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USERS' MANUAL

SCOUR MONITORING – SONAR SOLUTION

MODEL EBSM-101S

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1 INTRODUCTION

1.1 Why scour monitoring is required?

Scour can be defined as the excavation and removal of material from the bed and banks of streams as a result of the erosive action of flowing water. Bridge piers over rivers are embedded in the riverbed and are susceptible to be affected by scour depending on bed soil type and river water flow velocity. Scouring wears away riverbed material that supports piers or abutments. It results from erosive action of water flow against bridge support structures and abutments and scoops away or excavates the riverbed material around these structures.

Downward flow is induced at the upstream end of bridge piers, leading to much localized erosion in the direct vicinity of the structure. Horseshoe vortices develop due to the separation of the flow at the edge of the scour hole upstream of the pier and result in pushing the down-flow inside the scour hole closer to the pier. Horseshoe vortices are a result of initial scouring and not the primary cause of scour. Furthermore, separation of the flow at the sides of the pier results in wake vortices. Local scour depends on the balance between streambed erosion and sediment deposition.

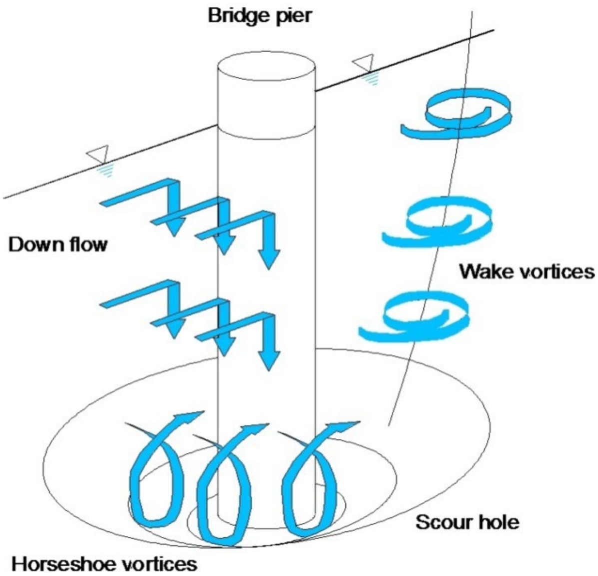


Figure 1: Schematic of scour process at piers of bridge

Scouring results in lowering of the river bed level and hence the supporting ground level around the pier foundation. The piles or pier foundation can get exposed down to significant depths due to large scale scouring. This may destabilize the foundation of the bridge causing bridge failure.

Scouring compromises the safety of the bridge. It has been the cause of failure of several bridges around the world. It is thus, critical for the stakeholders to detect the occurrence of stream/riverbed scour at bridge piers and monitor the scour depth variation.

1.2 Monitoring solutions to combat scour

Scour affect on bridges can be minimised in a number of ways. The most effective and economically viable method is to monitor its evolution over time and to implement suitable remedial works.

The monitoring can be carried out by visual inspections that involve use of divers to inspect the condition of foundation elements. However, two disadvantages are associated with visual inspection:

i. inspections cannot be carried out during times of flooding, when the risk of scour is the highest;

ii. maximum depth of scour can not be recorded as scour holes tend to be filled in as flood water subsides. The fact that scour holes tend to be refilled can be dangerous and misleading as the true extent of the scour problem may be missed in the inspection.

The most effective monitoring method is to use real-time scour monitoring instrumentation. Encardio-rite offers two innovative solutions to monitor the bridge scour. The monitoring solutions provide crucial information in near real time on the dynamics of sediment scour and aggregation.

1) Model EBSM-101M Magnetic sliding collar solution for scour monitoring

2) Model EBSM-101A Sonar solution for scour monitoring.

This users' manual focuses on model EBSM-101S sonar solution for scour monitoring.

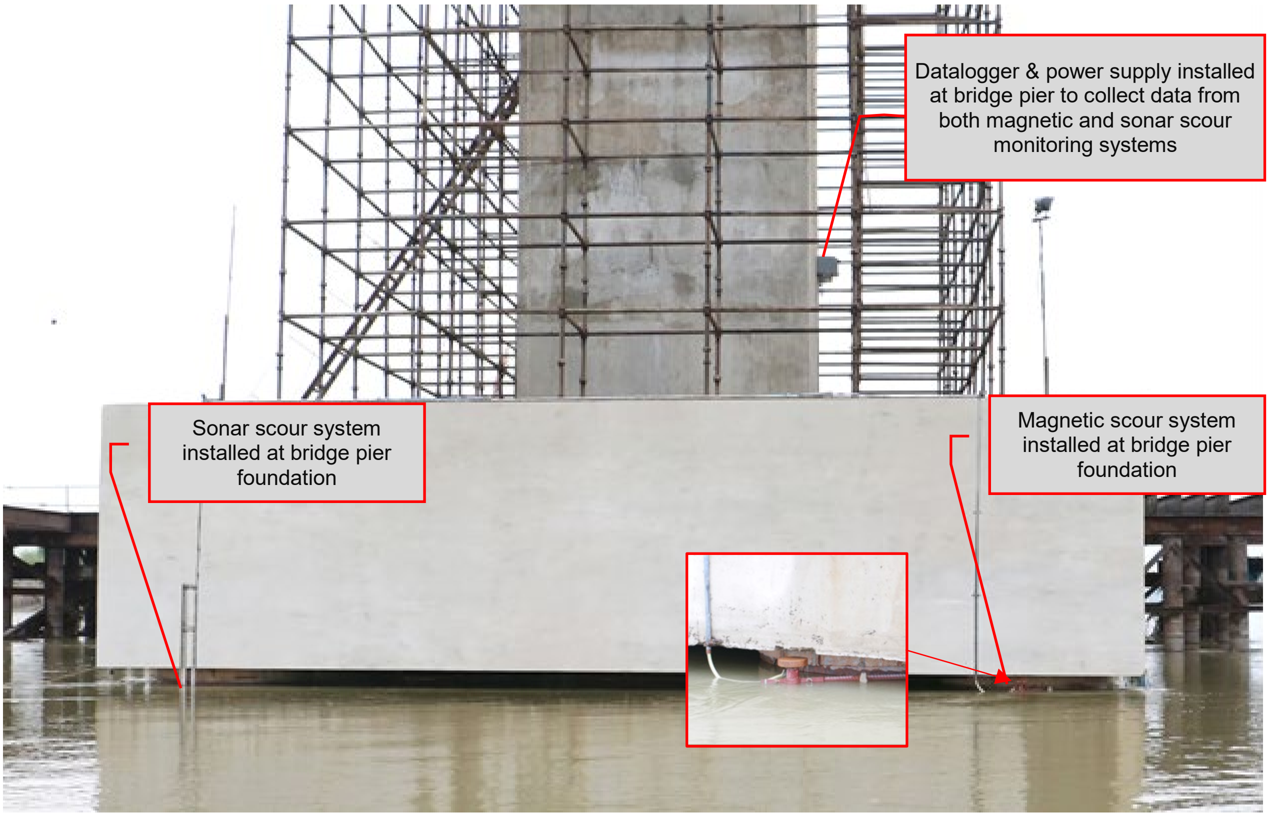


Figure 2: Encardio-rite Scour Monitoring Solutions Installed at a bridge in India

