V1.12 July 2020

VW PIEZOMETERS

INSTRUCTION MANUAL

GEOSENSE

CONTENTS

1.0 INTRODUCTION

This manual is intended for all users of Vibrating Wire Piezometers manufactured by **Geosense**® and provides information on their principle, installation, operation and maintenance.

It is VITAL that personnel responsible for the installation and use of the piezometers READ and UNDERSTAND the manual, prior to working with the equipment.

1.1 General Description

The **Geosense**® **Vibrating Wire (VW) Piezometer** is an environmentally sealed sensor that is used to register changes in fluid pressure, generally in, but not limited to, under ground locations.

VW Piezometers can be installed or included in many types of monitoring regime and can be linked to various types of readout and recording equipment.

The primary uses for piezometers are :-

Soil and rock porewater (and pore gas) pressure measurement.
Water level monitoring (groundwater or chambers)

With applications such as, but not limited to, the following :-

Embankment stability and safety monitoring
Measuring water loads behind retaining walls
Assessing soil consolidation
Measurement of uplift pressures acting on structural foundations
Verification of seepage patterns and models
Slope stability monitoring
Water level monitoring for Environmental control
Tidal influence assessment
Pump Testing

Particular features of **Geosense**® Vibrating Wire Piezometers are:-

Reliable long term performance.
Ruggidity; suitable for demanding environments.
High accuracy.
Insensitive to long cable lengths / joints

The **Geosense**® Piezometer is based upon the 'industry standard' Vibrating Wire technology. When electronically excited, the sensor produces an output signal in the form of an alternating current. The frequency of the alternating current can then be readily converted to a pressure by applying a factory generated, individual calibration factor.
Frequency signals are particularly suitable for the demanding environments of geotechnical and civil engineering applications, since they are capable of long

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transmission distances without degradation. They are also somewhat tolerant of damp wiring conditions and resistant to interference from external electrical 'noise'.

The **Geosense®** range of VW piezometers are supplied in various configurations to suit varying installation environments and techniques. Each VW piezometer is fitted with a length of connecting cable, an internal temperature sensor and an electrical surge arrestor.

For standard piezometers, a filter is used to protect and separate the sensing diaphragm from the surrounding materials. The shape and porosity of the filter varies according to the model of piezometer.

- The filter housings for standard piezometers are sealed and fitted to the body by an 'O' ring.
- The filter housings for heavy duty piezometers and pressure transducers have a threaded fitment and are sealed by an 'O' ring.
- The Push-in Piezometer has an annular filter located just behind the pointed tip.

For **Geosense®** Standard Piezometers, the filter is a sintered Stainless Steel 50 micron (µm) filter, sometimes referred to as Low (resistance to) Air Entry (LAE). However, a ceramic 3 micron (µm) 1 bar filter, sometimes referred to as High (resistance to) Air Entry (HAE) is available, where specifically required.

LAE HAE
Piezometer Filters

The filters is mounted within a Stainless Steel housings that is fitted onto the end of the sensor body.

The pressure transducer is fitted with a standard sintered stainless steel 50 micron (µm) filter fitted inside the bulkhead into which a 1/4" BSP female thread is tapped. This offers protection to the diaphragm when connected to liquid or gas pressure sources.

The Push-in Piezometer has an annular filter located just behind the pointed tip. This filter is made of granular plastic (Vyon®)) which has a pore size of approximately 50 microns.

Push-in Tip Filter

Operating / calibration range

During calibration, the **Geosense®** range of VW piezometers are calibrated over a temperature range of –20ºC to + 80ºC to prove their function over a wide temperature range and provide the input data for any temperature compensation that may be required.

HOWEVER, as under normal conditions they are monitoring water, their practical operating temperature range will above 0ºC. Where installations are carried out in sub-zero conditions, VW piezometers <u>**must**</u> be kept above freezing at all times especially if the filter has been saturated with plain water. Anti-freeze can be used to extend the practical operating range, where appropriate.
Piezometers and Transducers are <u>tested</u> to 1.5 times (150%) their standard, calibrated, working range to prove their function at overpressure.

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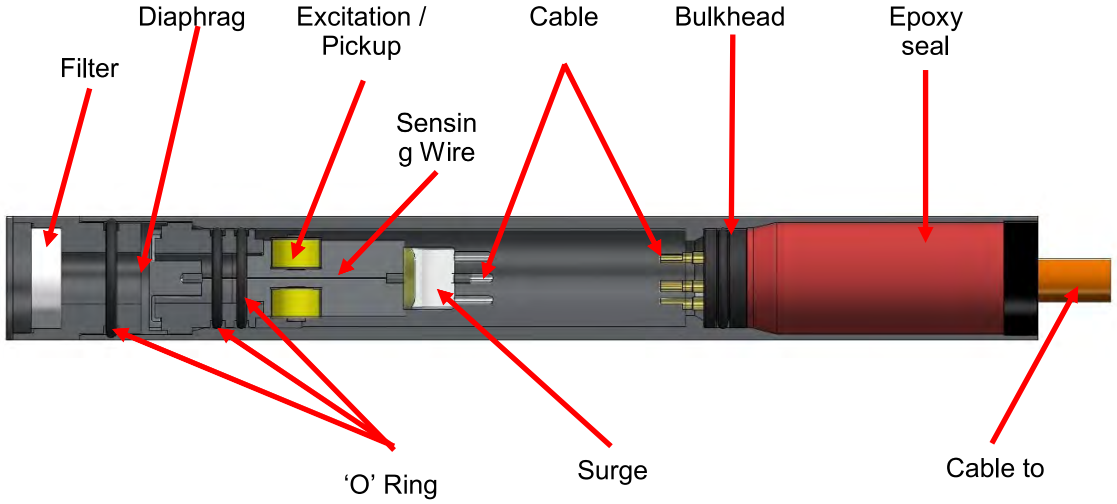
The calibration values will not be valid when the upper calibration value is exceeded. However, the validity of the calibration will not be affected, providing the overpressure % does not exceed 50 %. (applied pressure is 150% working range)

DO NOT ALLOW THE PIEZOMETER TO FREEZE WHEN FULLY SATURATED AS DAMAGE MAY OCCUR TO THE DIAPHRAGM WHICH WILL INVALIDATE ITS FUNCTION AND CALIBRATION

1.2 Theory of Operation

The Vibrating Wire Piezometer consists of a tensioned steel wire, anchored at one end to a flexible diaphragm (the sensing element) and at the other end to the inner body, all sealed into a stainless steel shell. The internal parts of all **Geosense®** piezometers and transducers are identical. Only the thickness of the diaphragm, the geometry of the shell and the filter arrangements change.
Two opposing coils are located within the inner body, close to the axis of the sensing wire. When a brief voltage excitation, or swept frequency excitation is applied to the coils, a magnetic field is generated causing the wire to oscillate at its resonant frequency. The wire continues to oscillate for a short period through the 'field' of the permanent magnets in the coils, thus generating an alternating current (sinusoidal) output.
The frequency of the generated current output is detected and processed by a vibrating wire readout unit, or by a data logger equipped with a vibrating wire



interface, where it can be converted into 'Engineering' units of pressure.

As pressure is applied to the exposed side of the flexible diaphragm (gas or liquid), the diaphragm deflects, causing a change in the tension of the sensing wire behind it. The change in tension of the wire results in a change in the resonant frequency at which the wire oscillates. The change in the square of the frequency of oscillation is directly proportional to the pressure applied.

For further information see Section 6 - Data Handling.

2.0 CONFORMITY

Geosense Ltd
Nova House
Rougham Industrial Estate
Rougham, Bury St Edmunds
IP30 9ND
Email: info@geosense.co.uk, Web: www.geosense.co.uk.

Declaration of Conformity

We **Geosense®** Ltd at above address declare under our sole responsibility that the **Geosense®** products detailed below to which this declaration relates complies with protection requirements of the following harmonized EU Directives:-

The Electromagnetic Compatibility Directive 2014/30/EU

Restriction on the use of certain Hazardous Substances RoHS2 2017/2102/EU

Waste electrical & electronic equipment WEEE 2012/19/EU

Equipment description	**Vibrating Wire Piezometers**
Make/Brand	**Geosense**
Model Numbers	**VWP-3000, VWP-3001, VWP-3100, VWP-3101, VWP-3200 VWP-3201, VWP-3300, VWP-3310, VWP-3311, VWP-3301,VWP-3400, VWP-3401**

Compliance has been assessed with reference to the following harmonised standard:

EN 61326-1:2013 Electrical equipment for measurement, control and laboratory use.
EMC requirements. General requirements.

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

Martin Clegg
Director

July 2020

3.0 MARKINGS

Geosense® piezometers are labelled with the following information:-

Product Name

Product Type

Calibrated Operating Range

Individual Serial Number

Manufacturers Name & Address

CE Mark

4.0 DELIVERY

This section should be read by all users of Vibrating Wire Piezometers manufactured by **Geosense**® .

4.1 Packaging

VW Piezometers are packed for transportation to site. Packaging is suitably robust to allow normal handling by transportation companies. 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 transportation company and **Geosense**®.

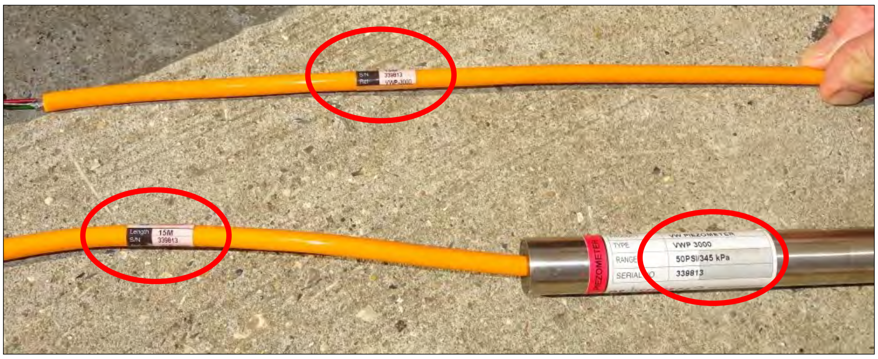
4.2 Handling

Whilst they are a robust devices, VW piezometers are precision measuring instruments. They, and their associated equipment, should always be handled with care during transportation, storage and installation.

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

Cable should also 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 and could render an installation useless.

4.3 Inspection / functionality check readings



It is important 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 detailed on the documents are included in the shipment. Check that the equipment has not been physically damaged.

ALL **Geosense**® Vibrating Wire piezometers carry a **unique** identification serial number which is also included on the labels on the cable close to the piezometer body and at the free end of the cable (see above). All VW piezometers are supplied with individual calibration sheets that include their serial numbers and these are shipped with the piezometers.

Cable marks also carry the model type and the length of cable fitted at the factory.

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4.3 Inspection/functionality contd…

**Calibration Sheets contain VITAL information about the piezometer. They MUST be stored in a safe place.
Only COPIES of calibration certificates should be taken to site
The original certificates should be stored safely.**

CHECK the piezometer readings against the factory 'Zero Readings' on arrival to ensure they have not changed significantly due to damage during transportation. This is a basic 'out of the box' functional check.

