Surface Water Level Instruments

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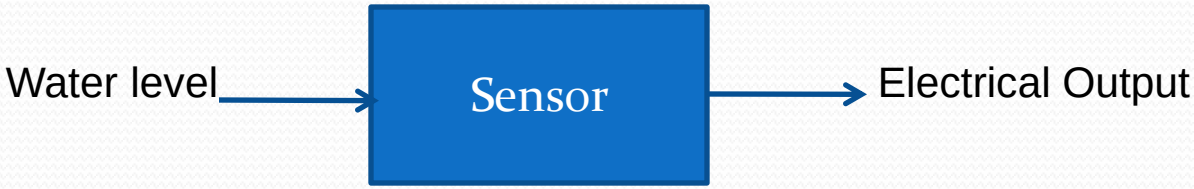
The photos, diagrams and related data used for different types of water level sensors in this presentation are for guidance and educational purposes only and do not recommend any make and model.

Water level measurement plays an important role in water resources management. In case of reservoirs water level is used for calculating available storage. In case of flowing rivers the water level represents the flow rate.

SURFACE WATER LEVEL MEASUREMENT

Sensor is a device which converts physical quantity (like level of water in river, dam, reservoir, lake or any other water body) into an electrical signal (current or voltage).



The main properties of water are its polarity, cohesion, adhesion, surface tension, high specific heat, and evaporative cooling. Its density is **997 kg/m³**.

Water has a high dielectric constant due to strong bonds between hydrogen and oxygen as well as hydrogen bonding between water molecules.

The value of the dielectric constant at room temperature is **1.00059 for air and 78.2 for water** when the electric field is applied perpendicularly to the principal axis of the crystal.

Types of Surface Water Level Sensors

Contact

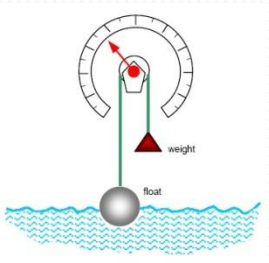
1. Shaft Encoder
2. Bubbler
3. Submersible Pressure Transducer

Non-Contact

1. Radar
2. Ultrasonic

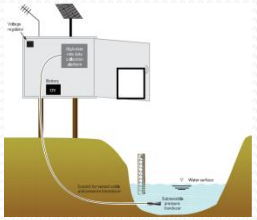
1. Position of a body floating on the water surface

Shaft Encoder



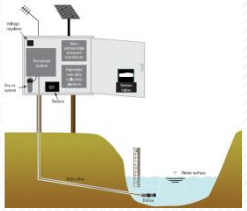
2. Pressure exerted by the water column on the diaphragm (weighing the water)

Submersible Pressure Sensor



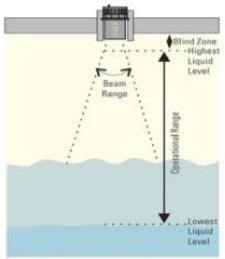
3. Pressure of gas required to displace the water in the orifice