1.3 EBSM-101S Sonar scour monitoring solution

Model EBSM-101S sonar based scour monitoring sensor provides an accurate and easy-to-use online monitoring system to assist in detecting and reporting the occurrence of streambed scour and take preventive action in time.

Encardio-rite offers an innovative bridge (streambed) scour monitoring solution using sonar based sensor. The real-time data from the sonar based scouring monitoring system provides crucial information on the dynamics of sediment scour and aggradations. The rugged design of the system is ideal for safety monitoring of structures such as bridges that are located in high-current or deep water environment.

The sonar solution is well suited for bridges over deep streams. It can be used to measure scour at piers and vertical wall abutments; it is slightly better than magnetic scour monitoring solution as it does not face problem of being jammed by debris and twigs from plants. However, it also has a limitation that its readings are effected in case water debris and air bubbles are present in good amount between sensor and stream bed.

This user manual covers description of the sonar based depth meter and its accessories, procedure for installation, method of taking observations and recording data.

1.4 Applications

Encardio-rite EBSM-101S is a system for measuring scouring in the riverbed near the pier/abutment of bridges using sonar sensor. It can also be used to measure scouring near the offshore structures like turbines and petroleum rigs. It finds application in dam design and water intake surveys.

One of the main advantages of sonar sensor solution is that it provides continuous bed depth readings with accuracy. Also its rugged design makes it suitable for long-term deployment in harsh conditions as it does not have any moving part.

It is capable of working in standalone mode and provide critical information about scouring in near real time and serve as an early warning system that is necessary for structural health of the installation.

1.5 Conventions used in this manual

WARNING! Warning messages calls attention to a procedure or practice, that if not properly followed could possibly cause personal injury.

CAUTION: Caution messages calls attention to a procedure or practice, that if not properly followed may result in loss of data or damage to equipment.

NOTE: Note contains important information and is set off from regular text to draw the users' attention.

This users' manual is intended to provide you with sufficient information for making optimum use of sonar solution for scour monitoring in your applications.

To make this manual more useful we invite your valuable comments and suggestions regarding any additions or enhancements. We also request you to please let us know of any errors that you may find while going through this manual.

1.6 How to use this manual

The manual is divided into a number of sections. Each section contains a specific type of information. The list given below tells you where to look for in this manual if you need some specific information.

For operating principle See § 2 'Operating principle".

For essential tools and accessories: See § 3 'Tools and accessories required for installation".

For installation of sonar solution for scour monitoring See § 2 4 'Installation procedure'

For recording readings from sonar sensor: See § 5 'Measurement and Recording'.

2 SONAR SCOUR MONITORING SOLUTION

2.1 Scour monitoring system components

The sonar based system consists of a sonar based depth meter installed at pier. The sensor is installed such that it always remains immersed in the water and the direction of its measuring cone is away from the pier towards the streambed. It is done so that while measuring depth the acoustic ultrasonic pulses are not affected by pier structure. The scour depth is measured by the help of time they take in the to and fro motion of ultrasonic pulses to streambed.

The scour monitoring system with sonar solution consists of following sub-units:

2.1.1 Sonar sensor

The sonar based depth sensor emits ultrasonic pulses at regular interval and then detects the reflected pulses from sand/silt and water interface. It is a digital sensor that works on Modbus protocol. The sensor is powered by a 24 V DC supply. It has rugged design with IP-68 protection. It can be used up to 200 m depth and has a measuring resolution of 1mm.

2.1.2 Sensor mounting frame

The sonar sensor is mounted on a stainless steel frame using Allen key and screws. It has provision for adjusting the sensor orientation as per the site requirement. The design of mounting frame may vary depending on the site conditions and requirement

2.1.3 Datalogger

Encardio model EBSM-101 datalogger is used with the sonar sensor to record and transmit the readings to a remote server. The datalogger has a rugged weather proof enclosure, suitable for rough weather.

2.1.4 Cables and conduits

Cables are routed from the sensor to data acquisition system through rigid or flexible conduits as per requirement.

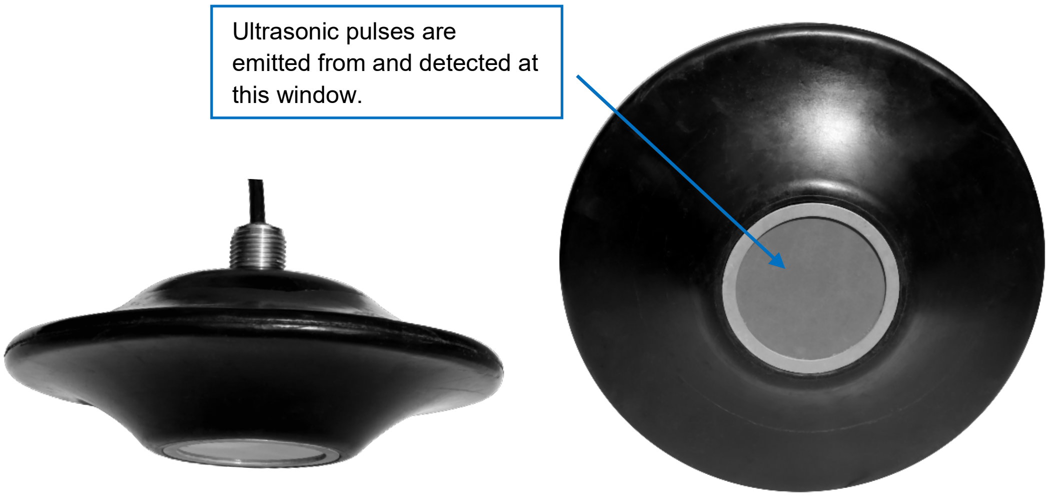


Figure 3: Sonar Sensor side and bottom view

2.2 Operating principle

Ultrasonic waves are reflected at boundaries where there is a difference in the acoustic impedances of materials on either side of the boundary. The difference in acoustic impedance is commonly referred to as impedance mismatch. Generally the greater the impedance mismatch, the greater the percentage of energy that will be reflected at the interface or boundary between one medium and another.

