

ShakeMonitor® Facility Forensics



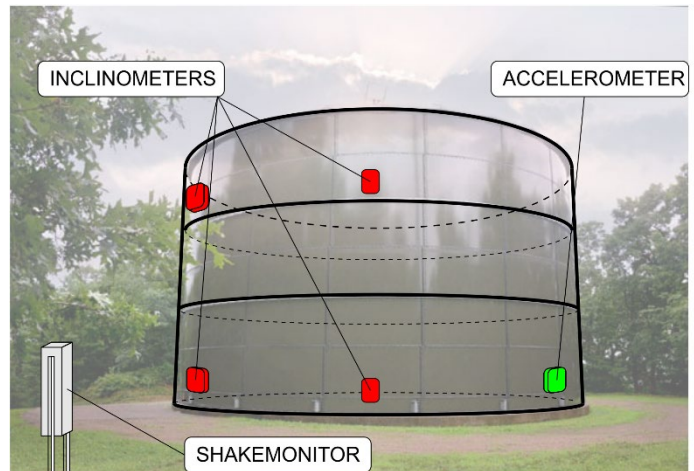
INTRODUCTION

If you are a Varius customer, and you are connected to the USGS ShakeAlert® alarm network, you can implement a post-disaster assessment and monitoring system that will automatically compare the before and after data of the health and operational capability of your most important assets - reservoirs, wells, pumps, pipes, etc. - following any type of destructive event, i.e., a subduction zone earthquake, flood or slide. This is accomplished with a system of sensors and electronics that are called ShakeMonitor®. ShakeMonitor® provides real time information about structural health and process integrity, together with an archival record of facility performance and seismic inputs and the response of the structure and the process to natural events, especially earthquakes.

ShakeMonitor® is an industrial hardened data acquisition and processing system (DAS) that connects to various field-mounted sensors which are mounted to your assets (like reservoirs, well facilities and pump stations). During and following an earthquake, ShakeMonitor® receives data from the sensors and compares the data with pre-event and 'normal' operational data, processes the data and presents the results nearly instantaneously to your SCADA system, your desktop computer, your handheld device or your mobile phone with a summary of the operational status of each site. ShakeMonitor® will tell you if your reservoir, pump station or well is operational and trouble-free without the need to visit the site or conduct on-site testing or surveying. ShakeMonitor® can automatically identify the following equipment damage or compromised facility capability:

Structure Tilt	Excessive Strain	Pump Imbalance
Structure Rotation	Phase Loss	Broken Pipe
Structure Translation	Pump Failure	Broken Impeller
Fire	Flood	Structural Failure

Initially, ShakeMonitor® is typically installed at a select combination of strategic water facilities. Although it's possible to equip all of your facilities it is usually sufficient to select a minimum number of 'critical' facilities (i.e. those facilities that are absolutely necessary to maintain minimum service levels after a disaster). The automated network of ShakeMonitors® at your critical facilities automatically connects to and communicates with your network and your OmniMonitor®. After the event, or in case of power loss, ShakeMonitor® is a standalone system, and its wireless network is not dependent on the power grid, SCADA communications network or telecommunication system and it will continue to collect data and store it for further review (if it is unable to deliver it to your staff via SCADA or network connection). Following a large earthquake, the ShakeMonitor® will send you and your staff status information using virtually any



Typical Reservoir Application



available telecommunications path including telephone, SMS text messaging, email, radio, microwave, satellite or internet.

STRUCTURES

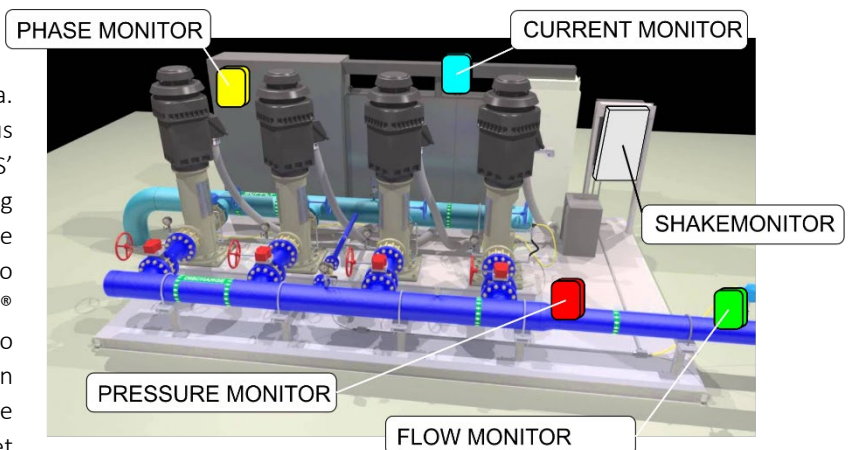
Each ShakeMonitor® connects wirelessly to sensors which are placed on the building or structure to measure building or structure movement. The ShakeMonitor® wireless sensor network operates on a frequency of 900 MHz so there is no risk of interference with existing WiFi or 2.4 GHz communication infrastructure. The system can automatically detect structural tilt (for example from ground settlement or structural deformation), lateral movement (such as sliding or building compression) and rotation. ShakeMonitor® can generally measure movements of less than 0.01" displacement (or rotation) and tilt of less than 0.01°. ShakeMonitor® can also measure strain and deformation and can be used to identify pending structural failures before they are visible or imminent. ShakeMonitor® can automatically sense if your structure has moved, tilted, settled, deflected or is near structural failure. It is even possible to monitor the natural vibrating frequencies of the structure and diagnose structural weakness (or damage) from changes in the frequency response to natural phenomena like wind and ground motion. Additionally, ShakeMonitor® is a versatile platform and can incorporate a wide range of sensors, can be bridged together for virtually unlimited channels of data acquisition and possesses enough processing power on board to run user specific applications, if required.

