ADVANCING WATER EXPLORATION FOR THE FUTURE

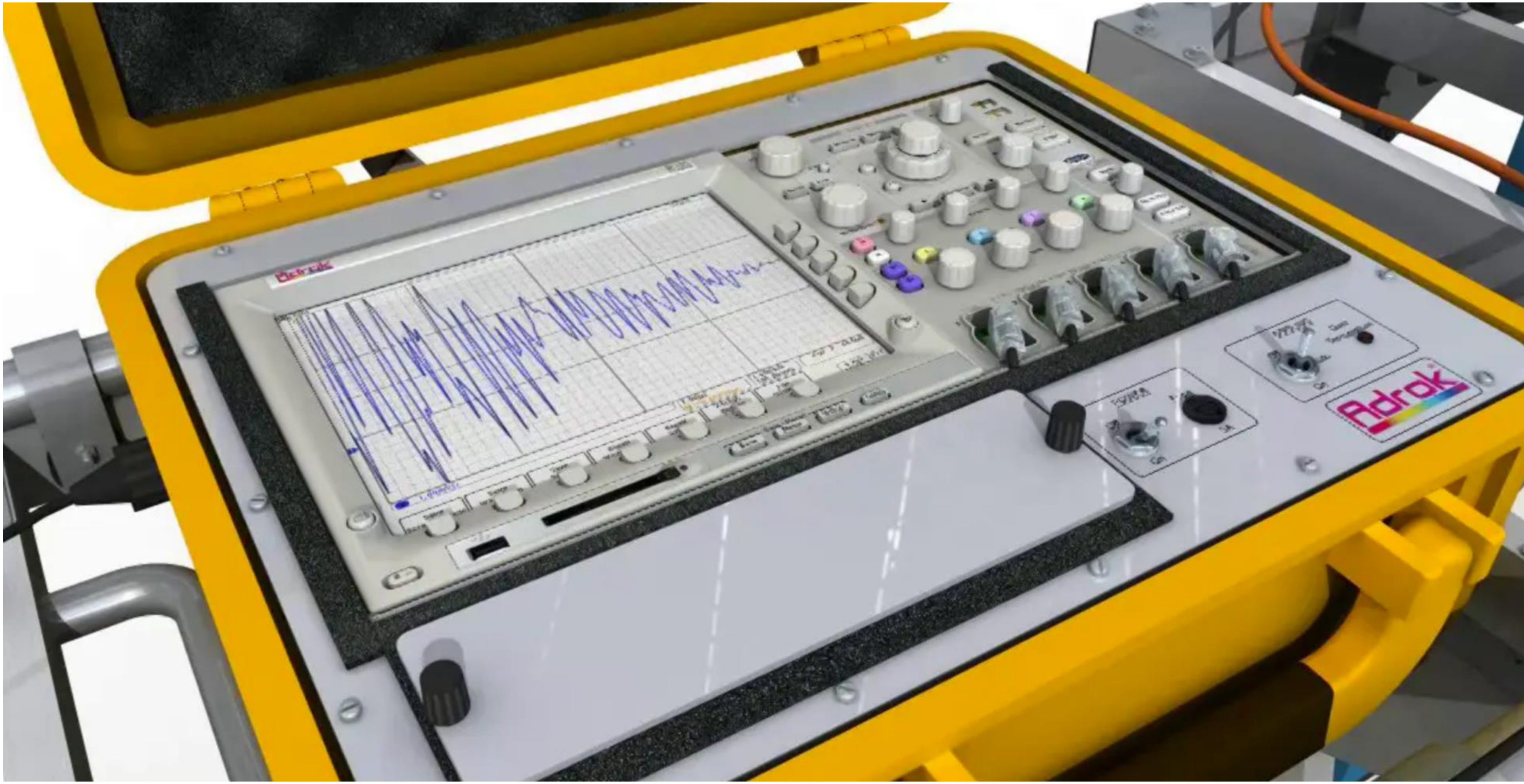
New technology for identifying deep aquifers

Adrok®

INNOVATION FOR A CHANGING WORLD

"Population growth combined with increasing standards of living combined with increasing levels of consumption has put an unprecedented strain on the planets known water resources. Adrok wants to provide a solution to this global problem. We have invented the technology to explore for untapped deep aquifers. Adrok's technology is faster, safer, quicker and has little to no impact on the environment. Leave only footprints"

INVENTION IS BORN FROM NECESSITY


Adrok

SMARTER WATER EXPLORATION FOR A SUSTAINABLE FUTURE

"Australia has one of the greatest mineral and agricultural industries in the world…the aim is to advance these industries in a sustainable way, for a sustainable future"

The technology is now available for trial in Australia and around the world to assist in the exploration and targeting of groundwater, particularly deep aquifers where physical drilling of trial targets can be avoided.


CABLES

THE ADROK POTENTIAL

A faster, cheaper and greener way for identifying and helping manage aquifers and groundwater

Adrok is a geophysics technology development company set out to create a technique that could "virtually see" different materials at great depths beneath the surface. Adrok's pulsed radar/Atomic Dielectric Resonance (ADR) scanner has been tested in many countries and for different commodities. Adrok has seen initial success in detecting water hundreds of meters depth below the surface.

The **aim** is to help ensure the future of water security for developed and developing countries where its required by helping governments, private organisations and individuals to meet strategic outcomes for the future development and/or community sustainability.

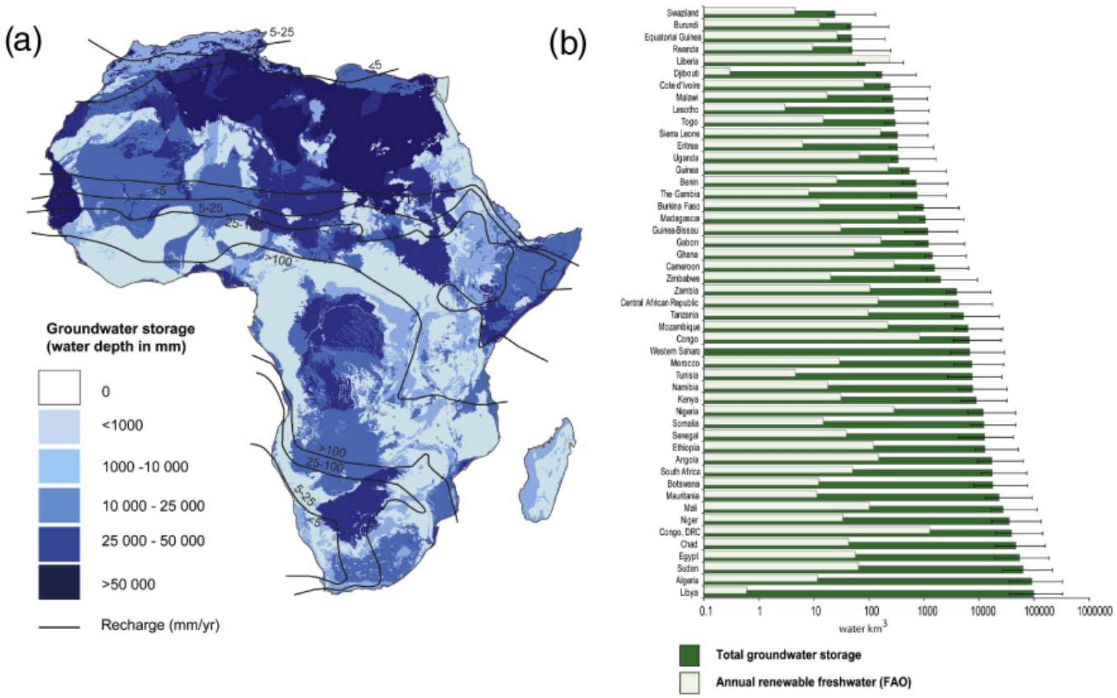
Australia, for example, is the driest continent in the world yet also consumes the most amount of water per-capita than any other country. The country sources billions of dollars from the agriculture and mining sectors but factors such as increasing population, increasing demand for minerals and food all combined with the reality of climate change means that the world must act quickly and collectively to increase its water reserves. Dams and other large infrastructure projects are just part of the solution. However, large infrastructure projects are expensive and often inefficient, particularly with such high evaporation rates and the long distances required to transport water to its required destination. Other countries have faced similar scenarios and have already started accessing aquifers and adopting/developing aquifer recharge as a more secure source of water.

GLOBALLY, shallow aquifers and some deep aquifers are being drained at a faster rate than they can be recharged. The result is a progressive depletion of some key aquifers. Satellite data has been used to demonstrate this impact, but the satellite-based results require a quick, simple, cost-effective and environmentally friendly ground-truthing technique to confirm and to monitor the results. Based on the proposed program, Adrok aims to develop the water-detection aspect of the technology, in collaboration with the BGS so that the technology can be quickly utilised in the real world.

African aquifers can protect against climate change

https://upgro.org/2016/03/21/african-aquifers-can-protect-against-climate-change/

Posted on 21/03/2016 by RWSN Secretariat



New research[1] suggests that Africa's aquifers could be the key to managing water better. Professor Richard Taylor at UCL explains: "What we found is that groundwater in tropical regions – and Sub-Saharan Africa in particular – is primarily replenished from intense rainfall events – heavy downpours. This means that aquifers are an essential way of storing the heavy rain from the rainy season for use during the dry season, and for keeping rivers flowing."

[1] Jasechko, S & Taylor, R.G **'Intensive rainfall recharges tropical groundwaters'** *Environmental Research Letters* 11 December 2015

Adrok aims to help provide a critical missing-step between target definition (TDEF) and drilling. This is often the highest risk and most costly part of a water exploration process. Adrok will carry out scans in regions that have been identified as high potential areas for aquifers but where drilling is required to prove their existence.

THE LACK OF DATA

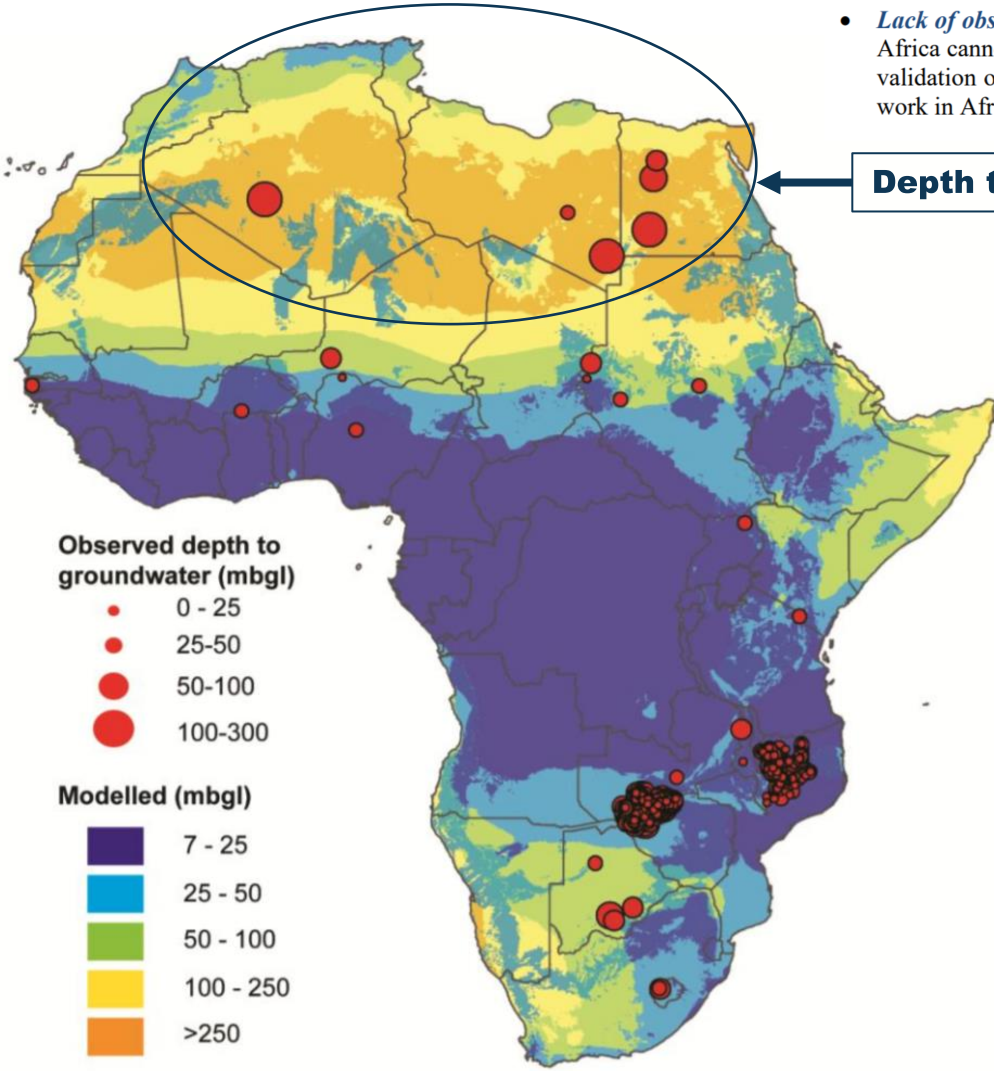


Figure 6 from - http://nora.nerc.ac.uk/id/eprint/17907/1/OR11067.pdf
Comparison of observed and estimated depth to groundwater.

- *Lack of observed groundwater-level data* – The need for observed groundwater-level data in Africa cannot be over-estimated; observed data would not only enable a much higher level of validation of the outputs from this work, but enhance many other aspects of hydrogeological work in Africa.