The reflection coefficient R is given as:

$$R = \left(\frac{Z2 - Z1}{Z2 + Z1}\right)^2$$

Where, Z1 and Z2 are acoustic impedance of materials on either side of a boundary. The acoustic impedance (Z) of a material is defined as the product of density (ρ) and acoustic velocity (V) of that material.

$$Z = \rho * V$$

The application of ultrasonic method for scour detection is based on determining the time required for receiving the echo signal reflected from the water/sediment interface. The speed of a compression wave in water is 1482 m/s at 20°C, which corresponds to 1450 × 102 g/cm2/s for the acoustic impedance. The acoustic impedance ranges from 2000~ 4000 × 102 g/cm2/s for silty clay to sandy gravel. As a result, the difference in acoustic impedance will cause appreciable reflections at the water/sediment interface. The location of the interface, which is a direct measure of scour depth, can be determined by analyzing the recorded ultrasonic signals.

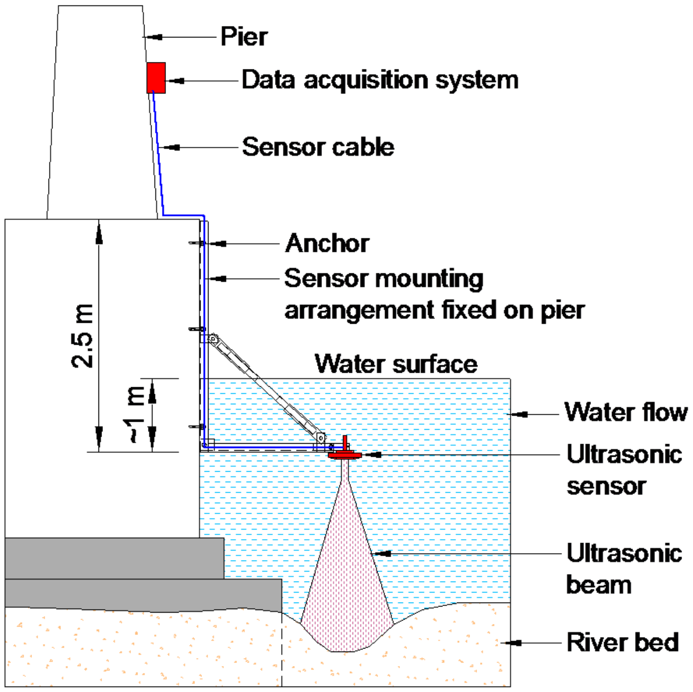


Figure 4: Typical Installation of Sonar Solution for Scour Monitoring

3 TOOLS & ACCESSORIES REQUIRED FOR INSTALLATION

The following tools and accessories are required for installation of Sonar Solution for Scour Monitoring

S No.	Description	Qty.
1	Laptop with charger	1 no.
2	Pipe wrench	01 no.
3	Tool kit	01 no.
4	Nylon rope	20 m
5	Spanner: 12-13	02 no.
6	Spanner: 14-15	01 no.
7	Spanner: 16-17	02 no.
8	Spanner: 18-19	01 no.
9	Hammer 500gm	01 no.
1	1/2" GI Pipe	As required
1	Sockets for 1/2" GI Pipe	As required
1	Pipe clamp for 1/2" GI Pipe	As required
1	Screw	1 pkt.
1	Plastic gully	1 pkt.
1	Hilti fastener HSTR M8X75/10 (sensor mounting frame)	As required
1	Hilti HPS-1 6/15x40 impact anchors (datalogger)	4 no.
1	Drill bit 6.5 mm	01 no.
1	Allen key set SS	01 no.
1	Sensor mounting frame	01 no.
2	Extension board	01 no.
2	Junction box 1:1	12 no.
2	Compound R-pack	01 no.
2	Cable 4-core CS0702	As required
2	Cable tie	100 no.
2	PVC tape	02 no.

4 INSTALLATION PROCEDURE

4.1 Site visit and establishing the installation location

An initial site visit is conducted with the client, to understand the location/probable piers at which the scour activity needs to be monitored. A typical initial visit would include:

1. Mapping a profile of the streambed with the portable sonar.
2. Investigating access to utilities for possible permanent installation.
3. Noting site characteristics such as water flow magnitude and direction.
4. Probing near the piers to detect scour counter-measures, such as rip-rap. Riprap should not be present between the streambed and sensor location. To check this, a driven pole test is performed at the installation location. A rigid pole of approximately 1.5" diameter is driven into the streambed. In case, rip-rap is present the pole cannot be driven easily. In such a case, the location is not suitable for installation of sonar-based scour monitoring system.

4.2 Preparing the installation location for sensor mounting frame on flat surface

- Secure the mounting frame with a nylon rope and gradually lower it at the installation location, upto the required depth of sensor position
- Mark the hole locations (for fasteners) on the structure, keeping the frame at installation position
- Remove frame and drill the holes at marked location, at first pilot holes are drilled using 4 mm drill bit; then the hole is drilled using 8 mm masonry bit.

