. (Setting range: 0.1 ~ 99999.9 [m3/h])

Use ↑ or ↓ to increase or decrease the value and input the relevant flow rate value and then, push SET button to save the flow rate value and go to an option for input of flow rate at 20% height. (Setting range: 0.1 ~ 99999.9 [m3/h])

In this way, input the flow rate values corresponding to 30%, 40%, 50%, 60%, 70%, 80%, 90%, and 100%.

After input of value for 100% with use of ↑ or ↓ button, push SET button to go to 2. DEVICE SELECTION. Push MODE button again to go to menu option.
Select 2. Q=K*H(PWR) and push SET button. Then, an option to input constants, K and PWR, will be displayed as shown in the above figure.

- Use ↑ or ↓ to input K constant, known or calculated, and push SET button to save the value and go to an option for input of PWR Constant. (Setting range: 0.001 ~ 9.999)
- In this way, input PWR Constant with use of ↑ or ↓ button and push SET button to save the value and return to 2. DEVICE SELECTION. (Setting range: 0.001 ~ 9.999)
- Push MODE button to return to main menu.
Rectangular Weir

- Select 3. Rectangular Weirs and push SET button. Then, two options to select the type of rectangular weir, *Selection and *Crest Length [m], will be displayed as shown in the above figure.
- If the weir is the suppressed weir, select 1. Suppressed Weir and push SET button. Then, move to the option for input of Crest Length [m]. (Setting range: 1 ~ 2)
- In this way, select 2. Contracted Weir and set the relevant Crest Length. And push SET button to save the value and return to 2. DEVICE SELECTION. (Setting range: 1 ~ 2)
- Push MODE button to return to menu option.

Auto Zero

- This is an option for automatic detection of bottom distance from the sensor to the bottom. 04. BOTTOM DISTANCE is used for manual input of the distance from the sensor to the bottom.
- Place the cursor at this option and push SET button. Then, the following screen will be displayed.

AUTO ZERO

1.234 m
Auto SET? SET, No? DOWN

DT
DT will flicker and the distance will appear. When the distance is stabilized after damping time (measurement response rate), "Auto SET? SET, No? DOWN" will be displayed.
If you want automatic setting of the measured value, push SET button. If not, push DOWN button and select other menu.

※ It is important to conduct measurement when the inflow water level is the same as the bottom of the channel and there should be no water overflow in the channel. If you select Auto, omit 04. BOTTOM DISTANCE.

**Bottom**

Factory Set = 1.200m

<table>
<thead>
<tr>
<th>01. PASSWORD CHANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>02. DEVICE SELECTION</td>
</tr>
<tr>
<td>03. AUTO ZERO</td>
</tr>
<tr>
<td>*04. BOTTOM DISTANCE</td>
</tr>
</tbody>
</table>

1.234m

This is an option to manually set the distance from the ultrasonic sensor to the bottom of the channel. For automatic setting, please refer to 3. AUTO ZERO.

Since the flow meter installed in open channel is a device to measure the water level and the flow rate, it requires input of accurate distance. Otherwise error will occur.

The unit for the distance is meter (m). Push SET button and the saved value will be displayed. In this condition, the value can be changed. Use ↑ or ↓ to input the desirable value. And push SET button again to save the value and return to main menu.

Distance detection will not be done beyond the set value. The initial value is 1.200 m.

**Max Flow**

Factory Set = Allowable Max. flow of selected device

<table>
<thead>
<tr>
<th>*05. MAX FLOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>06. 4mA POINT SET</td>
</tr>
<tr>
<td>07. 21mA POINT SET</td>
</tr>
<tr>
<td>08. RELAY1 ON POINT</td>
</tr>
</tbody>
</table>

Maximum or minimum flow rate based on the height of the channel can be searched in m3/h or gal/h unit.
Place the cursor at this menu and push SET button. Then, the following screen will be displayed.
Use ↑ or ↓ to change maximum acceptable height and the flow rate at the height will be displayed. The initial value is the channel-based maximum measurable height (Max Head).