Depth to groundwater model based on only 6 points

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

An initial estimate of depth to groundwater across Africa

Groundwater Science Programme
Open Report OR/11/067

http://nora.nerc.ac.uk/id/eprint/17907/1/OR11067.pdf

Developing geophysics for pre-drilling groundwater and deep aquifer identification

Faster and more cost effective than drilling with scans taking approximately 2 hours for >1000m of vertical data collection

Low impact, environmentally sensitive method of potentially testing for water prior to drilling

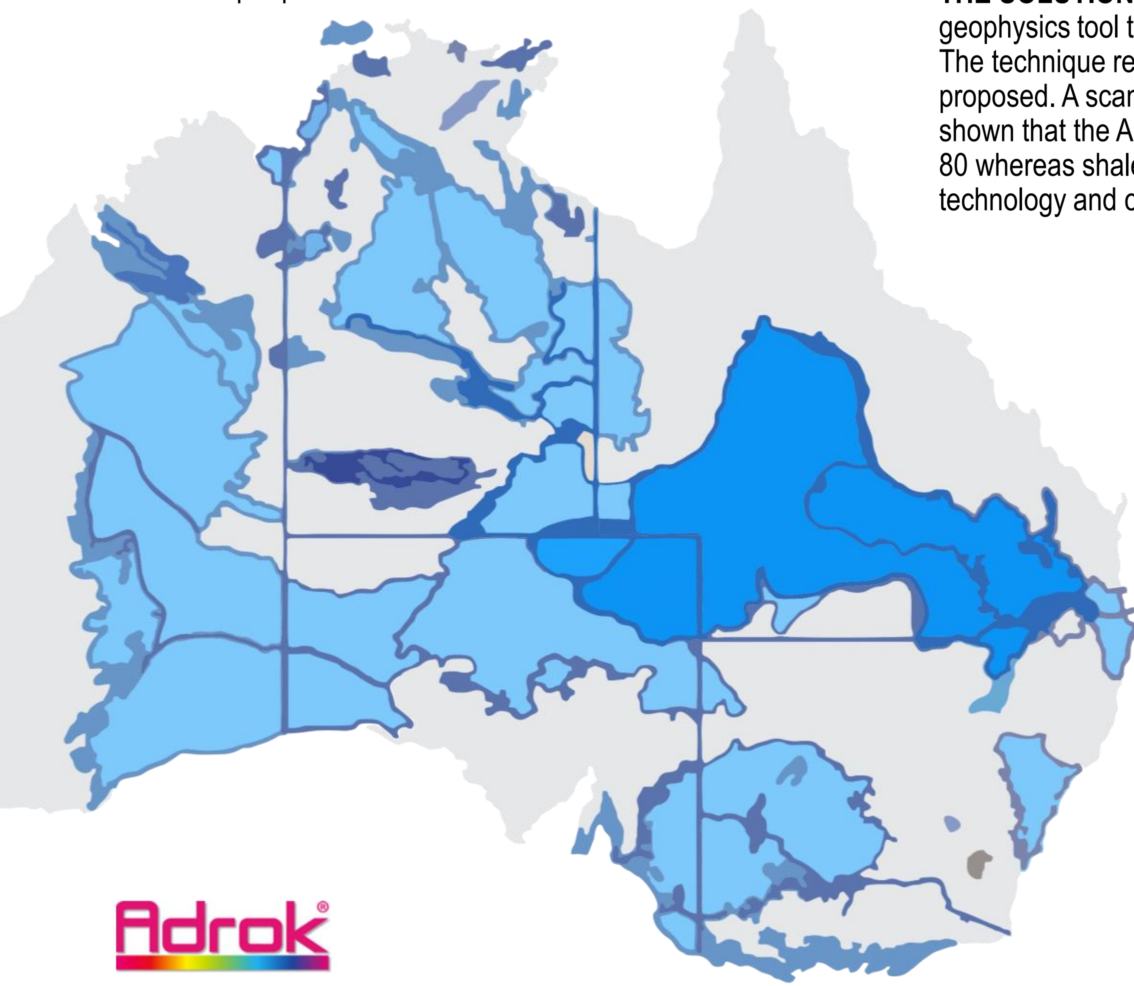
The scanner can be used almost anywhere regardless of how remote, dry, cold, hilly or flat

AUSTRALIA

Australia's "LOWER AQUIFERS"

source: www.bom.gov.au

Adrok can deploy equipment to almost anywhere in Australia to test for water in inferred deep aquifers.



THE PROBLEM: The world has a lack of water, yet development and community sustainability requires access to water reserves in order to facilitate economic growth in the area. **Groundwater stored in deep aquifers are an immediate source of water**, but the high risk and expense of drilling deep aquifers has presented a significant barrier to deep aquifer exploration, particularly in remote areas where drill-rig access can be limited by terrain, cost, access and a myriad of other limiting factors.

THE SOLUTION: Adrok is developing a quick, cost effective and environmentally friendly geophysics tool that has helped mining and oil companies remove some of the risk of drilling. The technique requires foot access to the site where a potentially deep aquifer has been proposed. A scan is taken on-site which is referred to as a "virtual borehole". So far, testing has shown that the ADR scan picks up the water table because water has a dielectric constant of 80 whereas shales and sands have dielectric constants of only 5-15 (further explanation of the technology and case studies are provided below).

PLANNED ACHIEVEMENTS: Adrok plans to fully develop the workflow and processing methodology to help define aquifers prior to drilling which in turn will save time, money and unnecessary environmental degradation of the landscape typically associated with test- or exploration-drilling.

- Adrok can complete, on average, 4 scans per day with data collected to over 1000m below the surface.
- Scans can be completed in a regular grid in order to build an approximately 3D image of the water tables(s).
- Adrok can carry out scans anywhere accessible by vehicle, helicopter, or even by foot.
- Adrok has the capacity to undertake profile scans (P-scans) in much the same way as GPR or SEISMIC, however they take longer to process than stationary linear scans.

THE REALITY

Day Zero for Cape Town In Spring of 2018, the world watched as Cape Town counted down 90 days to what was termed Day Zero where the entire city of over 3,500,000 million residents would completely run out of water. The crisis was only averted due to rapid re-thinking of water allocations but not after the world was made more aware of the crisis facing almost every corner of every continent which is a lack of **WATER SECURITY**. Cape Town anticipates that this crisis will be re-lived in the near future and with water already re-allocated from agriculture, food security now becomes a pressing issue.

RECOGNISING THE PROBLEM, PROVIDING A SOLUTION

Water use has been growing globally at more than twice the rate of population increase in the last century, and an increasing number of regions are reaching the limit at which water services can be sustainably delivered, especially in arid regions*. Demand is expected to outstrip supply by 40% in 2030, if current trends continue.

*Source: UN (United Nations) WATER
https://www.unwater.org/water-facts/scarcity/

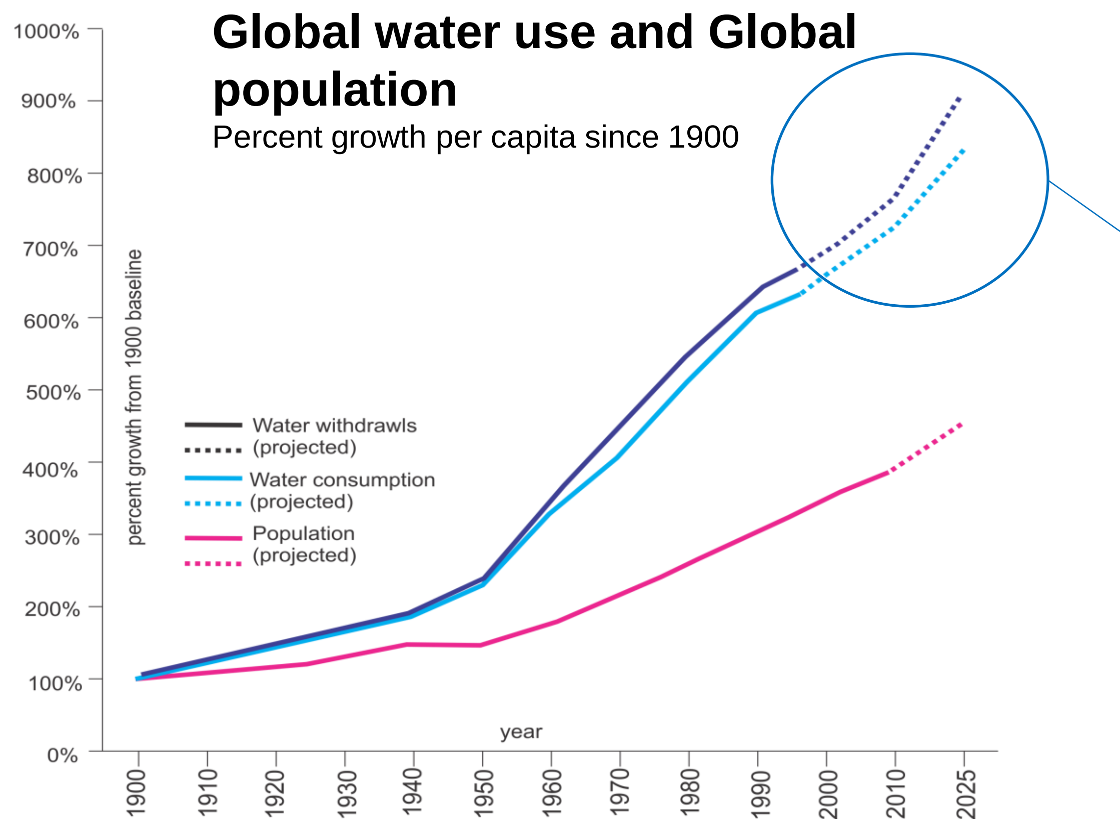
It is expected that the global freshwater deficit will worsen over time due to significant and accelerating climate change. With the existing climate scenario, by 2030 water scarcity in some arid and semi-arid places will displace between 24 million and 700 million people (UNESCO, 2009)

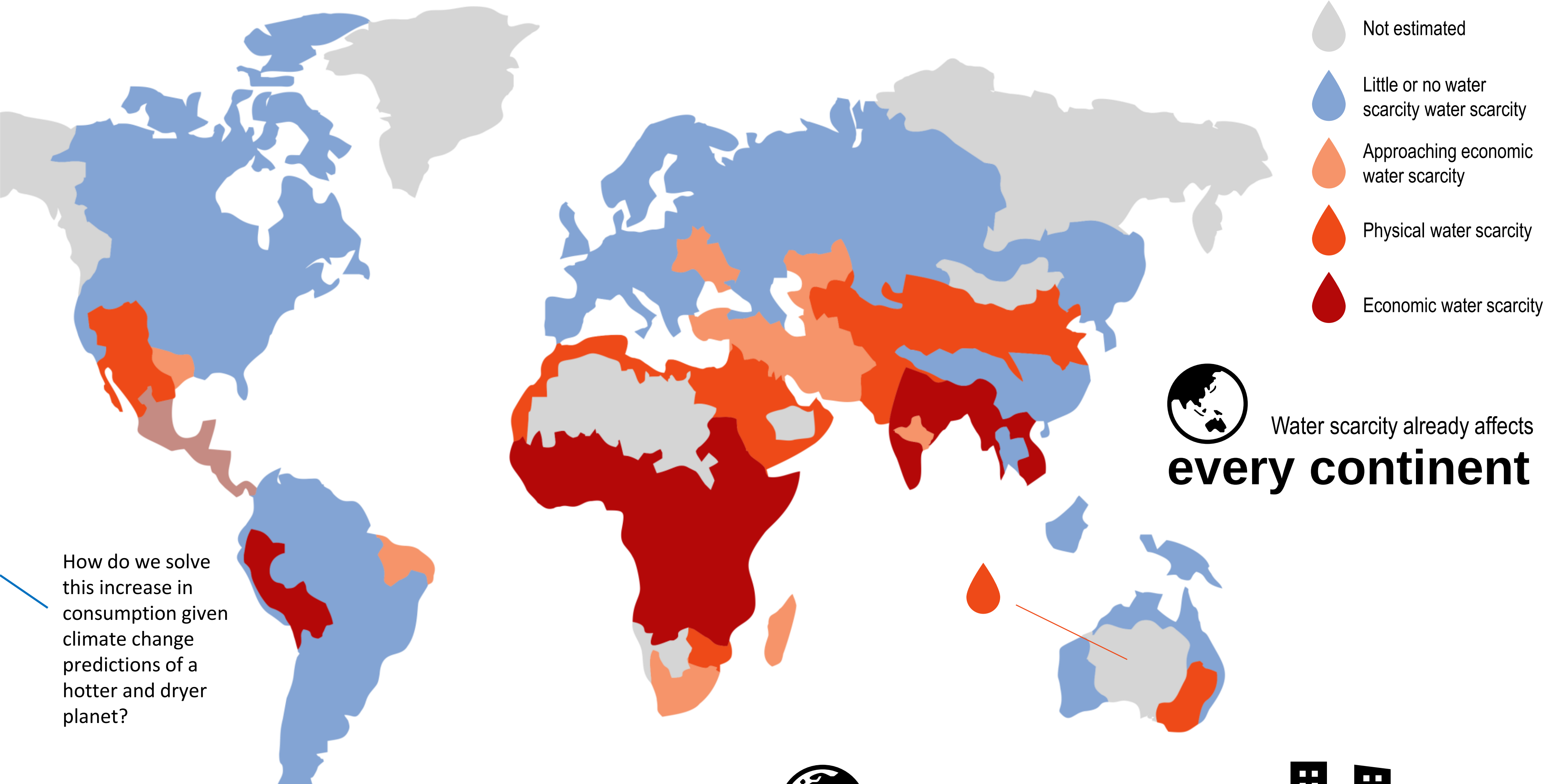
Nearly half the global population are already living in potential water scarce areas at least one month per year and this could increase to some 4.8 – 5.7 billion in 2050. About 73% of the affected people live in Asia (69% by 2050) (Burek et al., 2016).

A third of the worlds biggest groundwater systems are already in distress (Richey et al., 2015).

AIM
The aim is to combat this decline by providing a solution that will aid in providing water security both in Australia and around the world.

Adrok can help combat water stress and secure water security by developing the technology required to identify untapped water resources.





How do we solve this increase in consumption given climate change predictions of a hotter and dryer planet?

500,000,000

Half a billion people in the world face **severe** water scarcity all year round.

2/3

of the global population (4 billion people) live under conditions of severe water scarcity at least 1 month of the year.

1/2

of the world's largest cities experience water scarcity.

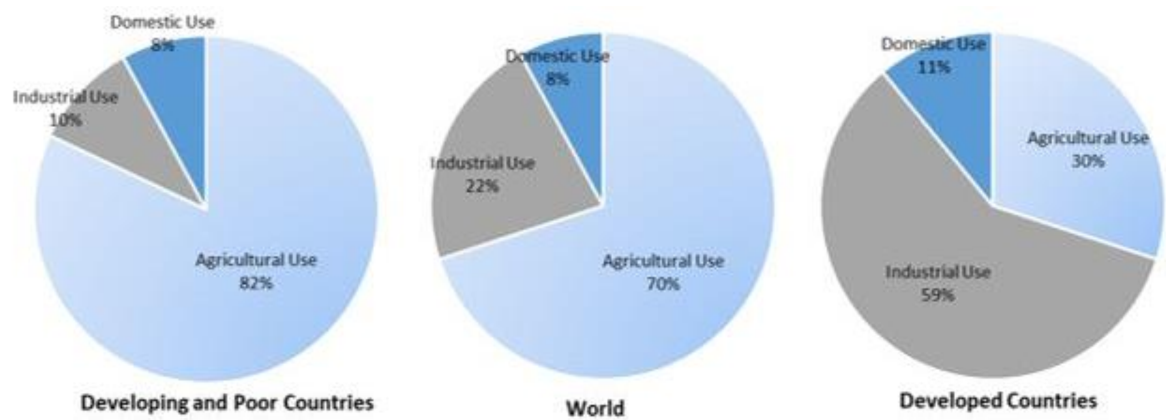
source: Wiki - https://en.wikipedia.org/wiki/Water_scarcity

WHY IS WATER SECURITY SO IMPORTANT?

"Challenges such as economic shocks, food shortages and climate change threaten to undercut economic and social progress made in recent years." (UN WATER WWDR2016)

The agricultural industry is dependent on a consistent supply of fresh water for irrigation. A lack of water results in poor production and an overall drop in crop productivity. Securing a local water supply for is critical to ensure the **FOOD SECURITY**

Ability to provide water for existing but also emerging mines in Australia and around the world is critical in order to maintain, but also grow the mining sector, particularly in the remote northern Australia. Ensuring water availability in highly prospective areas will ensure ongoing **MINERAL AND METAL SECURITY**



ECONOMIC IMPORTANCE OF WATER SECURITY

"Investments in water infrastructure are fundamental to unlocking the full potential of economic growth in the early stages of a country's economic development. Once the marginal benefits of further development decreases, emphasis must gradually shift towards building human and institutional capabilities to enhance water efficiency and sustainability, and secure economic and social development gains".