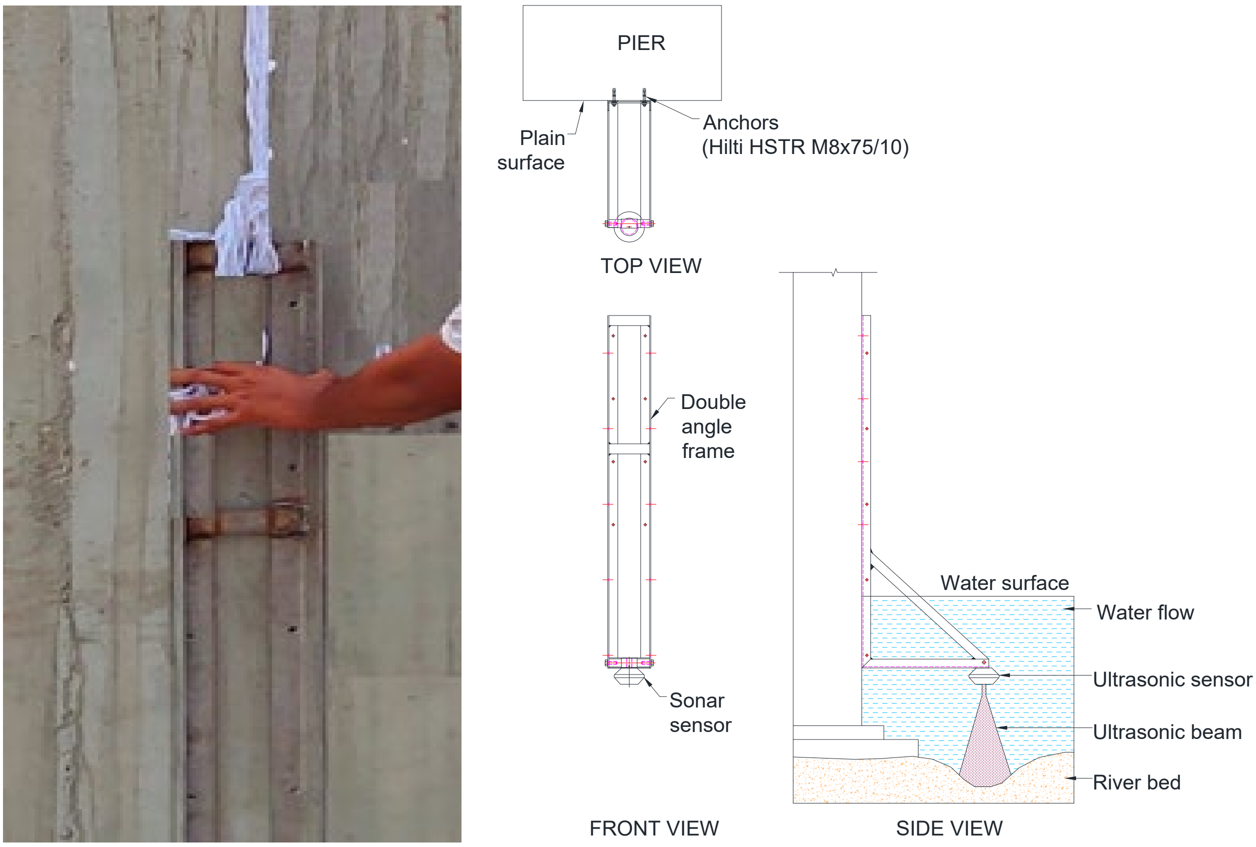


Figure 5: Marking drill holes for fixing sensor mounting frame at pier (left image). On the right, installation schematic is shown on flat surface.

4.3 Preparing the installation location for sensor mounting frame on curved surface

- On curved surface, use single angle frame for mounting the sensor as shown in figure 6. Mounting arrangement on installation location will be same as on flat surface as discussed in section in 4.2.

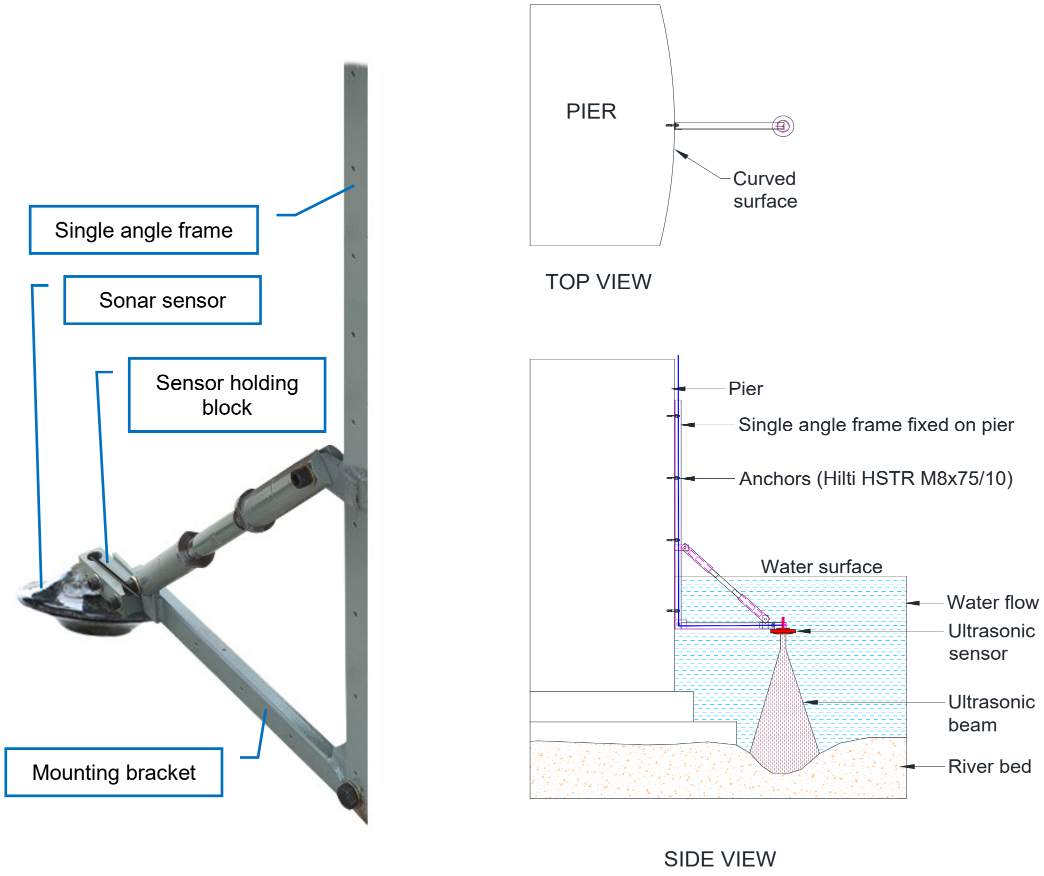


Figure 6: Single angle mounting frame for curved surface

4.4 Sensor mounting and installation for flat or curved surface

- To mount the sonar sensor on the frame, unscrew the grub screw on the sensor holding frame using Allen key (2 mm). Pass the sensor cable through the hole provided in sensor holding block. Now mount the sensor to the block using threads provided in the sensor and in the block. Tighten back the grub screw to secure the mounting.
- Tie the sensor cable along the mounting frame so that it is not damaged during installation.
- Secure the frame with a nylon rope. Lower the frame at the installation location. Once the sensor reaches the desired installation depth, fix the frame to the structure using Hilti HSTR M8X75/10 anchor bolts at the drilled holes.