Prior to carrying out a reading check, ensure that the piezometers have been stored in a reasonably stable temperature for at least 30– 60 minutes.

To carry out the check, connect a Vibrating Wire readout to the bare cable ends (Red connector to Red wire and Black connector to Black wire) – The Green and White connectors / wires are for the temperature sensor and are not required for this checking exercise - see the readout manual for connection guidance.

Record the values (and units) displayed on the readout together with the piezometer serial numbers.

The "CHECK" readings should coincide with the factory zero on the calibration sheet (see the example calibration sheet in Section 9) within +/- 50 digits after barometric and temperature corrections are made.

The elevation of the **Geosense®** factory is +60 metres above sea level and barometric pressures change with altitude by approximately 1.2kPa per 100 metres.

The 'CHECK Readings WILL be affected by changes in atmospheric pressure and temperature changes.

If any components are missing or damaged, please contact **Geosense®**.

4.4 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 inside them in the 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.

If a piezometer is supplied with a pre-saturated filter or has been saturated on site, it must be kept at a temperature **above zero degrees Celsius.** If the water freezes, damage could be caused to the diaphragm.

DO NOT ALLOW THE PIEZOMETER TO FREEZE WHEN FULLY SATURATED OTHERWISE DAMAGE MAY OCCUR TO THE DIAPHRAGM WHICH WILL INVALIDATE ITS FUNCTION AND CALIBRATION

5.0 INSTALLATION

This section of the manual is intended for all users of Vibrating Wire Piezometers manufactured by **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 piezometers READ and UNDERSTAND the manual, prior to working with the equipment.

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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.

5.1 ZERO PRESSURE Reading

Vibrating wire transducers differ from most other pressure sensors in that they indicate a positive value at zero applied pressure. They will never read ZERO. Their readings at **ZERO PRESSURE** can vary significantly between sensors.

IT IS THEREFORE, ESSENTIAL TO TAKE ZERO PRESSURE READINGS
BEFORE
INSTALLATION IS CARRIED OUT

As with most transducers, do not directly handle the piezometer when recording the **ZERO PRESSURE** readings, as this will cause local temperature gradients across the body that will distort the readings.

Where piezometers are to be installed with their bodies orientated either horizontally or with their filters upwards, record their **ZERO PRESSURE** readings in a similar orientation. In particular, piezometers with low pressure ranges can be very sensitive to orientation. Always, therefore, obtain **ZERO PRESSURE** readings with the sensor orientated in the same direction in which it will finally be installed.

Essentially, the method of obtaining a **ZERO PRESSURE** reference value is the same for all the models of sensor. Only the preparation and tip / filter configurations vary.

Overleaf are details of the various configurations and the recommended procedure.

All **Geosense®** piezometers are fitted with Low Air Entry (LAE) filters, as standard. These should be removed for de-airing and prior to establishing their **ZERO PRESSURE** values.

HAE filters are supplied separate from the piezometer bodies. They are factory de-aired and sealed into a PVC tube that is filled with a de-aired mixture of water and a non toxic anti-freeze, Propylene Glycol. It is not necessary to fit these filters to the piezometers until they are to be installed.

Only Push-in piezometers are fully de-aired and assembled in the factory and sealed with a rubber sleeve. The rubber sleeve should be fitted to the tip to maintain saturation when being prepared for installation. The pushing action will remove it.

The Pressure Transducer is supplied with a filter inside its threaded bulkhead. The bulkhead has a threaded socket (1/4" BSPF) that is used for connection to liquid (or gas) pressure sources. The treaded bulkhead should be removed prior to establishing **ZERO PRESSURE** values.

Geosense® supplies HAE filters for their Standard and Heavy Duty piezometers in a 'de-aired' condition so that they are ready for immediate onsite assembly and installation.

The 'on-site' **ZERO PRESSURE** readings for Vibrating Wire Piezometers and Transducers are obtained as follows:

1. Fill a large bucket with clean, potable water, ideally at a temperature close to that of the local air temperature. Ensure that the bucket is away from any heat sources and shaded from the sun. Remove any fitted filters and place the piezometer(s) in the bucket.

   Stir the water occasionally to ensure an even temperature. Leave the piezometer bodies covered with water for a minimum of 4 hours - preferably longer.

2. At the free end of the cable, connect the leads to a vibrating wire readout unit and occasionally monitor the transducer output by turning on the readout and observing the display (see the readout user manual for assistance).

   Be sure to turn off the readout between periods of readings so as to avoid 'heating' the Vibrating Wire element.

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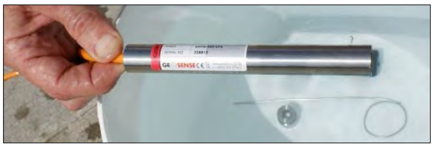
3. Turn on the readout and, **holding only the cable**, lift the piezometer out of the bucket, allowing it to hang vertically downwards and immediately record 2 or 3 readings. Replace the piezometer in the water as before.

   (If the piezometer is to be installed at an alternative angle; for example horizontal or with the filter uppermost, record the **ZERO PRESSURE** in the intended final orientation)

   After approximately two minutes of re-immersion, repeat and record another set of readings. Repeat three times, checking that the readings displayed are within +/- 0.5 digits of each other.

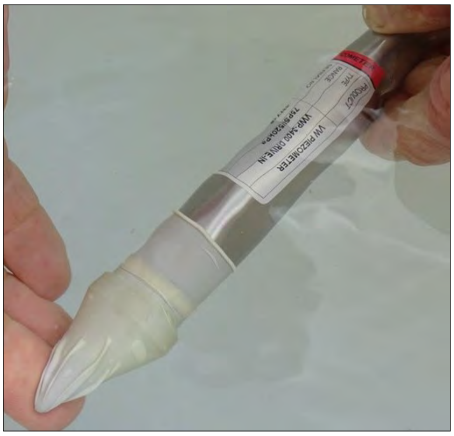


4. Note these readings together with the local barometric pressure, approximate elevation above sea level, date and time, on the calibration sheets.

5. Return the piezometer to the water or pack it carefully for installation at a later time.

Push-in Piezometers

The procedure for recording the **ZERO PRESSURE** for Push-in piezometers is the same as the standard piezometers explained above. However, these piezometers are supplied to site fully assembled and de-aired. The rubber sleeve, nose cone and filter have to be removed before the **ZERO PRESSURE** can be established.



1. Fill a large bucket with clean, potable water, ideally at a temperature close to that of the local air temperature. Ensure that the bucket is away from any heat sources and shaded from the sun. Place the piezometer(s) in the bucket.

2. Holding the piezometer underwater, roll back the rubber sleeve and twist off the nose cone and filter. Leave all the parts in the water. Stir the water occasionally to ensure an even temperature. Since these heavier piezometer bodies, leave them in the water for a minimum of 6 hours - preferably longer.

3. Once any inner temperature gradients have been removed by prolonged submersion at a

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stable temperature, the piezometer is ready to record the Zero Pressure values.

4. Connect and turn on the readout and, **holding only the cable**, lift the piezometer out of the bucket, allowing it to hang vertically downwards. Immediately record 2 or 3 readings and replace the piezometer in the water as before.

   (If the piezometer is to be installed at an alternative angle; for example horizontal, record the **ZERO PRESSURE** in the intended final orientation)

   After approximately five minutes of re-immersion, repeat and record another set of readings. Repeat three times, checking that the readings displayed are within +/- 0.5 digits of each other.

5. Record these readings together with the local barometric pressure, approximate elevation above sea level, date and time on the calibration sheet.

6. Return the piezometer to the water and ensure that no air is trapped inside the body.

7. Still **all underwater**, re-assemble the filter and nose cone, taking care not to trap air and tighten the thread.

8. Re-fit and un-roll the rubber sleeve to trap all the water in the body and filter. Carefully store until installation is to be carried out.

9. The rubber sleeve should remain in place as the installation is carried out. The pushing action will remove sleeve.

5.2 Preparation for Installation

Prior to installation of a piezometer it is essential to establish and confirm details of the installation to be carried out. Some of the main considerations are listed below :-

1. **Intended elevation and depth to Piezometer?**

   This can be calculated as either the depth below a known level (ground level for example) or as the elevation with respect to a remote datum. For borehole installations, the final depth should be determined from the intended installation elevation and then marked on the cable to show the intended installed position.

   For surface installations, a reference elevation could be determined and marked close to the final position of the piezometer.

   Which ever positioning system is adopted, it is very important to determine and record the final elevation of the piezometer diaphragm and its orientation.

2. **Borehole Installation type / specification**

   Where a piezometer is to be installed in a borehole, is it to be pushed into the base of the borehole; installed in a filter zone; grouted into the borehole or provided with a long filter for groundwater level monitoring?

   One of the most common types of borehole piezometer installation is the sealed, sand filter pocket and is adopted where a single piezometer is to be used to register water pressures changes at a specific sub-surface horizon.

   A more recently adopted borehole installation technique is the ‘Fully Grouted Method’. In this approach, there are no filter zones and a specially designed grout is used to backfill the borehole and surround the piezometer(s). The grout design is a major consideration as it can significantly affect the system performance. This approach can be particularly advantageous where more than one piezometer is to be installed in a single borehole.

   A full length filter zone (or observation well) installation is probably the next most common. A filter material, commonly sand, is washed into a borehole as a backfill. It simply allows groundwater from any horizon to flow into the borehole to be registered by the piezometer, located close to the bottom of the borehole.

   VW Piezometers are also commonly installed within standpipes, wells or as water level sensors. These are often ‘vented’ piezometers configured to compensate, automatically, for changes in atmospheric pressure.

   Where a rapid response is required from a saturated material with a low permeability, a specially configured piezometer can be pushed into the undisturbed base of the borehole to provide an intimate connection to the pore water pressure at a particular horizon.

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In softer material, the push-in piezometer can be pushed from ground level to its intended elevation, using hydraulic equipment such as a Cone Penetrometer machine. This removes the need for a borehole.

3. **Surface Installation type / specification**

Where a piezometer is to be installed at surface level (for example: as embankment fill is placed), is it to be pushed into a pre-formed cylindrical void or installed in a small excavated pocket? Piezometers in these installations would normally be covered by fill material which would be compacted manually to a certain depth and then mechanically, thereafter.

In a location where high permeability material is present, a sand filter pocket type installation is preferred but the sand has to be enclosed within a permeable ‘Geo-fabric’ pocket to prevent it being ‘lost’ into the surrounding materials.

Where a piezometer is to be installed in a material with a low permeability, it is normally better pushed into a pre-formed void so as to maintain intimate contact with the surrounding material. (Sand pockets should be avoided in low permeability surface installations).

