GUARDIAN
RESOURCES

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WHITE PAPER - MSR TECHNOLOGIES

Willowstick Technologies In Conjunction With Guardian Resources

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1. Executive Summary

1.1 The Problem: Finding Water in Fractured Rock

Groundwater in bedrock and fractured geological settings does not follow predictable, uniform pathways. It migrates preferentially through sub-vertical fracture networks, fault planes, permeable gravel bodies, and extensional weaknesses that are effectively invisible to surface observation and poorly resolved by conventional geophysical averaging methods. Without a technology capable of directly imaging these fracture systems at depth, well drillers and hydrogeologists cannot make fully informed decisions about drill target selection — resulting in dry holes, inadequate yields, and unnecessary expenditure.

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Accurate identification of subsurface fracture systems and high-porosity zones is a foundational requirement across groundwater supply, agricultural irrigation, municipal water management, and geothermal energy. The ability to locate, characterize, and rank sub-vertical fracture networks with precision directly determines the quality of drilling decisions, the productivity of completed wells, and the long-term reliability of water supply infrastructure.

Despite the fundamental importance of this capability, the methods most commonly relied upon for pre-drill site assessment — surface lineament mapping, resistivity surveys, and empirical rule-of-thumb placement — share a critical limitation: they either operate only at the surface or provide volumetrically averaged responses that lack the resolution to resolve the discrete fracture conduits on which productive wells depend.

The proprietary signal acquisition and processing methodology that underlies MSR is what makes it uniquely capable of producing depth-resolved images of subsurface fracture architecture. Conventional resistivity and electromagnetic methods characterize bulk electrical properties averaged across large subsurface volumes; the MSR system resolves mechanical structure at the scale of individual fracture systems — precisely the property that controls groundwater productivity and geothermal flow in hard-rock environments.

1.2 Global Water Demand and the Imperative for Precision

The global demand for reliable groundwater characterization has intensified significantly in recent decades, driven by converging pressures across agricultural, municipal, industrial, and energy sectors. Major aquifer systems across the American West and globally are experiencing accelerating rates of depletion, while the infrastructure responsible for managing water continues to age. In this context, the ability to drill with precision — minimizing dry holes and maximizing the probability of high-yield production — has become an economic and operational imperative rather than a technical convenience.

1.2 Global Water Demand and the Imperative for Precision Cont.

Well drillers and their clients face a fundamental problem: drilling a well is expensive, irreversible, and highly dependent on subsurface conditions that cannot be seen from the surface. In fractured bedrock environments — which encompass a large proportion of the world's hard-rock aquifer systems — the difference between a high-yield well and a dry hole can be a matter of meters in the horizontal dimension. The MSR instrument was developed specifically to resolve that uncertainty before the drill is deployed.

1.3 The MSR Instrument: A Purpose-Built Solution

The MSR Instrument is not a repurposed laboratory seismograph or a general-purpose passive seismic tool. It is a purpose-designed, single-channel piezometer developed specifically for the detection and characterization of sub-vertical fracture networks and porous gravel bodies at the depths relevant to water Guardian/Willowstick — Confidential Page 3 www.willowstick.com | +1 (801) 984-9850 well drilling and geothermal resource assessment.

The instrument operates by detecting naturally occurring micro-seismic energy that propagates through the Earth's subsurface from natural sources. Subsurface fracture networks, high-porosity zones, and extensional weaknesses respond to this energy in ways that are measurably distinct from intact, low-porosity rock — emitting characteristic resonance signatures that the MSR system detects at the surface. By mapping these signatures across a dense grid of stations, the MSR system produces depth-resolved profiles that directly indicate the location, depth, and relative intensity of subsurface fracture systems.

The resulting dataset is processed through a structured depth-profiling workflow to produce two- and three-dimensional resonance models that directly image the subsurface fracture architecture — providing drill targets with defined coordinates, estimated depth ranges, and relative productivity scores.

