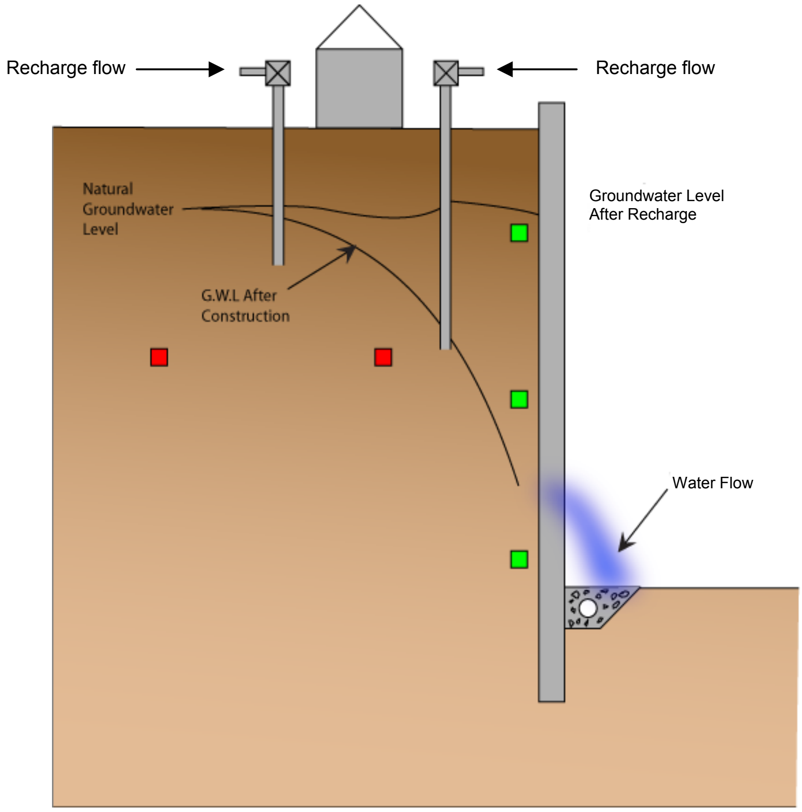
3.0 Typical applications contd...

Groundwater recharge

Where dewatering is carried out adjacent to structures the subsequent consolidation of the soil as the water is removed can cause damage. To minimise settlement, water from the dewatering wells is pumped back into the soil (recharge).

Piezometers are used to monitor groundwater levels and determine the effectiveness of recharge. They can also be used to monitor the passive loads being applied to the wall.