Bubbler Transducer



4. Change in Dielectric Permittivity between air medium and water medium

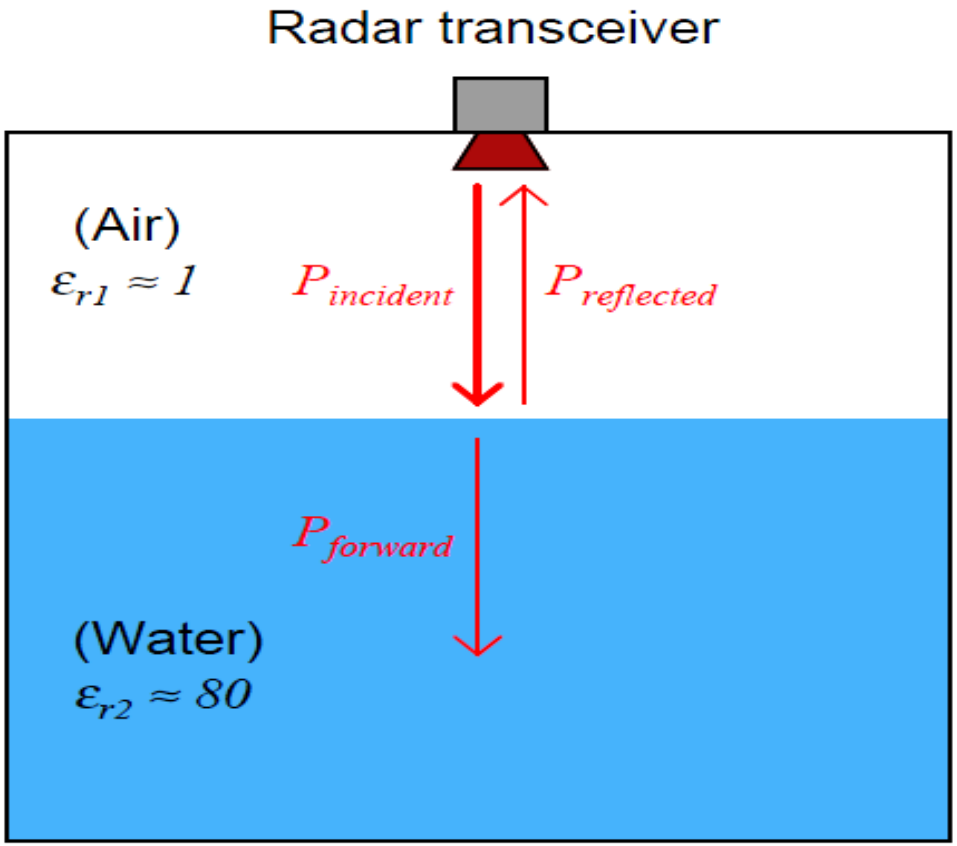
Radar / Ultrasonic Sensor



Radar Sensor

Radar Sensor

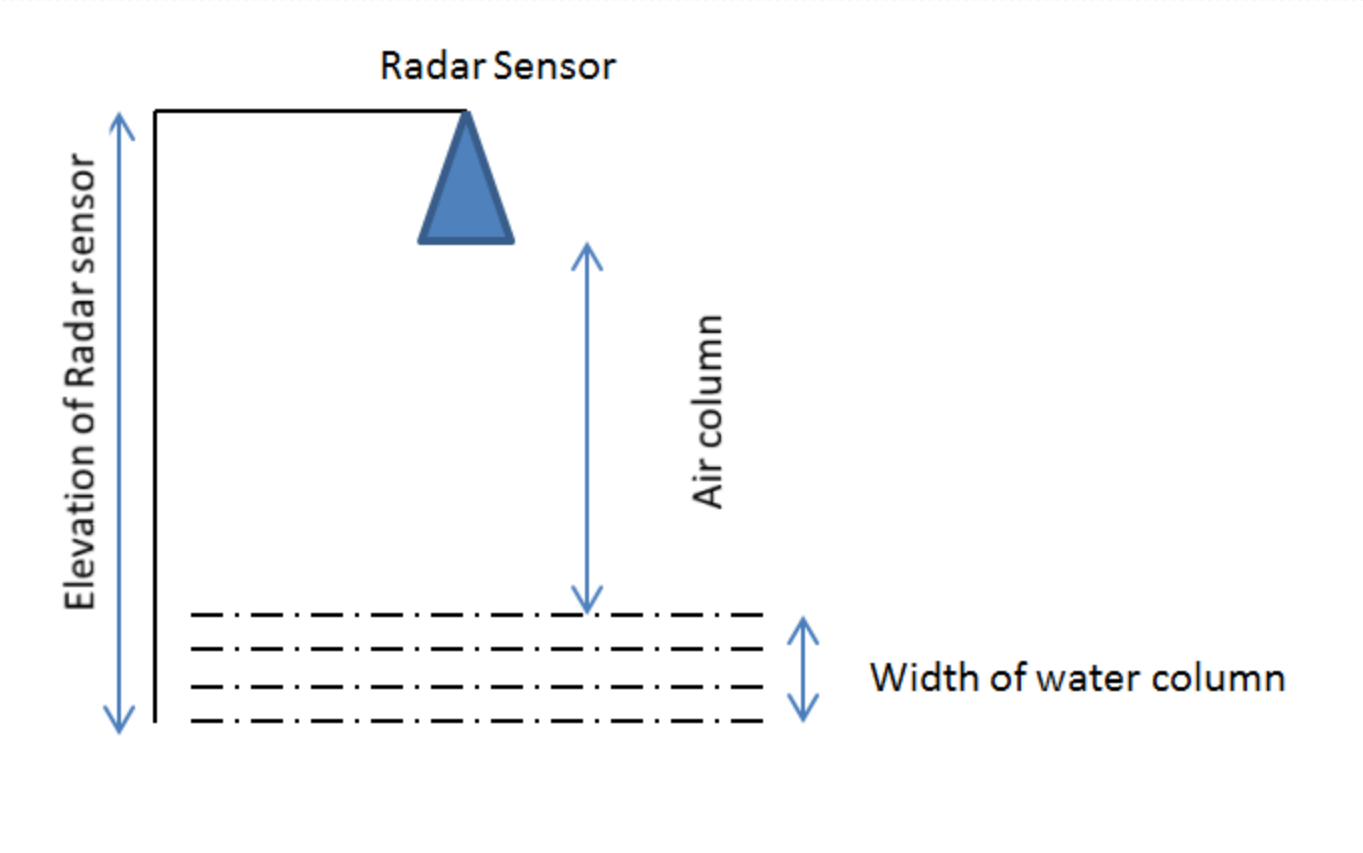
Radio Detection and Ranging



1. **Contact type**
   - Guided wave radar

2. **Non-Contact type**
   - Pulsed Radar
   - FMCW Radar (Frequency Modulate Continuous Wave Radar)

Sensor Type：Microwave non-contact sensor



Elevation of radar sensor – air column = water level

2-wire connection 4-20mA
Red goes to +24V DC
Black goes to –ve terminal of
Analog Input channel

Process Connection (thread)

Horn Antenna
Operating frequency 26 GHz
Wavelength 11.53 mm
Beam Angle 10^0
Antenna Size 80 mm
Horn Size 211mm

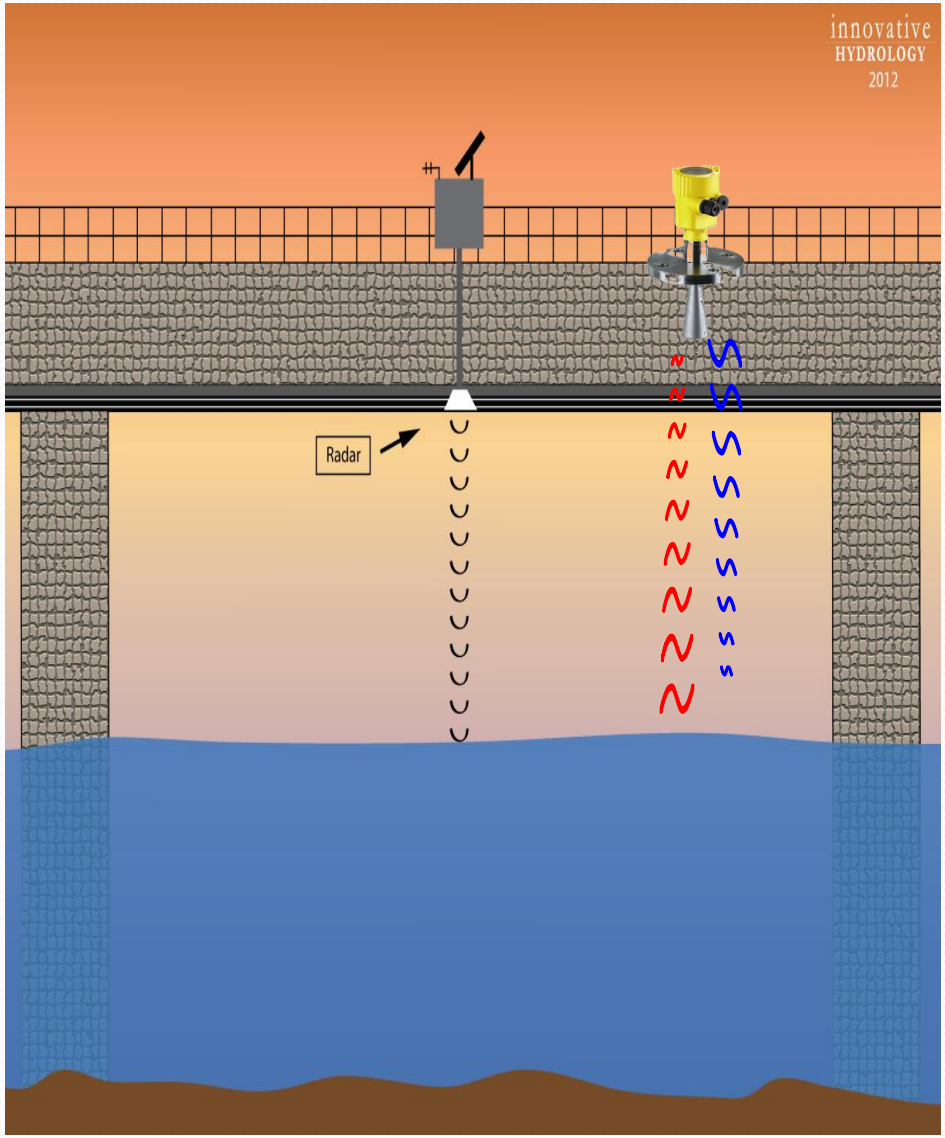
FMR 51 Pulsed Radar K band sensor 26 GHz frequency.
Output of Radar sensor is analog current signal (4-20 mA).
TWT, Magnetron, Klystron and Gyrotron are used to generate microwave signals.

Time of flight Method

The sensor measures the distance of water surface by sending microwave signal at the surface and then measuring the time for the pulse echo to return.