1.4 Why Investigate Before Drilling?

Guardian Resources advocates a diagnostic-first philosophy: conduct a comprehensive non-invasive geophysical characterization using the MSR Instrument, establish a verified depth model of subsurface fracture conditions, and then direct all subsequent drilling expenditure to precisely defined target locations.

a. Reduce drilling cost and risk. The MSR Instrument produces a cost-effective, timely, and verified image of subsurface fracture conditions. Drillers and asset owners are equipped to make well-informed decisions at the outset of a project, rather than iterating through expensive and inconclusive trial-and-error programs.

b. Minimize the number of dry holes. In the majority of projects, an MSR investigation identifies discrete high-potential targets within the survey area — directing drilling to the locations of highest diagnostic value and lowest risk.

1.4 Why Investigate Before Drilling? Cont.

c. Detect and rank fracture systems at depth. MSR resolves fracture intensity at depths to 2,000+ feet — well beyond the range of surface mapping methods. Deeper fracture systems are more likely to yield water regardless of drought conditions.

d. Enable confident drilling decisions. The MSR investigation provides drill targets with GPS coordinates, estimated depth ranges, and resonance intensity scores that allow drillers to proceed with confidence and clients to communicate clearly with contractors.

2.1 Instrument Overview

The MSR Instrument is an integrated passive seismic measurement system purpose-built for one specific application: detecting, characterizing, and ranking sub-vertical fracture networks and high-porosity zones at depth. It is a purpose-designed field instrument deployed at surface stations across a survey grid, requiring no ground disturbance, no active signal injection, and no specialized site preparation.

MSR measurements are collected along survey lines, processed into depth profiles, and analyzed to identify differences in resonance intensity at depth. These differences allow informed assumptions about where water sits within fracture zones in the subsurface. The instrument is hand-carried to each station, enabling deployment across steep terrain, agricultural land, and areas inaccessible to vehicle-mounted equipment — without requiring surface preparation or ground disturbance.

Figure 1 — MSR field instruments in pre-deployment staging. The MSR 2 instrument (current field-deployed version) is shown in its ruggedized carrying case, ready for field deployment. Multiple units are prepared for simultaneous multi-crew surveys.

2.2 Scientific Foundation: Why the Physics Works

The MSR method is grounded in well-established principles of geophysics and rock mechanics, applied through purpose-designed instrumentation and proprietary signal processing developed exclusively by Guardian/Willowstick. The specific combination of physical phenomena exploited, the signal acquisition approach, and the interpretation methodology are proprietary and protected.

At its core, the method exploits a measurable physical contrast between fractured and intact subsurface materials. Sub-vertical fracture networks, extensional weaknesses, and high-porosity gravel bodies exhibit distinct mechanical and acoustic properties relative to the surrounding intact rock matrix. The MSR Instrument is designed to detect and quantify this contrast at depth, producing a signal that reflects the presence, intensity, and geometry of subsurface fracture systems — not the bulk properties of the surrounding geology.

The energy source exploited by the MSR system is entirely natural and passive — the instrument introduces no signal into the subsurface and requires no active source equipment. This passive operating principle means the MSR method is not subject to the interference effects that limit conventional active seismic and electromagnetic methods in urban, agricultural, or industrially active environments, and produces results that are independent of surface conditions or seasonal variation.

Key Physical Principle — Because the MSR Instrument operates passively, it detects subsurface fracture signatures at depth without introducing any energy into the ground. Fracture zones at depth produce the same characteristic signatures regardless of surface conditions, time of day, or proximity to cultural infrastructure — enabling reliable characterization at depths that active investigation methods cannot cost-effectively reach.

The proprietary signal acquisition and processing methodology that underlies MSR is what makes it uniquely capable of producing depth-resolved images of subsurface fracture architecture. Conventional resistivity and electromagnetic methods characterize bulk electrical properties averaged across large subsurface volumes; the MSR system resolves mechanical structure at the scale of individual fracture systems — precisely the property that controls groundwater productivity and geothermal flow in hard-rock environments.

2.3 The Measurement Process

An MSR survey begins with a comprehensive desktop study. This research phase integrates geological mapping, faulting analysis, and lineament identification using high-resolution LiDAR topography and satellite imagery. Public-domain well driller reports from state water resources agencies are reviewed to establish local groundwater context and confirm the appropriateness of MSR-based fracture targeting for the site.