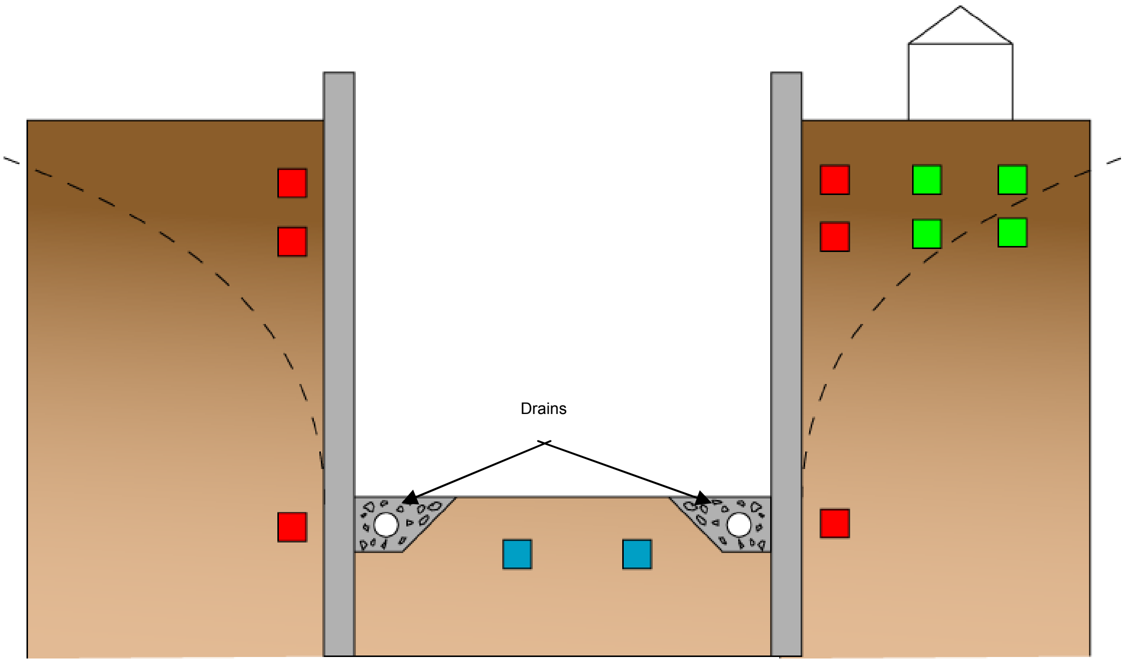


Where and what we monitor	Why we monitor
🟥 Monitor groundwater levels around the excavation.	If the recharge rate is too high the groundwater level will not be low enough to allow stable excavation. If too low, settlement may occur.
🟩 Monitor groundwater level on the outside of the wall	If the groundwater level is too high then the loading on the retaining structure may increase to an unsafe level.

3.0 Typical applications contd...

Deep excavation
Retaining walls are designed to support soil masses which cannot support themselves. The pressure exerted by the soil mass on the outside of the wall (active pressure) and the soil on the inside of the structure (passive pressure) is important for the stability of the excavation.

Pore-water pressure under the invert of the excavation can cause heave if not controlled.

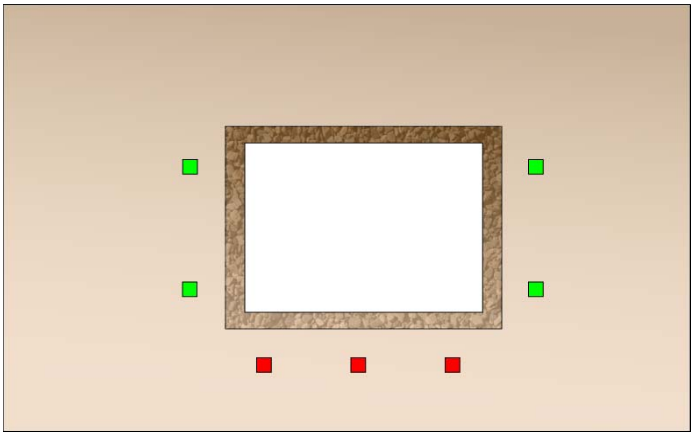


Where and what we monitor	Why we monitor
(blue) Monitor pore-water pressure and/or groundwater level under the base of the excavation	If the pore-water pressure is too high in the base of the excavation heave can occur causing instability of the excavation
(red) Monitor pore-water pressure and/or groundwater level behind the wall	Pore-water pressure is used to calculate active pressure behind the wall and then the subsequent load in order to ensure its stability as excavation progresses
(green) Monitor groundwater level on the outside of the wall & underneath adjacent buildings	Groundwater level is used to confirm the effectiveness of the dewatering system (where applicable) and the predict settlement underneath adjacent structures

3.0 Typical applications contd...

Underground Structures

Piezometers are also used to determine pore water and uplift pressures on underground structures; they can also be used to see what effect water pressures and levels are having on joints in the underground structure.



Where and what we monitor	Why we monitor
Beneath the structure Groundwater pressure	To determine uplift pressures to ensure the stability of the buried structure
Around the structure Groundwater pressure	To determine pressures acting on the buried structure to determine any joint movement and structural integrity

4.0 Installation

4.1 Introduction

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

Installations will always be site specific and the following are points to be considered when planning an installation:-

- Ensure correct filter type is suitable for the soil type
- Ensure the correct type of piezometer is selected for the application e.g. Filter pocket, fully grouted, Drive-in
- Do not allow saturated piezometers to freeze
- All equipment should be stored in an environment that is protected from direct sunlight
- Label tubing and cables clearly. Colour coded tapes are commonly used for instrument identification and to mark installation depth
- Borehole depth should be checked prior to installation
- Cable routing should be selected carefully so as to minimise the risk of breakages

4.2 Filter preparation

Piezometers are fitted with a filter. Transducer type piezometers are fitted with removable filters which should be saturated prior to installation.

Saturating LAE (Low resistance to air entry) for medium or high permeable soils:-

- Place piezometer probe in water for 15 minutes
- Gently tap the probe to remove any bubbles from the probe head

Saturating HAE (High resistance to air entry) for low permeable soils:-

Geosense HAE filters are always saturated in the factory and covered with an impermeable membrane in order to keep them saturated.