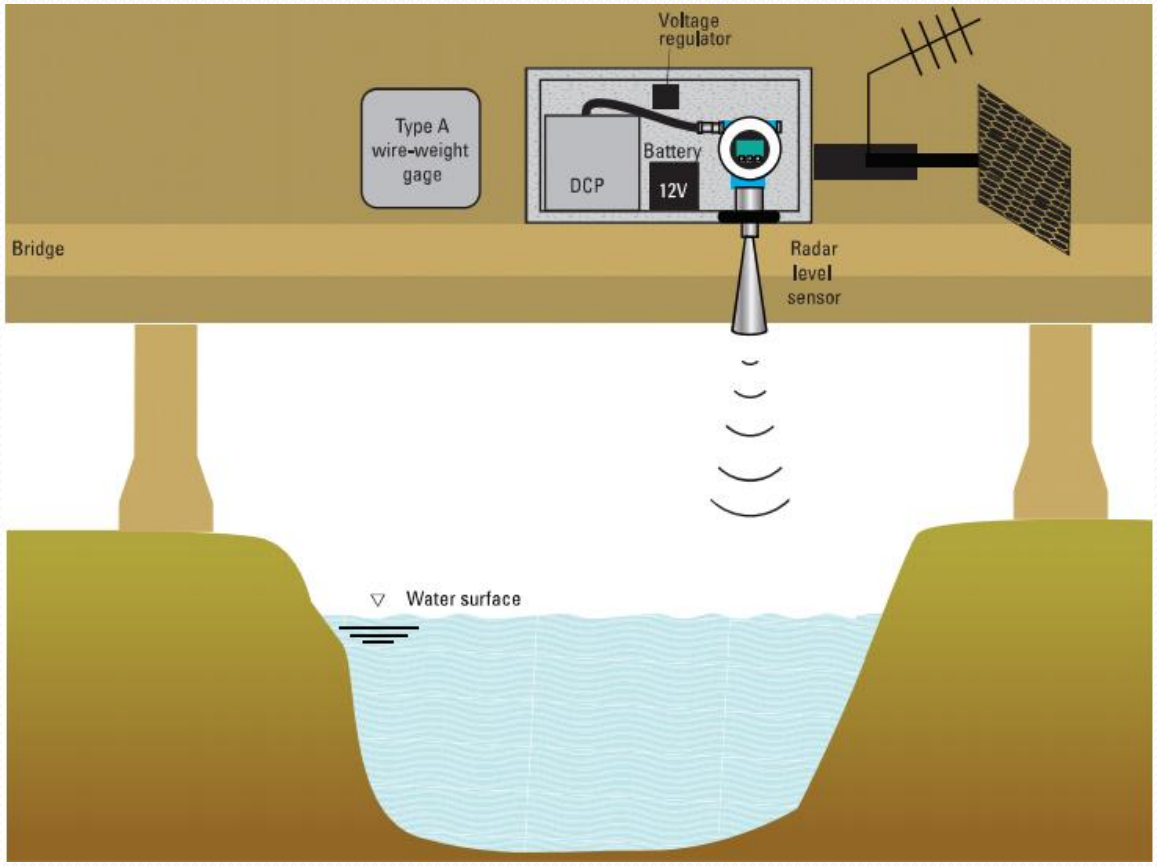
$d = c \cdot t / 2.$

Various frequencies from **1 GHz to 100 GHz** are typically used in Radar sensors.



Components of a Radar Surface water level measuring station

- Radar Sensor
- Mounting structure
- Data collection platform
- Solar panel
- Antenna & telemetry system

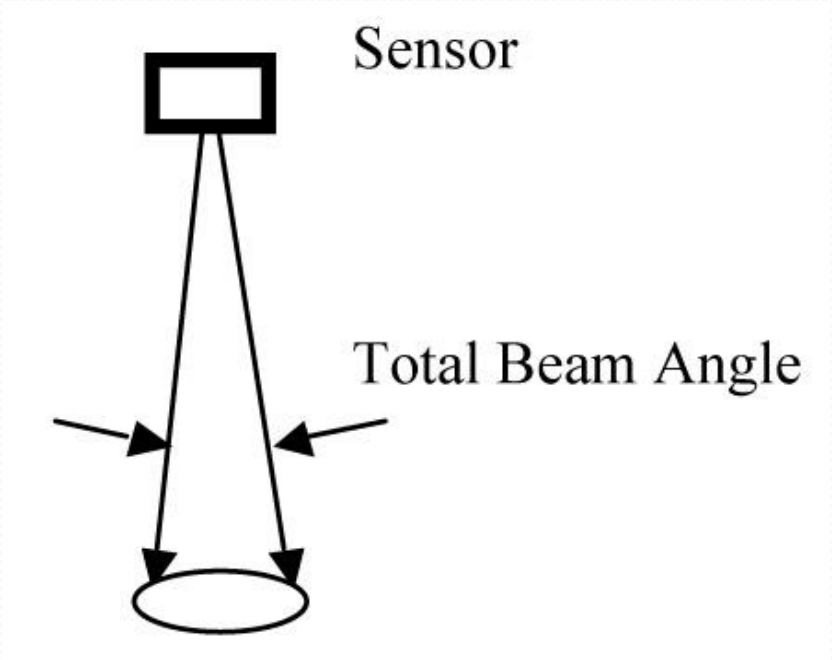


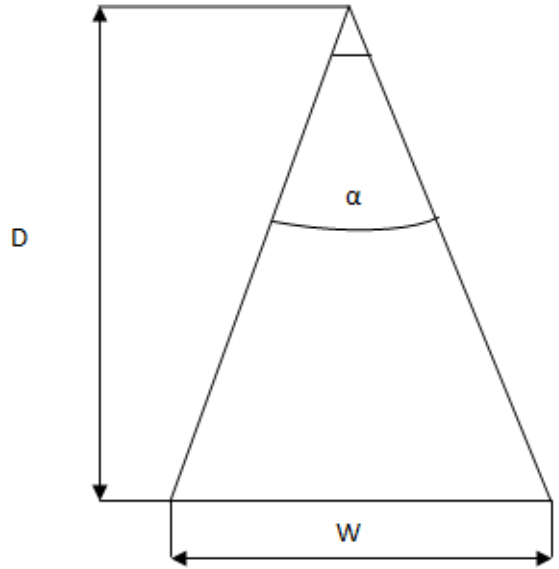
The radar wave signal travels in the shape of a cone, similar to the beam of a flashlight (getting wider as distance increases).

During radar sensor installation, sensor must not have any object within the area of signal projection like pillars, pipes, ladders, beams, brackets, side wall joints or any other equipment.

To avoid erroneous reflections, the sensor should be located such that there are no obstructions within or near the cone.

Beam Angle & Beam Diameter





Beam diameter, $W = 2D \tan \alpha/2$

Where;

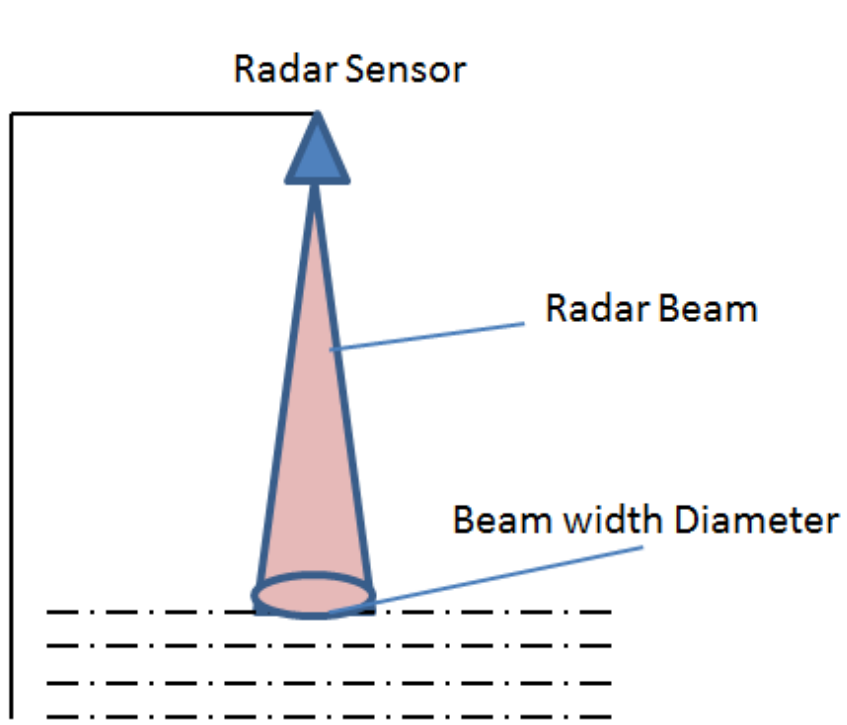
α is beam angle and

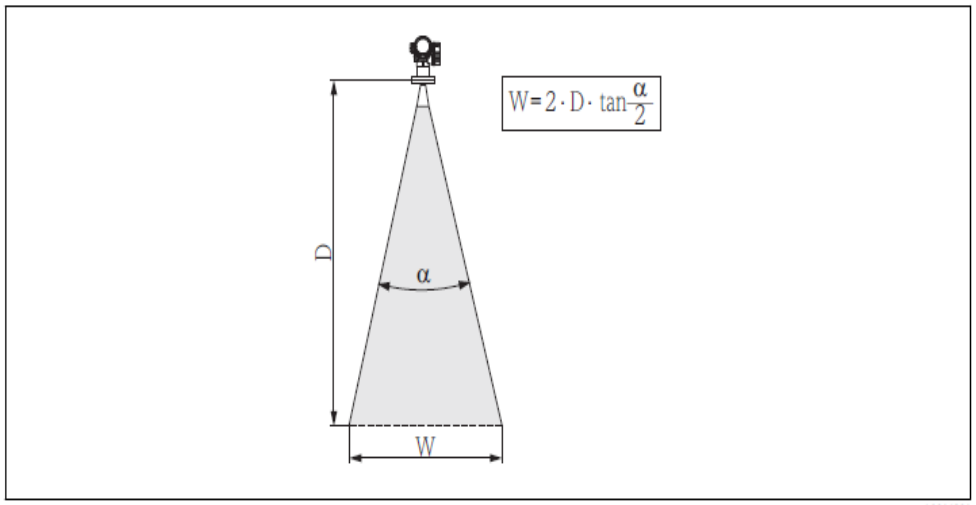
D is measuring distance.