Fieldwork is conducted in two sequential phases. First, a Radiometric Gamma survey is conducted across the site at regular intervals, collecting data in gamma counts per second (gCPS). Gamma data identifies lithologic changes, dikes, faults, and structural features that guide the placement of MSR survey lines and focus investigation on zones with the highest potential for fracture-enhanced permeability.

2.3 The Measurement Process Cont.

MSR data collection is then conducted along multiple lines at 5-meter intervals, with each shot marked in the field with a numbered pin flag for precise spatial tracking. The resulting dataset — which may comprise hundreds of individual shots across the survey area — is compiled with GPS coordinates into a GIS database enabling detailed two- and three-dimensional analysis.

2.4 Data Processing and Model Generation

Raw MSR data undergoes a structured processing workflow before the final interpretive models are produced. This workflow is executed using proprietary software developed and refined by Guardian Resources and Willowstick Technologies over successive instrument generations.

Process -

a. Desktop Study - Geological research, faulting analysis, lineament mapping using LiDAR and public driller reports — establishes site context and guides field deployment.

b. Gamma Survey - Radiometric data collected at regular intervals across the site; identifies lithologic variability, structural features, and fault traces; guides MSR line placement

c. MSR Data Collection - Passive seismic measurements collected along multiple lines at close station spacing; each station GPS-registered; data processed to depths appropriate for well siting or geothermal targets

d. GIS Compilation - All gamma and MSR data compiled with GPS coordinates into a GIS database for 2D and 3D spatial analysis

e. Depth Profile Analysis - Proprietary processing workflow builds resonance depth profiles; intensity differences at depth are analyzed to identify fracture zones and inform target ranking

f. Drill Target Report - Targets labeled T1, T2, etc., with GPS coordinates, estimated depth ranges, and resonance intensity scores; MSR sections carry approximately ±10% depth accuracy

2.5 The MSR Survey Layout

The flexibility of the MSR survey layout is one of its practical advantages. The number, placement, and length of survey lines can be adapted to the specific geometry of the investigation target — whether a residential property, a municipal water supply site, an agricultural holding, or a geothermal exploration area. Multiple overlapping lines can be conducted with different orientations, providing independent confirmation of identified anomalies and enabling triangulation of fracture geometry in three dimensions. In well siting investigations, grids typically span the full extent of the candidate drilling area and extend a sufficient distance in all directions to capture the regional fracture context. In geothermal investigations, grids may cover several square kilometers with higher-density patches deployed over areas of particular interest.

2.6 Technology Development and Generations

The MSR Instrument is currently in its second major field-deployed generation (MSR 2). The foundational scientific principles have remained constant since the instrument's initial development, but the instrumentation, software, and operational methodology have undergone continuous refinement. The MSR 3 — currently at Technology Readiness Level 7 (System Prototype Demonstration) — introduces Bluetooth connectivity, a redesigned ruggedized housing, new precision sensors, and eliminates wind and movement data corruption that affected earlier generations in challenging field conditions.

Successive generations have delivered improvements in measurement sensitivity, reduction of environmental noise interference, integration of high-precision GPS positioning for replicable survey layouts, and development of the proprietary depth-profiling algorithms that differentiate the current system from its predecessors.

2.7 What the MSR Instrument Does Not Do

A precise understanding of the MSR Instrument's performance envelope is as important as an understanding of its capabilities. The method operates within the following constraints:

- Groundwater guarantee: MSR cannot directly guarantee groundwater production or quality. It identifies conditions correlated with productive fracture zones — specifically the mechanical and structural signatures of sub-vertical fracture networks. An experienced driller remains essential to evaluate actual formation response during drilling.

- Volumetric flow measurement: The MSR Instrument characterizes the location, depth, and relative intensity of fracture systems. It does not directly measure discharge volume, flow velocity, or well yield.

- Saturated zone confirmation: MSR identifies fracture-enhanced permeability zones. Whether those zones are saturated at the time of drilling depends on regional hydrogeology, seasonal conditions, and recharge history — factors that are assessed during the desktop study phase but cannot be confirmed by geophysical methods alone.