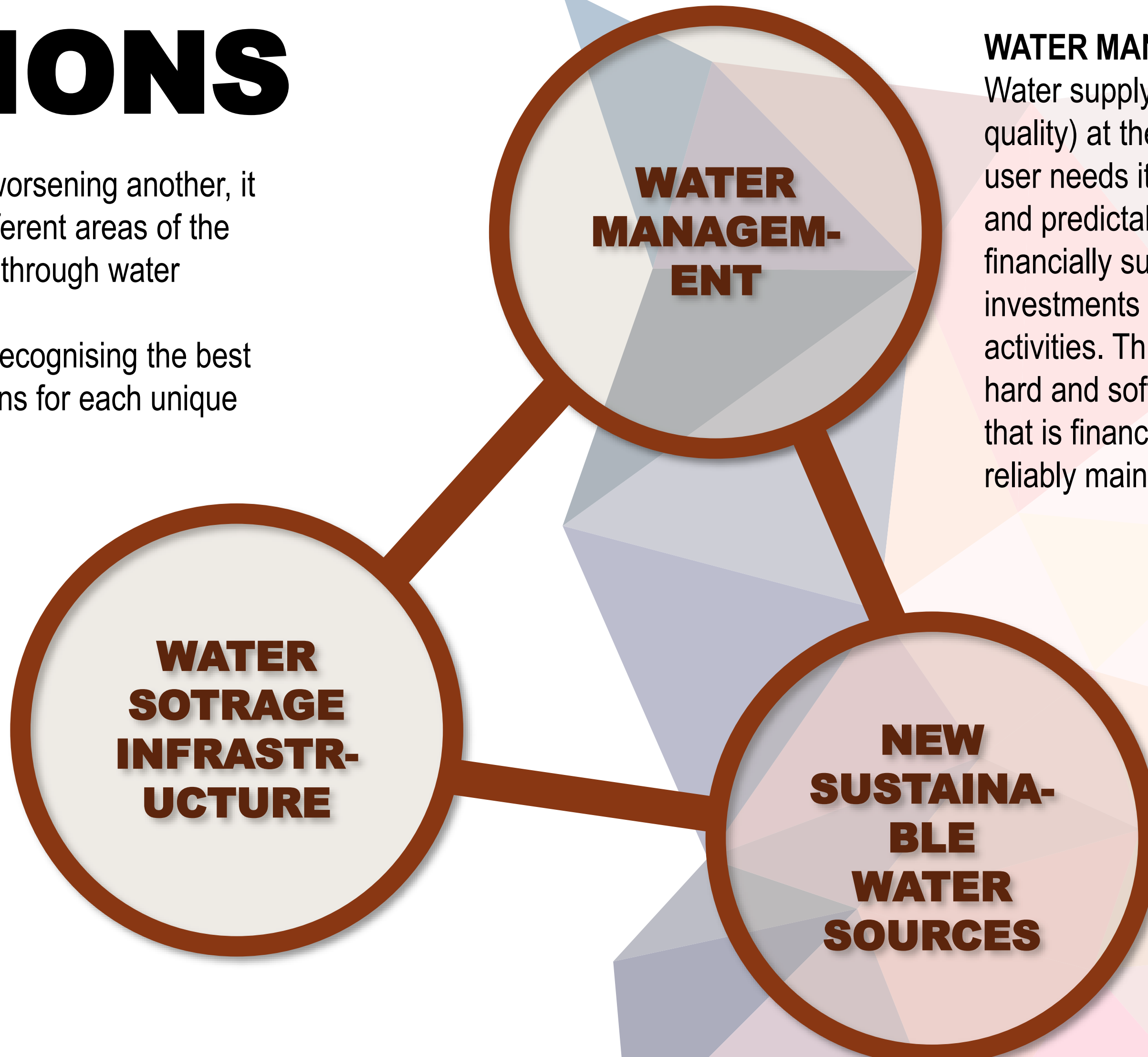
"Water supply (quantity and quality) at the place where the user needs it must be reliable and predictable to support financially sustainable investments in economic activities."
(UNWATER WWDR2015)

By 2050, agriculture will need to produce 60% more food globally, and 100% more in developing countries (Alexandratos and Bruinsma, 2012)

Nearly all forms of energy require water as part of their production process. Freshwater withdrawals for energy production account for 15% of the world's total (WWAP, 2014) and are expected to increase by 20% through 2035 (IEA, 2012)

SOLUTIONS

To avoid solving one problem by worsening another, it is essential to understand how different areas of the economy are linked to each other through water (WWAP, 2012).
Providing water security is about recognising the best water sources and storage solutions for each unique location or industry.



WATER MANAGEMENT
Water supply (quantity and quality) at the place where the user needs it must be reliable and predictable to support financially sustainable investments in economic activities. This requires both hard and soft infrastructure that is financed, operated and reliably maintained

WATER STORAGE INFRASTRUCTURE
The International Resources Panel of the UN states that
"governments have tended to invest heavily in largely inefficient solutions" :
mega-projects like dams, canals, aqueducts pipelines and water reservoirs, which are generally neither environmentally sustainable nor economically viable.

NEW SUSTAINABLE WATER SOURCES
One of the most affordable, easily accessible and environmentally sustainable sources of water in remote areas is groundwater stored in aquifers. Typically shallow aquifers (<100m) are utilised. Deep aquifers (hundreds to thousands of meters deep) provide an opportunity to provide long-term water security

NEW WATER RESOURCES

In the face of climate change and ever decreasing availability of water, Countries like Africa, South America, Australia and Asia need to embark on new programs to define **new water resources** to ensure that these two critical sectors of the worlds economies are sustainable.

AQUIFERS, natures water storage facility

→ **DISCOVERY**

→ **ESTIMATION**

→ **MONITORING**

→ **MANAGEMENT**

WHY AQUIFERS FOR A SUSTAINABLE WATER FUTURE

Extremely high evaporation rates in arid regions around the world negate the use of dams as a single source of water. Deep aquifers provide a solution whereby the water is stored and retained in its preferred location.

Initial trials of the ADR tool in Australia, for example have shown that deep aquifers, particularly in the GAB ((e.g. the Hooray sandstone formation at ~350m below surface) may be identified without the need for drilling. Drilling is only required after the suitable aquifer has been found.

Adrok's "Atomic Dielectric Resonance" (ADR) technology is a new and novel way to utilise low energy, non-destructive digital technology to scan to significant depths (>1000m) beneath the surface of the earth in just a matter of hours. If the detection and processing workflow is resolved during the proposed trials, the technique can help discover, but also manage aquifers.

ADROK IS ON THE CUSP OF DELIVERING NEW TECHNOLOGY TO THE GROUNDWATER SECTOR:

AN ALTERNATIVE, SMARTER SOLUTION

HERE'S HOW

- *Developing a geophysical technique that can distinguish water from other materials at depths in excess of 1000m below the surface.*
- *Providing the water sector with a quick and simple way to check the presence of water at depth prior to expensive drilling.*
- *A technique that can be transported to almost anywhere in the world and operated in extreme cold and heat.*
- *A technology that isn't always restricted by anthropogenic infrastructure (e.g. roads) and can therefore be used in cities or in deserts.*

HOW DOES THE SCANNER DO WHAT OTHER SCANNERS CAN'T?

The Adrok scanner transmits and then receives back, harmless pulses of micro and radio waves. When these waves cross a boundary between material types, an 'echo' is reflected back to the scanner. But the 'echo' that is received is different to the one that was sent out. It has a slightly different resonance. Why? Because a material has its own Dielectric Permittivity – or 'resistance' to the electromagnetic wave that we excite it with - think of it like pouring water on a variety of household objects - all will absorb and repel the water in a different and unique way depending on what it is made of.

WHY DOES THE TECHNOLOGY WORK SO WELL FOR WATER?

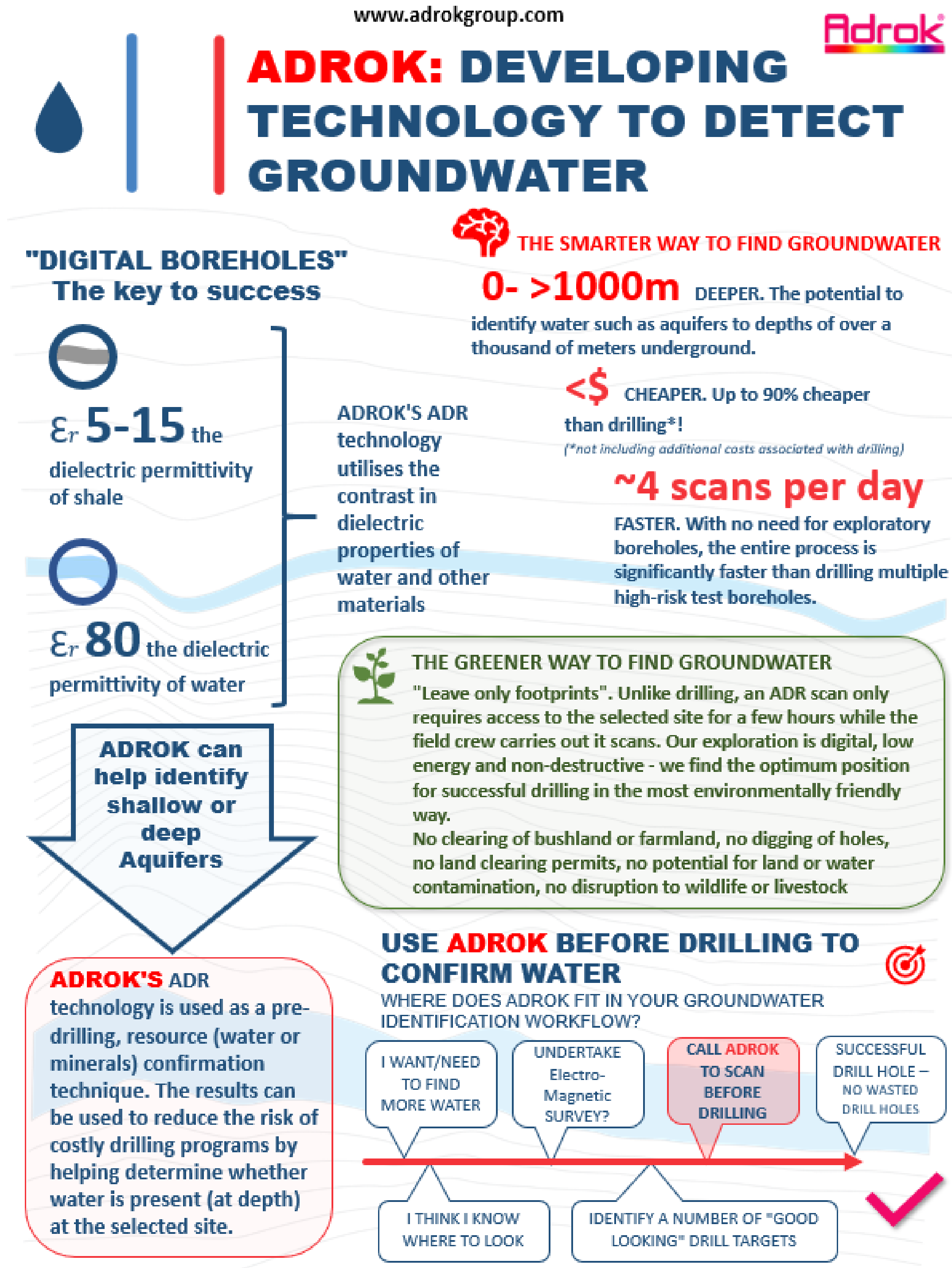
This '**echo**' is as unique as a fingerprint and can then be analyzed to reveal detailed information on the characteristics of the material that has been discovered.

Water has a dielectric permittivity of up to **80**, shales have a dielectric permittivity of only **5-15** and dry soil about **2.5-3**

ADR utilises this natural contrast in Dielectric Permittivity to distinguish water from other materials in the returned ADR signals

There is a perceived **inability** to quickly test for water in areas where water is necessary. Adrok plans to provide the **technical capacity** to meet the required exploration for water across Australia and the world

Adrok, PROVIDING GENUINE CUTTING-EDGE TECHNOLOGY TO HELP COMBAT THE WORLDS MOST SIGNIFICANT PROBELM



AN EXAMPLE: THE VALUE OF WATER IN A DEVELOPED CONOUNTRY: AUSTRALIA

WATER ECONOMICS IN AUSTRALIA:

AGRICULTURE

The **Agriculture Sector** is a significant contribution to the Australian economy with. The sector is a major export earner for the country but is at risk due to ongoing droughts driven by rapidly changing and unpredictable climate.





3% Australia's GDP is from Agriculture sector (at farm-gate)

$60 BILLION
The gross **value** of **Australian** farm production in 2016-17

50-70% of the water consumed in Australia per annum and irrigation uses 90% of that

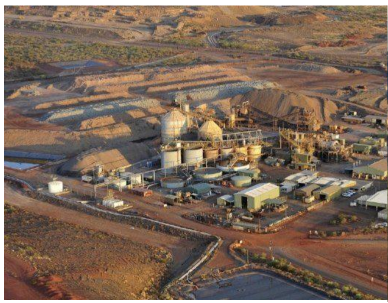
77% of what farmers produce is exported

(http://www.nswic.org.au)
(https://www.nff.org.au › farm-facts)

WATER ECONOMICS IN AUSTRALIA:

MINING

The **Mining Sector** is the largest export earner in Australia. The sector provides high paid jobs for hundreds of thousands of people and pays billions of dollars to governments each year in taxes and royalties. The mining sector has been the largest contributor to the rise in incomes and standards of living in Australia.



8% of Australia's GDP if from mining

$174 BILLION
In the last financial year, export earnings from resource and energy commodities.

Only 3.7% of Australia's water is consumed for Mining.

60% of all exports comes from mining

Mining is required for an effective transition to a carbon neutral planet. New mines will require new water

(https://www.minister.industry.gov.au)

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WATER PRIORITIES IDENTIFIED BY ADROK

Trials and projects completed in other industries and some trials in the water industry suggests that ADR can resolve many gaps in current water exploration toolkit

Number of aquifers

ADROK can help detect multiple stacked aquifers
Using measurements of Dielectric Constant (DC), water (high DC) can be distinguished from other host materials.

Flow rates

It is plausible that ADROK can detect flow rates (already used in the oil industry and currently trials in the water industry)
A developing area for Adrok testing on hydrocarbons in the USA.

Thickness of aquifers

ADROK can be used to determine thickness of aquifers
Processing the scans at very high resolution, it may be possible to pinpoint the thickness of the water-bearing zone (aquifer).

Salinity

ADROK can potentially distinguish saline from fresh water based on spectral fingerprint
Salty water has a slightly different DC than fresh water and may be distinguished in ADR measurements. This is in development.

Identifying aquifer location

Results indicate that Adrok can detect water below 300m underground
Adrok have examples of pinpointing deep water in Cornwall and Oklahoma.