It is typically 8^0-23^0 and conically shaped.

Beam Angle: ≤ 16^0

Distance (in m)	Beam width Diameter (in m)
10	1.749
20	3.498
30	5.247
35	6.1215
40	6.996
60	10.494
70	12.243





Radar Sensor Specifications

Ambient temperature	**: - 5 to +60^{0}C**
Humidity	**: 5 to 100 %**
Altitude	**: 0 to 2,500 meter**
Sensor Type	**: Microwave non-contact sensor**
Range	**: 15m/20m/35m/75m**
Resolution	**: 3 mm or better**
Accuracy	**: 0.02 % FSO**
Beam Angle	**: ≤ 16^0**
Output interface	**: SDI-12 / RS 485 / 4-20 mA / compatible with data logger**
Power supply	**: 12/ 24/ 36 V DC or to be powered by solar panel**
Protection	**: IP67 or better**
Local Display	**: Radar sensor should have local display for diagnostic purpose.**
Horizontal mounting	**: Above FRL, below a bridge girder wherever available otherwise horizontal cantilever arrangement from a mast/ wall/ pedestal.**

Radar sensor should have inbuilt diagnostic feature and averaging function.

(for FSO 75m, accuracy is +/- 15mm)

Advantages

- The radar is relatively easy to install.
- High accuracy along with the extended range of measurement over the Ultrasonic sensor.
- Unaffected by silt and debris in water, accuracy is not affected by air temperature variations.
- Unaffected by night, fog, clouds, precipitation, moisture, vapors, dust, and smoke.

Disadvantages

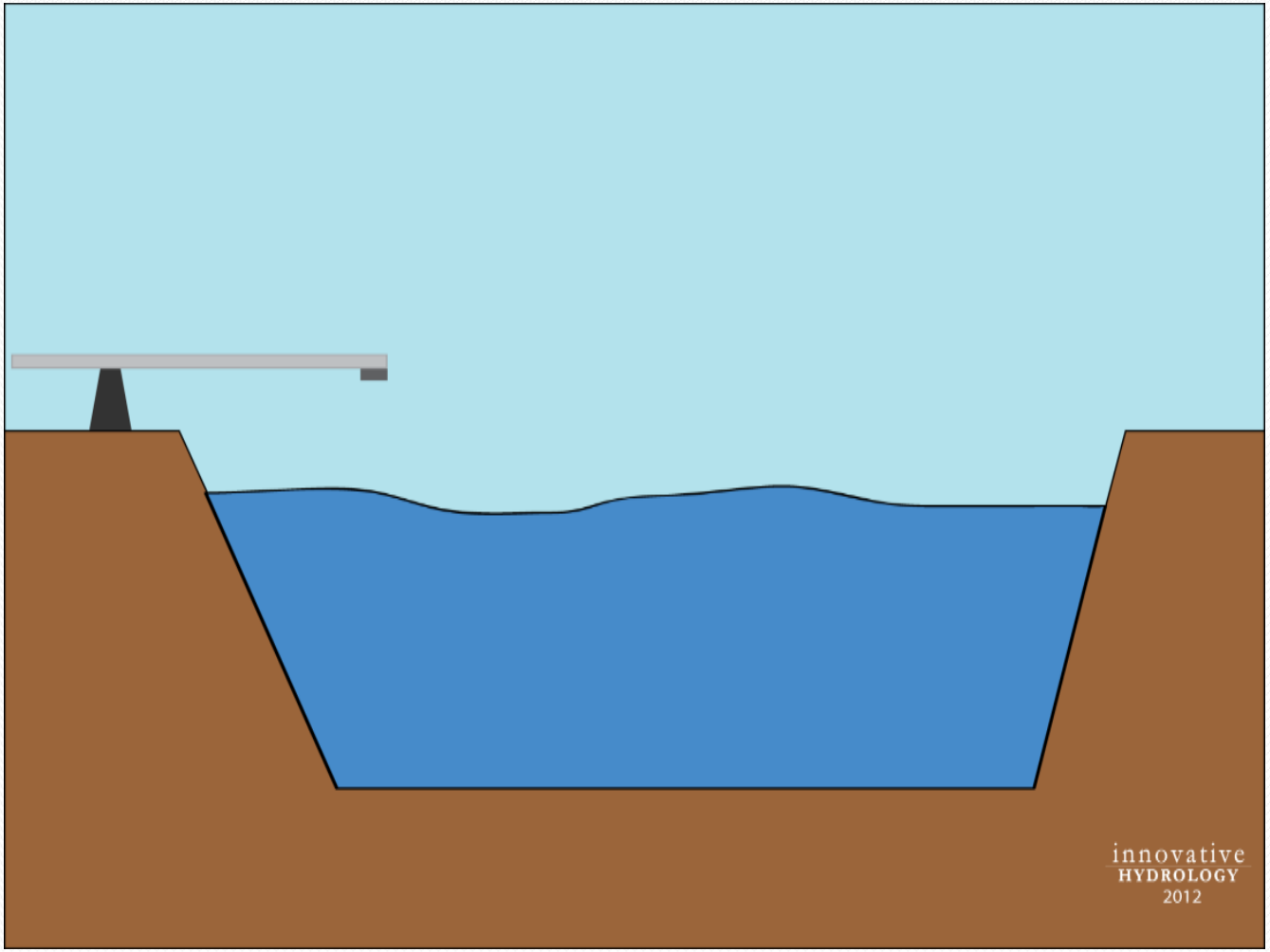
- Need some over hanging structure to mount the radar sensor.
- The disadvantages include the high cost of radar.

Ultrasonic Sensor

Ultrasonic Sensor

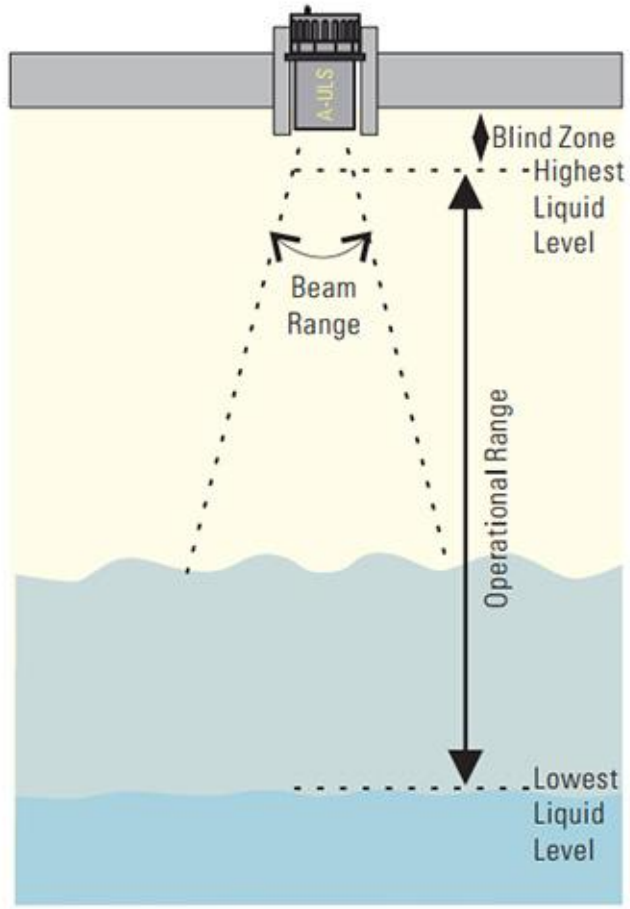
Model: FMU 42
Operating frequency: 42 KHz
Beam Angle: 9^0
Blanking Distance: 0.4 m
Output: 4-20mA

Piezoelectric crystals are used to generate ultrasound pulses. When an electric current is applied to a piezoelectric crystal, it starts to vibrate and these vibrations generate ultrasound waves.