- Accuracy limits: MSR depth sections provide estimations with approximately ±10% accuracy. Drill targets are provided with coordinate and depth ranges that reflect this inherent uncertainty.

These are narrow constraints that apply to a defined minority of real-world groundwater characterization problems. In the vast majority of fractured rock, valley alluvium, and bedrock aquifer contexts, the MSR Instrument is fully applicable and produces results of a quality that no conventional surface investigation alternative can match.

3. Comparative Performance Against Other Methods

3.1 MSR Vs. Industry

A rigorous evaluation of the MSR Instrument's performance relative to conventional alternatives requires an understanding of why conventional alternatives fall short of the resolution and depth required for definitive fracture-zone targeting in hard-rock environments.

Surface lineament mapping identifies linear features visible in satellite imagery and LiDAR topography that may indicate subsurface faults or fracture traces. While useful as a first-pass desktop tool, lineament mapping operates only at the surface. It cannot confirm whether identified lineaments represent open, water-bearing fractures at depth, nor can it resolve the depth, extent, or relative productivity of identified features. Guardian Resources uses lineament mapping as a component of the desktop study phase — as a complement to MSR, not a substitute.

DC resistivity and electromagnetic induction methods are the most widely deployed conventional alternatives for groundwater investigation. Both methods energize large volumes of subsurface material uniformly, and their measurements reflect the aggregate electrical response of the entire energized volume.

The limitation is structural: from this aggregate response, the contribution of a specific narrow fracture conduit cannot be reliably resolved — particularly in the presence of electrically conductive overburden or where fracture apertures are small relative to the bulk material volume. Ground Penetrating Radar achieves high spatial resolution in favorable conditions but is limited to investigation depths of a few meters in typical geological settings. It is not applicable to the characterization of fracture systems at the depths relevant to most water well drilling or geothermal applications.

Borehole data are accurate and physically verifiable, but represent point measurements at the precise location of the borehole. The spatial characterization of a fractured rock aquifer to the resolution required for confident drill targeting requires a large number of wells — whose placement cannot be optimally determined without prior spatial knowledge of subsurface fracture conditions. This is precisely the problem the MSR Instrument solves.

3.1 MSR Vs. Industry Cont.

Method	Depth Capability	Fracture Resolution	Limitation vs. MSR
MSR (passive seismic)	>2,000 ft	Sub-vertical fractures and porous zones at depth	Baseline — purpose-built for this application
Surface lineament mapping	Surface only	Surface traces only	Cannot confirm depth, aperture, or saturation of fractures
DC Resistivity / EM Induction	Variable; limited in conductive overburden	Bulk conductivity only — cannot resolve discrete fractures	Volumetric averaging; misses narrow fracture conduits
Ground Penetrating Radar	Typically <10 ft in rock	High near-surface	Entirely unsuitable at drilling depths
Borehole drilling	Unlimited	Point measurement only	Cannot characterize spatial fracture distribution before drilling

Guardian Resources does not position the MSR Instrument as a replacement for drilling. Rather, it is the optimal precursor: it defines where to drill, how deep to drill, what fracture intensity to expect — transforming a trial-and-error process into a targeted, evidence-based program. In this context, the MSR investigation reliably reduces overall program cost, improves data quality, and shortens the timeline from investigation to confident action.

4. Summary

4.1 Instrument Overview

The MSR Instrument represents a purpose-built application of passive seismic physics to one of the most consequential unsolved problems in applied hydrogeology: the direct, non-invasive characterization of sub-vertical fracture networks and high-porosity zones at the depths relevant to water well drilling and geothermal resource development.

Its scientific foundation — the measurable contrast in micro-seismic resonance response between fractured and intact subsurface materials — is grounded in well-established principles of rock mechanics and passive seismology. Its implementation through purpose-designed instrumentation, proprietary signal acquisition and depth-profiling software, and field-validated two- and three-dimensional fracture models represents a significant and protected technical innovation refined through hundreds of completed projects across diverse geological settings.

