

SETTLEMENT SYSTEMS

VIBRATING WIRE LIQUID SETTLEMENT SYSTEM *VWLSS-200*

INSTRUCTION
MANUAL



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1.0 INTRODUCTION

This manual is intended for all users of **Vibrating Wire Liquid Settlement System (VWLSS-200)** manufactured by Geosense and provides information on their installation, operation and maintenance.



It is VITAL that personnel responsible for the installation and use of this Settlement System, READS and UNDERSTANDS this manual, prior to working with the equipment.

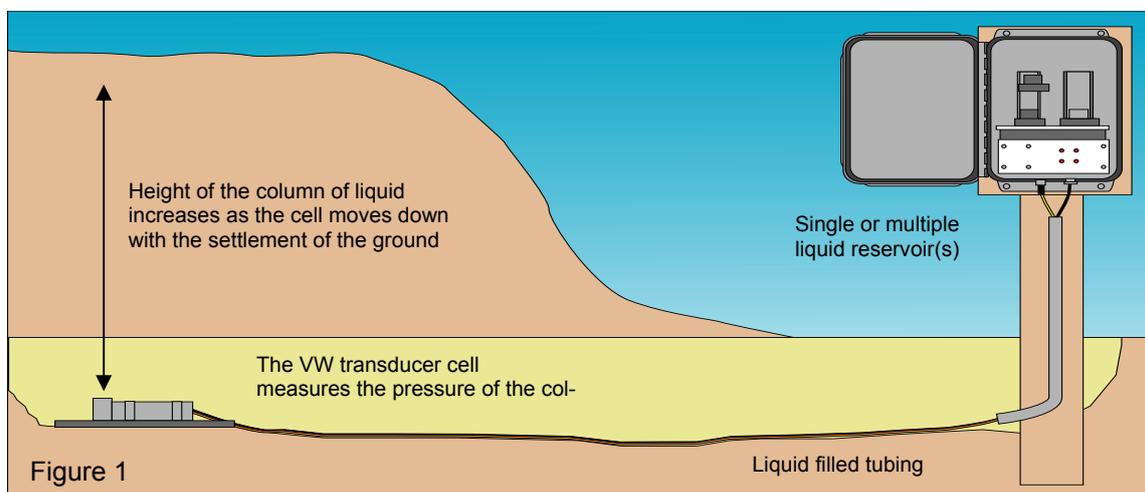
1.1 General Description

The **Vibrating Wire Liquid Settlement System (VWLSS-200)** is used to monitor settlement or heave in soils and other structures such as embankments, earth & rockfill dams. Typical installation is shown in Figure 1 below.

The main components are a reservoir (single or multiple), liquid filled tubing and a vibrating wire pressure transducer cell mounted on a plate or for borehole application attached to an anchor.

The vibrating wire sensor is attached to a settlement plate at the point of estimated settlement. The sensor is connected via two liquid-filled tubes which are connected to a reservoir located on stable ground. As the transducer settles with the surrounding ground the height of the column is increased and the corresponding higher pressure is measure by the transducer. Settlements are calculated by converting the pressure to millimetres of liquid head. Changes in atmospheric conditions and fluid level evaporation are compensated for by an additional vibrating wire sensor located at the manifold.

A typical **Vibrating Wire Liquid Settlement System (VWLSS-200)** consists of an array of vibrating wire sensors connected to fluid-filled tubes branching from the manifold. Each branch contains a sensor that is installed at a specific location. Each sensor contains a Thermistor for the temperature measurement, and gas discharge tubes for lightning protection. The system uses de-aired antifreeze solution to prevent algae growth and freezing. Furthermore, the system uses two liquid lines so that it may be flushed in order to remove air bubbles from the system.