4. **Filter zone**

A specially graded sand (commonly 600 - 1200 μm) is the most common material used to provide a filter zone within a borehole and support the borehole around the piezometer tip. The volume of material required will depend upon the diameter of the borehole and the length of the filter zone to be formed. Typically a 0.5 metre long filter zone is recommended but it should be in accordance with specific project requirements and specifications.

In some cases piezometers can be fitted inside small geotextile bags that are then filled with filter sand. This creates a small pre-formed filter pocket but also adds weight to the assembly to help with borehole installations. The filter bag should be fitted in advance of installation, filled with sand and allowed to soak in a bucket of water prior to placing.

5. **Bentonite seal**

Where a sealed piezometer filter zone is to be formed in a borehole, highly compressed and dehydrated Bentonite in the form of either pellets, balls or chips is commonly used to form the seal and is commercially available in bagged form. Balls can also be created on site using Bentonite powder and manual labour, However, small man-made bentonite balls are only suitable for shallow boreholes with a diameter ≥ 100mm. This is because they are more difficult to use as they can break-up before reaching their intended elevation in deeper boreholes.

Once in place, the Bentonite expands by absorbing water to form a highly impermeable borehole plug. Consequently, in dry boreholes, water must be added to allow the Bentonite to swell. Normally a plug is only required above any filter zone but a plug may also be used below a filter zone, for example,

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where the borehole extends beyond a piezometer filter base elevation.

6. **Cable marking**.

Cables should be marked with a unique identification system. Where multiple cables are to be grouped together along one route, markings should be repeated at regular intervals along the cable, so that in the event of cable damage, there may be a chance that the identification could be exposed and the cables re-joined. Multiple cable marks are particularly important close to the ends of the cables. The spacing of markings can vary according to specific site requirements. As a guide, 5m to 10m is commonly applied, but closer spacing nearer the ends.

7. **Tools.**

Obtain any tools necessary to carry out the installation. The following is a brief list of tools typically used during the installation of Vibrating Wire Piezometers. Some variation and addition may be necessary for different types of application.

- **Fibre measuring tape** with a weight added to the end for borehole depth measurement and cable length measurement.
- **Wire cutters and strippers**
- **Vibrating Wire Readout unit** for checking the piezometer function
- **Cable Marking** system / equipment (eg coloured PVC Tapes)
- **Grout mixing and placing equipment**
- **PVC tape**
- **Shovel** for placing and levelling fill by hand
- **Compactors** - and hand and mechanical

8. **Fitting the Filter to the Piezometer**.

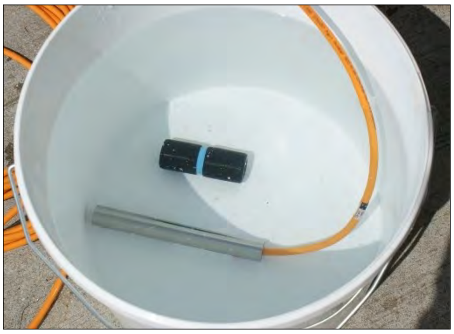
Filters can be fitted immediately after the **ZERO PRESSURE** has been recorded, just prior to installation or any time between. Once fitted, it is VITAL that the filters remain saturated so the piezometers should be stored and transported in water.

Standard Low Air Entry filters must be saturated prior to installation. Remove them from the piezometer or transducer and soak in clean water for at least 1 hour prior to re-assembly.

The special High Air Entry filters are de-aired in the factory and supplied sealed into a small tube filled with de-aired liquid.

Fitting the filters to the Piezometers is similar for all piezometers.

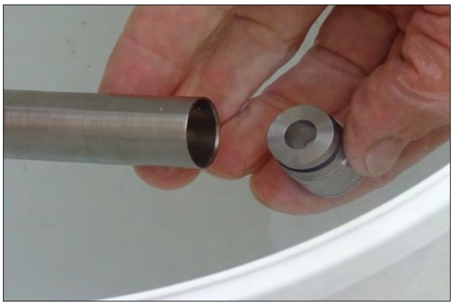
Typically as follows:



A. Fill a large container with clean, potable water and place the piezometer into it, together with the filter(s). Where LAE filters are to be used, they will be in their transport tube.

B. To remove HAE filters from a transport tube, maintain it underwater, remove one of the end covers. As the tube is full of water, this will not be easy to achieve. A small wire can be used to break the seal between the tube and the cap to help release any vacuum.

C. Maintaining all of the components underwater, remove one of the filters from the tube.



D. With all the components underwater, ensure that there is no air inside the end of the piezometer and insert the filter.

E. Carefully push the filter onto the piezometer.

Standard Low Air Entry filters are easily pushed onto the piezometer body, expelling any air from the filter.
High Air Entry filters are more difficult. Once the ‘O’ ring has engaged it may be necessary to rotate the filter whilst applying pressure, so as to fully fit the filter.

F. Once fully fitted, the gap between the piezometer body and the filter body will be closed.

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G. Maintain the piezometer in the water container or transfer it another water filled transport container. (A water bottle makes a good transport container).

Care must be taken when fitting HAE filters to Low Pressure piezometers and transducers. Always connect the readout to the cable and ensure that pressures induced during the filter fitting process do not exceed maximum operating range.

5.3 Installation Procedures - Boreholes

Each piezometer installation is different and requires both 'Common Sense' and a general understanding of the sub-surface conditions. There are many approaches to piezometer installation and, in addition to these broad installation guidelines, **Geosense®** are committed to providing technical support to help engineers and technicians adjust their procedures to match particular site conditions and requirements.

Where possible, boreholes should be flushed with clean water prior to installation operations, particularly if excessive sediment remains suspended in the water.

Each piezometer is supplied with a unique identification on its body and on the attached cable, however steps should be taken, perhaps with the aid of coloured tapes, to mark the cable so that there is no confusion over piezometer identification. This is particularly important for installations where more than one piezometer is to be installed in one location.

5.3.1 Cased boreholes with filter pocket.

When forming a borehole for a piezometer installation, it is sometimes necessary to use a temporary steel sleeve or 'casing' to hold the hole open during drilling and in-stallation operations. The following describes a series of steps that could be adopted to carry out a piezometer installation in such a fully cased borehole. This procedure can be adapted where boreholes are only partially cased.

1. Before drilling the hole it is important to ascertain the depth at which the piezometer is to be installed. An indication of the ground conditions may also be helpful.

2. The borehole should be formed to a depth of approximately half the sand filter depth below the intended elevation of the piezometer tip. If a Bentonite plug is required at the base of the borehole, it will have to be drilled further to accommodate the plug.

3. Before commencement of installation, the depth of the hole should be re-checked and the procedure you intend to follow should be confirmed with the engineer and discussed with the driller.

4. Confirm that all materials are available (filter sand, Bentonite pellets or balls and backfilling grout). The piezometer to be installed should be transported to the borehole locations in a container of clean water.

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5. Check the drill hole to ensure that the full depth is clear and free of obstructions and that any casing is free and can be withdrawn, when needed.

6. CHECK INITIAL READING OF PIEZOMETER.

   Where necessary, record a reading from the piezometer to confirm that it has not been damaged since establishing the **ZERO PRESSURE** readings (see Section 5.1)

7. Where necessary and possible, fill the borehole with clean water.

8. If a Bentonite plug is required at the base of the borehole, pull any temporary casing back so that its lowest level corresponds to the top of the intended plug. Slowly drop Bentonite pellets / balls down the borehole. Be sure not to let the pellets / balls plug or stick to the inside of the casing by checking the depth using a weighted tape. Ensure that the Bentonite level always remains below the bottom of the casing. (Feeding pellets / balls in to the borehole too quickly will result in ‘bridging’ of casing and make completion of the installation very difficult). The top of any base-plug must be below the intended piezometer installation elevation. Check frequently using a weighted tape.

9. Once any plug has been formed (if required), the casing should be pulled to about 500mm (or in accordance with specification) above the new base of the borehole (the intended top of the filter zone) and filter sand should be slowly added to fill the borehole up to the depth at which the piezometer diaphragm is to be installed. Check frequently using a weighted tape.

   Water can be used to wash sand off the sides of the borehole, down to the filter zone.

   Allow time for the sand to settle through the water and form the filter. A common fault is to rush this operation, resulting in poor installation.

10. With the filter securely fitted to the piezometer,

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lower it slowly down onto the sand at the base of the borehole and record another check reading.

If the piezometer reaches the base of the borehole and its position does not correlate with the mark on the cable, check the depth and marks again.

Any difference between the intended and actual elevation MUST be recorded.

11. If necessary, coil up and feed the piezometer cable into the casing so that the drilling rig can be used to extract the casing. Ensure that there is enough slack cable to prevent the casing pulling the piezometer back up the borehole. (This will have to repeated whenever casing is to be raised or removed.)

    When a section of casing is removed the cable passed through it.

12. Ensure that the lowest part of the temporary casing is above the elevation of the top of the filter and add more clean filter sand on top of the piezometer.

    Continually check the level of the sand using the weighted tape.

    Fill until the full filter pocket has been formed.

13. Pull the casing back another 500mm (or as project specification requires) and add a Bentonite seal of specified thickness. This could comprise pure Bentonite pellets / balls

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as described above for the base plug. Continue to pull the casing a little at a time whilst adding the Bentonite pellets. Once the borehole is sealed to the specified thickness. Check the piezometer readings again.

(In a 100mm diameter borehole the 5kg of Geosense Mikolit® Bentonite pellets will produce a seal approximately 500mm long)

14. Fill the remaining void with Grout as shown in the grouting procedure (See Section 5.6).

15. The piezometer installation is now complete but the initial, in-situ piezometer readings have yet to be recorded. Since the piezometric balance may have been disturbed by the installation operations, a series of piezometer readings may have to be recorded so as to determine when the piezometric balance has re-established.

    Only then can a true set of in-situ pore pressure readings be recorded.

16. Terminate the installation as specified. It is important to terminate the cable above ground level in a waterproof enclosure or with a waterproof connector. Protect the installation from construction traffic and mark its location.