The instrument delivers what conventional methods cannot: a spatially continuous, depth-resolved picture of subsurface fracture architecture at the resolution required to make definitive drilling decisions. It is the foundation upon which all Guardian/Willowstick groundwater exploration and geothermal targeting programs are built, and the reason our clients consistently achieve better outcomes — lower costs, fewer dry holes, more productive wells — than programs that rely on conventional approaches alone.

Survey results from the MSR Instrument are always interpreted in conjunction with all available site information — existing well data, geological mapping, driller reports, and operational records. This integrated approach produces the highest possible confidence in the resulting subsurface model and the strongest possible foundation for the drilling decisions that follow.

5. Selected Case Studies and Field Validation

5.1 Groundwater Well Siting — Preston, Idaho (2024)

The following case studies illustrate the performance of the MSR Instrument across representative well siting investigation types. These examples demonstrate the instrument's ability to identify, map, and rank fracture systems under real field conditions and to directly support drilling decisions that produce measurable, verified outcomes. Find more case studies at: **https://willowstick.com/library**
(Live as of 2026)

This investigation was conducted for Nephi Carlisle to locate potential groundwater drill targets on a 3.7-acre property near Preston, Idaho. The existing well on the property had run dry, and local drillers were skeptical that a geophysical investigation could identify a superior target. Fieldwork was conducted using a combined MSR and Radiometric Gamma approach, with a comprehensive desktop study integrating geological research, faulting analysis, and LiDAR lineament mapping.

Location: Preston, Idaho - USA

Client: Nephi Carlisle

Instruments: MSR, Gamma Scintillator

Site Size: 3.7 Acres

MSR Target: T1 -- Estimated Depth 300-375 ft

Result: Artesian water struck at 328 ft. Super potable, artesian pressure

Key Outcome: Existing well had run dry; new well exceeded all expectations

Investigative Approach - Groundwater Well Siting — Preston, Idaho (2024)

Radiometric Gamma data was collected across the site at regular intervals, measured in gamma counts per second (gCPS). This data was used to detect geologic changes and guide placement of MSR survey lines. MSR data collection then covered multiple lines across the property at close station spacing, with data processed to depths appropriate for the local geology. All data was compiled with GPS coordinates into a GIS database.

Initial analysis identified one primary target (T1) exhibiting the highest resonance values across the site. Local well drillers had recommended a different target (Tw) near the existing well. Due to poor correlation between the Gamma data and the Tw site, the MSR recommendation diverged from the driller's preference — the data clearly indicated T1 offered a fundamentally superior fracture system at depth. The MSR investigation estimated the optimal drilling depth at T1 between 300 and 375 feet.

Results - Groundwater Well Siting — Preston, Idaho (2024)

The survey report was delivered in May 2024. On July 1st, the client's existing well ran completely dry. Drilling commenced at T1 on July 8th. At approximately 200 feet, the driller encountered a small amount of water and suggested stopping — the client instructed the driller to continue to the MSR-predicted depth of 300+ feet. At 328 feet — precisely within the predicted range — the well struck large water with artesian pressure. The water was confirmed clean with no quality issues.

> “At 328 feet, exactly where you said to drill to, we hit a lot of water, and it was artesian.”
>
> — Nephi Carlisle, Client — Preston, Idaho

> “After hitting the artesian water at 328 feet, the driller was so amazed that they wanted to know everything about Willowstick. The cost for the survey was 100% worth the result we obtained.”
>
> — Nephi Carlisle, Client — Preston, Idaho

5.2 Groundwater Well Siting — Kanosh, Utah

A comprehensive geophysical survey was conducted to identify optimal water well drilling locations across two candidate sites — the "Canyon Area" and the "Arena Area" — each approximately 10 acres, in Kanosh, Utah. The investigation was grounded in extensive hydrogeologic research emphasizing the critical role of fractured rock zones in achieving optimal well yields in the volcanic and Basin-and-Range geology of central Utah.