The Vibrating Wire Liquid Settlement System (VWLSS-200) is available in two options and comprises of the following components:-



VW pressure sensor & plate

Pressure range 70 to 345 kPa



Drive-in VW pressure sensor

Pressure range 70 to 345 kPa



Tubing & cable

Twin tubing with over sheath

PUR cable

Lengths to suit individual requirements



Reservoir

Available in single and multiple up to 10

2.0 CONFORMITY

Marton Geotechnical Services Ltd

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Declaration of Conformity

We Marton Geotechnical Services Ltd at above address declare under our sole responsibility that the product detailed below to which this declaration relates complies with protection requirements of the following harmonized EU Directives:-

Low Voltage Directive 73/23/EEC (as amended by 93/68/EEC)
The Electromagnetic Compatibility Directive 2004/108/EC
The Construction Products Directive 89/106/EEC

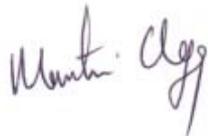
<i>Equipment description</i>	Vibrating Wire Liquid Settlement System
<i>Make/Brand</i>	Geosense
<i>Model Number</i>	VWLSS-200

This equipment has been designed and manufactured with reference to the following standards:

- All mechanical drawings used in the production of this equipment are based upon BS 8888
- Electrical/electronic drawings are based upon BS 3939.

A technical file for this equipment is retained at the above address

Bury St Edmunds, November 2010

A handwritten signature in black ink, appearing to read "Martin Clegg".

Martin Clegg
Director

3.0 DELIVERY

This section should be read by all users of Vibrating Wire Settlement Systems manufactured by Geosense.

3.1 Packaging

Vibrating Wire Liquid Settlement Systems (VWLSS-200) are packed for transportation to site. Packaging is suitably robust to allow normal handling by transportation companies. However, inappropriate handling techniques may cause damage to the packaging and the enclosed equipment. The packaging should be carefully inspected upon delivery and any damage **MUST** be reported to both the

3.2 Handling

Whilst they are a robust devices, **Vibrating Wire Liquid Settlement System (VWLSS-200)** are precision measuring devices. They and their associated equipment should always be handled with care during transportation, storage and installation.

Once the shipment has been checked (see below), it is recommended that Settlement Systems remain in their original packaging for storage or transportation.

Cable should be handled with care. Do not allow it to be damaged by sharp edges, rocks for example, and do not exert force on the cable as this may damage the internal conductors/reservoir line and render the instrument useless.

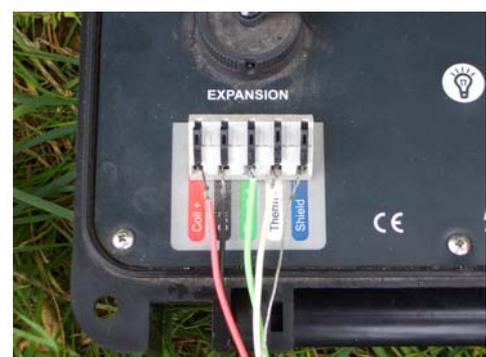
3.3 Inspection

It is vital to check all the equipment in the shipment as soon as possible after taking delivery and well before installation is to be carried out. Check that all the components that are detailed on the documents are included in the shipment. Check that the equipment has not been physically damaged.

Although the system is not fully connected to reservoir, a function check can still be carried out by connected the VW Cable to the Readout as in picture.

Prior to carrying out function checks, ensure that the Settlement System has been stored in a reasonably stable temperature for at least 2 hours.

The displayed values of the gauge reading and temperature, should be reasonably stable (+/- 3 full digits) for this check. (ensure body/plate is stationary)



(Continued on page 7)

(Continued from page 6)

Where possible, select the audio function on the readout and listen to the 'ring' of the gauge. The 'ring' should be clear and un-distorted.

If components are missing or damaged, contact the delivery company, the supplier and / or Geosense.



Typical readout panel and connections

3.4 Storage

All equipment should be stored in an environment that is protected from direct sunlight.

It is recommended that cables be stored in a dry environment to prevent moisture migrating along the cable in the unlikely event of prolonged submersion of exposed conductors.

Storage areas should be free from rodents as they have been known to damage connecting cables.

No other special requirements are needed for medium or long-term storage although temperature limits should be considered when storing or transporting associated components, such as readout equipment.

4.0 INSTALLATION

The following sections describe some typical installation procedures for Geosense Settlement Systems.

This section of the manual is intended for all users of Vibrating Wire Settlement Systems manufactured by MGS Geosense and is intended to provide guidance with respect to their installation.

It must be remembered that no two installations will be the same and it is inevitable that some 'fine tuning' of the following procedures will be required to suit specific site conditions.