The ultrasonic sensor measures the distance of water surface by sending pulsed ultrasound waves at the water surface and then measuring the time for the sound echo to return.
Knowing the speed of sound, the sensor can determine the distance to the water.

Ultrasonic Sensor Blanking Distance



Since the ultrasonic transducer is used both for transmitting and receiving the acoustic energy, it is subject to a period of mechanical vibration. This vibration must stop before the echoed signal can be processed.

The net result is a distance from the face of the transducer that is blind and cannot detect an object. It is known as the “blanking zone”, typically 40 cm, depending on the range of the transducer.

Ultrasonic Sensor Specifications

Ambient temperature	:	From -5 to +60^{0}C
Humidity	:	5 to 100 %
Altitude	:	0 to 2,500 meter
Sensor type	:	Ultrasonic non-contact sensor
Range	:	up to 10m
Resolution	:	3 mm or better
Accuracy	:	0.2 % of FSO (for FSO 10m, accuracy is +/- 20mm)
Output interface	:	SDI-12 / RS 485 / 4-20 mA / compatible with data logger
Power supply	:	12/24/36 V DC or to be powered by solar panel
Protection	:	NEMA 4X or IP67

Advantages

- Non-contact method of measurement.
- The measurement is generally unaffected by dirty water, floating debris, or aquatic wildlife.
- Also unaffected by the transparency, reflectivity, opacity or color of the water.
- Not affected by high flow rates.

Disadvantages

- Narrow range, limited to 10 m in most applications.

- The accuracy of ultrasonic sensor can be affected by temperature variations or dust in the space between the sensor and the water surface. Temperature fluctuation affects the speed of an ultrasonic sensor's sound waves. As temperature increases the sound waves travel faster to and from the water surface, while the water surface may not have shifted. It will seem to the sensor that the water surface is closer.

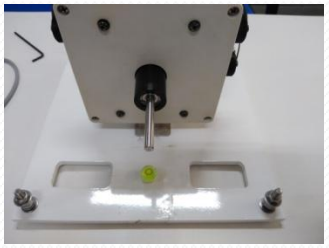
- You need some structure to mount the sensor (bridge railing or boom).

- You need to make this measurement directly over the body of water being measured, which is not practical in rivers that have shallow slopes.