Location: Kanosh, Utah — USA

Client: Kanosh City / Municipal

Instruments: MSR, Gamma Scintillator

Site Size: Canyon Area (Site 1) + Arena Area (Site 2), ~10 acres each

MSR Target: T1 (Site 1), T2 (Site 2)

Result: 1,000 GPM sustained; 14 ft drawdown; specific capacity >3,000 GPM

Key Outcome: Fracture depth correlated precisely with MSR survey

Investigative Approach

The investigation began with a detailed desktop study, encompassing geological research, faulting analysis, and lineament mapping using imagery and LiDAR topography, supplemented by public-domain driller reports. Radiometric Gamma data was collected across the site, with measurements compiled into a GIS database alongside GPS coordinates. Following gamma data collection, MSR measurements were performed along multiple lines at close station spacing, with data processed to depths appropriate for the Basin-and-Range fractured volcanic geology of central Utah.

At Site 1 (Canyon Area), MSR analysis identified primary target T1 as the highest-ranked location on the site, exhibiting the strongest resonance intensity at depth — indicating substantial fracture-enhanced porosity and permeability in the target zone. At Site 2 (Arena Area), target T2 emerged as a secondary option with strong resonance at a comparable depth interval. Both targets were delivered with GPS coordinates, estimated depth ranges, and resonance intensity rankings.

Results

Drilling at T1 confirmed the MSR predictions with exceptional precision. The driller reported competent formation until approximately 600 feet, where fractures were encountered and all circulation was lost — consistent with the high-intensity MSR zone predicted at 700–800 feet. The well was completed with a sustained test flow of 1,000 gallons per minute (GPM) with only 14 feet of drawdown. Based on step testing, the project manager estimated specific capacity of the well to be north of 3,000 GPM — one of the most productive wells in the region.

> “Kanosh was a smashing success. We sustained a 1,000 gpm flow with only 14 ft of drawdown. Based on the step test, specific capacity is estimated north of 3,000 gpm. I couldn't be happier with how things turned out. The town is very pleased.”
>
> — Project Manager, Kanosh Municipal Well — Utah

> “The depth of the fracture zone is correlating very well with your MSR survey.”
>
> — Project Manager, Kanosh Municipal Well — Utah

6. MSR Applications by Service

6.1 Applications

The MSR Instrument is deployed across multiple Guardian/Willowstick service lines. While groundwater well siting and geothermal resource targeting represent the primary applications, the instrument's ability to detect deep fracture architecture makes it relevant wherever subsurface structural information is required.

Groundwater / Well Siting - Primary instrument alongside Radiometric Gamma

Key Output: Drill targets T1, T2, etc. with GPS coordinates, depth range, and resonance score

Geothermal - Primary instrument for fracture-controlled geothermal conduit mapping

Key Output: 3D MSR model delineating high-resonance corridors interpreted as active geothermal conduits

Mining & Porosity - Subsurface structure characterization at mine sites

Key Output: Identification of fracture systems relevant to dewatering and hazard assessment

Civil, Tunnels & Pipelines - Structural context for civil investigations

Key Output - Subsurface geological characterization supporting engineering decision-making

6.2 Groundwater Exploration and Well Siting

MSR is the primary instrument for Guardian/Willowstick's groundwater exploration service. Combined with the Radiometric Gamma survey and a thorough desktop study, the MSR investigation provides a complete subsurface fracture model that enables confident, targeted drilling. The standard workflow produces drill targets with defined GPS coordinates, estimated depth ranges, and relative resonance intensity scores that allow drillers and clients to proceed with the highest possible confidence.

Note: The Willowstick electromagnetic method has limited applicability for well siting — MSR and Gamma are the primary tools for this service category.

6.3 Geothermal Resource Targeting

MSR is deployed as the primary instrument in Guardian/Willowstick's geothermal service alongside the Radiometric Gamma system. The workflow mirrors the groundwater well siting approach, with the addition of thermal gradient data and geothermal gradient records incorporated into the desktop study. The 3D MSR model delineates high-resonance corridors interpreted as active geothermal conduits controlling both temperature and yield. MSR targets fractures at depths exceeding 2,000 feet — precisely the range relevant to geothermal resource assessment.

Case reference — Fairmont Hot Springs, Montana: MSR + Gamma surveys identified primary NW-SE trending geothermal conduits associated with deep-seated faults sustaining long-standing thermal water production. Result: production flow exceeding 600 GPM at 180°F (82°C).

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