ADROK PLANS TO TAKE THE GUESSWORK OUT OF DEFINING GROUNDWATER/AQUIFERS

ADR is being developed as a pre-drilling confirmation technique. The results can be used to reduce the risk of costly drilling programs by providing, with much greater certainty, whether water is present at depth or not at the determined site.

ADROK's SOLUTION IN A BOX

>1000m

Deeper. The ADROK scanner can, with high vertical resolution, help identify water to depths several thousands of meters underground.

<$

Cheaper. Up to 90% cheaper than drilling*!

*(*this cost does not include many of the additional costs associated with drilling like core logging, storage, core trays etc. All in costs would be well below 90%)*

~4 scans/day

Faster. With no need for exploratory boreholes, the entire process is significantly faster than drilling multiple sometimes unsuccessful boreholes.

0 surface disturbance

Greener: The ADR scanner requires just access to the site. No clearing, no tracks or pads. The equipment can be easily transported to site.

THE SCIENCE

How does the scanner do what other scanners can't?

Refer to next page for Teck Resources successful >350m DEPTH-OF-PENETRATION test

ADR stand for 'Atomic Dielectric Resonance' and is the key to how the scanner works. This is what we create and what we interpret. We measure 'dielectric resonance', which is the unique way materials resonate when hit by electromagnetic waves.

Dielectric Permittivity

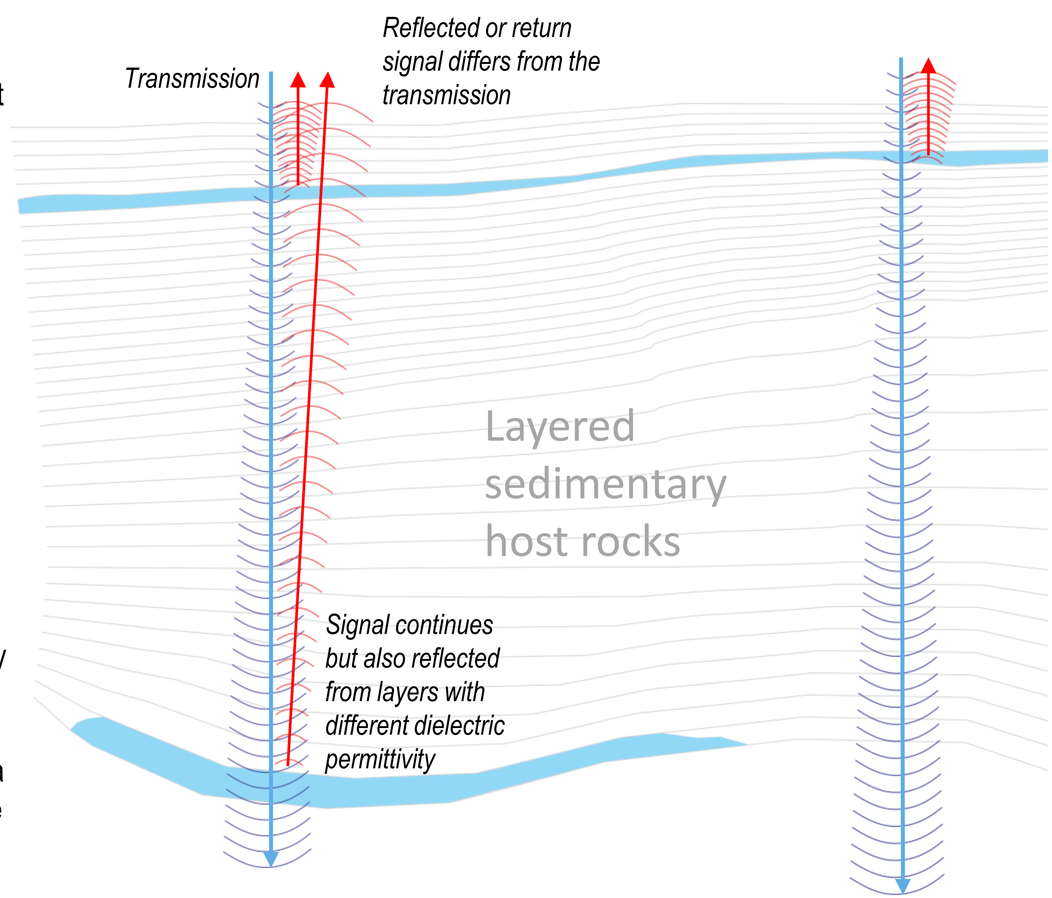
The Adrok scanner transmits and then receives back, narrow pulsed beams of micro and radio waves. When these waves cross a boundary between material types, an 'echo' is reflected back to the scanner. But the 'echo' that is received is different to the one that was sent out. It has a slightly different resonance because each material has its own Dielectric Permittivity or 'resistance' to the electromagnetic wave that we hit it with.

Defining materials

This 'echo' is as unique as a fingerprint and can then be analyzed to reveal detailed information on the characteristics of the material that has been discovered. Because the micro and radio waves are both absorbed and reflected by materials, we can also obtain accurate measurements of the shape and depth of the materials scanned (effectively a map).

Spectroscopy and Dielectrics

After obtaining subsurface data received by the scan, we positively identify the substances using two methods: spectroscopy (this turns our wavelength data into a decipherable spectrum), and Dielectrics - where the readings we obtain are compared with our existing table of substance classification. For example, water has a reading of 80, whereas shales, which are often associated with the sedimentary host-rocks to aquifers have a dielectric permittivity of 5-15.

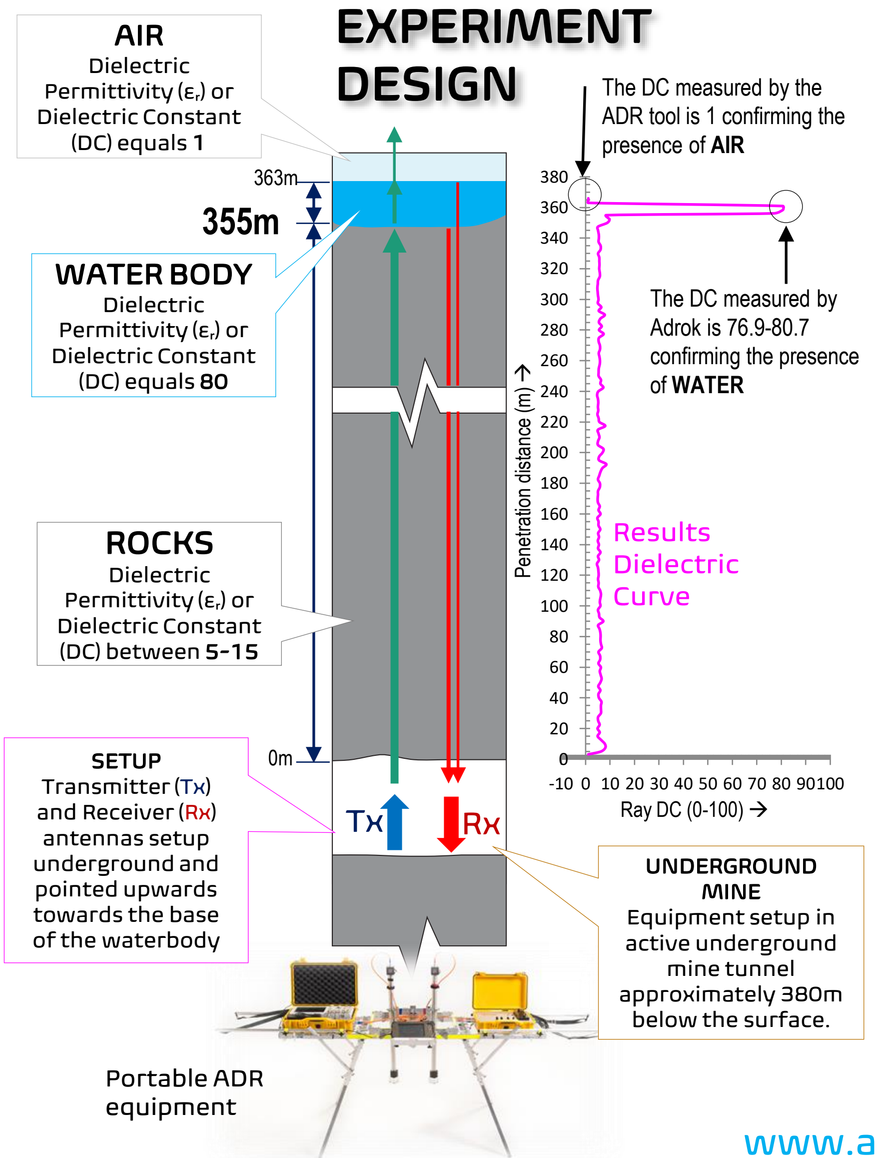


DEPTH-OF-PENTRATION TEST by TECK RESOURCES

Upwards-directed pulsed radar test in an underground mine *(page 1 of 2)*

The following experiment was carried out in collaboration with Teck Resources as a test of Adrok's technology to be able to penetrate significant thicknesses of rock and detect materials with different Dielectric Permittivities.

EXPERIMENT DESIGN

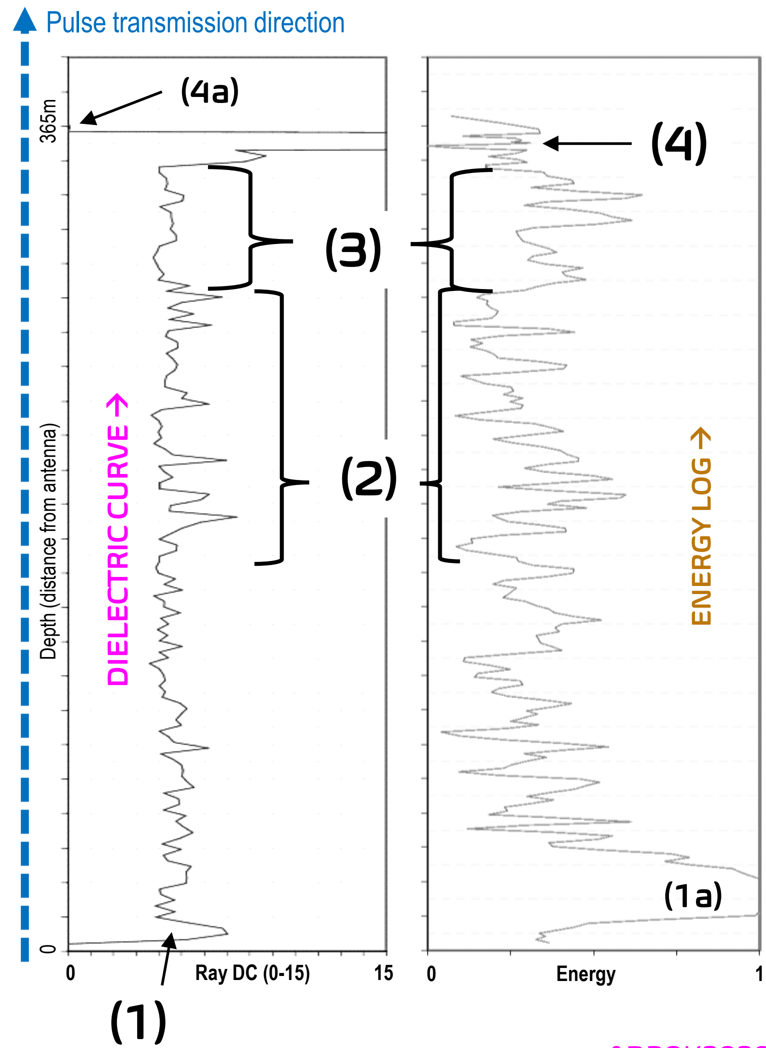


(4) (water-rock interface) The lowest energy (strongest relative energy return) is recorded at the boundary between rock (DC=3-12) and the overlying waterbody (DC=80). The sharp boundary between rocks with contrasting DC acts as a strong reflector at the 1-70MHz range (refer to GPR overleaf). The ADR measurements record the thickness of the body of water (approximately 5.2m thick) as a section of continuously high DC. At point **(4a)**, the DC measurements return to a value of 1, consistent of the known DC of Air (DC=1).

(3) Relatively smooth DC curve suggests few changes in rock type and, with consistently higher energy values. This section **(3)** is interpreted as a separate unit of rock than below **(2)** where DC values are variable and energy response is generally lower.

(2) Changes in DC (Δ < 5 units) and fluctuations in returned energy indicate that the pulse is reflecting small amounts of energy from boundaries between rock types with small differences in (ε_r).

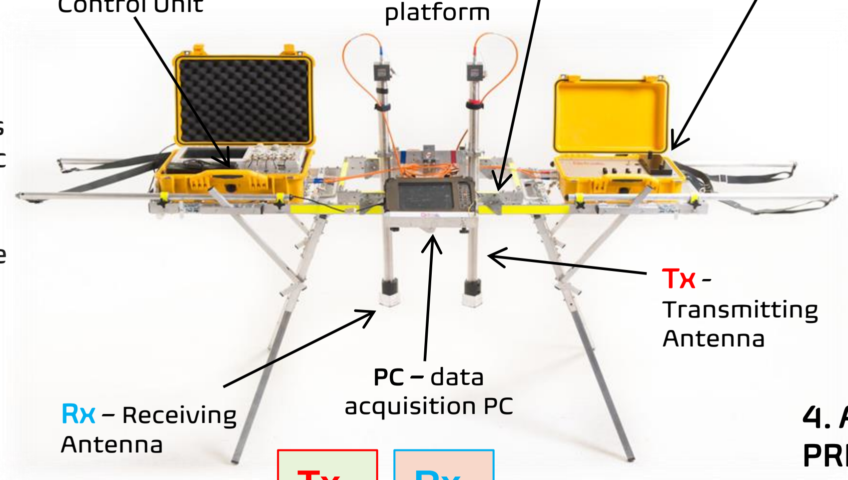
(1) The rapid increase in measured DC from 0 (air) to DC=8 occurs when the transmitted pulse passes from air (DC=1) into the overlying rock. The transition is marked by an equivalent jump in energy **(1a)** marking the absorption of energy by the country rocks.



Using measured ENERGY AND DIELECTRICS to detect water/sulfides under cover *(page 2 of 2)*

1. DETECTING WATER VERSUS DETECTING SULFIDES

WATER and sulfides share similarly high dielectric constants or, dielectric permittivies (ε_r). Working closely on real world tests with clients, Adrok have found that deposits containing layers of massive sulfide respond in a similar way to the example presented for detecting water whereby, boundaries between rocks displaying large changes in Dielectric Permittivity such as granite (DC=5-10 and Massive sulfides (DC>70) return a strong energy signal. A bit like a mirror. For a real-world minerals example case study, visit the following site and read all about the results.