Preparation by Immersion:

- Prepare de aired water (this is boiled water and allowed to cool down)
- Plug the ends of the probe so that water is only allowed to react with the outside of the probe
- Allow air to escape from the top plug (as seen in the diagram below)
- Allow the probe to stand in de-aired water for 24 hours

4.3 Piezometer installation

The requirements for piezometer installations are wide and varied and therefore for details of full installation of each individual type of piezometer please refer to the installation manual.

Key Note:
De-aired water is either by boiled water that is allowed to cool under vacuum or produced by special water de-aerators

5.0 Reading piezometers

The information in the following section only refers to that of vibrating wire piezometers. For details on other types of piezometer please refer to the individual installation and operation manuals.

VW piezometers

Interrogation of vibrating wire piezometers can be carried out using hand held readouts and/or automatic data acquisition systems (data loggers).

5.1 Signal output

The signal generated by a vibrating wire piezometer is a frequency. A specialist vibrating wire readout or data logger is used to excite and measure the response of the sensor. The measurement of the response is displayed by the readout in the following formats:-

- **Frequency** - the unit of which is Hertz (Hz)

- **Linear Digits (B unit)**
  The frequency output from VW sensors is not proportional to the applied change in length of the wire. In order to overcome the problem of a linear conversion described the frequency value can be squared, thereby rendering it linear, but quite large. To reduce its size, it is often divided by 1000 (or multiplied by 10^{-3}). The expression $Hz^2/1000$ (or $Hz^2 \times 10^{-3}$) is the most commonly adopted as a 'linear' digital output often referred to as B Units.

- **Period Units (P)** Some readout devices utilise the 'counter' function available in many common integrated circuits.

  Period Units represent the time taken for the wire to vibrate over one full oscillation, expressed in seconds. Due to the very small size of the number generated most equipment manufacturers display the unit multiplied by either 1000 (10^3) or 10000000 (10^7).

  The relationship between Period units and Frequency units is expressed as

$$P = \frac{1}{\text{Frequency}}$$

5.2 Signal conversion

To enable conversion from the raw data (in the units described above) into engineering units such as pressure an instrument requires a Calibration Factor . The value of the calibration factor will vary depending upon the engineering units into which the raw data is to be converted.

The engineering units typically associated with vibrating wire piezometers are:

- Metres of water
- kPa
- psi

5.0 Reading piezometers contd...

5.2 Signal conversion contd...

Linear Calculation
This is the most straightforward 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 for kPa (k) x (Current Reading - Zero Reading)

An example of the calculation from Linear Digits (Hz2/1000) to kPa using a
Polynomial equation is given below:-
Calibration Factors for kPa A = - 6.3014 -7
B = - 0.1685013
C = 1664.594
Current Reading in Linear Digits = 9244.3
Equation
Pressure in kPa = [A x (Reading)2] + [B x Reading] + C
= [- 6.3014 -7 x (9244.3)2] + [- 0.1685013 x 9244.3] + 1664.594
= - 53.85 - 1557.67 + 1664.59
= 53.07 kPa

5.0 Reading piezometers contd...

5.3 Hand held readouts

There are several types of handheld readouts available most of which, are able to read any type of vibrating wire instrument and options include:-

- Direct display - readings need to be manually recorded
- Data storage - readings can be stored for later downloading
- Facility to convert to engineering units - calibration factors and zero values are entered and stored on the unit allowing the conversion to be performed.

5.4 Automatic data acquisition systems

A system designed to regularly record data from instruments independent of operator input, often used in remote environments. A data logger controls and logs the sensor readings and can respond to pre-set alarm trigger levels through on-board software.

Typical components could include:-

- **Central processing unit** (CPU) – to which all the components are linked
- **Vibrating wire interface**
  A vibrating wire interface is used to excite VW sensors and on measuring the response performs a Fourier transform which converts the signal frequency into a digital signal e.g. RS 232 which can be transferred to a CPU
- **Multiplexers**: A relay mechanism controlled by the CPU to switch between multiple sensors so that they can be monitored by a single CPU
- **Power Supplies**: A power supply provides regulated power to the logger and sensors. Power is drawn from a battery that is charged either from an AC supply or a solar panel
- **Communication**: Remote or local connection to the CPU to program or download data including GSM, GPRS, radio and cable
- **Software**: Which allows the user to configure code to control the CPU, interrogate and download stored readings either as raw data or engineering units.

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V1.1 May 2021