5.3.2 Open (Un-cased) Boreholes.

When forming a borehole for instrument installation, it may not be necessary to use a temporary steel sleeve or ‘casing’ to hold the hole open during drilling and installation operations. These holes may be described as ’open holes’. The following describes a series of steps that could be adopted to carry out a piezometer installation in an open or uncased borehole. It is similar to, but simpler than, the procedure for the cased borehole (5.3.1)

1. Before drilling the hole it is important to ascertain the depth at which the piezometer is to be installed. An indication of the ground conditions may also be helpful.
2. The borehole should be formed to a suitable depth below the intended elevation of the piezometer tip. If a Bentonite plug is required at the base of the borehole, it will have to be drilled further to accommodate the plug.
3. Before commencement of installation the depth of the hole should be re-checked and the procedure you intend to follow should be confirmed with the engineer and discussed with the driller.
4. Confirm that all materials are available (filter sand, Bentonite pellets or balls and backfilling grout). The piezometer to be installed should be transported to the borehole locations in a container of clean water (see section 5.1.13).
5. Check the drill hole to ensure that the full depth is clear and free of obstructions.
6. CHECK the **FUNCTIONALITY** of the PIEZOMETER. If necessary, record a reading from the piezometer to confirm that it has not been damaged since establishing the **ZERO PRESSURE** readings (see Section 5.1)
7. Where necessary and possible, fill the borehole with clean water.
8. If a Bentonite plug is required at the base of the borehole, slowly drop Bentonite pellets / balls down the borehole. Be sure not to let the pellets / balls plug or stick to the inside of the borehole. Feeding pellets / balls in to the borehole too quickly will result in ‘bridging’ of the hole and make completion of the installation very difficult). The top of any base-plug must be below the intended piezometer installation elevation.
9. Once the plug has been formed (if required), filter sand should be slowly added to fill the borehole up to the depth at which the piezometer is to be installed. Use a weighted fibre tape to control the level of the filling materials.
10. With the filter securely fitted to the piezometer, lower it slowly down onto the sand at the base of the borehole and record another reading.
11. Add more clean filter sand on top of the piezometer to provide the required filter above the piezometer level. Continually check the level of the sand using the weighted tape.
12. Add a Bentonite seal of specified thickness. This should comprise Bentonite

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pellets / balls as described above for the base plug. Once borehole is sealed to the specified thickness, check piezometer readings again.

13. Fill the remaining void with grout as detailed in the Section 5.6.

14. The piezometer installation is now complete. In-situ piezometer readings should now be recorded. Since the piezometric balance may have been disturbed by the installation operations, a series of piezometer readings may have to be recorded so as to determine when the pressure balance has re-established. Only then can a true set of in-situ pore pressure readings be recorded.

15. Terminate the installation as specified. It is important to terminate the cable above ground level in a waterproof enclosure or with a waterproof connector. Protect the installation from construction traffic and mark its location with a highly visible stake.

5.3.3 Push-in Installations

Some installations require a Piezometer to be pushed into undisturbed material at the bottom of a borehole or pushed into soft ground from the surface. For this purpose, **Geosense**® produces a specially designed Push-in Piezometer. 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 piezometer body into the material at the base of the borehole or from ground level to its intended elevation.

<u>Only purpose built PUSH-IN piezometers can be used for this type of installation.</u>

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

Push-in adaptor for BSP pipe or CPT rods

Push-in adaptor for Drill Rods

There are two types of pushing adaptor to match the Push-in VW Piezometer supplied by **Geosense**®. Where drilling rods are to be used to push the piezometer only into the base of the borehole, it is suggested that the cable from the piezometer passes out from the side of the pushing adaptor and up outside the rods. This will make it easier to withdraw the rods once the installation has been finalised. Obviously, the piezometer cable must not be attached to the drilling rods as the installation is inserted into the borehole and care must be taken to protect the cable.

For pushing deeper into a borehole base, the cable must remain inside the rods to protect it, as with BSP tube or CPT rods.

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 piezometer and obtain the **ZERO PRESSURE** as described in Section 5.1 and transport it to the drilling location.

2. Base grouting need not be carried out since the intention is that the piezometer 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,

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the piezometer 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 piezometer dropping out of the shoe and to maintain control of the cable.

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

Never rotate the lower rods when adding further rods. This may cause the piezometer cable to become wrapped around the rods and will result in a failed installation due to either cable damage or pulling the piezometer back out of its intended location when the rods are extracted.

6. When the piezometer is just above the base of the borehole connect a portable readout to the piezometer cable to monitor any changes in the pressure registered by the piezometer, particularly when it is being pushed into the base.

7. If necessary, use hydraulic equipment (rig head or jacking ram) to apply gradual loading to the rods to push the piezometer to its intended elevation.

These pressures MUST NOT significantly exceed the maximum pressure shown on the calibration sheet. If it exceeds the calibrated values by more than 50%, irreparable damage to the piezometers <u>may</u> occur. The calibration and ZERO PRESSURE values would then be invalidated. The piezometer would not then provide any useful data.

8. No filter zone is required. Bentonite pellets can be used to provide a plug behind the piezometer, but generally the borehole would be backfilled with Bentonite / Cement grout once the rods have been extracted. When water is present in the borehole, grouting <u>must</u> be carried out from the bottom of the hole, upwards, using a tremie pipe. Where the borehole is dry, liquid grout can be placed from the top.

Where a Cone Penetrometer Testing Rig (CPT rig) is to be used to place the piezometers, it will be necessary to use a special adaptor shoe and to run the piezometer cable up <u>inside</u> 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. A pre-driven CPT hole with a 'lost' head can also be utilised to prevent pressure build up on the piezometer.

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

5.3.4 Borehole Installation (Fully Grouted Method)

This is an alternative method of installing either single or multiple piezometers in a single borehole. Rather than creating a filter pocket or pushing the tip into the parent material, the piezometer(s) would commonly supported on a PVC or Polyethylene pipe in a borehole. The borehole is then backfilled with a specially designed Cement & Bentonite liquid grout.

1. Drill the borehole below the required depth of the piezometer. Flush the borehole with water or biodegradable drilling mud, to remove drilling fluids and cuttings.

2. Prepare the piezometer by obtaining the **ZERO PRESSURE** reading as described in Section 5.1 and transport it to the drilling location.

3. Establish the elevation of the base of the borehole.

4. Piezometer(s) are commonly attached to a PVC or Polyethylene pipe to maintain their position in the borehole. This pipe can double as the Tremie pipe for placing the grout. They are also commonly installed in an inverted orientation, with their filters uppermost.

5. Measure along the support tube and mark the piezometer elevations with reference to the top of the borehole, remembering that the elevation of the Piezometer sensing element (diaphragm) is measured just behind the filter. Also consider that the tube will rest on or close to the base of the borehole if it not independently supported from the top.

6. Use strong tape to attach the piezometers to the tube. Also use tape to attach the cable(s) to the pipe, along its length. Fix the cable at regular intervals to prevent it tangling or snagging.

7. If the piezometer(s) are to be installed together with inclinometer casing, they can be attached to the casing.

8. Lower the piezometer assembly to its intended location, referring to the marks placed on the tubes. If a separate Tremie pipe is to be used to place the grout, it must be installed together with the piezometers and NOT afterwards.

9. The properties of the grout are very important for fully grouted piezometer installations. A suitable grout mix must be designed to closely replicate the properties of the surrounding materials (see section 5.6)

10. Back-fill the borehole with liquid grout. Use either of the grout mixtures detailed in Section 5.6 as a starting point for the grout mix. Add the cement to the water first, and then add the Bentonite. Adjust the amount of Bentonite to produce a grout that is 'just pumpable' mix (heavy cream consistency). If the grout is too thin, the solids and the water will separate. If the grout is too thick, it will be difficult to pump.

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11. Extreme care must be taken to ensure that the piezometer(s) remain supported and un-disturbed whilst any drill casing is removed and the grout reaches an initial set.

12. Readings taken immediately after installation will be high, but will decrease as the grout cures. Once it has cured, the response time lag caused by the grout itself is believed to be measured in minutes.

13. Terminate the installation as specified. It is important to terminate the cable(s) above ground level in a waterproof enclosure or with a waterproof connector.

14. Protect the installation from construction traffic and mark its location with a highly visible stake. Hydration of the grout may take time in low permeability soils and have an impact on the curing time.

5.3.5 Deep Borehole Installation

Significant challenges may be faced during the installation of deep piezometers which are defined as having a depth greater than 50m.

These installations create a range of challenges, the impact of which increases with depth.

These challenges include:-

- The positioning of the response zone
- Placing of the piezometer,
- Protection of the sensor and cable
- Backfilling of the borehole

All of these will have significant impacts on a successful installation.

For further information on Deep Piezometer Installations please request Knowledge Article LR18/08/2016 V1.0 from Geosense.

5.4 Installation Procedures - Trenches and Pockets

This type of installation is carried out where the intended piezometer position is accessible. Commonly this would be during the construction of a structure where the piezometer would form part of a future monitoring regime. Typically this might include embankments, culverts, cut & cover tunnels, dams, etc.

In materials that have a low permeability, no sand pocket should be included in the installation since this would lead to a reduced response time and may provide a trap for air which would render the piezometer less responsive.

In granular materials, where permeability is medium or high, a sand filter pocket can be formed around the piezometer tip.

In some installations, particularly where saturation of the piezometer location is due to occur after a long period (dams for example), the piezometer can be orientated so that its filter end is raised above the cable entry end. This will help to minimise the risk of air being trapped around the diaphragm when saturation occurs.

Alternatively, to maintain short term saturation (in highly permeable, tidal locations for example), piezometers can be installed with their filter downwards, in a small plastic container filled with saturated coarse sand. This will prevent water from draining away, thereby maintaining the tip in a saturated condition.

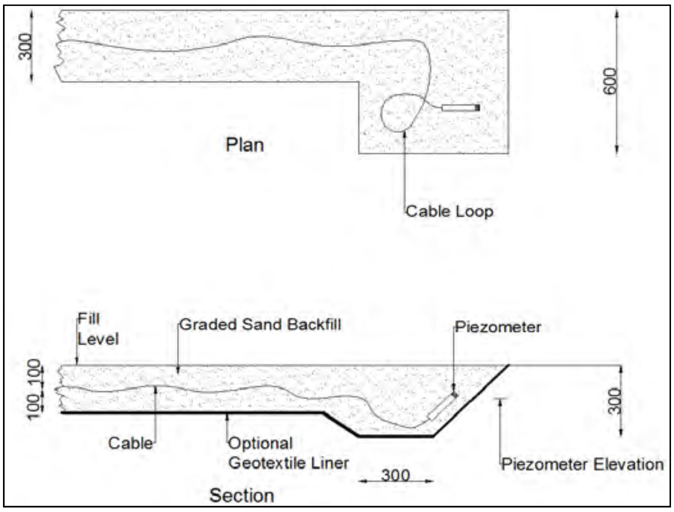
Once again, no two installations are the same but common practice in most materials involves excavating a small pit in the material in which the piezometer is to be installed. Once in position, the piezometer should be surrounded by the material in which it is being installed. This will ensure that its environment replicates, as closely as possible, the surrounding conditions.

Where piezometers have to be connected to extension cables, this would preferably be carried out prior to installation. In some cases, however, this may not be possible. Cables must be marked with identification prior to installation.

5.4.1 Permeable Materials

1. Once the cable route has been defined, excavate a trench (minimum 300mm deep) along the route from the piezometer installation location to the intended cable termination point. Where compaction of backfilled material is critical (dams for example), the trench should have sides raked at an angle of a minimum 45 degrees.

2. Create a small pocket



Piezometer in a pocket in a permeable material

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(minimum 300mm x 300mm x 300mm) into which the piezometer can be installed. Check the elevation of the pocket to ensure that the piezometer will be installed at the correct level.