2. Typical SURVEY PARAMETERS

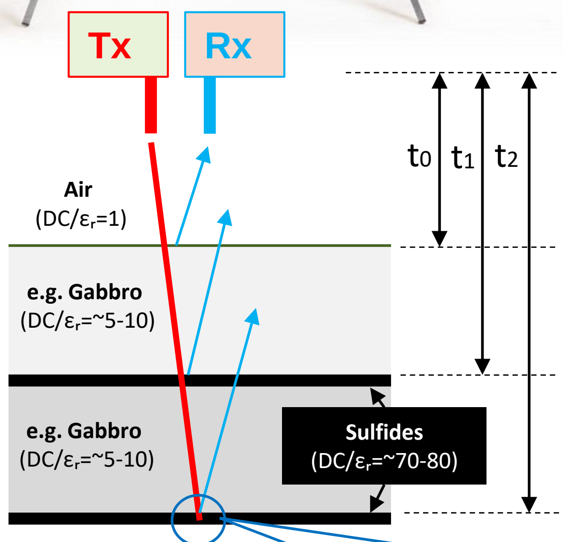
- Sulfide reflection surveys 1MHz – 70MHz
- Typically >4 scans per day
- Pulse penetration depths of up to and over 1000m deep depending on geology
- Training site desirable (vertical drill hole with target sulfide type).
- 3-person field operation

3. BORROWING SOME PRINCIPALS FROM GROUND PENETRATING RADAR (GPR):

GPR (1-1000MHz) uses similar frequencies to the ADR tool used for detecting massive sulfides (1-70MHz). There are, however, some fundamental differences in the technology, particularly in the transmitter and antenna design, but many of the physical principals for GPR are the same as those for ADR.

"GPR *for example* consists of an antenna that produces short duration electromagnetic pulses that penetrate…materials. The radar pulses are reflected at interfaces where the dielectric constants of material layers change. The reflected amplitude depends on the change in dielectric constant, while the arrival time of a reflected wave at a detector also depends on the depth at which the discontinuity is encountered. Layer material's dielectric property is used for pulse velocity and thickness calculation. "

Exert taken from:
https://www.researchgate.net/publication/318152161_Ground_Penetrating_Radar_for_Measuring_Thickness_of_an_Unbound_Layer_of_a_Pavement



Transmitted pulse (red) is reflected from boundary (blue) between sulfides and host rocks. The strongest reflections occur at boundaries between rocks with greatest contrasting Dielectric Permittivities (ε_r) or Dielectric Constants (DC).

4. ALSO BORROWING PRINCIPALS FROM SEISMIC REFLECTION:

"When a seismic wave encounters a boundary between two materials with different acoustic impedances, some of the energy in the wave will be reflected at the boundary, while some of the energy will be transmitted through the boundary. The amplitude of the reflected wave is predicted by multiplying the amplitude of the incident wave by the seismic *reflection coefficient*, determined by the impedance contrast between the two materials"

Source: https://en.wikipedia.org/wiki/Reflection_seismology
See also animations:
https://en.wikipedia.org/wiki/Reflection_coefficient

ADR typically does NOT measure the thickness of sulfide layers, simply the depth of the reflected energy. The strong reflection coming from metal sulfides in preference to any other discrepancies in the relatively homogeneous host granite/country rock.

Traditional (outdated) exploratory drilling

- Requires several environmental permits
- More rigorous landholder negotiations
- Not always successful in intercepting water table (especially in areas with complex structure of deep paleochannels and/complex lithological variations)
- Can take a long time from setup to completion
- Requires road clearing and pad (drill site) clearing
- Increased risk of introducing weeds on drill rigs traveling between sites around the country
- Increased risk of "Lost Time Injury" (LTI).
- Not cost effective, especially at depths of over 300 meters beneath the surface
- Noise and dust pollution generated by drilling rig
- Can require a water source and/or water trucks to transport water to site.
- Disruptive to crops and livestock and native wildlife

THE BENEFITS OF ADROK'S ADR VIRTUAL BOREHOLE TECHNOLOGY

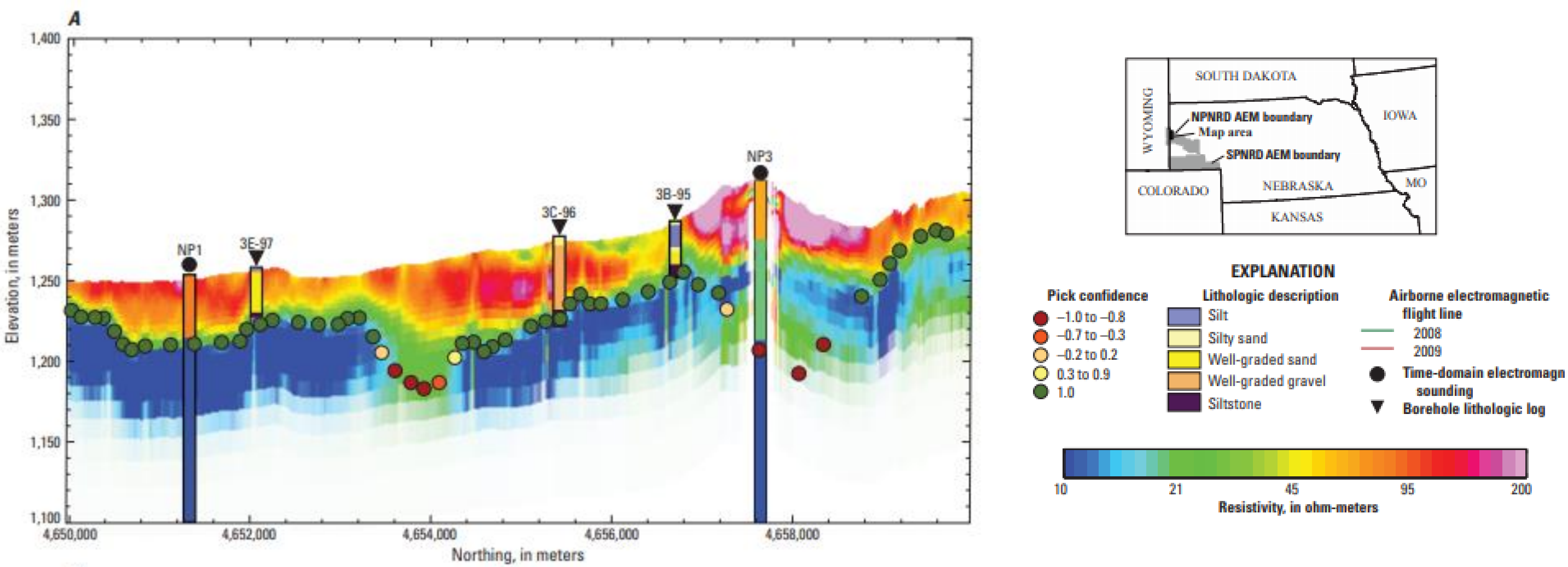
- No special environmental permits (non-destructive digital technology).
- Easy landholder negotiations as there is no impact.
- Almost no impact with no surface disruption, just footprints.
- Pre-drill confirmation - can help identify depth to multiple water tables to >1000m.
- Av. 4 scans per day to >1000m meaning it saves time. Scans take hours, not weeks.
- No road clearing and no pad (drill site) clearing.
- Only one 4WD, helicopter or other transport required to site therefore limiting risk of introducing weeds.
- Decreased risk of LTI's because its non-mechanical, quick and simple.
- Very cost effective, especially to depths over >300 meters where it is up to 90% less than the cost of drilling.
- No pollution and no diesel required (small carbon footprint)
- No additional resources such as water or diesel required at site.
- Not disruptive to native flora and fauna, to crops or livestock.

Adrok®

ADROK COMPLIMENTS
Airborne Electromagnetic Mapping

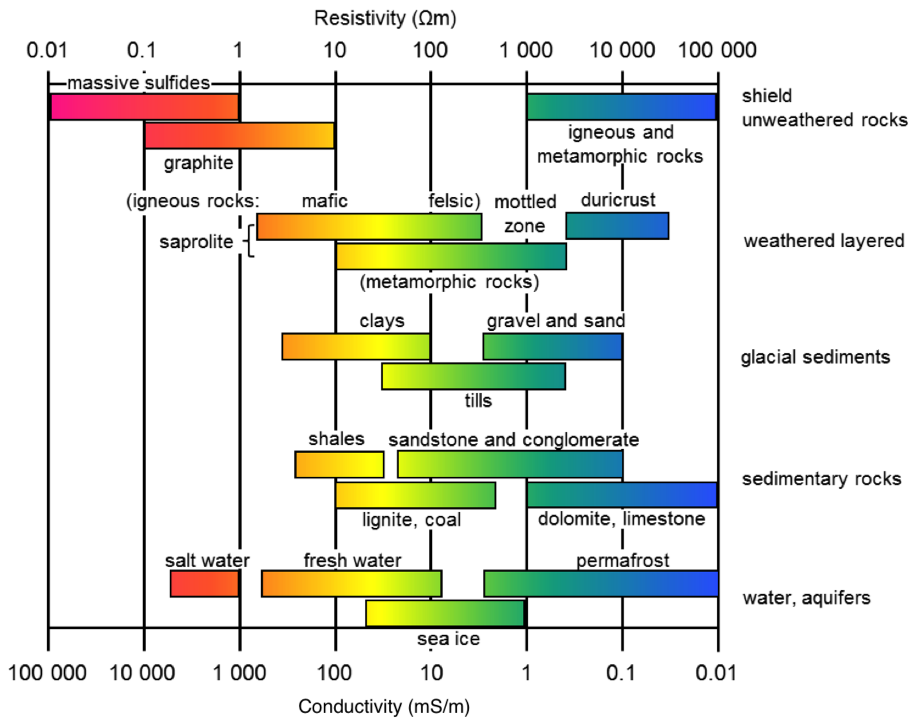
Airborne Electromagnetic (AEM) Interpretation of Aquifers

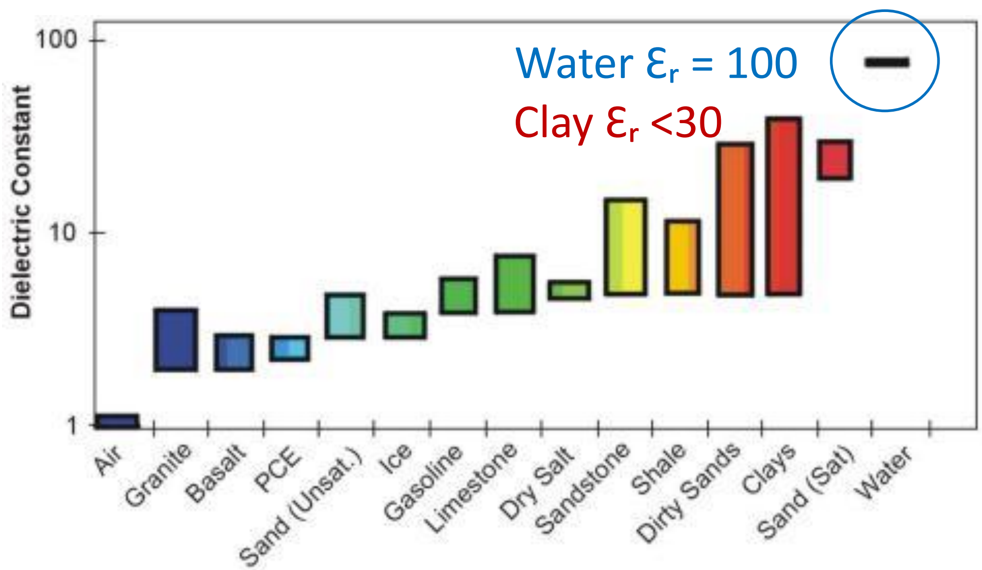
The interpretation of aquifers using AEM requires several assumptions about the subsurface geology, in particular the resistivity of the rocks and other materials. In order to gain a greater, more reliable interpretation, the resistivity of the rocks are measured prior to the survey being undertaken (e.g. "**Electrical resistivity can be correlated with geologic units on the surface and at depth using lithologic logs"** https://pubs.usgs.gov/sir/2011/5219/sir2011-5219.pdf). Typically, granite and other metamorphic rocks that are low in graphitic phases for example have high resistivity whereas saline sediments or saline water within pore spaces of normally resistive rocks can also be low resistivity. Clays and fresh water tend to have the same resistivity, so they are difficult to distinguish using EM (ref. adjacent table of resistivities)



https://pubs.usgs.gov/sir/2011/5219/sir2011-5219.pdf

Additional benefits of ADR





- **No prior drilling required** as DC is a measurable value. Values higher than 15-20 almost always have a water component.
- **Multiple stacked aquifers** can be targeted which is difficult for the EM technique.
- **Depth of investigation** can be over 500m.
- **Water has a very different ε_r** (or Dielectric Constant, DC) from rocks and minerals whereas the resistivity of rocks and water can overlap significantly.
- Can add value to EM by confirming the presence or absence of water without the need for drilling
- **Adrok collects a suite of data**, not just ε_r /DC so there are multiple ways to check the presence or absence of water

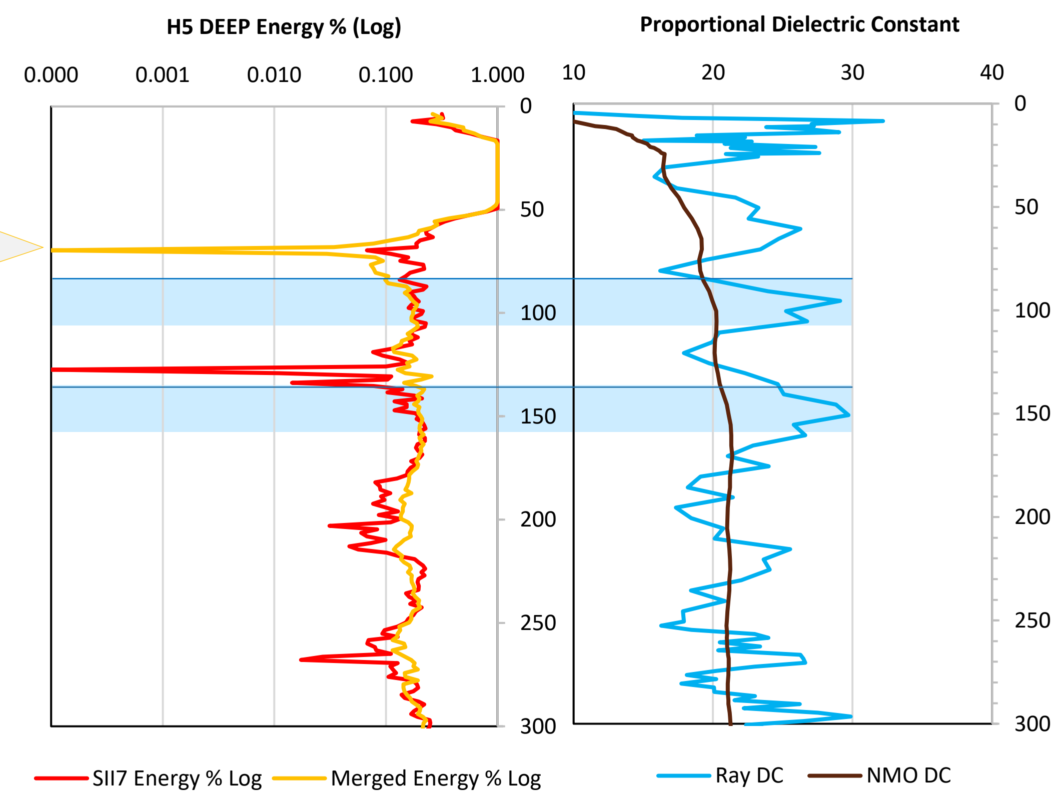
"On Earth, values greater than **15** are seldom associated with dry materials. RES data collected in Antarctica and Greenland show that a **permittivity larger than 15 is indicative of the presence of liquid water below polar deposits**." (https://science.sciencemag.org/content/361/6401/490)

Water was defined on Mars using the principals of:

1) Signal power, which Adrok refer to as Energy and presented as E%Log (see example below) which in turn is an inverse of the relative reflected energy from layers within the Earth's crust and
2) The variation in permittivity between different materials which are air, water and rock.