It is VITAL that personnel responsible for the installation and use of the Settlement System READS and UNDERSTANDS the manual, prior to working with the equipment.



As stated before, it is vital to check all the equipment in the shipment soon after taking delivery and well before installation is to be carried out. Check that all components that are detailed on the shipping documents are included.

4.1 Preparation for Installation

When installing more than one System Plate/Body, record the assigned unique identifying code for particular positions (remembering to ensure that the System fitted with the longest cables are identified for most distant installations).

Ensure there will be enough cable to route it to the intended readout / monitoring location.

The elevation / location of the Settlement System installations should be identified by the Engineer responsible for the interpretation of the data, or as detailed on contract drawing or in the specification.

It is important to consider the protection of the Reservoir when selecting a suitable location. It must be remembered that Reservoir must be protected from damage as it is a sensitive measuring instruments. In some locations it will be necessary to install in a protective enclosure.

The function of the system should be checked prior to installation as described in section 3.3. Check the system using a readout with the audio function switched on. A clear 'ring' should be produced.

For the installation of a **Vibrating Wire Liquid Settlement System (VWLSS-200)** with the plate option use the following guide:

1. Pour a layer of sand upon the surface plane intended for installation of the Settlement Plate, approx. 2-3 inches thick.
2. Pat down a little to firm the layer and smooth the surface of the sand.
3. Lay the Settlement Plate, smooth face down. Putting force only on the plate itself, firmly push the metal onto the sand, Twisting slightly from side to side to ensure that good contact is made.
4. Starting from the centre, pour a cover layer of sand over the entire Settlement Plate, approx. 2-3 inches thick.
5. This is now a good time to do a final CHECK, before complete cover, by connecting the Readout.



Response Check

6. Connect the Readout to the VW Cable (Orange cable).
 7. Install the Reservoir.
The reservoir should be mounted outside the settlement area, with sufficient weather protection for stable temperature.
 8. You can now do a simple response test by raising/lowering the connector end of the settlement Settlement Systems body through 0.5m, and checking for a reading change.
-



9. After the Settlement System has been buried/driven to the required depth, it can be connected to the reservoir.
10. Top up the quick connect socket with the De-aired water-glycol mix.



11. Remove the protective cap from the relevant reservoir connector and push on the socket.



12. Remove the lid of the reservoir and fill with the de-aired water-glycol mix until the level of the liquid reaches the overflow.



13. Remove the nuts to release liquid and add more liquid to make up to the overflow level again.



4.2 Push-in Installations

Some installations require a Settlement System to be pushed into undisturbed material at the bottom of a borehole or pushed into the ground from the surface. For this purpose, Geosense produces specially designed Push-in Settlement Systems. The installation involves the use of a pushing adaptor connected to steel placing rods, drilling rods or Cone Penetration Testing (CPT) rods. The rod(s) must be strong enough to withstand the load that will be required to push a Push-in Settlement System body into the material at the base of the borehole or from ground level.



Only purpose built PUSH-IN Settlement Systems can be used for this type of installation.



A special pushing adaptor is required to support and push the Settlement System body into the base of a borehole. This adaptor is a purpose built component, normally manufactured by Geosense, that can be supplied or modified to suit the size of the drilling rods to which it will be connected. The design of the adapter is such that once the Settlement System has been pushed to the required elevation, the rods and adaptor can be extracted, leaving the body in place.

Where drilling rods are to be used to push the Settlement System into the base of the borehole the Settlement System cable must remain inside the rods to protect it and not be attached to the drilling rods as the installation is inserted into the borehole.

The borehole may be cased or un-cased. The final installation procedure will need to be created to include the following variations and based upon the previously described borehole installation procedures.

1. Prepare the Settlement System and that a frequency reading is obtainable as described in Section 4 and transport it to the drilling location.
2. Base grouting need not be carried out since the intention is that the Settlement System will be pushed into un-disturbed material at the base of the borehole.
3. With the specially designed pushing shoe fitted to the lower end of the first rod, the Settlement System must be pushed up inside the shoe until it is firmly in place against the back of the shoe.

4. As the rods are lowered into the borehole, the cable must be restrained to prevent the Settlement System dropping out of the shoe and to maintain control of the cable.