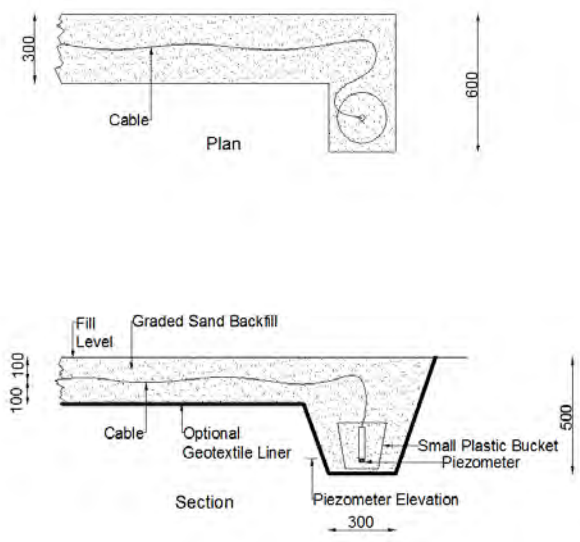
3. Having prepared the piezometer for installation and recorded its site Zero Pressure Reading (see Section 5.1), bring it to site for installation. Check the function of the piezometer using a portable readout.

4. Where the excavation is in a granular material, place a layer of Geotextile material in the base and up the walls of the excavation, then a 100mm layer of graded sand in the base of the trench and pocket.

5. Carefully remove the piezometer from the water filled container and place it in the sand pocket as shown.

6. Coil the cable in the pocket, to form a loop as shown. This helps to reduce the risk of cable damage due to excessive settlement or stretching.

7. Lay a section of the cable into the trench and backfill the pocket and trench with stone free sand as shown in the above sketch. It may help to pour some water over the sand to assist with compaction.



Piezometer in a pot in a permeable material

8. Complete the cable laying operation, snaking the cable in the trench only when particularly specified. (Laying the cable in a 'zig - zag' or 'snaking' pattern is sometimes specified with the intention of reducing the risk of cable breaks due to stretching. The preferred solution is to use a good quality cable without steel armouring, laid without snaking).

9. Backfill the trench with sand, ensuring it is free from stones or any material that could damage the cables.

10. Before resuming any further filling operations, check the function of the piezometer using a portable readout.

11. Add the excavated fill over the sand to complete the backfilling and compact with mechanical plant.

5.4.1 Impermeable Material

1. Once the cable route has been defined, excavate a trench (minimum 300mm deep) along the route from the piezometer installation location to the intended cable termination point. Where compaction of backfilled material is critical, the trench should have sides raked at an angle of a minimum 45 degrees.

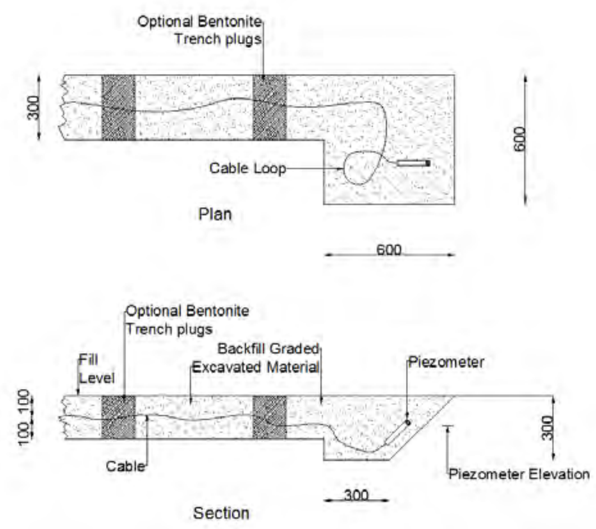
2. Place a minimum 100mm thick layer of graded backfill in the base of the trench. The backfill should be similar to the excavated material, graded to remove any stones or objects that may damage the cable. The backfill material must have a low permeability.

3. Create a small pocket (minimum 300mm x 300mm x 300mm) into which the piezometer can be installed. Check the elevation of the pocket to ensure that the piezometer will be installed at the correct level. See sketches for level details.

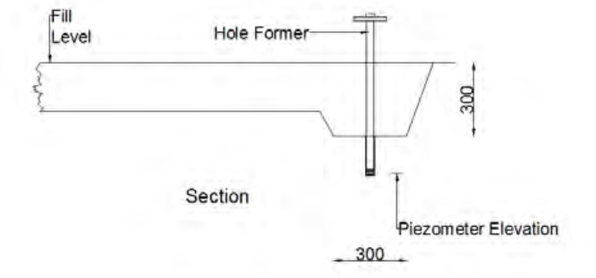
4. Place a 100mm layer of graded backfill in the base of the pocket.

5. The piezometer can be either placed in the pocket and surrounded with selected, stone-free fill material or it can be pushed into a pre-formed socket in the base of the pocket.

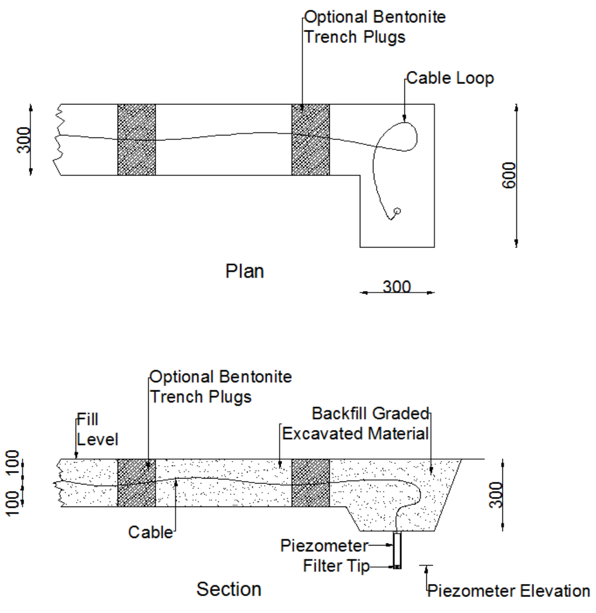
6. To form a socket, make or obtain a 'mandrel'. This should be the same diameter as the piezometer and the socket is generally formed so that the whole piezometer body can slide into it.



Piezometer in a pocket in an impervious material



Forming hole for Piezometer in impervious material



Piezometer pushed into an impervious material

7. Having prepared the piezometer for installation and recorded its site Zero Pressure Reading (see Section 5.1), bring it to site for installation in a water filled container. Check the function of the piezometer prior to its installation, using a portable readout.

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8. Carefully remove the piezometer from the water filled container and place it in the pocket or into the socket, as shown in the sketches.

9. Coil the cable near the piezometer, forming a loop as shown.

10. Lay a section of the cable into the trench and backfill the pocket and trench with graded material as shown in the sketch. Carefully compact the material around the piezometer by hand, and using **only** light hand held machines around the cable.

11. Complete the cable laying operation, snaking the cable in the trench only where specified, and backfill the trench with graded material, compacting it in layers to ensure an adequate seal.

12. Before resuming any further filling operations, check the function of the piezometer using the portable readout.

13. Bentonite can be used to provide additional sealing material. Either Bentonite powder can be mixed into all the backfill material used in the impervious zones or pellets / balls of partially saturated Bentonite can be used to form plugs at intervals along the cable route (see sketch).

14. Extension cables should be marked / coded at regular intervals so that, in the event of damage, they could possibly be traced and re-connected.

5.5 Installation Procedures - Observation Wells or as Water Level Transducer

Vibrating Wire Piezometers can be installed in Observation Wells or Standpipe Piezometers to monitor water levels.

It must be remembered that the standard piezometer is a sealed unit and is, therefore, sensitive to pressure changes only on one side of its diaphragm. When installed in a well that is open to atmosphere, the piezometer reading WILL BE affected by changes in atmospheric pressure in addition to any changes in water level.

When an accuracy better than ±100 mm head of water is required, the piezometer readings must be adjusted for changes in atmospheric pressure. Atmospheric pressure could be monitored by an on-site recording barometer or by a low pressure range VW Transducer that is dedicated to monitoring atmospheric pressure.

Alternatively, special ’vented’ VW Piezometers are available. In these instruments, the rear of the diaphragm is ‘vented’ to atmospheric pressure by a fine tube included in a special cable. This removes the need for barometric compensation as both sides of the diaphragm are affected by changes equally. These are often employed where only small pressures changes are expected or water level monitoring (reservoirs etc.)

For shallow installations it is acceptable to suspend the piezometers on their connecting cables. For deeper installations, it is recommended that they be supported on stainless steel suspension cables.

Installation

1. Carry out all pre-installation checks and record the site Zero Pressure reading (s) as described in Section 5.1 of this manual.

2. Measure and mark the cable to indicate the level at which the piezometer should be installed. It should be located either at a specified depth or just below the minimum expected ’Low Water’ level.

3. If turbulence is expected in the well, fit a perforated centraliser to keep the piezometer stable inside the well tube.

4. Lower the piezometer into the well and secure the signal cable or suspension cable at the top so as to maintain the piezometer in position.

5. Terminate the piezometer installation as required. It is important to terminate the cable above ground level in a waterproof enclosure or with a waterproof connector. Protect the installation from construction traffic and mark its location with a highly visible stake.

6. Vented piezometer cable is usually terminated close to the top of the installation using a special vented terminal / junction box.

5.6 GROUTING

Backfilling of boreholes and other excavations for piezometer installation often calls for the preparation and installation of a grout.

Grout should be mixed in a purpose designed grout mixer so as to ensure a complete mix. However, and only as a last resort, grout can be mixed in a large container using a high volume pump for circulating, mixing and placing the liquid.

The grout is used as either a sealing compound, a void filling material, or as a combination of both. Commonly the components and proportions of the mixture are designed to reflect the characteristics of the material into which it is to be placed. Where a specific design is not required, generalisations can be made with regard to the mix proportions.

Since the materials also vary from batch to batch, it is important to use representative samples of the material that will be used on site, when preparing samples for lab testing and mix design.

Where the grout is to be used to backfill for a borehole, the commonly adopted mix proportions, by weight, would be :-

Grout Mix for Hard and Medium Soils (incl Fully Grouted Method)		
Materials	Weight	Ratio by Weight
Portland cement	50 Kg (2 bags)	1
Bentonite	15 Kg	0.33
Water	125 Litres	2.5
Grout Mix for Soft Soils		
Materials	Weight	Ratio by Weight
Portland cement	50 Kg (2 bags)	1
Bentonite	20 Kg (as required)	0.4
Water	325 Litres	6.5

Bentonite quantities can be adjusted to make the mix ‘Just Pumpable’

Other compounds can be added to the grout mixture to alter its characteristics:-

- Expanding agents are added to introduce small bubbles into a cement and water mix as it cures to prevent it from shrinking.
- Plasticisers can be added to a mixture to allow it to flow more freely through small bore pipe work.
- Fillers are added to provide weight and / or bulk to the mixture for use where grout may have a tendency to flow through the borehole walls.

6.0 DATA HANDLING

The function of an 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.

6.1 Monitoring the Piezometer Readings

Geosense® Vibrating Wire Piezometers include both pressure and temperature sensors. Where a piezometer is installed in a zone where its temperature is likely to fluctuate significantly, records of both pressure and temperature data should be recorded. This data can then be used to assess any temperature effects on the pressure readings.