**Process Menu Options**

*4mA Point Set*

Factory Set = 0.00m/h³

<table>
<thead>
<tr>
<th>05. MAX FLOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>*06. 4mA POINT</td>
</tr>
<tr>
<td>07. 20mA POINT</td>
</tr>
<tr>
<td>08. RELAY 1 ON POINT</td>
</tr>
</tbody>
</table>

This is an option for setting the flow rate value corresponding to 4 mA output. The set value determines Zero current output. In general, 0 is set. The initial value is 0.00 m³/h. (Setting range: 0.00 ~ Max. Flow Rate, Unit: 0.01 m³/h)

Push SET button to display the saved value and change it. Use ↑ or ↓ to input the desirable value. Push SET button again to save the value and return to main menu.

*20mA Point Set*

Factory Set= Max. flow rate

<table>
<thead>
<tr>
<th>05. MAX FLOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>06. 4mA POINT</td>
</tr>
<tr>
<td>*07. 20mA POINT</td>
</tr>
<tr>
<td>08. RELAY 1 ON POINT</td>
</tr>
</tbody>
</table>

This is an option for setting the flow rate value corresponding to 20 mA output. The set value determines Span current output. In general, maximum flow rate is set. The initial value is the maximum measurable flow rate (m³/h) of the device set in 02. (Setting range: 0.00 ~ Max. Flow Rate, Unit: 0.01 m³/h)
**Relay1 On Point**

Factory Set= 10% of Max. flow value set at option 02 “Device Selection”

| 05. MAX FLOW |
| 06. 4mA POINT |
| 07. 20mA POINT |
| *08. RELAY 1 ON POINT | \( m^3/h \) |

- When the measured flow rate is below RELAY 1 On Point, the device's RELAY 1 is turned on. The initial value is the flow rate corresponding to 10% of the maximum measurable flow rate (m³/h) of the device set in 02. (Setting range: 0.00 ~ Max. Flow Rate, Unit: 0.01 m³/h)

**Relay1 Off Point**

Factory Set= 20% of Max. flow value set at option 02 “Device Selection”

| *09. RELAY 1 OFF POINT | \( m^3/h \) |
| 10. RELAY 2 ON POINT |
| 11. RELAY 2 OFF POINT |
| 12. RELAY SIMULATION |

- When the measured flow rate is above RELAY 1 Off Point, the device's RELAY 1 is turned off.
- The initial value is the flow rate corresponding to 20% of the maximum measurable flow rate (m³/h) of the device set in 02. (Setting range: 0.00 ~ Max. Flow Rate, Unit: 0.01 m³/h)

**Relay2 On Point**

Factory Set= 90% of Max. flow value set at option 02 “Device Selection”

| 09. RELAY 1 OFF POINT |
| *10. RELAY 2 ON POINT | \( m^3/h \) |
| 11. RELAY 2 OFF POINT |
| 12. RELAY SIMULATION |

- When the measured flow rate is above RELAY 2 On Point, the device's RELAY 2 is turned on.
- The initial value is the flow rate corresponding to 90% of the maximum measurable flow rate (m³/h) of the device set in 02. (Setting range: 0.00 ~ Max. Flow Rate, Unit: 0.01 m³/h)
Relay2 Off Point

Factory Set = 80% of the Max. flow value set at option 02 “Device Selection”

09. RELAY 1 OFF POINT
10. RELAY 2 ON POINT
*11. RELAY 2 OFF POINT
  \[ \text{\text{m}}^3/\text{h} \]
12. RELAY SIMULATION

- When the measured flow rate is below RELAY 2 Off Point, the device’s RELAY 2 is turned off.
- The initial value is the flow rate corresponding to 80% of the maximum measurable flow rate (m\(^3\)/h) of the device set in 02. (Setting range: 0.00 ~ Max. Flow Rate, Unit: 0.01 m\(^3\)/h)

<Examples of RELAY ON/OFF POINT Setting>

- RELAY 1 & 2 can be used for generation of alarms (low or high flow) and control of water supply pump or drain pump.
- Example 1: Use of RELAY 1 for control of water supply pump (low flow alarm). If RELAY 1 ON POINT is set at 1.00 m\(^3\)/h and OFF POINT is set at 2.00 m\(^3\)/h, RELAY 1 is turned on when the flow rate is below 1.00 m\(^3\)/h. If the water supply pump is turned on in this case, the water level is increased. When the level reaches OFF POINT (2.00 m\(^3\)/h), RELAY 1 becomes off and the pump stops.
- Example 2: Use of RELAY 2 for control of water drain pump (high flow alarm). If RELAY 2 OFF POINT is set at 1.00 m\(^3\)/h and ON POINT is set at 2.00 m\(^3\)/h, RELAY 2 is turned on when the flow rate is above 2.00 m\(^3\)/h. If the water drain pump is turned on in this case, the water level is decreased. When the level reaches OFF POINT (1.00 m\(^3\)/h), RELAY 2 becomes off and the pump stops.