Never rotate the lower rods when adding further rods. This may cause the Settlement System cable to become twisted and could result in a failed installation due to cable damage.



5. Always count the rods into the holes so as to be sure of the Settlement System elevation at any time. (In soft ground, heavy rods could push the Settlement System past its intended location without applying any driving force.)

Where a Cone Penetrometer Testing Rig (CPT rig) is to be used to push the Settlement System, it will be necessary to use a special adaptor shoe and to run the Settlement System cable up inside the CPT rods. Each rod must be threaded over the cable as pushing is carried out. A standard electronic CPT pushing head can be used to allow the cable to pass though under the pushing head.

This system can be a cost effective solution where Settlement Systems are to be installed in soft ground but care must be taken not to damage the cable when the CPT rods are withdrawn.

For the installation of a Drive-in VW Settlement Systems, complete the installation using the following guide:

1. Place the Settlement System Body at the driving location then unroll the VW Cable and the Reservoir Line.
2. Feed the VW Cable and the Reservoir Line through the Driving Rods. This will protect them inside during the driving procedure and importantly will not retract the Body position during rod removal.
3. With the specially designed pushing shoe fitted to the lower end of the first rod, the Settlement System must be pushed up inside the shoe until it is firmly in place against the back of the shoe.



5.0 DATA HANDLING

The function of the instrument is to provide useful and reliable data. Accurate recording and handling of the data is essential if it is to be of any value.

5.1 Monitoring the Settlement System Readings

Geosense **Vibrating Wire Liquid Settlement System (VWLSS-200)** bodies normally contain Temperature sensors. Where a system is installed in a zone where its temperature is likely to fluctuate significantly, records of both settlement and temperature data should be used to assess any effects temperature has on the data.

5.1.1 Portable Readouts

Geosense offer a range of readout and data logging options. Specific operation manuals are supplied with each readout device.

Below is a brief, step-by-step procedure for use with the **RST VW2106** portable readout.

1. Connect signal cable from the sensor to the readout following the wiring colour code. Conductor colours may vary depending upon the extension cable used.

RED	=	VW +
BLACK	=	VW -
GREEN	=	Temp
WHITE	=	Temp
2. Switch on the unit and, where necessary, select range B
3. The recorder displays the current VW reading (in Hz²/1000) and a temperature reading in degrees Centigrade.

Whilst it is not critical that the polarity be observed for most VW instruments, a stronger signal may be obtained if the correct polarity is adopted. Since the temperature sensor is a Thermistor, its connection polarity is not important.

5.1.2 Data Loggers

A number of data loggers are available to automatically excite, interrogate and record the reading from Vibrating Wire instruments. These include devices manufactured by Geosense / RST in both single and multi-channel configurations, together with equipment manufactured by independent suppliers.

Geosense configure and supply equipment manufactured by both Campbell Scientific and DataTaker. These are the most commonly adopted third party manufacturers of data loggers that can be readily used with Vibrating Wire Settlement Systems. Specific configuration and programming advice can be obtained from Geosense and or the manufacturers documentation.

5.2 Data Reduction

Overview

Readings from a VW Settlement System are typically in form that is a function of frequency . Commonly the units would be either **Frequency** - Hertz, **Linear** - Hz²/1000 or Hz²/1000000 or **Period** - 1/T.

Having recorded the initial reading and temperature after installation, the zero reading is now established and all subsequent data can be referred to these numbers. Use the initial count reading as R₀ and the initial temperature recorded as T₀. Refer to the calibration sheets for the appropriate calibration and thermal factors for each system. Use the following formula to determine settlement.