Case example

Higher E% is representative of higher reflectivity at boundary between materials with different permittivities e.g. rock-water interface



A real-world case example from an Adrok survey where water-saturated sediments are interpreted at around 100 and 150m depth.

The peaks in Proportional Dielectric Constant (or Dielectric Permittivity) correspond with troughs in energy which indicate a "reflective" boundary between materials.

E% is plotted as a derivative (%) from total return energy and is the inverse of total energy response per unit depth. Low values = high reflectivity/high energy return.

WATER TARGETING

Principals of water targeting are the same on Earth as they are on Mars

Higher power (dB) is representative of higher reflectivity at boundary between materials with different permittivities

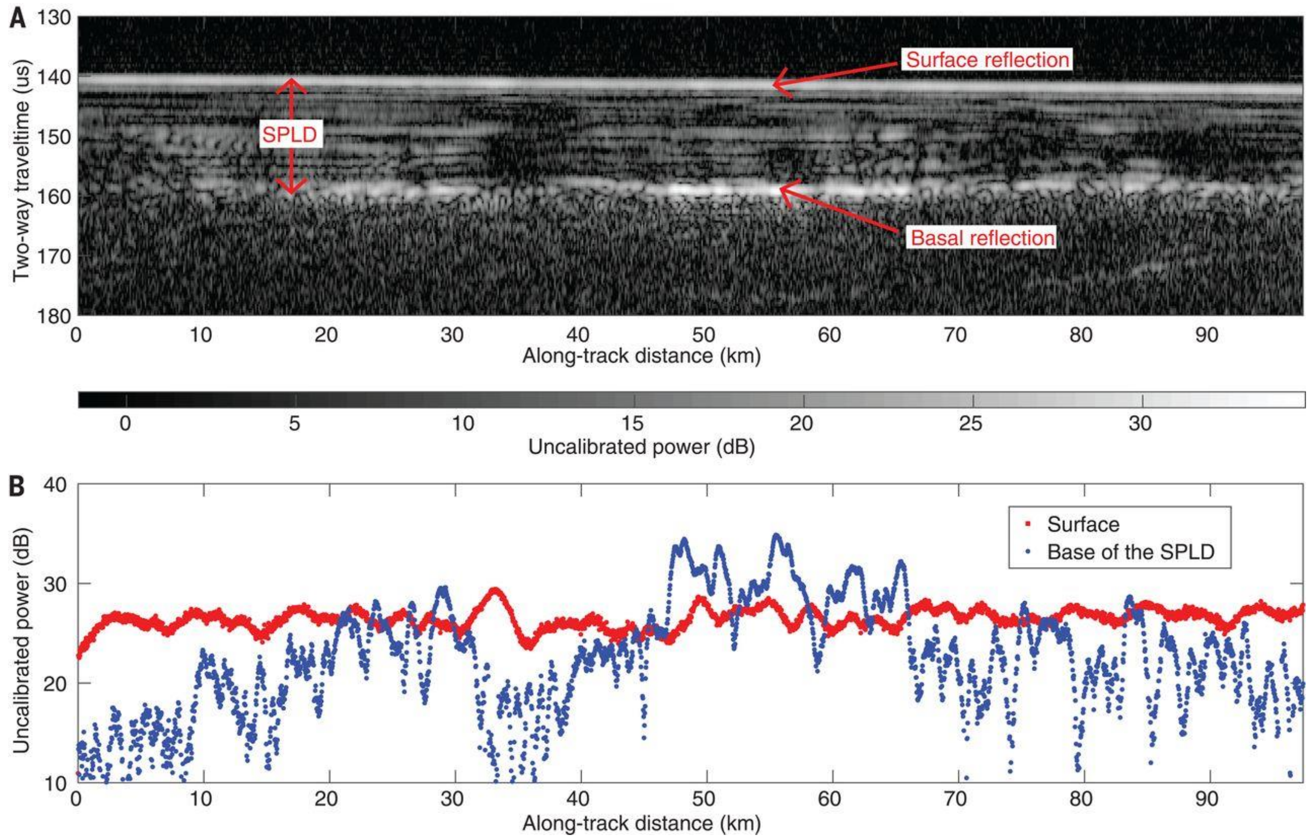
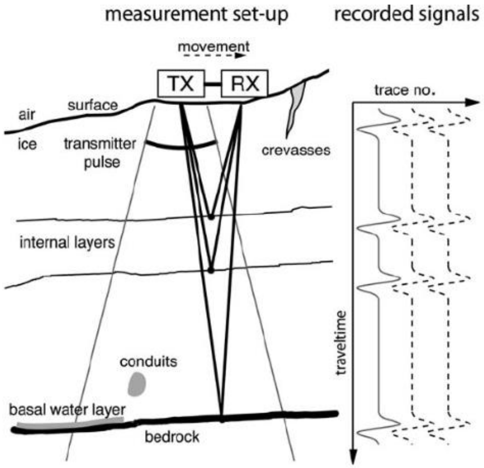


Fig. 2 from https://science.sciencemag.org/content/361/6401/490 **overleaf - Radar data collected by MARSIS.**(A) Radargram for MARSIS orbit 10737, whose ground track is shown in Fig. 1B (refer to original paper). A radargram is a bi-dimensional color-coded section made of a sequence of echoes in which the horizontal axis is the distance along the ground track of the spacecraft, the vertical axis represents the two-way travel time of the echo (from a reference altitude of 25 km above the reference datum), and brightness is a function of echo power. The continuous bright line in the topmost part of the radargram is the echo from the surface interface, whereas the bottom reflector at about 160 μs corresponds to the SPLD/basal material interface. Strong basal reflections can be seen at some locations, where the basal interface is also planar and parallel to the surface. (B) Plot of surface and basal echo power for the radargram in (A). Red dots, surface echo power; blue dots, subsurface echo power. The horizontal scale is along-track distance, as in (A), and the vertical scale is uncalibrated power in decibels. The basal echo between 45 and 65 km along-track is stronger than the surface echo even after attenuation within the SPLD.

11. Ground-penetrating radar in glaciological applications

Francisco Navarro and Olaf Eisen



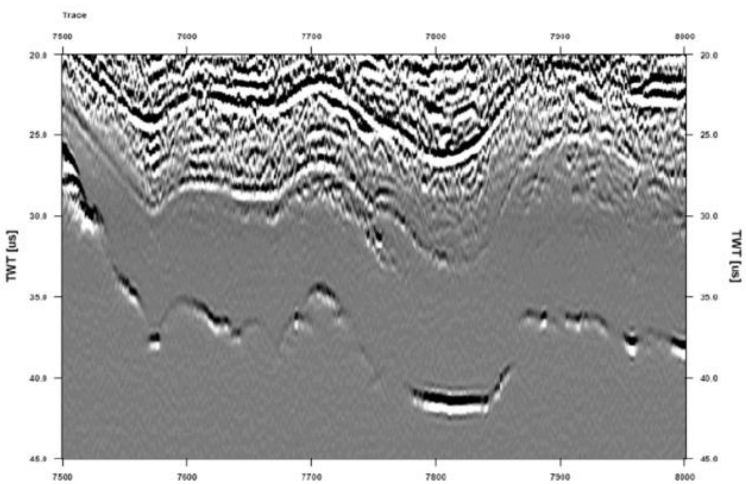


Fig. 11.6. Example of radargram showing a subglacial lake, corresponding to the bright nearly flat reflector in the lower part of the figure around trace 7800, also showing a very low reflection at the steep flanks of the lake. Image courtesy of Daniel Steinhage, AWI.

https://www.researchgate.net/publication/279611860_Ground-penetrating_radar_in_glaciological_applications

https://library.seg.org/doi/abs/10.1190/1.1443105

Radar detection of subglacial sulfides

W. R. Hammond* and K. F. Sprenke*

ABSTRACT

Using an ice radar system, we detected anomalous reflection strengths over subglacial disseminated sulfide zones beneath the Mt. Henry Clay Glacier in southeast Alaska. The subglacial sulfide zones, which were verified by drill holes, were not detected by previous magnetic, helicopter EM, or ground-based time-domain EM surveys. The sulfide zones were mapped by measuring lateral variations in the strength of radar echoes from the ice-bedrock interface at the base of the glacier. The reflected power from these disseminated occurrences ranged from 20 percent to 60 percent of the theoretically predicted reflected power from a perfect conductor at the base of the ice. The empirical results of this experiment suggest that ice radar may be a useful tool for direct mineral exploration in ice-covered terrain.

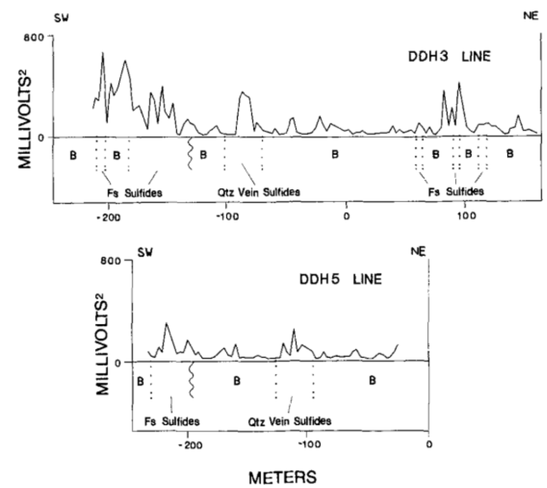


FIG. 4. Radar bottom echo strength and drill hole results on the Mt. Henry Clay Glacier. The echo strength plotted is the squared peak-to-peak amplitude. See Figure 2 for line locations and a plan view of subglacial geology. B = basalt and andesite; Fs = felsic schist.

WATER TARGETING

The physics and methodologies used in the GPR industry are similar, Adrok has the hardware that delivers the capacity for <u>depth penetration</u> as demonstrated by in-field and actual user results including:

Teck, Chevron, McEwan Mining, Gensource, Caithness Petroleum, Citigold, Scottish Water…and the list goes on.

https://www.youtube.com/watch?v=L3yorQapu1I&t=41s

http://732d260b3b2c4785e6ba-5e7fb0973d416887bfa95eb918035568.r88.cf1.rackcdn.com/FP%2030.04.2019%20Dr%20Dave%20Waters_Paetoro%20Consulting%20UK%20Ltd.m4v

Calculation and Interpretation of Ground Penetrating Radar for Temperature and Relative Water Content of Seasonal Permafrost in Qinghai-Tibet Plateau

Qing Wang [1] and Yupeng Shen [2,*]

1 School of Information and Communication Engineering, Beijing Information Science and Technology University, 100192 Beijing, China
2 School of Civil Engineering, Beijing Jiaotong University, 100044 Beijing, China
* Correspondence: ypshen@bjtu.edu.cn; Tel.: +86-1381-087-3345

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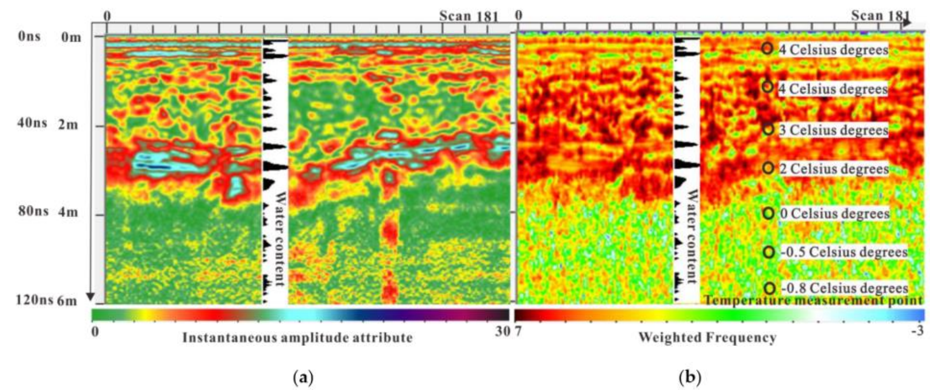


Figure 9. Correspondence diagram between electromagnetic wave attribute and measured data. (**a**) Absolute instantaneous amplitude attribute; (**b**) weighted average frequency attribute; water content is inserted in (**a**) and (**b**); black circle notes temperature in (**b**). The dielectric constant of the medium is 11.

Abstract: Due to the seasonal permafrost thawing, the Qinghai–Tibet Highway has a depression and instability of the roadbed. In order to obtain the ablation interface and water content characteristics of seasonal permafrost areas, non-destructive ground penetrating radars using electromagnetic wave detection methods are widely used. Regarding the imaging of the ablation interface in permafrost regions, this paper proposes a high-precision procedure for seasonal permafrost media using waveform difference analysis, electromagnetic wave attenuation attribute calculation and relative wave impedance conversion. It improves the resolution and division accuracy of the imaging. In addition, the study demonstrates a method to calculate the temperature and water content of the ablation zone by mining attenuation attribute, relative wave impedance attribute, absolute instantaneous amplitude attribute and the weighted average frequency attribute parameters under the constraints of the measured data. This method has high accuracy and high efficiency and can be used in the rapid calculation of temperature and water content of seasonal permafrost on the Qinghai–Tibet Highway.

CASE STUDY

Some background information of GEOTHERMAL

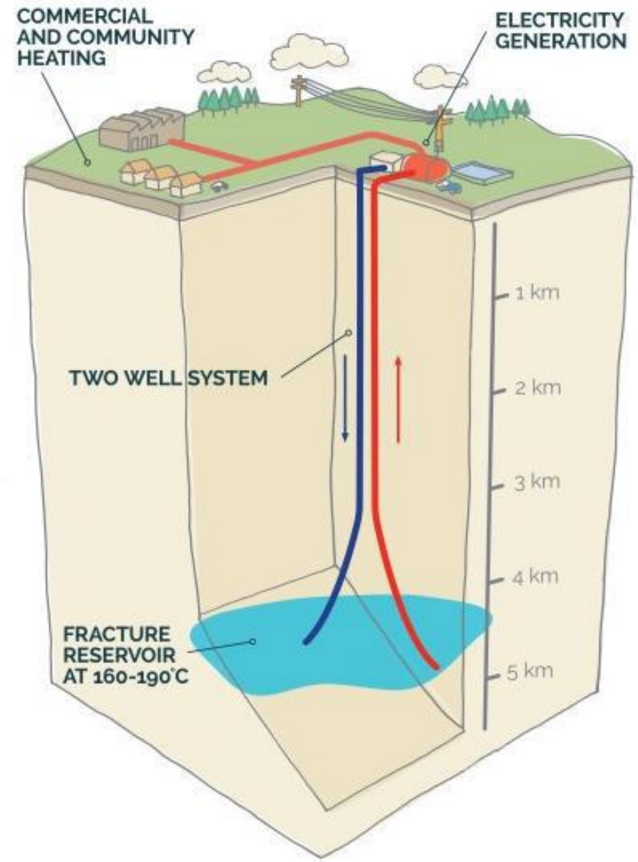
Info from: Clean Energy Council of Australia

cleanenergycouncil.org.au

Geothermal energy uses the Earth's natural internal heat to generate electricity and heating. Geothermal energy may be stored in granite rocks (often called ‘hot rocks’) or trapped in liquids such as water and brine (hydrothermal process).