Relay Simulation

Factory Set = 0.00 m\(^3\)/h

09. RELAY 1 OFF POINT
10. RELAY 2 ON POINT
11. RELAY 2 OFF POINT
*12. RELAY SIMULATION
  \[ \text{\text{m}}^3/\text{h} \]

- This is an option to check if RELAY is in normal operation after setting 08, 09, 10, and 11 items.
- Place the cursor at this menu and push SET button. Then, the following screen will be displayed.
This shows flow rate values set in 08, 09, 10, and 11. Further, virtual flow rates will flicker.

Use ↑ or ↓ to adjust those virtual values. In this way, operational conditions of R1 and R2 can be checked.

When it is below R1 ON POINT, RELAY 1 will be turned on and A1 will be displayed. When it is above R1 OFF POINT, RELAY 1 will be turned off and A1 will disappear.
When it is above R1 ON POINT, RELAY 2 will be turned on and A2 will be displayed. When it is below R1 OFF POINT, RELAY 2 will be turned off and A2 will disappear.

**Low Cut Value**

Factory Set = 0.00 m³/h

- This is an option to set minimum measurable flow rate. Those below this value will be treated as "0". The initial value is 0.00 m³/h. (Setting range: 0.00 ~ Max. Flow Rate, Unit: 0.01 m³/h)

**High Cut Value**

Factory Set = Max. flow rate

- This is an option to set maximum measurable flow rate. Those above this value will be treated as the maximum flow rate. The initial value is maximum flow rate of the device (m³/h). (Setting range: 0.00 ~ Max. Flow Rate, Unit: 0.01 m³/h)
**Time**

- Push SET button and the month/date/year/day and hour:minute will be displayed. If you don't want to change the value, push SET button again. If you want to change the value, push ↑ or ↓ to change the month. Push SET button again to change the date with use of ↑ or ↓. In this way, the day, hour, and minute can be changed.

**Totalizer**

- This is an option to set the initial values of total flow and total time.
- Place the cursor at this menu and push SET button. Then, the following screen will be displayed.

### TOTALIZER

1. **Total Flow Set**
   - Use ↑ or ↓ to set the integral number of the initial value and push SET button to save value. The decimal number flickers automatically. Use ↑ or ↓ to set the value and push SET button to save the value (Setting range: 0.00 ~ 999999999.99, Unit: 0.01 m³).

2. **Total Time Set**
   - After completion of setting in 16-1), push SET button and values in Total Time Set will flicker.
Use ↑ or ↓ to set total time and then, push SET button to save the value and go to other menu. (Setting range: 0 ~ 999999999, Unit: 1 h)
※ Delete all data previously saved.

**Data Save Period**

FactorySet = 10 mins

- Period for storage of total flow data can be set.
- The period for storage of data can be calculated as follows:
  - Min x 3 = (day) In other words, if 10 minutes are set, data for about 30 days can be saved. When 30 days have passed, total flow data before 30 days are eliminated. Only the current total flow data for 30 days are saved.
- The initial value is 10 min. (Setting range: 1 ~ 60, Unit: 1 min)

**Pulse Value**

FactorySet = 30.00 m³

- This is an option for setting the flow rate value for output of one pulse.
- Pulse output is applicable to total flow meter in pulse count type and this menu determines the flow rate for one pulse. The initial value is 30.00 m³. (Setting range: Max. flow rate per second ~ 100.00, Unit: 0.01 m³)

※Minimum value of setting range is automatically limited against maximum measurable flow rate of the device.
**Pulse period**

FactorySet = 0.10 sec

- This is an option for setting the width for one pulse output according to the flow rate set in No. 18. The initial value is 0.10 sec. (Setting range: 0.01 ~ 1.00, Unit: 0.01 sec)