5.2.1 Calculation of data without Barometer

$$\Delta \text{Settlement} = CF_m * \Delta R - T_{km} * \Delta T$$

$$\Delta R = R_c - R_0$$

$$\Delta T = T_c - T_0$$

Where:

CF_m = Calibration Factor (from Calibration Sheet)

R_0 = Initial Readout Box reading

R_c = Current Readout Box reading

T_{km} = Thermal Factor (from Calibration Sheet)

T_0 = Initial Temperature

T_c = Current Temperature

For example, if the initial readings at installation were 7905 Hz² /1000 and 17°C, and the current readings are 7530 Hz² /1000 and 15°C (and the calibration sheet shows – 0.0015936 m/(Hz² /1000) for CF_m and –0.0043 m/(°C) for T_{km} , a sample calibration sheet is included in the appendix), then the plate has settled a distance of 0.589m:

$$\Delta \text{Settlement} = -0.0015936 \frac{m}{\text{Hz}^2 * 10^{-3}} * (7530 - 7905) \frac{\text{Hz}^2}{1000} + 0.0043 \frac{m}{^\circ\text{C}} * (15 - 17)^\circ\text{C} =$$

$$= 0.598m - 0.009m = 0.589m$$

From the above sample calculation, it can be seen that generally the temperature effects are small, which is especially true for buried cable.

5.2.2 Calculation of data without Barometer

Linear:

$$\Delta\text{Settlement} = (CF_m * \Delta R) - (T_{km} * \Delta T) + (\Delta R_m) + (0.0953 * \Delta B)$$

$$\Delta R = R_C - R_0$$

$$\Delta C = T_C - T_0$$

$$\Delta R_m = (CF_m * \Delta R) - (T_{km} * \Delta T)$$

$$\Delta B = B_C - B_0$$

Where:

CF_m = Calibration Factor (from Calibration Sheet)

R_0 = Initial Readout Box reading

R_C = Current Readout Box reading

T_{km} = Thermal Factor (from Calibration Sheet)

T_0 = Initial Temperature

T_C = Current Temperature

ΔR_m = Reference Error Correction

B_0 = Initial Barometric pressure (at installation)

B_C = Current Barometric pressure (at time of reading)

Polynomial:

$$\Delta\text{Settlement} = [A * (\Delta R)^2] + [B * \Delta R] + [C] + [T_{km} * \Delta T] + [\Delta R_m] + [0.0953 * \Delta B]$$

$$\Delta R = R_C - R_0$$

$$\Delta C = T_C - T_0$$

$$\Delta R_m = (CF_m * \Delta R) - (T_{km} * \Delta T)$$

$$\Delta B = B_C - B_0$$

Where:

A, B, C = Polynomial Gauge Factors in kPa

6.0 MAINTENANCE

If Readings appear unusual (*see 7.0 Troubleshooting*) then it maybe necessary to flush the system.

The **Vibrating Wire Liquid Settlement System (VWLSS-200)** is designed so that if the contained fluid becomes contaminated or a significant number of air bubbles appear, the system can be flushed through and fluid replaced with fresh de-aired Water/Glycol mix. (Contact Geosense for advise & assistance)

Maintenance is not required on the sensor body/plate, or any below soil surface parts.

Very low and general maintenance is sufficient for the remainder of the (above soil) System, consisting mainly of visual checks every 2-3 months for:

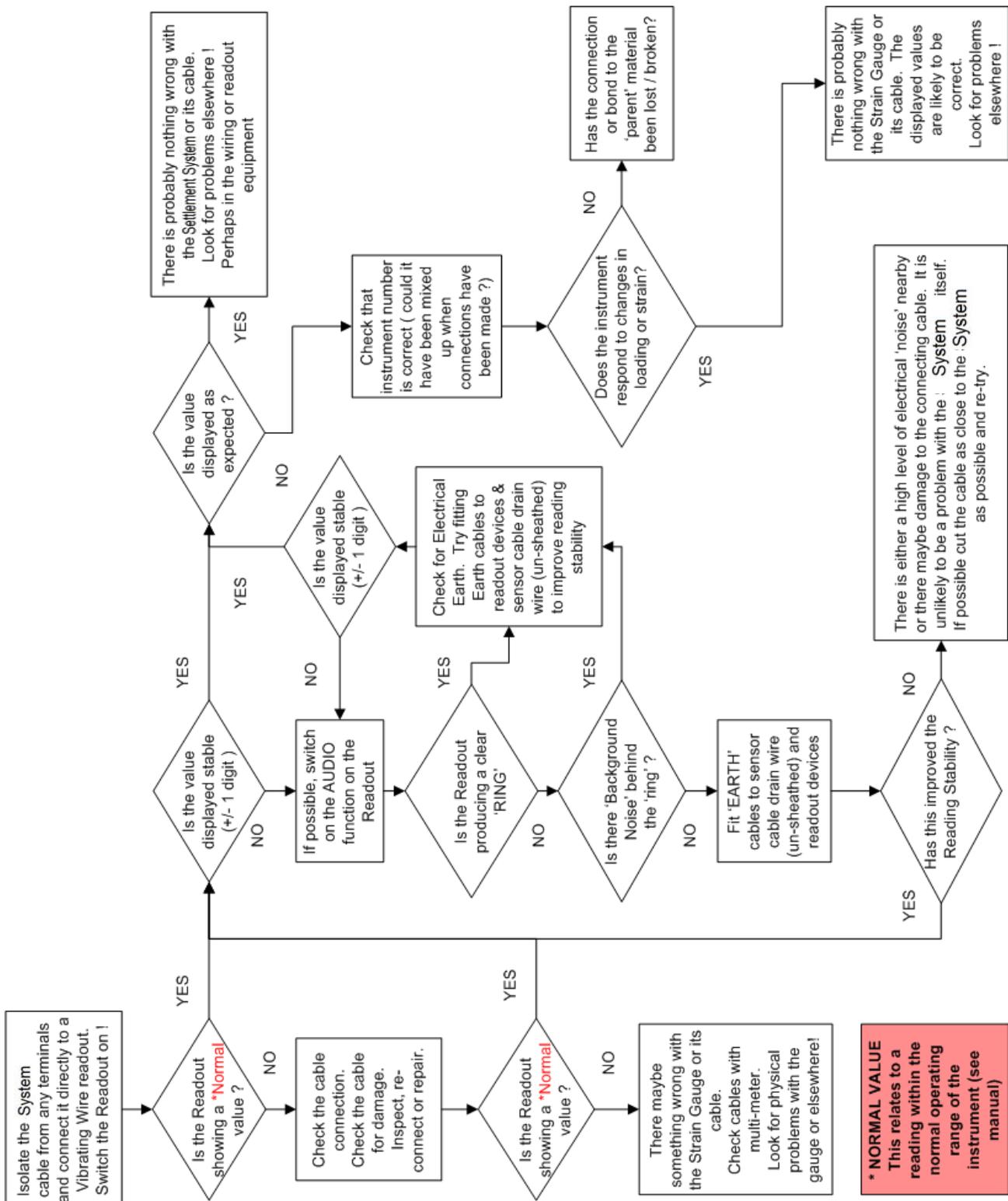
- Ensure the reservoir level is up to the overflow tube - top up if necessary,
- Connection tubes are still firmly in place and sealed,
- The fluid has no congealing, growth or blocked pipes.
- Wiring connection.

Maintenance of wiring connections between the **Vibrating Wire Liquid Settlement System (VWLSS-200)** and any terminal panels / or loggers should involve occasional tightening of any screw terminals to prevent loose connections or cleaning contacts to prevent the build up of corrosion.

7.0 TROUBLESHOOTING

It is generally accepted that when a Vibrating Wire instrument is producing a stable reading on a suitable readout, the value will be correct. Only on very rare occasions will this be untrue.

In almost all cases, a fluctuating reading is a sign of a faulty signal from the sensor. The fault could be in either the sensor, the connecting cable, any switch boxes or the readout. The best way to fault find an instrument is to isolate it from all other instruments and connections. Where possible begin fault finding from the sensor itself.



8.0 SPECIFICATION

Resolution	0.05% Full Scale
Accuracy	0.1% Full Scale
Thermal Effect	Less than 0.02% Full Scale per °C **
Operating Range	-20 to + 80 °C
Temperature Sensor (optional)	Thermistor (3kΩ @ 25°C)
Over Range Capacity	Range + 20%
Excitation	Pluck or Swept Frequency
Initial Zero Value	Mid Range (or user specified)

The above technical specification is accurate at the time of the last document revision and is intended as guide only.

The information above is liable to change without notice and may not, therefore, be 100% accurate for the supplied sensors.

9.0 SPARE PARTS

The Liquid Settlement System consists of both buried components and above soil components.

The Vibrating Wire Settlement System Body (Drive-in or Plate) is a sealed unit, it is neither serviceable nor does it contain any replaceable parts.