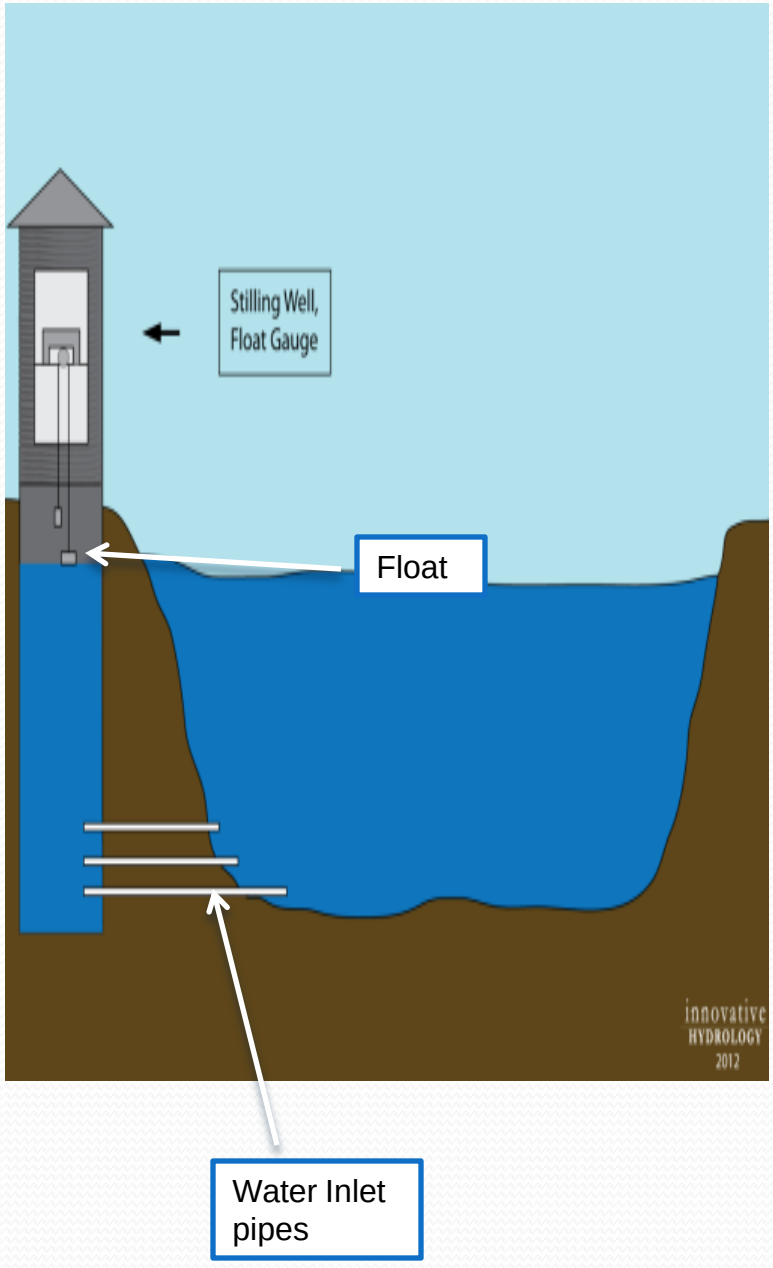
Shaft Encoder

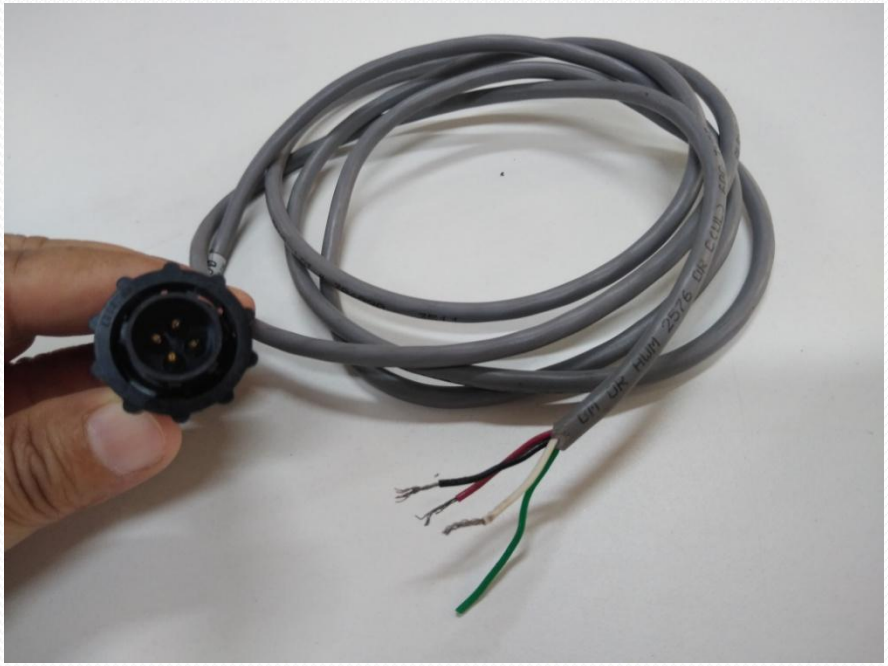
Shaft Encoder

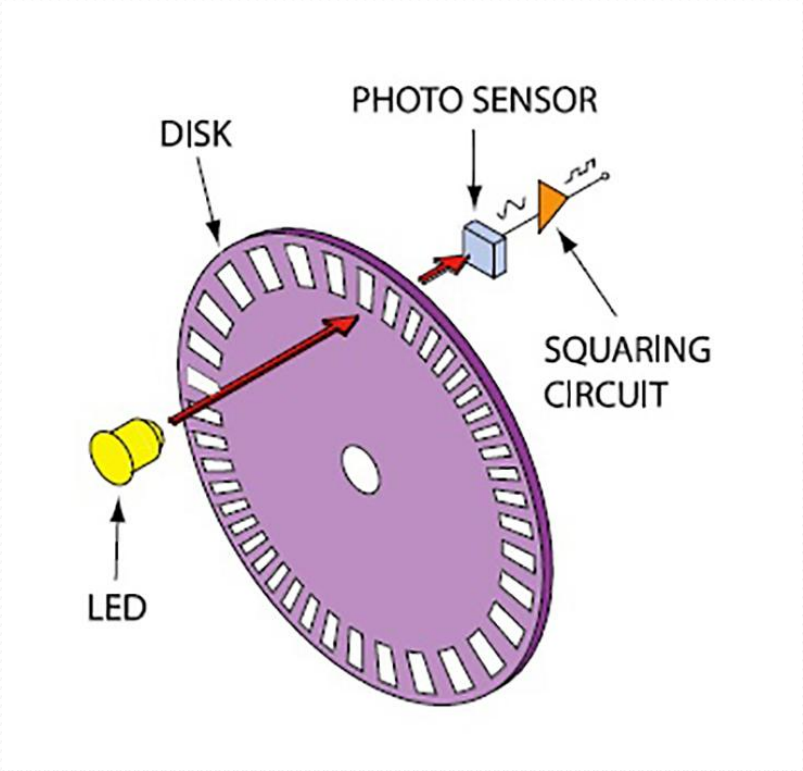
The components of this type of gauge include a stilling well, inlet pipes from the water, float, tape, counter weight, wheel, and shaft encoder which electronically sends signals to the data collection platform.



- Water comes into the stilling well through inlet pipes from the water source.
- As water level increases and decreases, a float moves up and down with the water level.
- A tape attached to the float turns a pulley which is connected to the shaft on the encoder.
- The shaft encoder will convert the shaft rotations to an electronic signal, which will be measured by a data logger.







Serial Data Interface -12 Cable Connections is a 4-pin connector.
(a) White wire Data
(b) Red wire +12 volts
(c) Black wire Ground
(d) Fourth wire optional earth ground / wire shield

The graduated tape should be of high quality to withstand harsh and humid environment, should not get twisted or wrinkled while operation.

Shaft Encoder Type Water Level Sensor at Bhakhra Nangal Dam

Advantages:

- Float-operated systems are easy to understand and troubleshoot.
- Most encoders offer good temperature stability.
- The float is protected in a stilling well and the sensor is not in direct contact with the water. Therefore the risk of damage is low.
- Highly accurate with large sized floats.

Disadvantages:

- Expensive civil works.
- Requires occasional flushing to remove sediments that may have collected at the bottom of the stilling well.
- If left unchecked, the sediments could block the inlet/outlet pipes.

At some places, a steel pipe of diameter about 200mm is attached to the bridge pier, to act as a stilling well. This pipe is open at the bottom end. Since it is installed in the river directly, there are no horizontal pipes to get chocked. This type of arrangement drastically reduces the overall cost and also gets rid of the problem of chocked connecting pipes.

Shaft encoder installation at ISP dam, M.P.

Shaft Encoder Sensor Specifications

Sensor Type	:	Shaft Encoder based incremental rotary position sensor with Digital Display
Range	:	10m, 20m, 30m, 50m,100m
Resolution	:	3 mm or better
Accuracy	:	0.025 % FSO (for FSO 100m, accuracy is +/- 25mm)
Output Interface	:	SDI-12 / RS 485 / 4-20 mA / compatible with data logger
Power Supply	:	12V DC or Switch rated for 12V DC/24V DC/ powered by solar panel
Material	:	Corrosion Resistance Metal (Stainless steel or Al)
Enclosure	:	Lockable (key) box provided by the supplier to be mounted in stilling well or gauge hut, with IP65 or NEMA 4 protection
Graduated Tape	:	The tape should be of high quality to withstand harsh and humid environment, should not get twisted or wrinkled while operation.
Accessories	:	Sensor Mounting support, Floats, graduated tapes (metric), wheel, counterweight, & cabling.

Bubbler Sensor

Bubbler Sensor

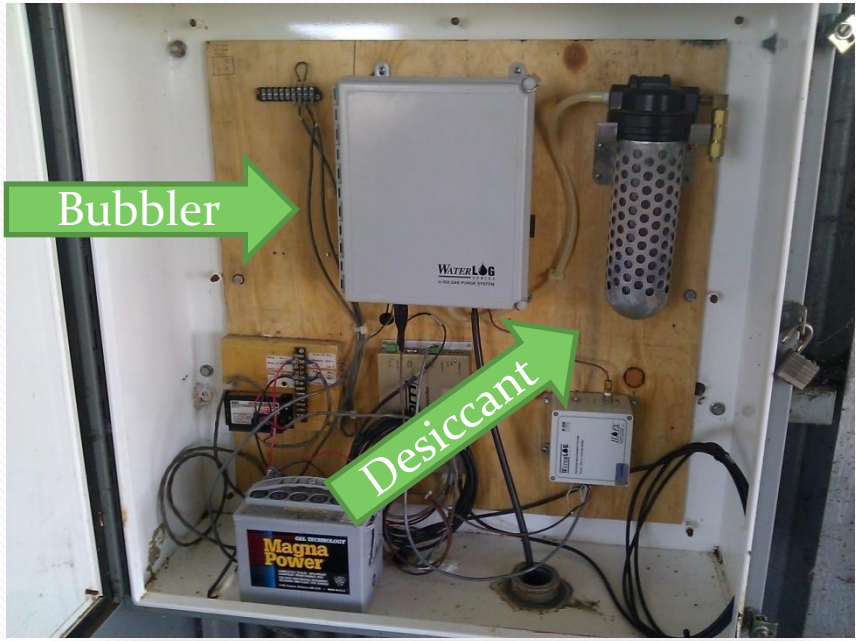
Also known as a **gas-purge system.**

The system allows a small quantity of air or inert gas to bleed through a pipe to an orifice in the stream.

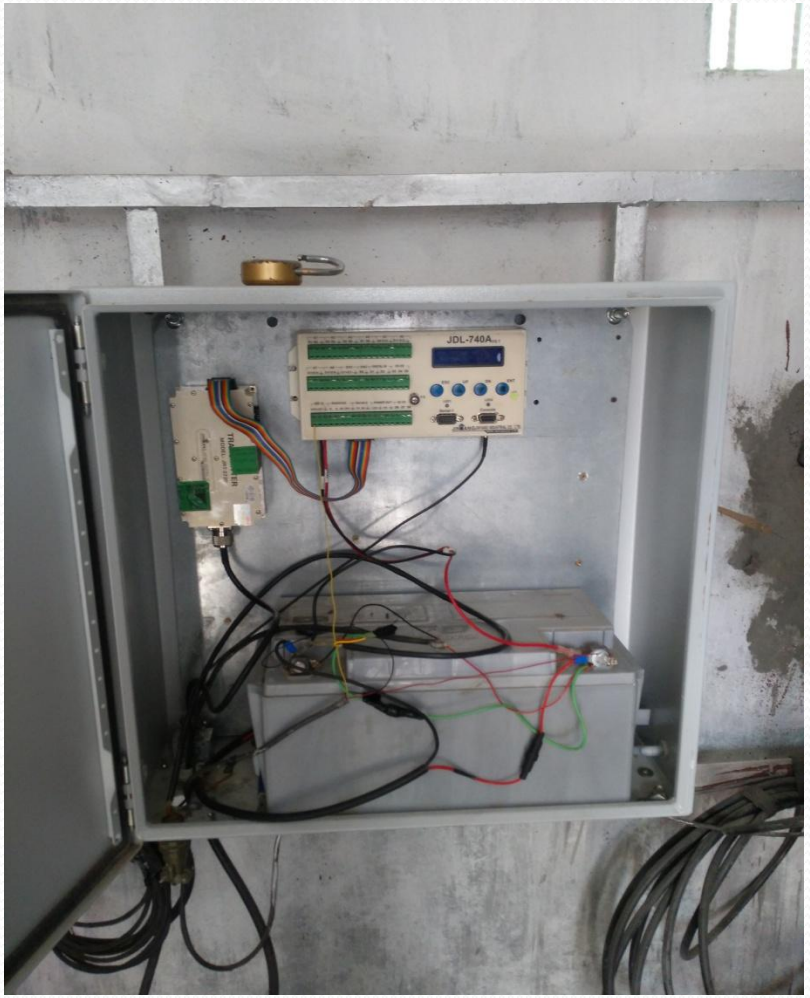
The pressure of the gas that displaces the liquid in the orifice is then measured by a pressure transducer located in the gauge house.