**Data Transfer**

Factory Set = N/A

- Place the cursor at this menu and push SET button. Then, data saved from the initial time to the present will be transferred according to RS-232 communication protocol (BPS: 9600, Parity Bit: None, Data Bit: 8, Stop Bit: 1).
- In the course of data transfer, "RS-232C Transfer!" and "STOP? DOWN" are repeated. If you want to stop data transfer, push DOWN for 2 seconds.
- On completion of data transfer, "RS-232C Transfer END!" will be displayed if there are no previous data. Push DOWN to go to other menu. If there is any previous data, "Want Before Data?" and "Yes? SET, No? DOWN" will be repeated.
- Push SET button for 2 seconds and the remaining data will be dumped. Push DOWN button to go to other menu. In the course of DUMP, "RS-232C Transfer!" and "STOP? DOWN" will be repeated. If you want to stop it in the course of DUMP, push DOWN button.
In general, the ultrasonic sensor cannot detect any object within a specific distance from the sensor. The distance is about 0.250 ~ 0.350 m for this product.

If a user increases this value, false detection arising from an obstacle close to the sensor can be prevented.

The initial value is 0.350 m. (Setting range: 0.250 ~ 3.000, Unit: 0.001 m)
Compensation Menu Options

Transmit Power

Factory Set = 3

21. BLANKING

*22. TRANSMIT POWER

23. OUTPUT DAMPING

24. FAIL SAFE CURRENT

- This is an option for setting the ultrasonic sensor's output. This menu adjusts the output and maintains optimal conditions under operating environments.
- Set low TRANSMIT POWER if there are many obstacles around it. Increase TRANSMIT POWER value for remote measurement.
- At the time of release from the manufacturer, the value is set at 3, which is optimal one for normal operating environments. The initial value is 3. (Setting range: 1 ~ 5, Unit: 1)

Output Damping

Factory Set = 2

21. BLANKING

22. TRANSMIT POWER

*23. OUTPUT DAMPING

24. FAIL SAFE CURRENT

- This option determines the maximum rate at which the unit will respond to an increase/decrease in level

- Setting Range:
  1 = 0.1m/min
  2 = 0.5m/min
  3 = 1m/min
  4 = 10m/min
**Fail Safe Current**

*Factory Set = 3.8mA*

- This is an option for setting FAIL SAFE CURRENT. If the reflected wave is not sufficiently received, a specific current different from normal output current is generated to indicate the error. 3.8 mA, HOLD, or 21mA is used for this purpose.
- If measurement is not normally conducted, FAIL SAFE CURRENT is generated after FAIL SAFE TIME.
- If HOLD is set, the flow under HOLD is totalized. In the case of other settings, totalization is not conducted. The initial value is 3.8 mA. (Setting range: 3.8 mA, HOLD, 21 mA).

**Fail Safe Time**

*Factory Set = 120 sec*

- This is an option for setting FAIL SAFE TIME. If the reflected wave is not sufficiently received, FAIL SAFE CURRENT output and ERROR relay operation are held for some time.
- The initial value is 120 sec. (Setting range: 20 ~ 999, Unit: 1 sec)

**Detect Threshold**

*Factory Set = 4*

- This is an option for setting DETECT THRESHOLD.
- This is an option for setting threshold for detection of the reflected wave. This menu adjusts the threshold for detection of the reflected wave and maintains optimal conditions under operating environments.
- To reduce the probability of false detection or at an environment generating lots of noise, increase the threshold value. For detection of weak signals, decrease the value. In this way, set the threshold value according to the environmental conditions. The initial value is 4. (Setting range: 3 ~ 15, Unit: 1)

**12mA Output**

- This is an option for 12 mA output, regardless of measurement result. Such output is used to check operation conditions of current output circuits and interface with other equipment. On returning to Operation Mode, this function is automatically cancelled.

**Flow Switch**

- This function is used when an external flow switch is installed. If the measured flow rate is 0, the flow rate is displayed as 0, regardless of the measurement level.
- Place the cursor at this menu and push SET button. Then, the following screen will be displayed.
<table>
<thead>
<tr>
<th><strong>28. FLOW SWITCH</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Selection.</strong></td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>1. Installation</td>
</tr>
<tr>
<td>2. Uninstallation</td>
</tr>
</tbody>
</table>

- If a flow switch is installed and used, select "1". If not, select "2".
- Push SET button to display the saved value and change it. Use ↑ or ↓ to select the one you want. Push SET button again to save the value and return to main menu.
Chapter 5  Maintenance