PROCESSES

Each ShakeMonitor® can connect to sensors that may already be in-place in your facility such as flowmeters, pressure sensors, phase monitors, and current monitors with the ability to process hydraulic and electrical information which can be used to discriminate normal from abnormal pump startup and pump operation. For example, ShakeMonitor® can sense broken impellers, broken shafts, bent shafts, unbalanced equipment, broken watermains, plugged watermains and a compromised power supply; virtually any possible failure scenario can be automatically sensed and alarmed. It is even possible to discriminate between high flows caused by broken mains and high flows as a result of hydrant flows, a feature that may prove invaluable after a large earthquake.

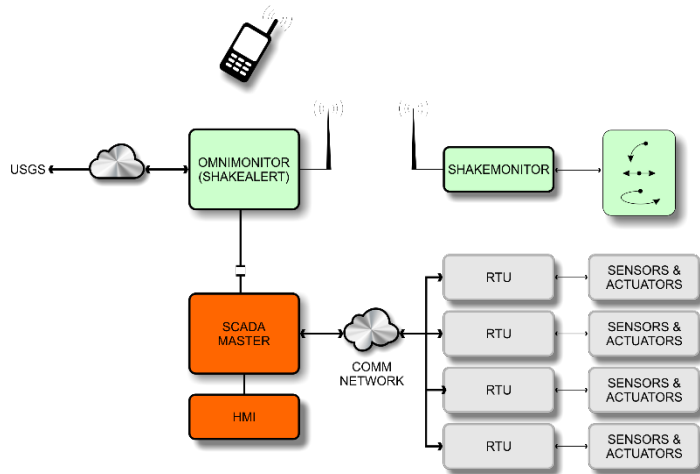
APPLICATION

ShakeMonitor® is an industrial-hardened data acquisition system manufactured by Weir-Jones Group in Vancouver, Canada. The base Unit has been modified for Varius in order to be compatible with the USGS' ShakeAlert™ earthquake early warning system and is compatible with a wide range of communication modules to connect to the ShakeMonitor® System. ShakeMonitor® also provides a cyber-safe connection to control systems and communication systems. Installation is simplified since ShakeMonitor® can connect to the Internet via several means – Ethernet, cellular modem, or a satellite modem – using dynamic IP addressing, without the need for a static IP address. Software updates and configuration changes can all be done remotely. ShakeMonitor® is manufactured at Weir-Jones' ISO 9000:2015 certified facility and has been reliably used throughout the world for more than 35 years.



Typical Pump Station Application





Typical Block Diagram (Used with SCADA)

ShakeMonitor® is designed to communicate with a pre-defined list of contacts via email, text messaging (SMS), radio and through connection to any user-owned control and communication systems. Following an earthquake or other natural disaster, ShakeMonitor® will quickly diagnose the condition of each critical facility without the need to visit each site or to send personnel into a potentially compromised facility or structure.

ShakeMonitor® is an economical and easily maintained system. It can be installed in remote locations without power or communications equipment and a wide variety of wireless sensor options helps minimize installation costs and complexity.

ShakeMonitor® can be used independently if you don't have a ShakeAlert® earthquake early warning (EEW) system as a standalone system. It is not necessary to also be connected to the USGS' ShakeAlert™ EEW network in order to monitor the condition of assets at a given facility. ShakeMonitor® has built-in health monitoring for reliable operation.

Depending on your system layout and geography, one ShakeMonitor® may be able to support multiple pieces of infrastructure on a given property as ShakeMonitor® can typically communicate with wireless sensors as much as 3 miles away (with line-of-sight).

The ShakeMonitor® alarms and status updates can also be ported directly into your existing SCADA system giving you the ability to not only know which facilities have survived a large quake, but also the ability to automatically start, stop and lockout the best combination of facilities to meet minimum service levels after a quake. This level of control is an industry first, elevating your emergency response planning, and the ability to provide lifeline services, to new levels of reliability and resiliency.