Bubbler Components

- Compressor
- Orifice Line
- Pressure Transducer
- Tank
- Desiccant



Sensor is not in contact with water, any debris in the water won't cause damage to the most expensive part of the bubbler system which is the pressure transducer and compressor.



Bubbler Type Water Level Sensor Pandoh

Advantages:

- This technology does not require a stilling well or bridge to mount the sensor.
- The pressure transducer and compressor are securely located in a locked gauge shelter minimizing the possibility of theft of these expensive components.

Disadvantages:

- High cost of the bubbler system. It requires lot of maintenance. A large nitrogen tank is required, which must be periodically refilled.

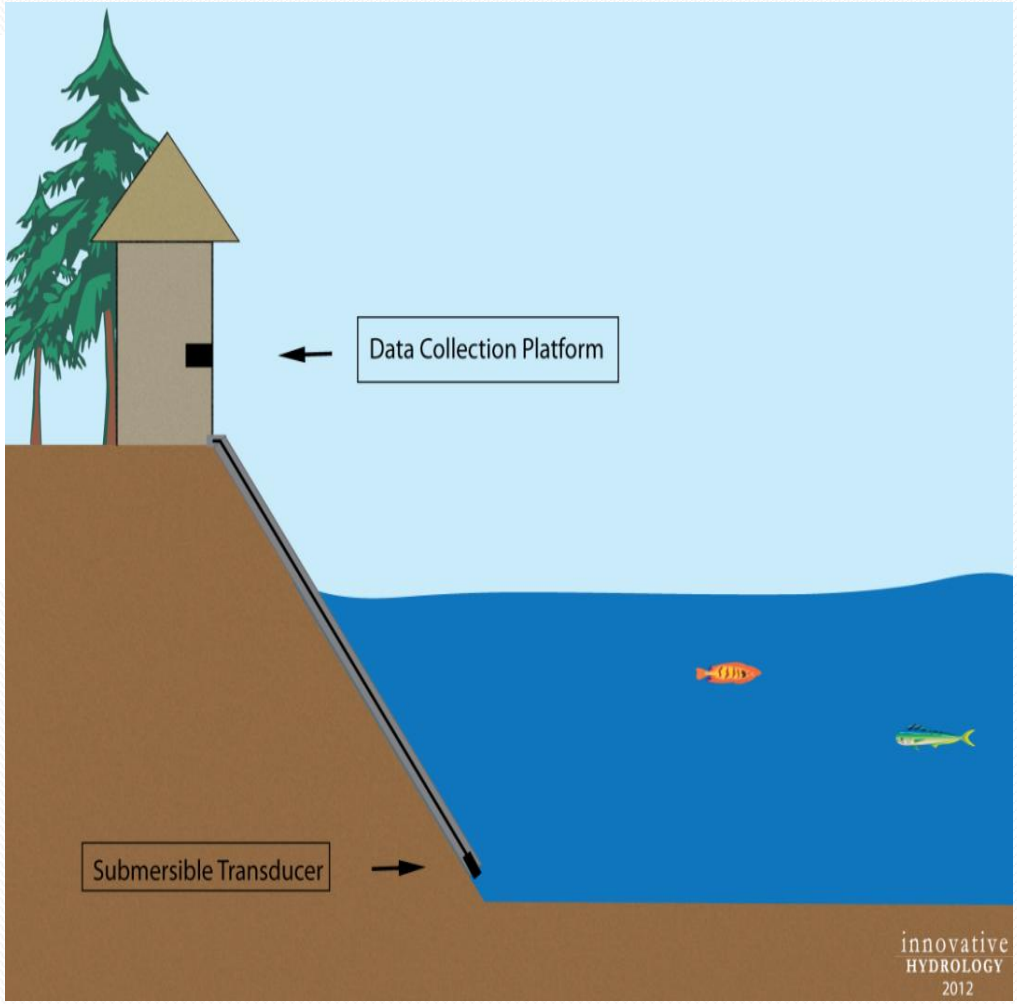
- The desiccating system that is normally needed to keep water out of the compressor system is a recurring maintenance item.

Standard Specification

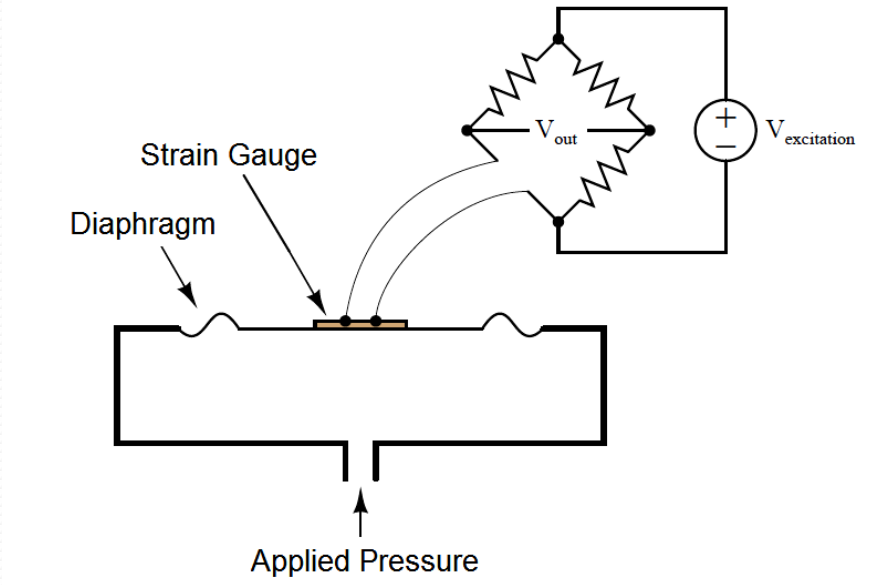
Site Conditions	
Ambient Temperature	From – 5 to $+60^0$ C
Humidity	5 to 100 %
Altitude	0 to 2,500 meter
Sensor	
(*) Sensor Type	Continuous bubbling system and non-submersible transducer
(*) Range	15 psi / 30 psi
(*) Resolution	0.0001 psi or better
(*) Accuracy	0.2 % FSO (for FSO 15m, accuracy is +/- 30mm)
Output Interface	SDI-12 / 4-20 mA / RS485, compatible with Data logger
Power Supply	12/24/36V DC or to be powered by solar panel
Average current Draw	<15mA based on 1 bubble per second
Purge	Manual line purge
Bubble Rate	Programmable 30–120 bubbles per minute