Sondar 5000 does not require any special maintenance work. However, in areas where there are lots of floating matters or viscous sludge, the sensor's surface may be contaminated by them. Therefore, for accurate measurement, it is necessary to install a device to clean the sensor at appropriate interval.
## SONDAR 5000

### APPLICATION

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>Factory Set</th>
<th>Value Range</th>
<th>Entered Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Password Change</td>
<td>0</td>
<td>0~1000</td>
<td></td>
</tr>
<tr>
<td>02</td>
<td>Device Selection</td>
<td>1 (Parshall Flume)</td>
<td>Refer to manual</td>
<td></td>
</tr>
<tr>
<td>03</td>
<td>Auto Zero</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>04</td>
<td>Bottom</td>
<td>1.200m</td>
<td>0.400~4.000m</td>
<td></td>
</tr>
<tr>
<td>05</td>
<td>Max Flow</td>
<td>Refer to manual</td>
<td>Refer to manual</td>
<td></td>
</tr>
</tbody>
</table>

### PROCESS

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>Factory Set</th>
<th>Value Range</th>
<th>Entered Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>06</td>
<td>4mA Set Point</td>
<td>0.00m³/h</td>
<td>0.00~Max flow</td>
<td></td>
</tr>
<tr>
<td>07</td>
<td>20mA Set Point</td>
<td>Max flow rate</td>
<td>0.00~Max flow</td>
<td></td>
</tr>
<tr>
<td>08</td>
<td>Relay 1 on Point</td>
<td>Refer to manual</td>
<td>0.00~Max flow</td>
<td></td>
</tr>
<tr>
<td>09</td>
<td>Relay 1 off Point</td>
<td>Refer to manual</td>
<td>0.00~Max flow</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Relay 2 on Point</td>
<td>Refer to manual</td>
<td>0.00~Max flow</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Relay 2 off Point</td>
<td>Refer to manual</td>
<td>0.00~Max flow</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Relay simulation</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

### COMPENSATION

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>Value Range</th>
<th>Entered Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>Low cut value</td>
<td>0.00</td>
<td>0.00~Max flow</td>
</tr>
<tr>
<td>14</td>
<td>High cut value</td>
<td>Refer to manual</td>
<td>0.00~Max flow</td>
</tr>
<tr>
<td>15</td>
<td>Time</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>16</td>
<td>Totalizer</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>17</td>
<td>Data save time</td>
<td>10 min.</td>
<td>1~60 min</td>
</tr>
<tr>
<td>18</td>
<td>Pulse save time</td>
<td>30.00m³</td>
<td>Refer to manual</td>
</tr>
<tr>
<td>19</td>
<td>Pulse period</td>
<td>0.10sec</td>
<td>0.01~1.00sec</td>
</tr>
<tr>
<td>20</td>
<td>Data transfer</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>21</td>
<td>Blanking</td>
<td>0.350m</td>
<td>0.250~3.00m</td>
</tr>
<tr>
<td>22</td>
<td>Transmit power</td>
<td>3</td>
<td>1, 2, 3, 4, 5</td>
</tr>
<tr>
<td>23</td>
<td>Output damping</td>
<td>10 sec</td>
<td>0.1, 2, 5, 10, 20, 50, 100 sec</td>
</tr>
<tr>
<td>24</td>
<td>Fail safe current</td>
<td>3.8mA</td>
<td>3.8mA/HOLD 21.0mA</td>
</tr>
<tr>
<td>25</td>
<td>Fail safe time</td>
<td>120 sec</td>
<td>20~999 sec</td>
</tr>
<tr>
<td>26</td>
<td>Detect threshold</td>
<td>4</td>
<td>3~15</td>
</tr>
<tr>
<td>27</td>
<td>12mA output</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
A. Parshall Flume

Parshall Flumes are standardized. Depending on the channel width, there are 15 kinds of Parshall Flumes.
B. Rectangular Weir, Triangular Weir, Suppressed Rectangular Weir, and Cipolletti Weir

<Fig. B-1 > Front Views of Weirs

- **h**: Water level
- **B**: Suppressed Rectangular Weir's Width (m)
- **b**: Rectangular Weir's Width (m)
- **D**: Thickness from Weir's Bottom (m)
<Fig. B-2 > Aerial View of Rectangular Weir

Bottom Zero

4~5 × hmax

B

b

h

D

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