NOTE 1: Sensor should be mounted on the frame in such an orientation so that its measuring cone points away from the structure on which it is installed. It should be installed in such a manner that it has a clearance radius of 50 cm around the sensor.

NOTE 2: Care must be taken about the installation depth of the sensor;

⇨ Sensor must remain immersed in water during operation (minimum 20 cm below water level).

⇨ Sensor must be at least 2 m above the streambed for proper readings

CAUTION: Do not power up the sensor when it is not submerged in water.

Figure 7: Mounting frame with the sonar sensor fixed on flat surface pier (sensor submerged on water in the right side image)

4.5 Cable routing

Once the sensor is installed at the pier, the sensor cable is routed through flexible and stainless steel conduits (as per requirement) to the data acquisition system. The entire cable length should be dressed properly in order to avoid any damage to the cable.

NOTE: If cable extension is required then a junction box shall be used and after ensuring proper connections it should be sealed using suited sealant. Please refer next figure for connection details.

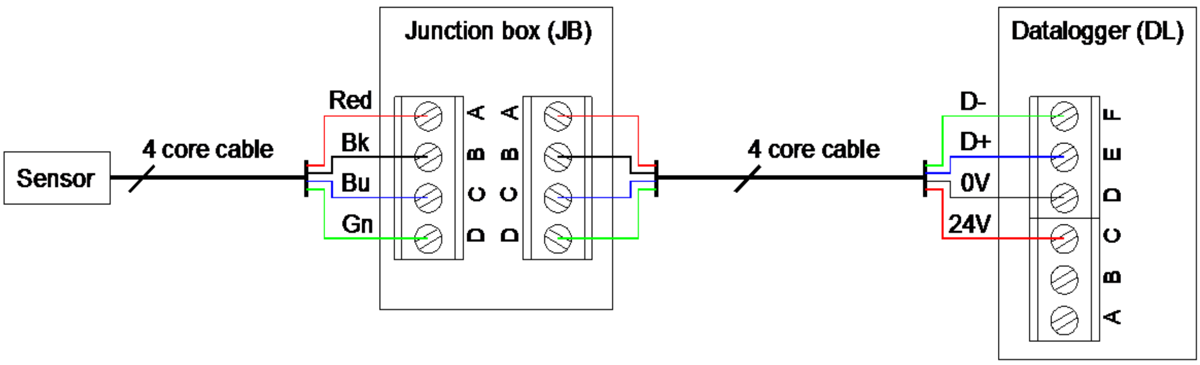


Figure 8: Cable connections at Junction box and datalogger

4.6 Installation of datalogger

- Mark the holes to be drilled by keeping the datalogger at the desired installation location.
- Drill the holes and fix the datalogger using HPS-1 6/15x40 Hilti impact anchors.

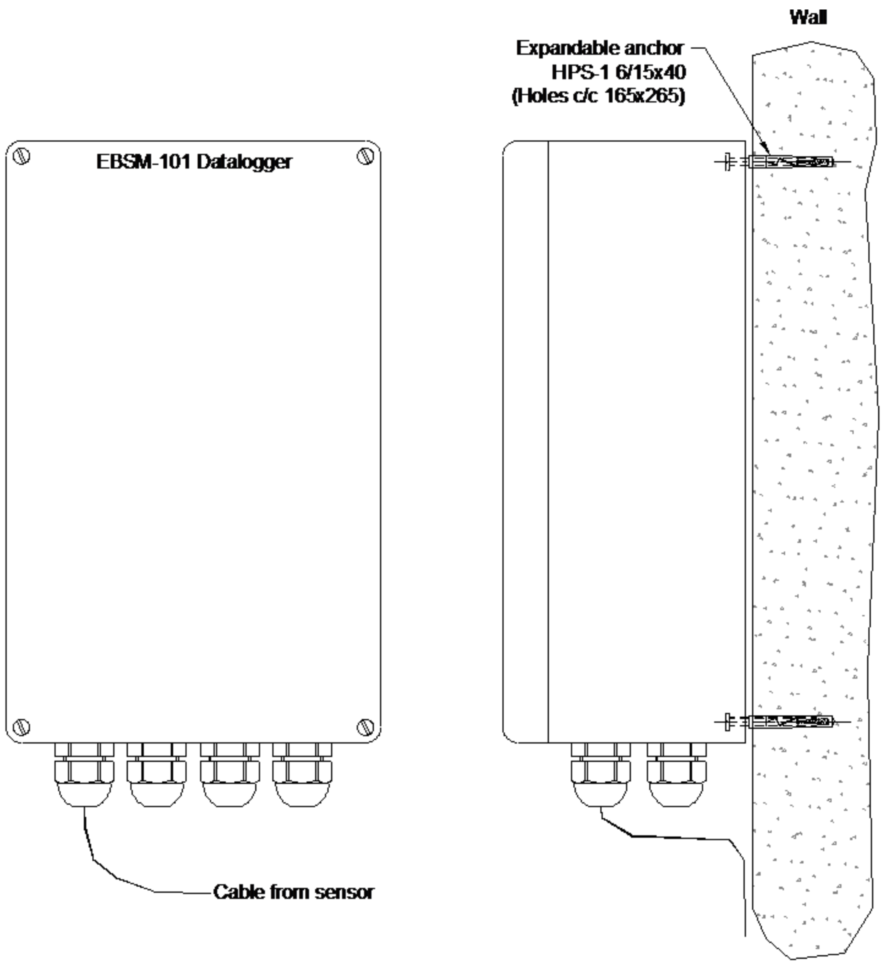


Figure 9: Installation schematic of datalogger

5 MEASUREMENT AND RECORDING USING EBSM-101 DATALOGGER

EBSM-101 datalogger is used for measurement, recording and transmission of data to remote server. The sensor is connected to the datalogger through a four core bus cable. The sensor should be within a maximum distance of up to 200 m from the datalogger.

The datalogger has the facility to collect and store recorded data and transfer it to a central remote server at desired intervals over a wired or cellular telemetry link.