How an enhanced geothermal system works

Getting energy from 'hot rocks' relies on techniques established by the oil and gas industries. Wells are drilled to a depth of 3–5 km below the surface to find heat-producing granites. Water is pumped into the wells and through cracks in the rocks, where it becomes heated to a temperature of up to 300°C.
This extremely hot water is then pushed back to the surface, where the heat is used to drive a turbine and produce electricity. The water is recycled and the process can begin again.



Schematic diagram of geothermal energy derived from circulation of water through hot bodies of rock (typically granites) at depths of up to 5km

25%

The amount of electricity generated by Iceland via geothermal sources

17%

The amount of electricity generated by Philippines and Kenya via geothermal sources

0.001%

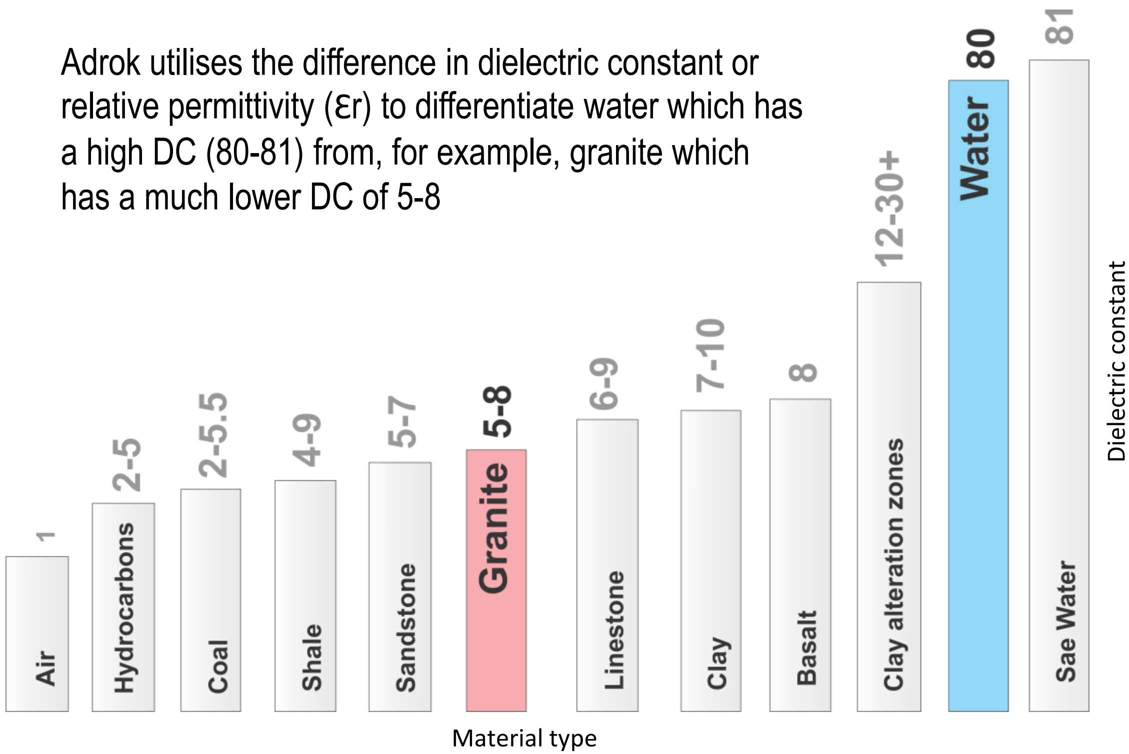
The amount of electricity generated by AUSTRALIA from geothermal sources

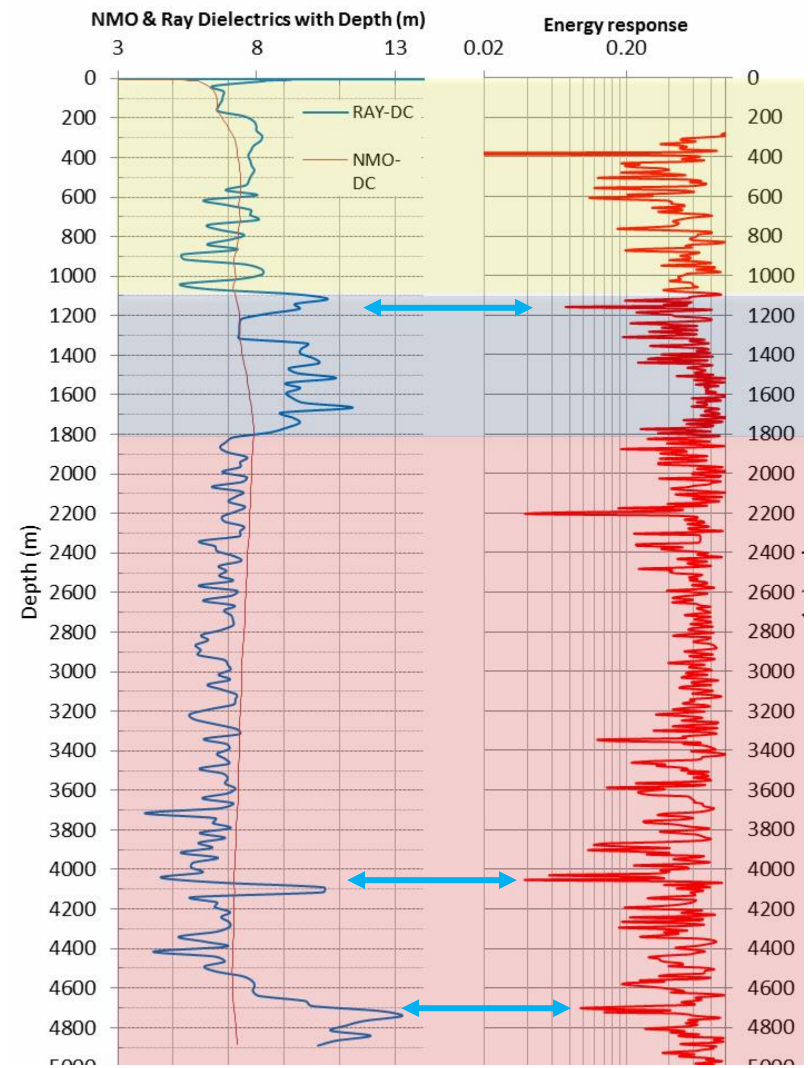
ADROK RESULTS CORNWALL GEOTHERMAL

Cornwall Geothermal - Identifying hydrated fracture in granite at >4000m depth

For more information see www.adrokgroup.com – "Together we rock" Volume 3, Case Study 4.1

Adrok utilises the difference in dielectric constant or relative permittivity (Ɛr) to differentiate water which has a high DC (80-81) from, for example, granite which has a much lower DC of 5-8





Exert from processed scan

Water-rich fractures in granite are characterised by Low Energy (high energy reflectivity) and expectedly high DC

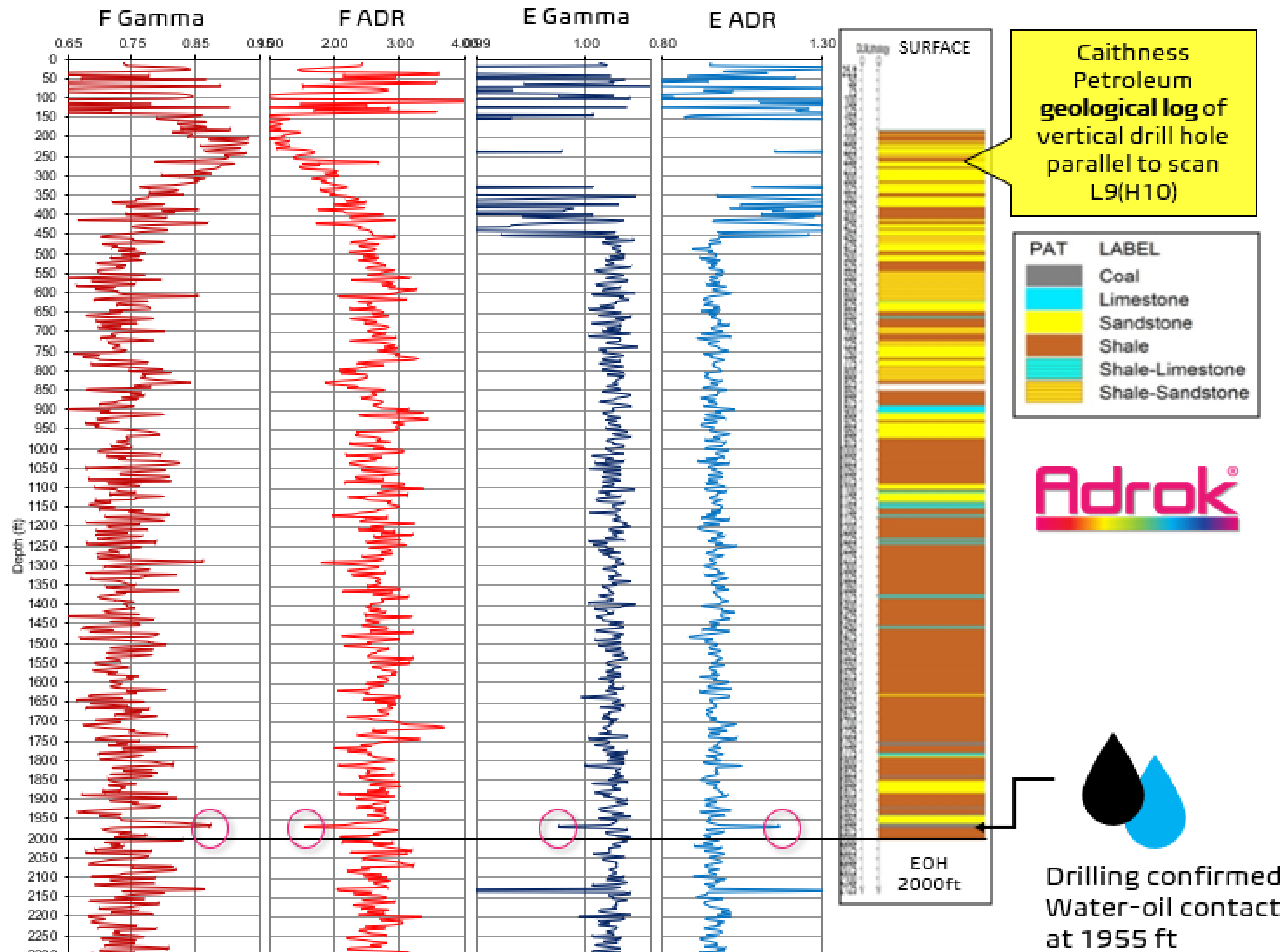
CASE STUDY

Oil-water boundary, OKLAHOMA

Pulsed Radar scan results (vertical graphs) showing the characteristics of the reflected signal relative to depth.
E = Energy
F = Frequency

Water-oil boundary at 1967 feet below surface

Deep (2000ft) Petroleum and Water detection using Pulsed Radar

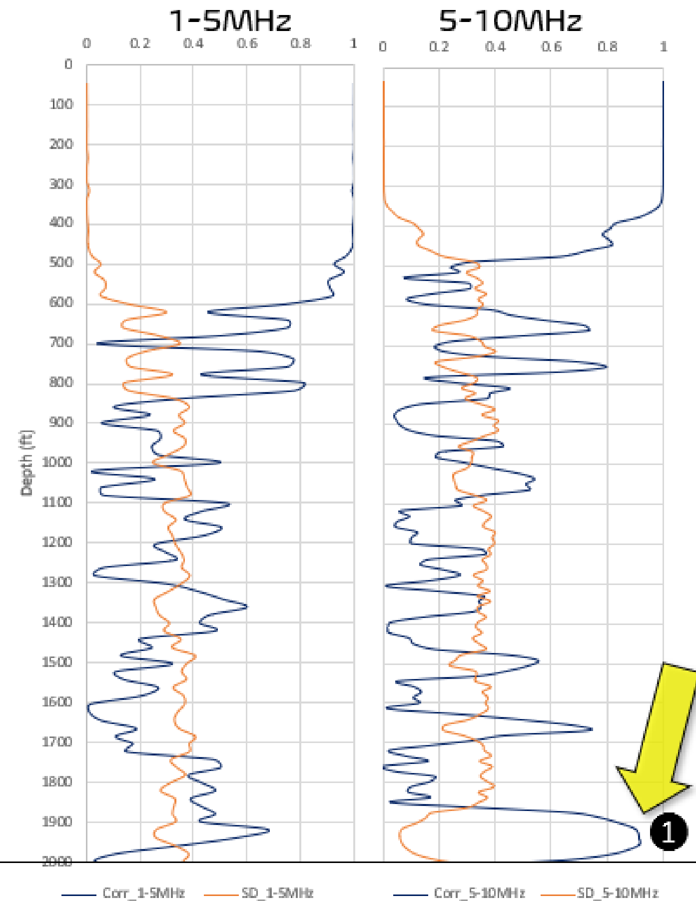


CAITHNESS PETROLEUM LIMITED

Adrok were contracted to carry out a test of the deep penetrating pulsed radar at detecting oil in Oklahoma for Caithness Petroleum Limited. Results returned a strong anomaly in frequency (F-Gamma and F-ADR) and Energy (E-Gamma and E-ADR) at 1967ft. Ciathness confirmed the water-oil contact at 1955 feet, a difference of 8ft.

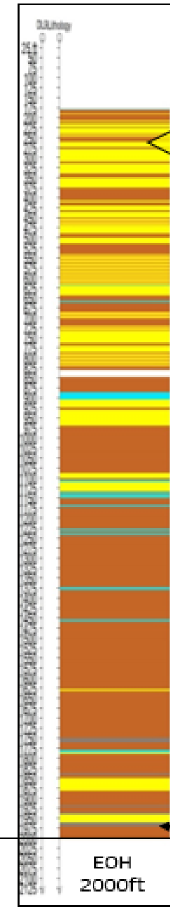
Deep (2000ft) Petroleum and Water detection using Pulsed Radar

Pulsed Radar scan results 1-5 MHz and 5-10MHz results



Water-oil boundary at 1967 feet below surface

Caithness Petroleum **geological log** of vertical drill hole parallel to scan L9(H10)



PAT	LABEL
	Coal
	Limestone
	Sandstone
	Shale
	Shale-Limestone
	Shale-Sandstone

Adrok®

Drilling confirmed Water-oil contact at 1955 ft

Very high values for correlation in 5-10MHz bandwidth (1 maximum at 1953.45ft) support the presence of oil between 1940-1950ft deep. Combined with other ADR results and when used together, the multiple datasets support the presence of oil and water near the anomaly at 1968ft depth. Drill hole data confirmed water-oil contact at approximately 1955ft depth.