6.1.1 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 **Geosense® VWR1** 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. Commonly these are:

RED	=	VW +
BLACK	=	VW -
GREEN	=	Temp
WHITE	=	Temp

2. Press the 'On/Off' button to switch the unit on. Press it again to acquire a reading from the connected instrument.

3. The readout displays the Vibrating Wire readings in both 'Frequency' (in Hz) and Linear 'B' Digits (in $Hz^2/1000$). Temperature reading in both resistance (Ohms) and degrees C.

   For more details see the readout manual.

4. Press and hold down the On/Off' button to switch the unit off.

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

6.1.2 Data Loggers

A number of data loggers are available to automatically excite, interrogate and record

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the reading from Vibrating Wire instruments. These include the GeoLogger G8 Plus, GeoLogger Linx and equipment manufactured by Campbell Scientific Ltd.

6.2 Data Reduction

Overview

Readings from a Vibrating Wire Piezometer are in a form that is a function of frequency, rather than in units of pressure. Commonly the units would be either **Frequency** - Hz, **Linear B Digits** - $Hz^2/1000$ or $Hz^2/1000000$ or, less commonly, **Period** - Time - (Seconds $x10^{-2}$ or $x10^{-7}$). **Linear B Digits** are required for all calculations.

To convert the readings to units of pressure some calculation is required. Calibration factors must be applied to the recorded values. For most Vibrating Wire sensors, these factors are unique and are detailed on the individual sensor calibration sheets. A unique calibration sheet is supplied with every **Geosense®** Vibrating Wire Piezometer.

If the readout displays 'Frequency' values, (e.g. 2768.5 Hz) only a simple calculation is required to convert the readings to Linear Digits.

$$\text{Linear Digits } (Hz^2/1000) = (2768.5)^2 / 1000 = 7664.6$$

Certain data loggers store their Vibrating Wire data in Linear Digits but further divided by 1000. In this case the data would have to be multiplied by a further 1000 to maintain the standard Linear Digits ($Hz^2/1000$) format for standard calculations.

If the readout display is in the less common, Period units (e.g. 0.03612 or 3612 - depending upon the readout used), the first step to producing an engineering value is to convert the reading to Linear Digits ($Hz^2/1000$). Two examples of this calculation can be seen on the next page. The first (1) where the readout includes a decimal point and displays the Period in ***Seconds x*** 10^{-2} and the second (2) where the readout displays the Period in ***Seconds x*** 10^{-7}

(1) Readout Display = 0.03612

$$\text{Linear Digits } (Hz^2/1000) = (1 / 0.03612 \times 10^{-2})^2 / 1000 = 7664.8$$

(2) Readout Display = 3612

$$\text{Linear Digits } (Hz^2/1000) = (1 / 3612 \times 10^{-7})^2 / 1000 = 7664.8$$

There are a number of ways to achieve the conversion from recorded 'RAW' data to useful engineering values. The following are included as a guide only and as a basis for alternative approaches.

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Linear Calculation

This is the most simple calculation to convert 'raw' data to engineering units. It can be easily carried out using a simple calculator. It assumes that the reading is in Linear Digits ($Hz^2/1000$). Where this is not the case, the reading should be converted to these units prior to application of the calibration factors. For most applications this equation is perfectly adequate and is carried out as follows:

Pressure (kPa) = Linear Factor (k) for kPa x (Current Reading - Zero Pressure Reading)

Polynomial Calculation

The polynomial calculation can be more precise as it accommodates any slight deviation from a perfect linear correlation. However, to use the polynomial equation, the "C" Constant for the site must be calculated using a "Site Zero" Reading.

Once the Site "C" Constant is established the polynomial formula can be used to convert Raw Data to Engineering Units.

Eng. Value = (A x Reading^2) + (B x Reading) + Site 'C'

Where ***Site 'C' = (-A x Site Zero^2) - (B x Site Zero)***

Therefore ***Eng. Value = (A x Reading^2) + (B x Reading) + (-A x Site Zero)^2) - (B x Site Zero)***

The above formula essentially gives the relative change in the variable being measured.

Where the Pressure is required in an alternative format, mH_2O for example, a simple conversion using standard conversion factors can be applied to each factor or at the end of the equation. (1 psi = 0.7031 mH_2O for example).

An instrument calibration sheet similar to the example in the Section 9 of this manual includes the following information:

Model	This refers to the Geosense model number.
Serial Number	This is a unique sensor identification number that can be found on the cable just behind the piezometer body and, for long cables, at the end of the cable.
Works ID	Unique works batch and range code
Cal Date	Date the calibration was performed
Baro	Barometric Pressure at the time of calibration
Temp °C	Temperature at which the piezometer was calibrated
DPI SN	Serial number of the Digital Pressure Indicator used in conjunction with the pressure generator
Readout No.	Serial Number of the readout used to display the transducer output
R/O Cal Date	The date on which the Readout was calibrated to a traceable standard

(Continued on page 39)

(Continued from page 38)

Applied Pressure	Pressure applied to the transducer as part of the calibration cycle in both psi and kPa
Readings [digit]	Readings from the transducer as pressure is applied and as pressure is reduced, in steps. The average is calculated.
Calculated Pressure	Calculation of the applied pressure using the calculated Linear and Polynomial for comparison with the actual Applied Pressure.
Error % fso	Non Linearity expressed as a percentage of the transducers Full Scale.
Calibration Factors	'Linear' and 'Polynomial' factors are provided for a selection of engineering units (other units can be calculated directly from the kPa values). Examples of calculated values are detailed below.

The following are examples of data reduction calculations and are based upon the piezometer to which the attached example calibration sheet refers.

A. An example of the calculation from Frequency units (Hz) to Metres of Water (mH_2O) using a Linear equation is given below:-

Site Zero Reading in Hz = 3102
Site Zero Reading in Linear Digits = 9622.4 (calculated)

Calibration Factor for mH_2O (K) = - 0.008953

Current Reading in Hz = 2955.1
Current Reading in Linear Digits = 8732.6 (calculated)

Equation

Water Pressure mH_2O = K x (Current Reading - Zero Reading)
Water Pressure mH_2O = -0.008953 x (8732.6 - 9622.5)
Water Pressure mH_2O = 7.967m

B. An example of the calculation from Linear Digits ($Hz^2/1000$) to kPa using a Polynomial equation is given below:-

Calibration Factors for kPa A = - 5.23752 $^{-7}$
B = - 0.079754701

Site C = (- (-5.23752x 10^{-7} x 9622.5^2) - (- 0.079754701 x 9622.5)
C = -815.927

Current Reading in Linear Digits = 8732.6

Equation

Pressure in kPa = [A x (Reading $)^2$] + [B x Reading] + Site C

= [- 5.23752x10^{-7} x $(8732.6)^2$] + [- 0.079754701 x 8732.6] + 815.927
= - 39.940 - 696.466 + 815.927

(Continued on page 40)

(Continued from page 39)

Pressure in kPa = 79.521 kPa

Barometric Pressure Considerations

In some locations, barometric pressure varies only a little, except when there are storms. In other locations, normal weather may bring barometric pressure changes as large as 35 mb (0.35 mH_2O) during a day, and 70 mb (0.70 mH_2O) during a year.

If a piezometer is sealed into a borehole to measure pore-water pressure, the only pressure acting on the piezometer’s diaphragm is the water pressure at that depth, and a barometric correction need not be applied. Even if it is later found that there is a relationship between barometric pressure and pore-water pressure, it will probably not be necessary to apply any correction as any influence will be negligible.

If the piezometer is measuring the water level in a standpipe or well that is open to atmosphere, the pressure measured by the piezometer is the combined pressure of water and the air above the surface of the water. If the barometric pressure drops, the piezometer will show a decreased pressure, even if the water level remains unchanged. To eliminate the measurement uncertainty introduced by changes in barometric pressure, a correction can be applied.

Either a special barometric transducer or an additional low pressure VW Transducer can be used to measure atmospheric pressure. The following is an example of how to carry out the correction using data from a special barometric transducer or other weather station information:-

1. Obtain barometric pressure readings on site at the time of reading the piezometer. Ideally the barometer should provide the actual pressure of the atmosphere at the location of the monitoring site. Off-site reports from weather stations can also be adequate for this purpose since it is only the relative change in pressure that will be used to calculate the effect. The same source of pressure that was noted when the piezometer zero values recorded must be used for all subsequent readings.

2. Subtract the barometer reading obtained when the site zero value was recorded, from current barometer reading in millibars. This is the barometric pressure correction value.

3. Convert the barometric correction value to the engineering units being used for the piezometer data, by multiplying it by the applicable factor (for example:- 0.1 for kPa, 0.014504 for psi or 0.0101972 for mH_2O)

4. Add the barometric correction, in engineering units, to the pressure reading, remembering that the compensation could be positive or negative.

Example

Zero Reading in Linear Digits	9555.5
Atmospheric Pressure when Zero recorded	1022mb
Current Reading in Linear Digits	9244.3

(Continued on page 41)

(Continued from page 40)

Current Atmospheric Pressure		1007mb
Calculated water pressure in mH_2O (see prev. section)		5.651m
Change in Atmos Pressure (Current - Zero)	=	1007 - 1022 mb
	=	- 15 mb
Convert mb change to mH_2O (15 x 0.0101972)	=	$-0.153mH_2O$
Compensate for pressure change (5.651-(- 0.153)) (*Calculated H2O - (Change in Atmospheric Pressure)*)	=	**$5.498mH_2O$**

Where a low pressure piezometer is used to measure the barometric pressure, the atmospheric pressure data can be recorded in the same units as the other piezometers, making compensation a simple addition of the difference (positive or negative).

Temperature Considerations

Where the piezometer is sealed in a borehole or buried in fill, there is usually little variation in temperature, so temperature effects will be small and corrections will not be necessary.

However, if a low range piezometer is suspended in a shallow standpipe or well, it may be affected by seasonal changes in the temperature of the water. In this instance, temperature corrections could become more important.

Thermal influences on Piezometer readings are complex. A Thermal Factor is provided on the Calibration sheet but this relates purely to the ‘sensor’.

Therefore, in order to accurately correct for in-situ temperature changes, it is first necessary to establish the effects of temperature changes on a particular piezometer and the medium in which it is installed. (It must be remembered that the density of water also changes with temperature).

To establish the true affects of temperature changes, it is necessary to accurately verify the head acting on a particular piezometer using alternative means. It is necessary to record both the water pressure from the piezometer, the piezometer temperature and the true water depth over the piezometer diaphragm. Over a full annual cycle, both the seasonal and daily thermal affects can be computed from these data.

Mathematical corrections would be carried out using a similar principle as for Barometric Pressure.

7.0 MAINTENANCE

The Vibrating Wire piezometer is a maintenance free device for most applications. This is because it is intended for sub-surface installation and would normally be irretrievably sealed into boreholes or fill materials.