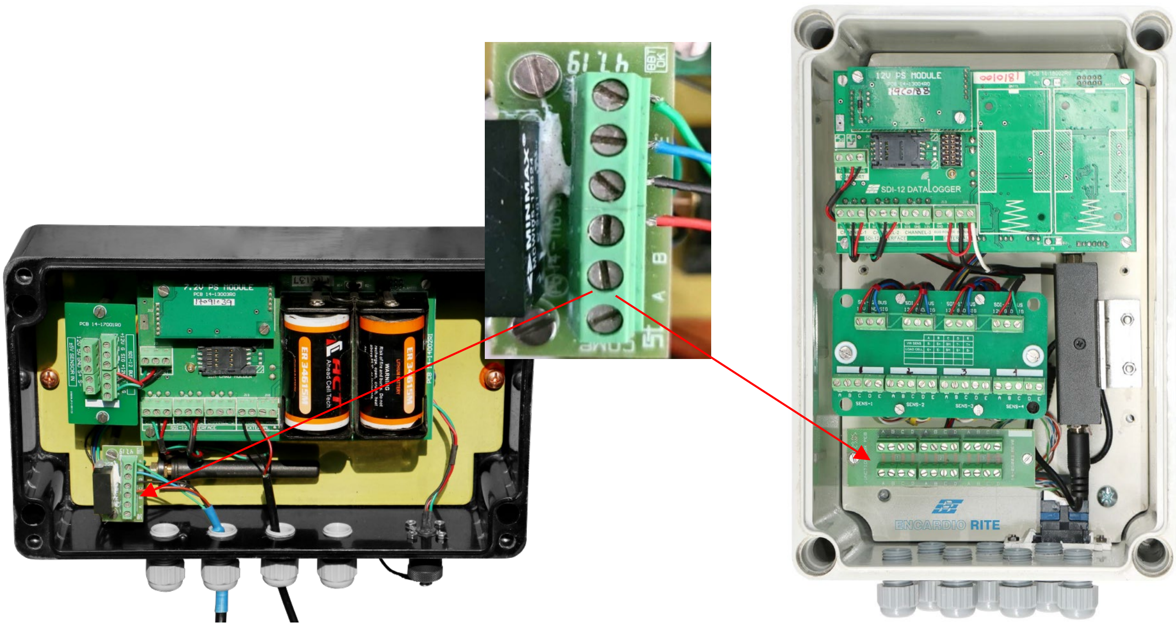
Each reading is stamped with date and time at which the measurement was taken. It has non-volatile flash memory to store up to 2 million data points. The data files can also be downloaded to PC using Configuration Manager Software by connecting logger with data cable or Bluetooth. The downloaded readings get stored in the PC's home directory in CSV format. The downloaded files can be transferred to FTP server using internet connection. For more details, please refer to the users' manual of EBSM-101 datalogger. A brief on sensor configuration is given in next section.

Figure 10: EBSM-101 Datalogger variants

5.1 Sensor connection to datalogger

Sonar sensor bus cable connection to EBSM-101 datalogger is shown in the figure 10 and table below. The connections details are shown in figure 11:

Connection Detail	Cable Color	Datalogger Terminal
Sensor supply (+)	Red	C
Sensor supply (-)	Black	D
Data +	Blue	E
Data -	Green	F



(For single sonar sensor connection) (For connecting 3 sonar sensors)

Figure 11: Sensor connection to the EBSM-101 datalogger

5.2 Sensor configuration

- Connect the datalogger to a laptop/PC with the Datalogger Configuration Manager software (pre-installed). Refer to the users' manual on datalogger for details on how to install software and connect datalogger.
- Once the datalogger is connected to laptop, home screen will appear as shown in figure 12.

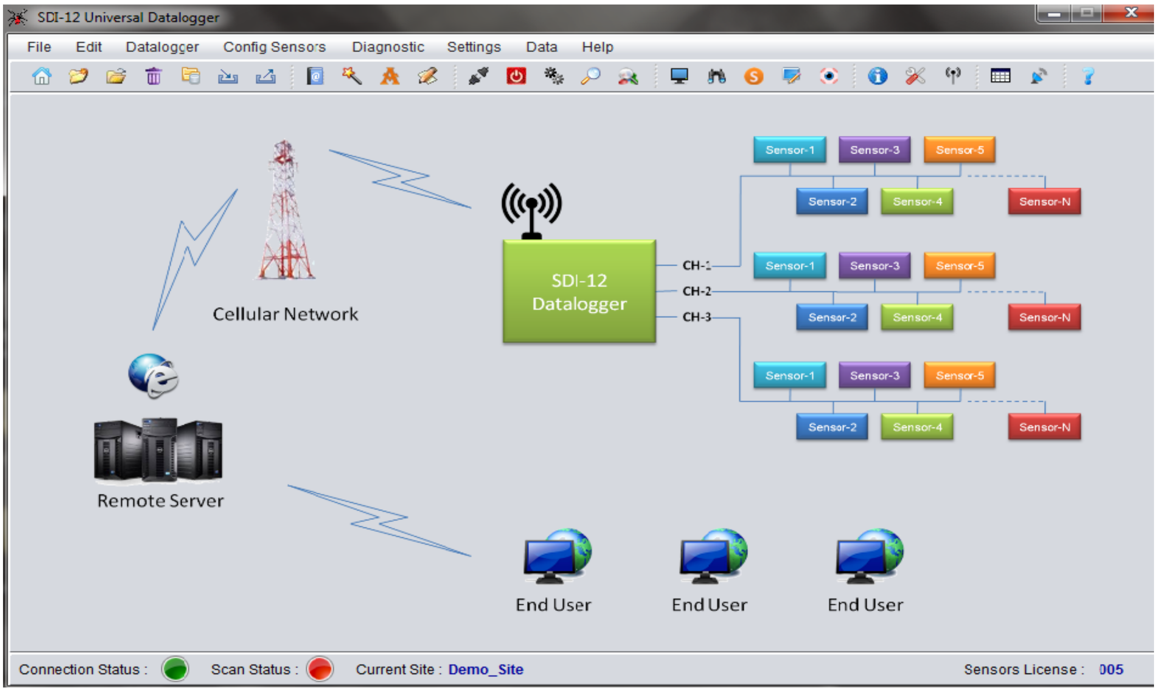


Figure 12: Configuration Software Home Screen after successful connection to data logger