Above soil component items such as the Reservoir, junction box and readout are all freely compatible and replaceable.

Civil engineering sites are hazardous environments and instrument cables can be easily damaged, if they are not adequately protected. Geosense can therefore provide the following parts that may be required to effect repairs to instrument cables:

- PU coated 4 Core cable with foil shield and copper drain.
- PVC coated, armoured, 4 Core cable suitable for direct burial.
- Epoxy jointing kit for forming a waterproof cable joint.

Please contact Geosense for price and availability of the above components.

10.0 RETURN OF GOODS

11.1 Returns procedure

If goods are to be returned for either service/repair or warranty, the customer should contact Geosense for a **Returns Authorisation Number**, request a **Returned Equipment Report Form QF034** and, where applicable, a **Returned Goods Health and Safety Clearance Form QF038** prior to shipment. Numbers must be clearly marked on the outside of the shipment.

Complete the **Returned Equipment Report Form QF034**, including as much detail as possible, and enclose it with the returned goods.

All returned goods are also to be accompanied by a completed **Returned Goods Health and Safety Clearance Form QF038** attached to the outside of the package (to be accessible without opening the package) and a copy of both forms should be faxed in advance to the factory.

10.1.1 Chargeable Service or Repairs

Inspection & estimate

It is the policy of Geosense that an estimate is provided to the customer prior to any repair being carried out. A set charge for inspecting the equipment and providing an estimate is also chargeable.

10.1.2 Warranty Claim

(See Limited Warranty Conditions)

This covers defects which arise as a result of a failure in design or manufacturing. It is a condition of the warranty that the Vibrating Wire Strain Gauge must be installed and used in accordance with the manufacturer's instructions and has not been subject to misuse.

In order to make a warranty claim, contact Geosense and request a **Returned Equipment Report Form QF034**. Tick the warranty claim box and return the form with the goods as above. You will then be contacted and informed whether your warranty claim is valid.

10.2 Packaging and Carriage

All used goods shipped to the factory **must** be sealed inside a clean plastic bag and packed in a suitable carton. If the original packaging is not available, MGS Geosense should be contacted for advice. MGS Geosense will not be responsible for damage resulting from inadequate returns packaging or contamination under any circumstances.

10.3 Transport & Storage

All goods should be adequately packaged to prevent damage in transit or intermediate storage.

11.0 LIMITED WARRENTY

The manufacturer, **Marion Geotechnical Services Limited (MGS)**, warrants the **Vibrating Wire Liquid Settlement System (VWLSS-200)** manufactured by it, under normal use and service, to be free from defects in material and workmanship under the following terms and conditions:-

Sufficient site data has been provided to **MGS** by the purchaser as regards the nature of the installation environment to allow **MGS** to check material compatibility of the **Vibrating Wire Liquid Settlement System (VWLSS-200)** and other component parts.

In the absence of any site data being provided by the purchaser standard construction materials will be supplied. All costs for subsequent modifications will be borne by the purchaser.

The **Vibrating Wire Liquid Settlement System (VWLSS-200)** equipment shall be installed in accordance with the manufacturer's recommendations.

The equipment is warranted for 1 year from the date of shipment from the manufacturer to the purchaser.

The warranty is limited to replacement of part or parts which, are determined to be defective upon inspection at the factory. Shipment of defective part or parts to the factory shall be at the expense of the Purchaser. Return shipment of repaired/replaced part or parts covered by this warranty shall be at the expense of the Manufacturer.

Unauthorised alteration and/or repair by anyone which, causes failure of the unit or associated components will void this **LIMITED WARRANTY** in its entirety.

The Purchaser warrants through the purchase of the Vibrating Wire Liquid Settlement System (VWLSS-200) equipment that he is familiar with the equipment and its proper use. In no event shall the manufacturer be liable for any injury, loss or damage, direct or consequential, special, incidental, indirect or punitive, arising out of the use of or inability to use the equipment sold to the Purchaser by the Manufacturer.

The Purchaser assumes all risks and liability whatsoever in connection with the **Vibrating Wire Liquid Settlement System (VWLSS-200)** equipment from the time of delivery to Purchaser.



Geosense is a division of Marton Geotechnical Services Ltd

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