(Continued on page 42)

However, when the piezometer is installed in a location where a flow of water moves past it and it can be recovered, a check should be made to determine the condition of the filter. If any crystalline chemical deposits or algae are present on or in the filter, it could affect the performance of the filter and, therefore, the piezometer.

It may be necessary to determine the nature of any build up, so that a suitable chemical compound can be sourced to dissolve the build up, without damaging the stainless steel of the body, filter and diaphragm. The body and sintered filter are fabricated from Grade 316 stainless steel, the white coloured filter (HAE) is a ceramic material and the pressure sensing diaphragm is Grade 17/4 stainless steel. There are also a Nitrile rubber 'O' rings sealing the diaphragm and the stainless steel body.

It would only be necessary to resort to dissolving any build-up if it either blocked the filter or there was any sign of build up on the surface of the diaphragm.

Maintenance of wiring connections between the piezometer and any terminal panels / or loggers should involve occasional tightening of any screw terminals to prevent loose connections or cleaning to prevent the build up of corrosion.

On vented style piezometers the desiccant material in the moisture trap changes colour as it absorbs moisture within the system. Although the sensor is made completely from stainless steel this still helps to protect the sensor from saturation/ corrosion etc. The material when new is orange in colour but changes to green as it maximises its moisture content. At this point the material should be replaced as soon as practicably possible to allow the product to continue working to its full capacity. The lifespan of the material is site condition specific and cannot be advised so regular periodic inspections are recommended to identify when the material needs replacing.

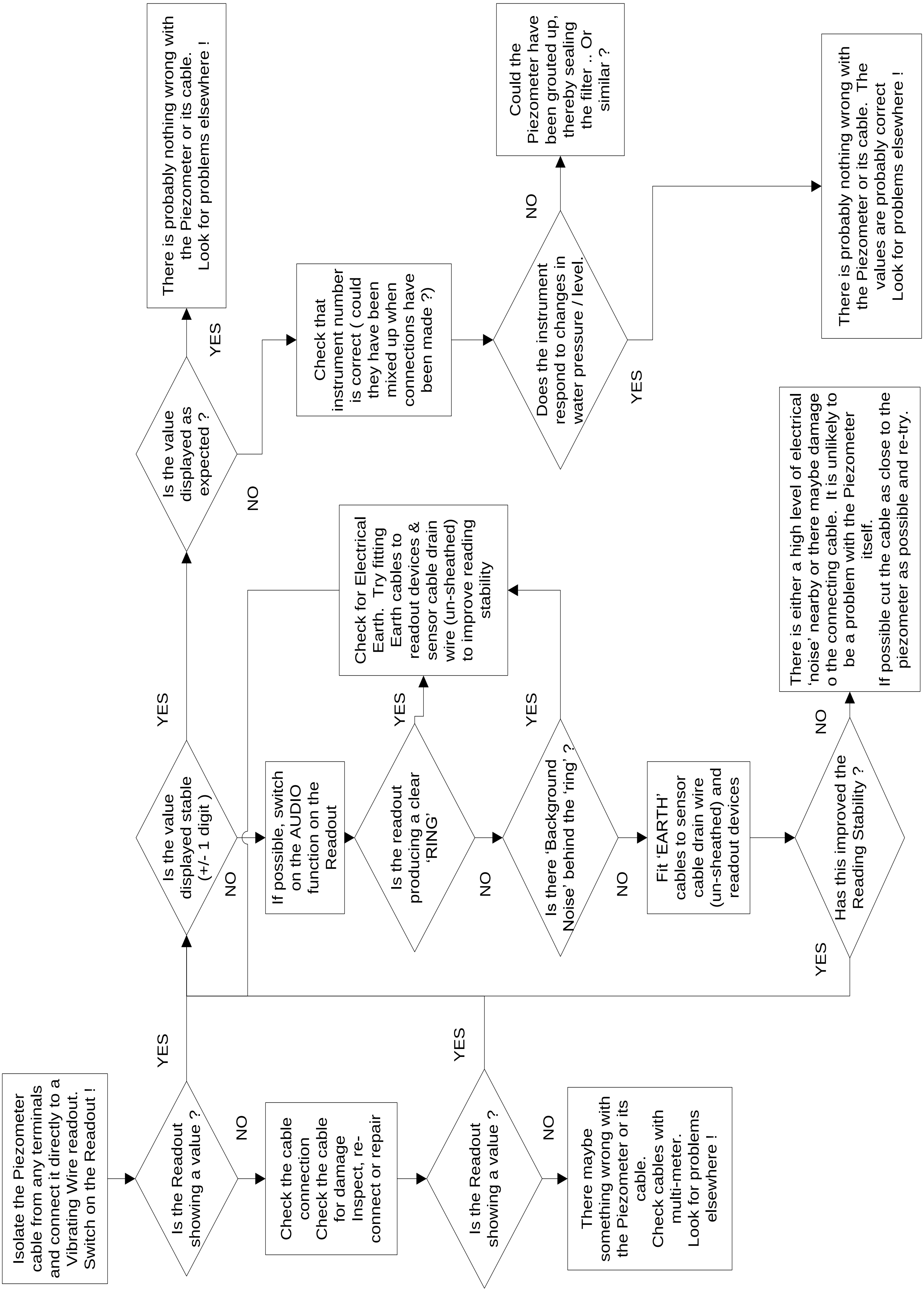
8.0 TROUBLESHOOTING

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.

A fault finding flow diagram is included on the next page, to help with troubleshooting.

A diagnostic resistance check routine is also included to help identify problems with cables.

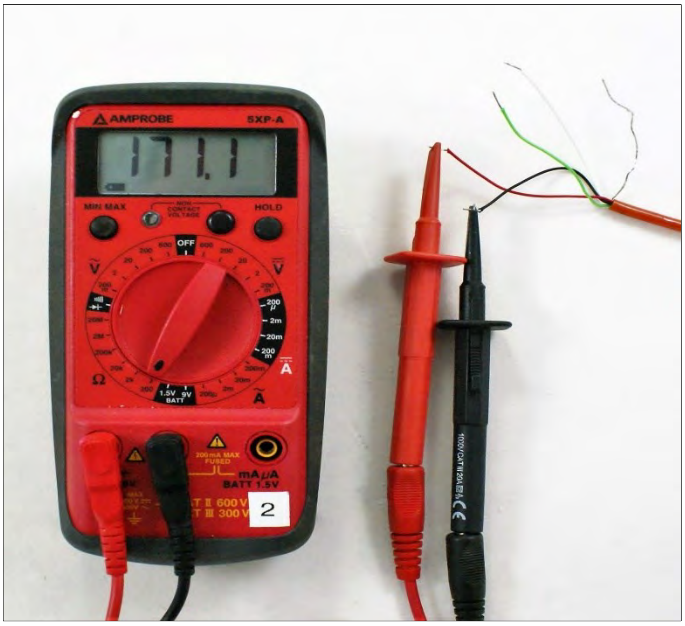

Isolate the Piezometer cable from any terminals and connect it directly to a Vibrating Wire readout. Switch on the Readout !
Is the Readout showing a value ?
YES
NO
Check the cable connection
Check the cable for damage
Inspect, re-connect or repair
Is the Readout showing a value ?
YES
NO
There maybe something wrong with the Piezometer or its cable.
Check cables with multi-meter.
Look for problems elsewhere !
Is the value displayed stable (+/- 1 digit)
YES
NO
If possible, switch on the AUDIO function on the Readout
Is the readout producing a clear 'RING'
YES
NO
Check for Electrical Earth. Try fitting Earth cables to readout devices & sensor cable drain wire (un-sheathed) to improve reading stability
Is there 'Background Noise' behind the 'ring' ?
YES
NO
Fit 'EARTH' cables to sensor cable drain wire (un-sheathed) and readout devices
Has this improved the Reading Stability ?
YES
NO
There is either a high level of electrical 'noise' nearby or there maybe damage o the connecting cable. It is unlikely to be a problem with the Piezometer itself.
If possible cut the cable as close to the piezometer as possible and re-try.
Is the value displayed as expected ?
YES
NO
There is probably nothing wrong with the Piezometer or its cable. Look for problems elsewhere !
Check that instrument number is correct (could they have been mixed up when connections have been made ?)
Does the instrument respond to changes in water pressure / level.
YES
NO
Could the Piezometer have been grouted up, thereby sealing the filter .. Or similar ?
There is probably nothing wrong with the Piezometer or its cable. The values are probably correct
Look for problems elsewhere !

8.0 TROUBLESHOOTING contd…

RESISTANCE DIAGNOSTICS

Where damage to a sensor or cable is suspected this guide illustrates the way in which simple resistance checks can be taken to identify the possible cause of the problem.

Resistance checks can be made with most types of multi-meter which are readily available in the market.



RESISTANCE OF THE COILS

STEP 1

Set the range to 200Ω (or Ω if using a multi-meter which has automatic ranging).

STEP 2

Connect the VW+ (red) conductor to the red lead on the multi-meter and the VW- (black) to the black lead on the multi-meter.

The correct readings should be as follows ±10%

Pressure Transducer	~ 160Ω
Strain gauge	~ 180Ω
Load Cell / Sister Bar / Miniature Strain gauge	~ 50Ω

IF THE VALUES ARE OUT OF THESE RANGES THEN THERE IS A FAULT IN THE CABLE OR (Less Likely) THE COILS

8.0 TROUBLESHOOTING contd…

RESISTANCE OF THE THERMISTOR

STEP 1

Set the range to 20kΩ (or Ω if using a multi-meter which has automatic ranging).

STEP 2

Connect the T+ (green) conductor to the red lead on the multi-meter and the T- (white) to the black lead on the multi-meter.