- On the home screen of configuration manager software, click on the "Config Sensors" tab on the top menu bar. A drop down menu will appear, on that menu choose "SDI-12 Interfaces" a subsequent dropdown menu will appear on that menu choose the interface card used here i.e. "SDI-MODBUS"

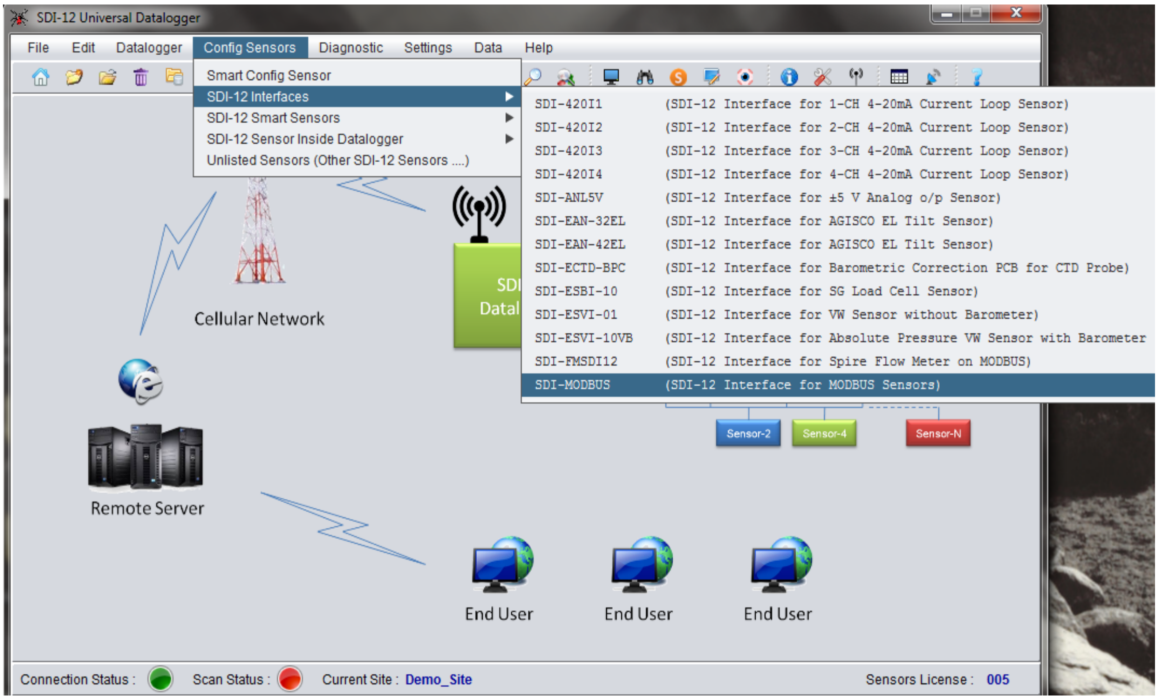


Figure 13: Configure Sensors Screen

- A screen as shown in figure 14 will appear.

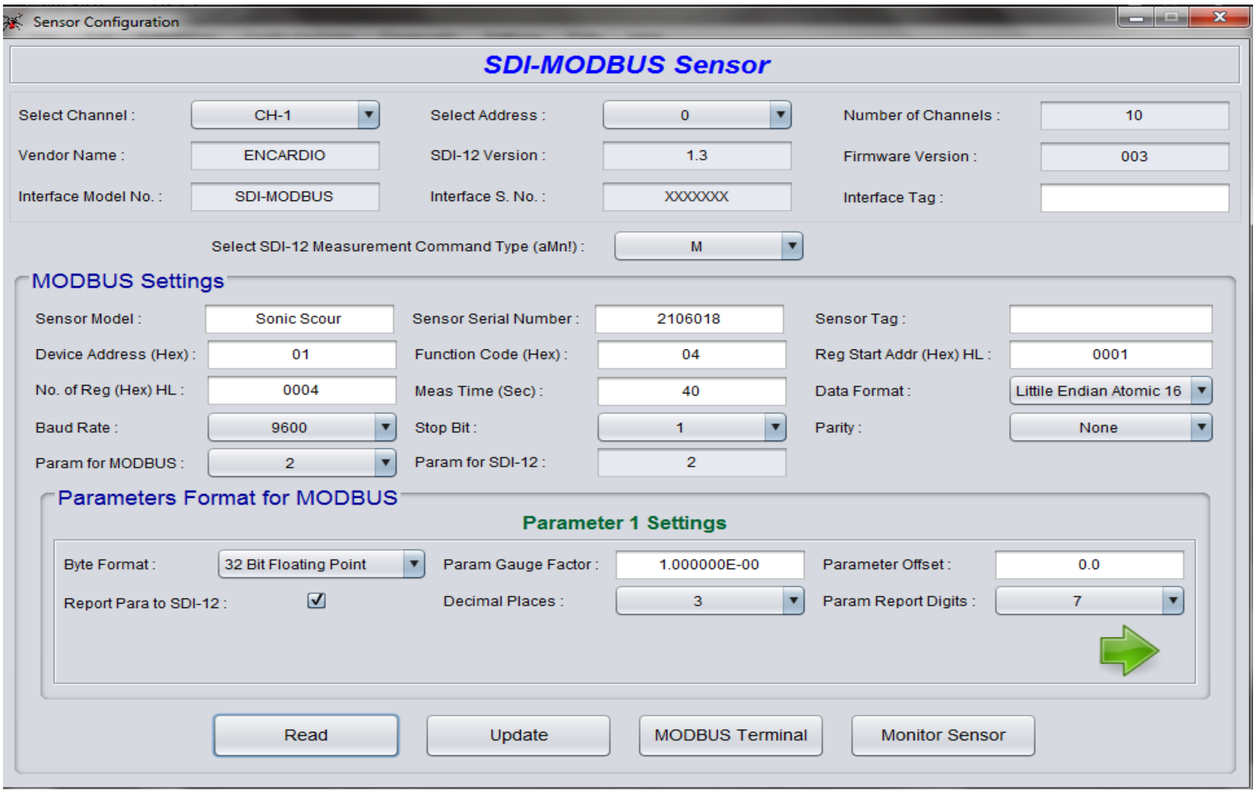


Figure 14: Sensor and Interface configuration screen

- At "Select Channel" tab, select the channel on which the sensor is connected

- At "Select Address" tab, select the suitable sensor address.
- Press "Read" button at the bottom left of the screen.
    - If the datalogger is pre-configured for the connected sonar sensor, then on pressing "Read" button, Sensor and Interface information will appear.
        - In case the datalogger is not pre-configured, pressing "Read" button will not fetch any stored values. Fill in the required fields as depicted on the screen (the values of will be mostly same as shown in figure 14). Press the "Update" button. The new values will be updated into logger's non-volatile memory.