Submersible Pressure Sensor

Submersible Pressure Sensor



Pressure Transducer



Pressure = Force / Area

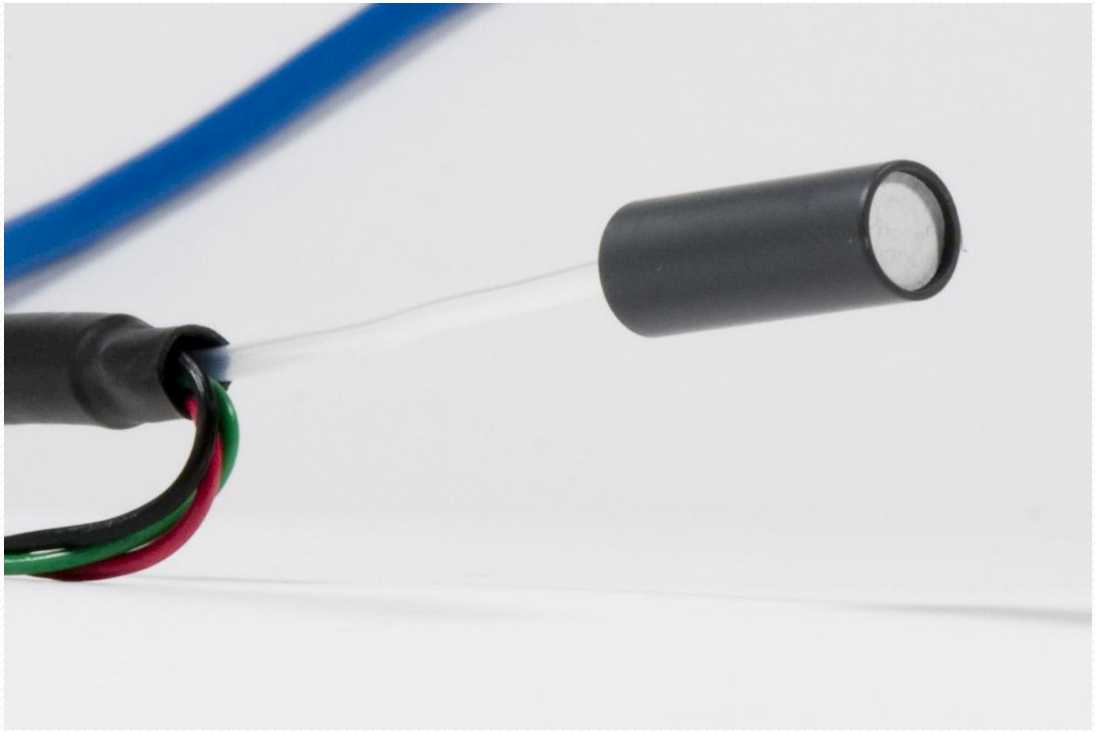
$$R = \frac{\rho L}{A}$$

ρ = resistivity
L = length
A = cross sectional area

$$GF = \frac{\left(\frac{\Delta R}{R}\right)}{\epsilon}$$

Absolute (non-vented) and vented (gauged) pressure sensors

Absolute pressure sensors respond to both atmospheric (barometric) pressure as well as the pressure head of water above the sensor.



Vented pressure sensors utilize a very small vent tube. This vent tube acts as a conduit to compensate for barometric pressure changes at the surface, thereby, allowing the barometric pressure on the water column to be cancelled out by the pressure transmitted in the tube.

Advantages:

- This technology does not require a stilling well or bridge to mount the sensor.
- Sensor requires the simplest installation, as the sensor only needs to be run down a pipe to some level that is lower than the expected minimum water level.
- A low profile installation site can be achieved using pressure sensors with internal data logging.

Disadvantages:

- The sensor is in contact with the water, which means any debris in the water can cause damage to the sensor.

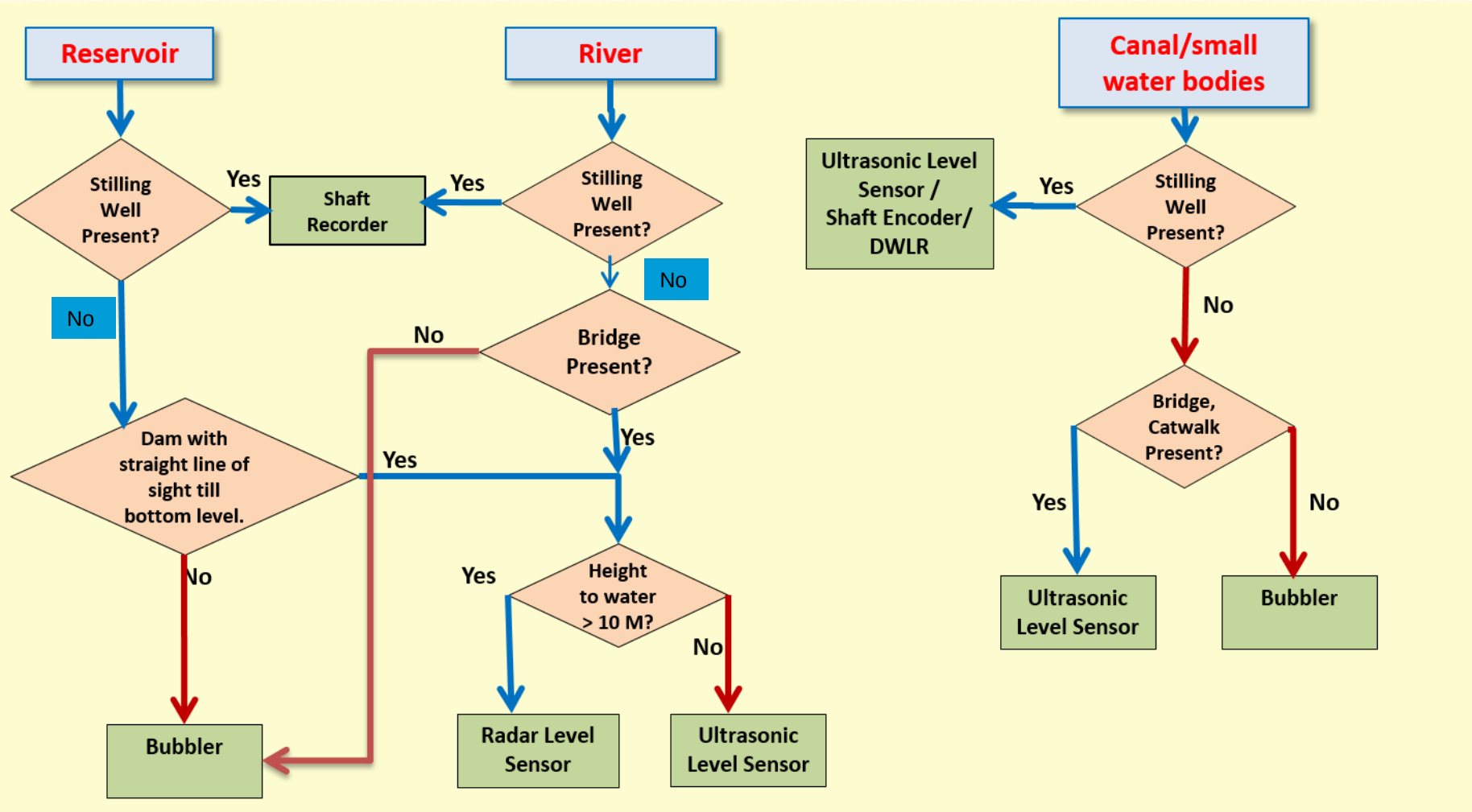
- Submersible Pressure Transducers are not good option for high elevation streams that are subject to ice in the winter.

- Lightening protection required.

Standard Specification

Site Conditions	
Ambient Temperature	From - 5 to +60^{0}C
Humidity	5 to 100 %
Altitude	0 to 2,500 meter
Sensor	
(*) Sensor Type	Pressure Sensor
(*) Range	30 meter
(*) Resolution	3 mm or better
(*) Accuracy	0.2 % FSO
Output Interface	SDI-12 / RS 485 / 4-20 mA / compatible with data logger
Power Supply	10-24 V DC / to be powered by solar panel
Protection	IP 67 or better

Selection of water level measurement technology



Thank you