The readings will be dependent on the temperature as below:-

10°C ~ 5.971kΩ (5971Ω)
15°C ~ 4.714kΩ (4714Ω)
20°C ~ 3.478kΩ (3478Ω)
25°C ~ 3.000kΩ (3000Ω)

PLEASE REFER TO THE THERMISTOR LOOK UP TABLE ON THE NEXT PAGE

IF THESE VALUES DIFFER THEN THERE IS A PROBLEM WITH THE THERMISTOR OR IT’S CONNECTING CABLE

8.0 TROUBLESHOOTING contd…

Thermistor Linearization

USING STEINHART & HART LOG

Thermistor Type: 3K @25°C

Resistance/ temperature equation:-

$$T = (1 / (A + B (LnR) + C(LnR)^3)) - 273.2$$

Where:-

T = Temperature in degrees Centigrade
LnR= Natural log of Thermistor resistance.
$A = 1.4051 * 10^{-3}$
$B = 2.369 * 10^{-4}$
$C = 1.019 * 10^{-7}$

Resistance versus temperature table

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
201.1K	-50	16.60K	-10	2417	30	525.4	70	153.2	110
187.3K	-49	15.72K	-9	2317	31	507.8	71	149.0	111
174.5K	-48	14.90K	-8	2221	32	490.9	72	145.0	112
162.7K	-47	14.12K	-7	2130	33	474.7	73	141.1	113
151.7K	-46	13.39K	-6	2042	34	459.0	74	137.2	114
141.6K	-45	12.70K	-5	1959	35	444.0	75	133.6	115
132.2K	-44	12.05K	-4	1880	36	429.5	76	130.0	116
123.5K	-43	11.44K	-3	1805	37	415.6	77	126.5	117
115.4K	-42	10.86K	-2	1733	38	402.2	78	123.2	118
107.9K	-41	10.31K	-1	1664	39	389.3	79	119.9	119
101.0K	-40	9796	0	1598	40	376.9	80	116.8	120
94.48K	-39	9310	1	1535	41	364.9	81	113.8	121
88.46K	-38	8851	2	1475	42	353.4	82	110.8	122
82.87K	-37	8417	3	1418	43	342.2	83	107.9	123
77.66K	-36	8006	4	1363	44	331.5	84	105.2	124
72.81K	-35	7618	5	1310	45	321.2	85	102.5	125
68.30K	-34	7252	6	1260	46	311.3	86	99.9	126
64.09K	-33	6905	7	1212	47	301.7	87	97.3	127
60.17K	-32	6576	8	1167	48	292.4	88	94.9	128
56.51K	-31	6265	9	1123	49	283.5	89	92.5	129
53.10K	-30	5971	10	1081	50	274.9	90	90.2	130
49.91K	-29	5692	11	1040	51	266.6	91	87.9	131
46.94K	-28	5427	12	1002	52	258.6	92	85.7	132
44.16K	-27	5177	13	965.0	53	250.9	93	83.6	133
41.56K	-26	4939	14	929.6	54	243.4	94	81.6	134
39.13K	-25	4714	15	895.8	55	236.2	95	79.6	135
36.86K	-24	4500	16	863.3	56	229.3	96	77.6	136
34.73K	-23	4297	17	832.2	57	222.6	97	75.8	137
32.74K	-22	4105	18	802.3	58	216.1	98	73.9	138
30.87K	-21	3922	19	773.7	59	209.8	99	72.2	139
29.13K	-20	3748	20	746.3	60	203.8	100	70.4	140
27.49K	-19	3583	21	719.9	61	197.9	101	68.8	141
25.95K	-18	3426	22	694.7	62	192.2	102	67.1	142
24.51K	-17	3277	23	670.4	63	186.8	103	65.5	143
23.16K	-16	3135	24	647.1	64	181.5	104	64.0	144
21.89K	-15	3000	25	624.7	65	176.4	105	62.5	145
20.70K	-14	2872	26	603.3	66	171.4	106	61.1	146
19.58K	-13	2750	27	582.6	67	166.7	107	59.6	147
18.52K	-12	2633	28	562.8	68	162.0	108	58.3	148
17.53K	-11	2523	29	543.7	69	157.6	109	56.8	149

8.0 TROUBLESHOOTING contd…

RESISTANCE OF ALL INDIVIDUAL CONDUCTORS

STEP 1

Set the range to 20kΩ or Ω if using a multi-meter which has automatic ranging.

STEP 2

Both pairs of conductors should be checked by connecting them to the red and black leads on the multi-meter as follows:-

Red to Red / Black to Black

Red to Green / Black to White

A value of approximately 0.2 kΩ is expected for the Red / Black pair

A value of between 1 and 10 kΩ is expected for the Green / White pair

A value of O.L (open loop) means that there is a high / infinite resistance and therefore it is likely that the cable or a joint has been cut / disconnected / damaged.

A value of close to 0 (short circuit) means that there is a very low resistance and therefore it is likely that the cable or a joint has been shorted / damaged.

If one of the above pairs is OK, check each individual conductor against the earth drain wire (as shown above)

9.0 SPECIFICATION

TYPE	DESCRIPTION	PRESSURE RANGE	OVER RANGE PRESSURE[1]	RESOLUTION	ACCURACY	NON-LINEARITY	CALIB TEMP RANGE	THERMAL EFFECT	DIAMETER X LENGTH	WEIGHT
VWP-3000	Standard LAE	345, 518, 690 kPa 1,2,3.5 MPa	1.5	0.025% FS	± 0.1% FS	< 0.5% FS	-20 to + 80°C	< 0.05% FS/°C	20 x 178mm	240g
VWP-3001	Standard HAE	345, 518, 690 kPa 1,2,3.5 MPa	1.5	0.025% FS	± 0.1% FS	< 0.5% FS	-20 to + 80°C	< 0.05% FS/°C	20 x 178mm	240g
VWP-3310	Standard Vented LAE	345, 518, 690 kPa 1,2,3.5 MPa	1.5	0.025% FS	± 0.1% FS	< 0.5% FS	-20 to + 80°C	< 0.05% FS/°C	20 x 178mm	240g
VWP3311	Standard Vented HAE	345, 518, 690 kPa 1,2,3.5 MPa	1.5	0.025% FS	± 0.1% FS	< 0.5% FS	-20 to + 80°C	< 0.05% FS/°C	20 x 178mm	240g
VWP-3100	Heavy Duty LAE	345, 518, 690 kPa 1,2,3.5 MPa	1.5	0.025% FS	± 0.1% FS	< 0.5% FS	-20 to + 80°C	< 0.05% FS/°C	25 x 182mm	500g
VWP-3101	Heavy Duty HAE	345, 518, 690 kPa 1,2,3.5 MPa	1.5	0.025% FS	± 0.1% FS	< 0.5% FS	-20 to + 80°C	< 0.05% FS/°C	25 x 182mm	500g
VWP-3200	Low Pressure LAE	70, 173 kPa	1.5	0.025% FS	± 0.1% FS	< 0.5% FS	-20 to + 80°C	< 0.05% FS/°C	32 x 179mm	600g
VWP-3201	Low Pressure HAE	70, 173 kPa	1.5	0.025% FS	± 0.1% FS	< 0.5% FS	-20 to + 80°C	< 0.05% FS/°C	32 x 179mm	600g
VWP-3300	Low Pressure Vented LAE	70, 173 kPa	1.5	0.025% FS	± 0.1% FS	< 0.5% FS	-20 to + 80°C	< 0.05% FS/°C	32 x 179mm	600g
VWP-3301	Low Pressure HAE	70, 173 kPa	1.5	0.025% FS	± 0.1% FS	< 0.5% FS	-20 to + 80°C	< 0.05% FS/°C	32 x 179mm	600g
VWP-3400	Drive-in LAE SPT	345, 518, 690 kPa 1,2,3.5 MPa	1.5	0.025% FS	± 0.1% FS	< 0.5% FS	-20 to + 80°C	< 0.05% FS/°C	35 x 200mm	500g
VWP-3401	Drive-in LAE 1" BSPM	345, 518, 690 kPa 1,2,3.5 MPa	1.5	0.025% FS	± 0.1% FS	< 0.5% FS	-20 to + 80°C	< 0.05% FS/°C	35 x 200mm	550g

[1]The maximum pressure that may be applied continuously without causing damage and maintaining set point repeatability

[2] < 0.1% FS available on request

DESCRIPTION	
Materials	Stainless steel
Operating temperature	0 to + 70°C
Over voltage protection	90V plasma arrester
Thermistor	3k Ohms @ 25°C
Frequency range	1850—3500 Hz

** When the temperature has stabilised to remove any thermal gradients across the sensor.

GEOSENSE QUALITY FORM	
FORM No G/QF/149	
ISS.	7
DATE :	Jan-16
SIG.	GC

STANDARD VW PIEZOMETER LAE CALIBRATION

Model	VWP-3000	Cal date	27/10/2016	SN.	8233
Serial	339813	Baro	1020.7	Readout No.	2108
Works ID	87 9 335	Temp °C	20	R/O Cal. date	18/04/2016

Applied pressure		Readings [digit]			Calculated Pressure		Error % fso	
psi	kPa	1 up	1 down	avg.[digit]	lin.[kPa]	polyn.[kPa]	linear	polynomial
0.000	0.000	9638.7	9643.3	9641.0	1.15	0.09	0.33%	0.02%
10.007	69.000	8870.0	8873.3	8871.6	68.70	68.91	-0.09%	-0.03%
20.015	138.000	8092.3	8094.6	8093.5	137.02	137.88	-0.28%	-0.03%
30.022	207.000	7304.9	7306.8	7305.9	206.17	207.05	-0.24%	0.01%
40.029	276.000	6510.9	6511.3	6511.1	275.95	276.19	-0.02%	0.05%
50.036	345.000	5713.5	5714.1	5713.8	345.95	344.89	0.28%	-0.03%

Calibration of Fluke Pressure Controller PPC4EX S/N: 8233 valid from 9th March 2016. Certificate of Calibration No 4160291, issued by Minerva Metrology and Calibration (ILAC RVA No K048)

CALIBRATION FACTORS

Linear factor (k)

kPa per digit	psi per digit	mH_2O per digit
-0.087797132	-0.012733	-0.008953

Polynomial factors

	kPa	psi	mH_2O
A	-5.23752E-07	-7.59611E-08	-5.3408E-08
B	-0.079754701	-0.011567	-0.008133
C			

Thermal factor (T)

kPa per °C	psi per °C	mH_2O per °C
0.004893097	0.000709659	0.000499

Note: Digits are $Hz^2 \times 10^{-3}$ units.

(please consult the User Manuals for conversion of alternative reading units)

Polynomial calculation [kPa] = A * (Reading)^2 + B * (Reading) + C + T * (Current Temp - Site Zero Temp)

C = -A*(Site Zero Reading^2) - B*(Site Zero Reading)

Linear calc = k (kPa) * (Current Reading - Site Zero Reading) + T * (Current Temp - Site Zero Temp)

THIS CERTIFICATE IS VALID ONLY WHEN CARRYING THE OFFICIAL ORIGINAL STAMP OF GEOSENSE BELOW

10.0 SPARE PARTS

As a Vibrating Wire Piezometer is a sealed unit, it is neither serviceable nor does it contain any replaceable parts.

Replacement filter units are available as follows:-

Part number	Description
VWT-300101	LAE (Low Air Entry) Stainless Steel filter assembly
VWT-300102	HAE (High Air Entry) Ceramic filter assembly.

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 prices and availability of the above components.

11.0 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.

11.2 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.

11.3 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 Piezometer 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.

11.4 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, **Geosense®** should be contacted for advice. **Geosense®** will not be responsible for damage resulting from inadequate returns packaging or contamination under any circumstances.

11.5 Transport & Storage

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

12.0 LIMITED WARRANTY

The manufacturer, (**Geosense Ltd)**, warrants the **Vibrating Wire Piezometers** 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 **Geosense®** by the purchaser as regards the nature of the installation to allow **Geosense®** to select the correct type and range of **Vibrating Wire Piezometer** and other component parts.

The **Vibrating Wire Piezometer** equipment shall be installed in accordance with the manufacturer's recommendations.

The equipment is warranted for 2 years 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 Piezometer 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 Piezometer equipment from the time of delivery to Purchaser.

NOTES

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