NOTE: Care should be taken when feeding essential information before pressing update button on this screen as wrong values entered may lead to vague readings.

The sonar sensor is a digital sensor that works on Modbus protocol. It gives the depth of streambed as well as the water temperature as output values. The sensor's default Modbus parameters are as follows:

Sensor Modbus Parameter	Value
Baud Rate	9600
Parity	None
Stop Bit	1
Address	01H
No. of Registers	04
Starting Address	0001H
Data Type	32 bit float

5.3 Monitor Data

Press "Monitor Sensor" button (shown in figure 15). The current sensor readings i.e. the streambed depth and water temperature is displayed on screen. If the position matches the bed depth measured manually during installation then the readings is verified.

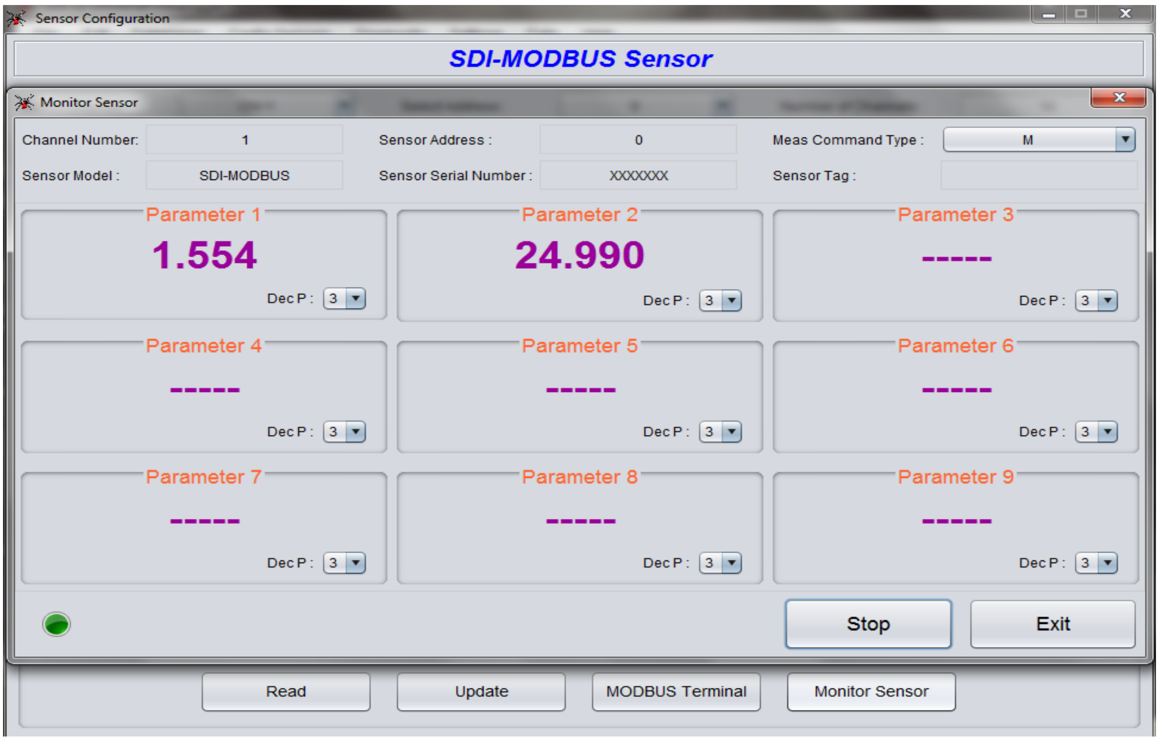


Figure 15: Monitor Sensor Screen

5.4 Setting Scan Rate and FTP Configuration

After the sensor's readings are verified, configure the datalogger to record, retain and transmit data to remote server, where monitoring data can be used long term and short term analysis. This in turn enables the user in taking important structural health decision.

Please refer to users' manual of ESDL-30 Configuration Manager for scan and FTP settings and other configuration details.

6 WARRANTY

The Company warrants its products against defective workmanship or material for a period of 12 months from date of receipt or 13 months from date of dispatch from the factory, whichever is earlier. The warranty is however void in case the product shows evidence of being tampered with or shows evidence of damage due to excessive heat, moisture, corrosion, vibration or improper use, application, specifications or other operating conditions not in control of Encardio-Rite. The warranty is limited to free repair/replacement of the product/parts with manufacturing defects only and does not cover products/parts worn out due to normal wear and tear or damaged due to mishandling or improper installation. This includes fuses and batteries.

If any of the products does not function or functions improperly, it should be returned freight prepaid to the factory for our evaluation. In case it is found defective, it will be replaced/repaired free of cost.

A range of technical/scientific instruments are manufactured by Encardio-rite, the improper use of which is potentially dangerous. Only qualified personnel should install or use the instruments. Installation personnel must have a background of good installation practices as intricacies involved in installation are such that even if a single essential but apparently minor requirement is ignored or overlooked, the most reliable of instruments will be rendered useless.

The warranty is limited to as stated herein. Encardio-rite is not responsible for any consequential damages experienced by the user. There are no other warranties, expressed or implied, including but not limited to the implied warranties of merchantability and of fitness for a particular purpose. Encardio-rite is not responsible for any direct, indirect, incidental, special or consequential damage or loss caused to other equipment or people that the purchaser may experience as a result of installation or use of the product. The buyer's sole remedy for any breach of this agreement or any warranty by Encardio-rite shall not exceed the purchase price paid by the purchaser to Encardio-rite. Under no circumstances will Encardio-rite reimburse the claimant for loss incurred in removing and/or reinstalling equipment.

A lot of effort has been made and precaution for accuracy taken in preparing instruction manuals and software. However best of instruction manuals and software cannot provide for each and every condition in field that may affect performance of the product. Encardio-rite neither assumes responsibility for any omissions or errors that may appear nor assumes liability for any damage or loss that results from use of Encardio-rite products in accordance with the information contained in the manuals or software.

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