LIMAX The automatic slug tester

The Limax slug tester brings slug testing from a guessing game into the new world of science based sinusoidal stimulus for groundwater systems using real-time visualisation and analysis to provide solid estimates of aquifer properties.

Standard parameters such as Transmissivity, Hydraulic Conductivity and Storage coefficient, now with much narrower error bands can be used in further analysis to provide robust estimates of aquifer performance. These include drawdown, recharge, discharge, the probable cone of depression and practical parameters such as pumping interference, allocation, and entitlement.

The Limax system

The equipment is light, portable and rugged. Assembling a slug of up to six metres in length is simple and fast. The electronically controlled winch requires no additional setup other than threading the stainless-steel cable over the supplied tripod and attaching the slug.

Sensors in up to three wells can be quickly setup and are automatically integrated into the test results. All Limax components use wireless for inter-communication – no connecting leads required.

At last, a slug test system that is easy to setup, produces reliable and science-based results, and allows on-sight test analysis.

The Limax Equipment ready to deploy

The Equipment

The basic Limax system consists of six rugged and easily transportable cases and four 1.5 metre by 40 mm slugs. Optional equipment are pressure sensors, a two-metre tripod, and 80 mm slugs.

The two large cases contain the electronically controlled winch and the substantial lithium-ion rechargeable battery, easily capable of powering a test for over twenty-four hours.

The Limax Slug Winch

Of the four smaller cases, one contains the Limax winch Controller. This connects the battery to the winch motor via an integrated controller specifically designed to provide the ultra-low frequencies needed for the slug sinusoidal control. The Controller includes a processor to integrate the wireless control details from both the operator's laptop and the pressure data from the well sensors. An in-built GNSS satellite receiver provides accurate time and location details.

The three other small cases contain an interface for standard high quality pressure sensors such as from In-Situ, Solinst, etc, along with a barometric pressure sensor and a wireless interface back to the Limax Controller. Each case includes a rechargeable lithium-ion battery providing twenty-four-hour use.

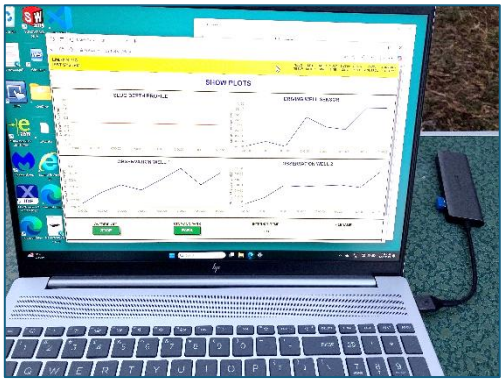
The Winch Controller

Once the slug is positioned in the driving well the operation of the test is completely controlled over WiFi from a laptop or similar computer positioned in the near vicinity.

All parameters that specify the slug travel, its sinusoidal period and test length are all easily setup via this remote control. A variety of excitation sequences are available including single frequency, multiple frequency, and swept frequency, each easily setup and verified. The operator has instant visual access to both the current slug position in the well and the outputs from all sensors. The test so far can even be downloaded to the laptop as CSV data for on-the-spot analysis by the user's own proprietary software.

The Limax in operation

Slug tests performed using this system provide greatly improved estimates of aquifer parameters. Tests using the new system are considerably shorter than traditional pumping tests and consequently incur lower costs. The system can be used to identify and characterise subsurface hydraulic barriers, such as faults or dykes, and can be used to characterise hydraulic connectivity between aquifers and surface water features.



The system allows measuring aquifer pressure response in the production well and two observation wells simultaneously. The observations are made, displayed, and recorded in real time, allowing the technician to adjust the test parameters while testing is underway.

Periodic oscillations of a solid cylindrical slug in a production well create water level fluctuations as a series of sinusoidal waves that propagate to nearby observation wells. Pressure sensors in all wells during testing provide time-based measurements over a wireless network at user-specified sample intervals and are automatically recorded by the test equipment. Calibrated and auto-scaled graphics update at every sample to graphically display the sensor readings along with the current slug position in a visual indication of how the test is proceeding. The recorded pressure head fluctuations from all wells can serve as inputs to aquifer test analysis software. Because the results to date can be copied to the user's computer at any time, an analysis can present results in near real-time. Typical results include estimates of aquifer transmissivity, storativity, and other important hydraulic properties. Together these provide an accurate and current picture of the aquifer's hydraulic characteristics.

The operator chooses the sine wave parameters based on their knowledge of the geology, water table position and aquifer type at that location. From one to three different sine waves can be combined with the frequencies, amplitudes, and phases chosen to suit prior knowledge of the test site and its geological characteristics.

During a slug test, the cyclic immersion of the slug in the production well changes the volume of water in the well, and the corresponding pressure change is recorded by the production well pressure sensor. The sensors in the nearby observation wells record how far and how quickly this pressure change propagates.

The specific data recorded for each sample interval is in the form of a CSV table and includes the current time, slug position, and the corresponding pressures recorded in each well. Any standard pressure unit can be used such as PSIG, PSIA, cmH2O, etc. The metadata describing the test parameters, well physical characteristics, and other geo- and hydro-logical data are also recorded. The system provides real time estimates of conductivity (T), storativity (S), and transmissivity (T) during and at the end of the test.

Limax Applications

There are many standard and well-known algorithms currently in use for combining this well data with other environmental parameters to arrive at a test result including storage, flow, porosity, etc. In addition, there is considerable scientific interest in the higher fidelity results produced by sine wave excitation currently driving a wealth of new research and how it can be used.

Examples

Engineers: Use computer models to estimate the changes in groundwater level over time, based on pumping rate, recharge, and local geology.

Councils: Approximately 60 cities and towns across Victoria, including Geelong and Ballarat, rely on groundwater as either a supplementary or primary water supply. Deep groundwater reserves are more resilient to changes in rainfall than dams, lakes and rivers. However, refilling deep aquifers can take many, many years. Governments need to know the storage and recharge rates of aquifers.

Mining: Local country councils using the Limax slug tester can monitor the many exploration companies in Victoria who use licensed water drillers to drill exploration holes, to take rock samples or to monitor groundwater. Exploration drillers often also operate as water bore companies. Prior to drilling, explorers should seek the advice of regional water authorities and their hydrologists about information on local groundwater systems and expected groundwater conditions at specific drill sites. Examples of areas of interest include managing mining and minerals processing wastes, such as the management and disposal of alumina production wastes.

Landowners: Need to get permission from the local councils and water resources bodies before drilling and extracting water from aquifers. There is a need to gather the information on aquifer characteristics before making an application to the authorities.