CAITHNESS PETROLEUM LIMITED

GAB BACKGROUND

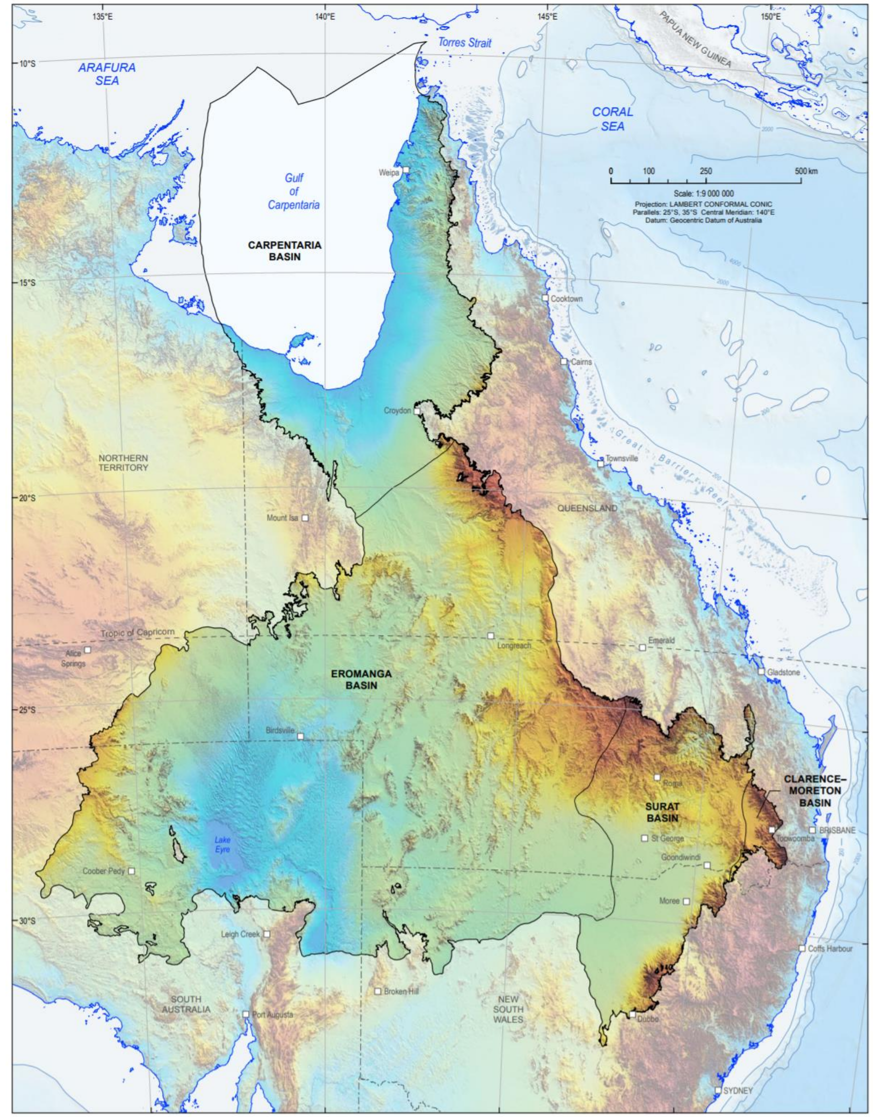
Geoscience Australia – Summary of the Great Artesian Basin Research Priorities Workshop

http://dx.doi.org/10.11636/Record.2016.023

"The Great Artesian Basin (GAB) is the largest groundwater basin in Australia, underlying parts of Queensland, New South Wales, South Australia and the Northern Territory. The GAB contains a vast volume of underground water and it is a vital resource for pastoral, agricultural, and extractive industries as well as for town water supplies. Properly managing these groundwater resources, often with competing interests, requires sound understanding of the whole groundwater system.

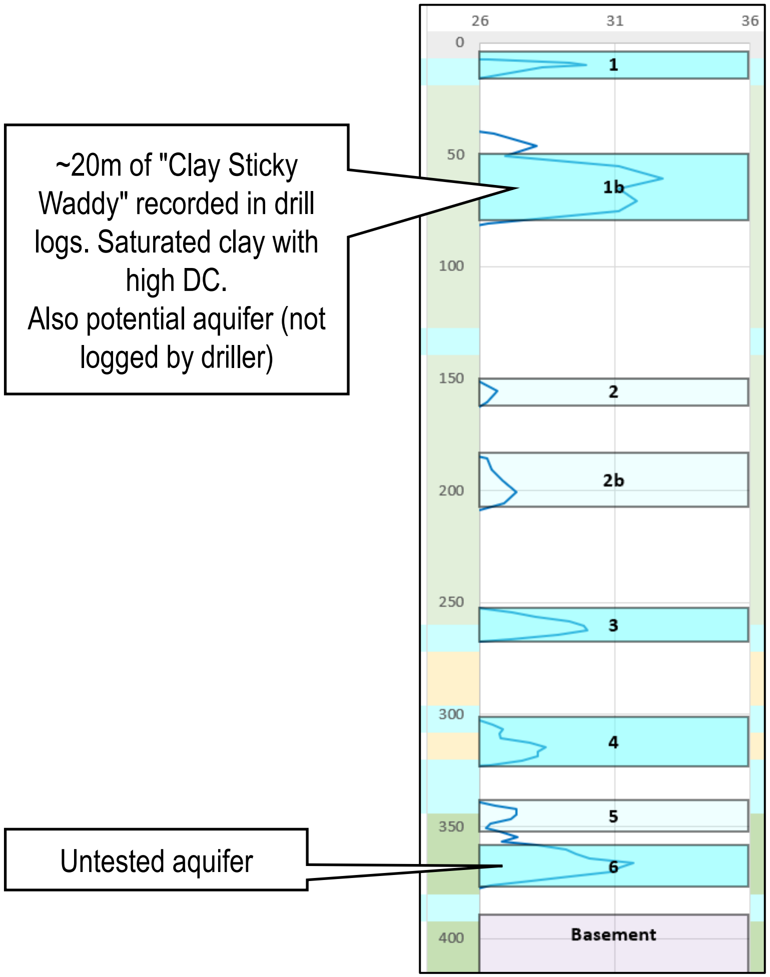
The outcomes from past projects have ***identified numerous knowledge gaps*** and have clearly shown that the GAB is a complex groundwater basin with a large component of vertical flow through geological structures and hydraulic connections in some areas to basins above, below and within the GAB.

New information is required as new challenges arise; this knowledge evolution leads to a recognition that current key science issues exist that need to be explored. It is essential to share information about GAB water policy, management and research activities with relevant stakeholders and decision makers and ***work collaboratively to develop future science priorities***."



CASE STUDY: GAB AQUIFER TARGETING

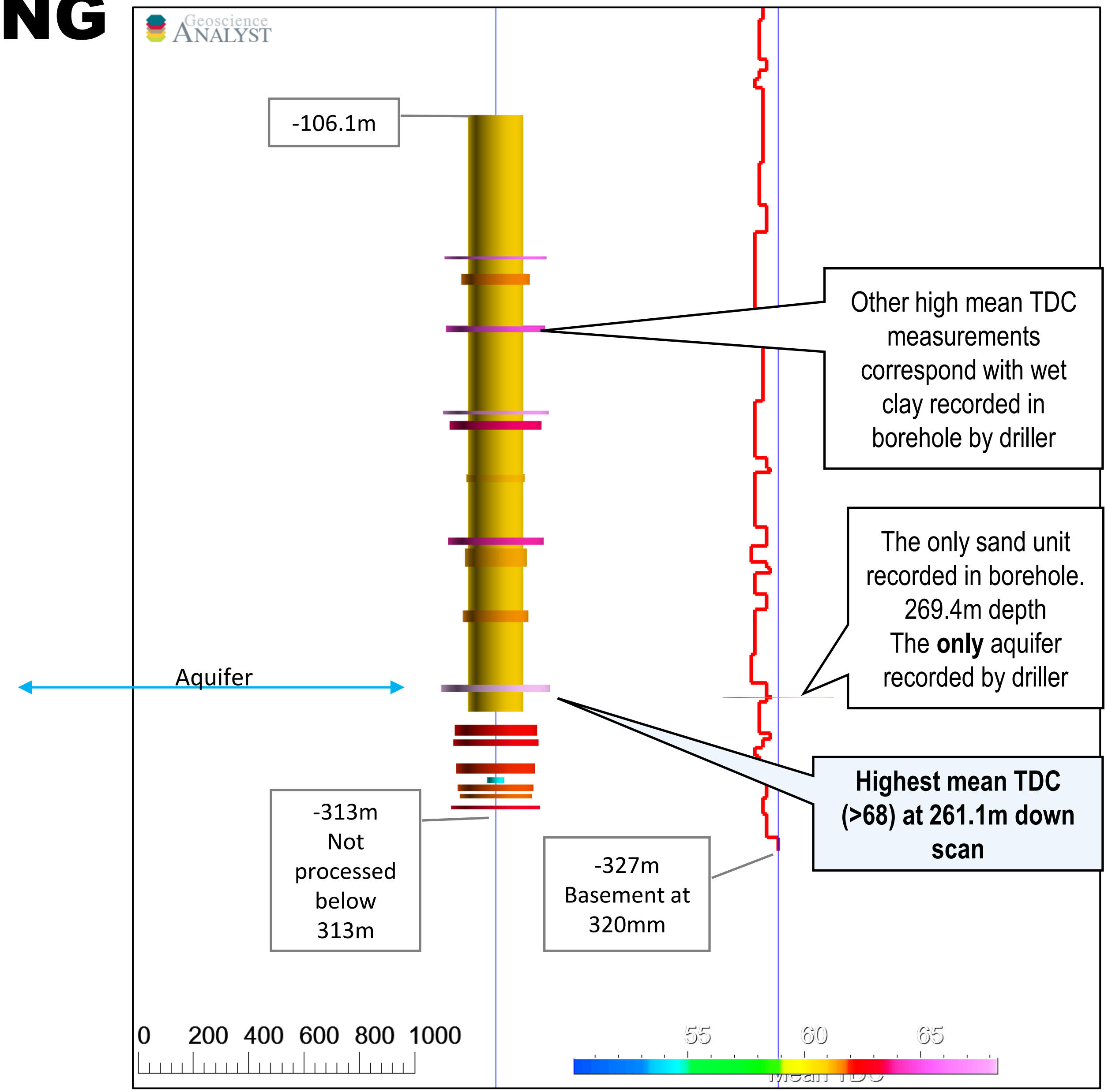
ADR scan example
(processing type 1)



Extract of possible water-rich layers from Adrok's processing results

ADR Scan example
T-DC mean
(processing type 2)

Borehole ID (client)
Rock type (est DC only)



Screen capture from Geoscience Analyst 3D model showing ADR scan (left) and borehole log (right)

Adrok

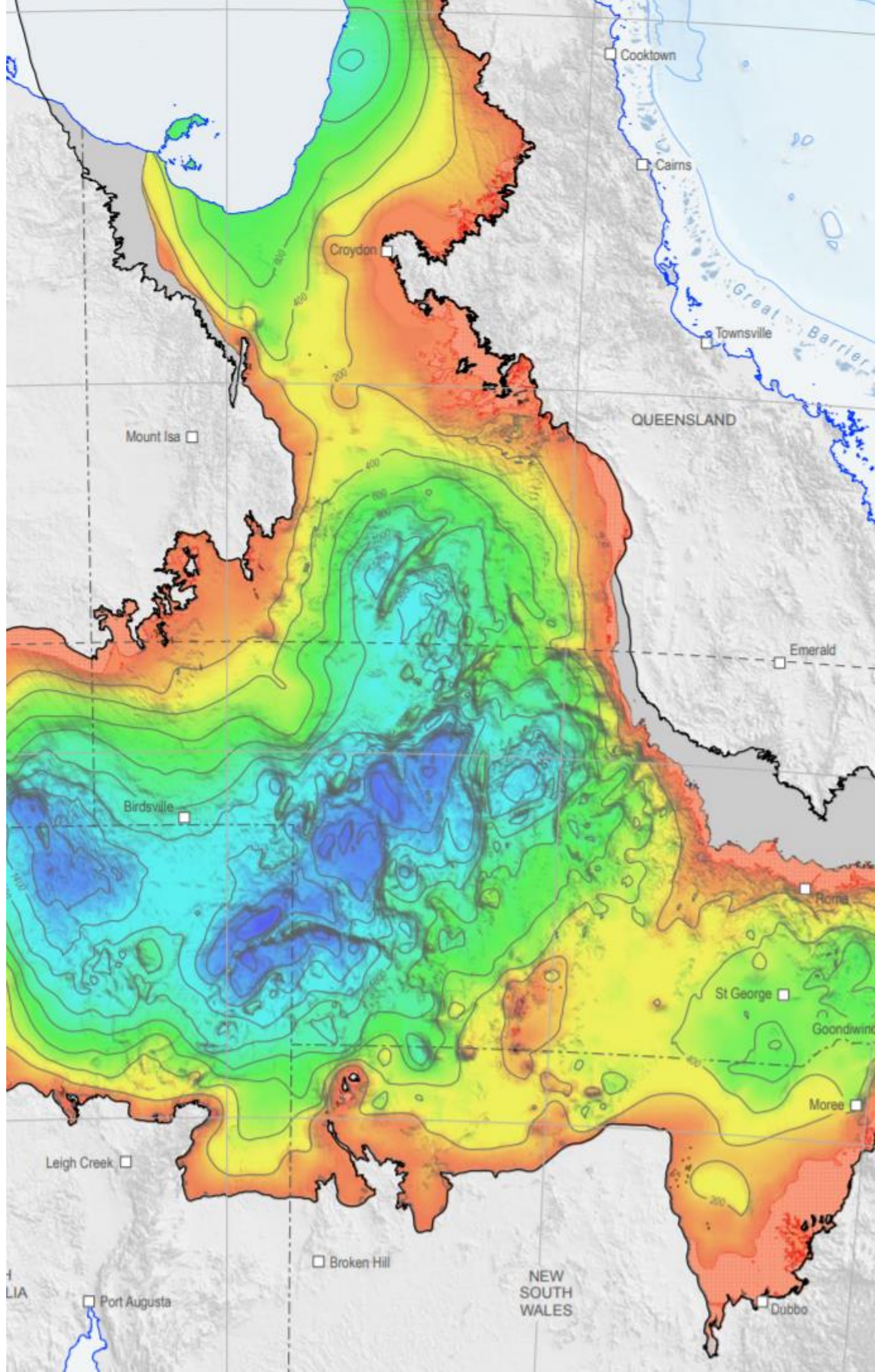
FUTURISING WATER EXPLORATION

SMATER, BETTER, FASTER , GREENER
A MORE SUSTAINABLE WAY TO HELP THE PLANET

Australia needs a quick and reliable way to map groundwater between sites, particularly where other geophysical datasets such as seismic reflection or TEM have already been used. ADR does not completely replace drilling; it can be developed to identify and match different aquifers across a region either using 2D scan or a set of "virtual boreholes".

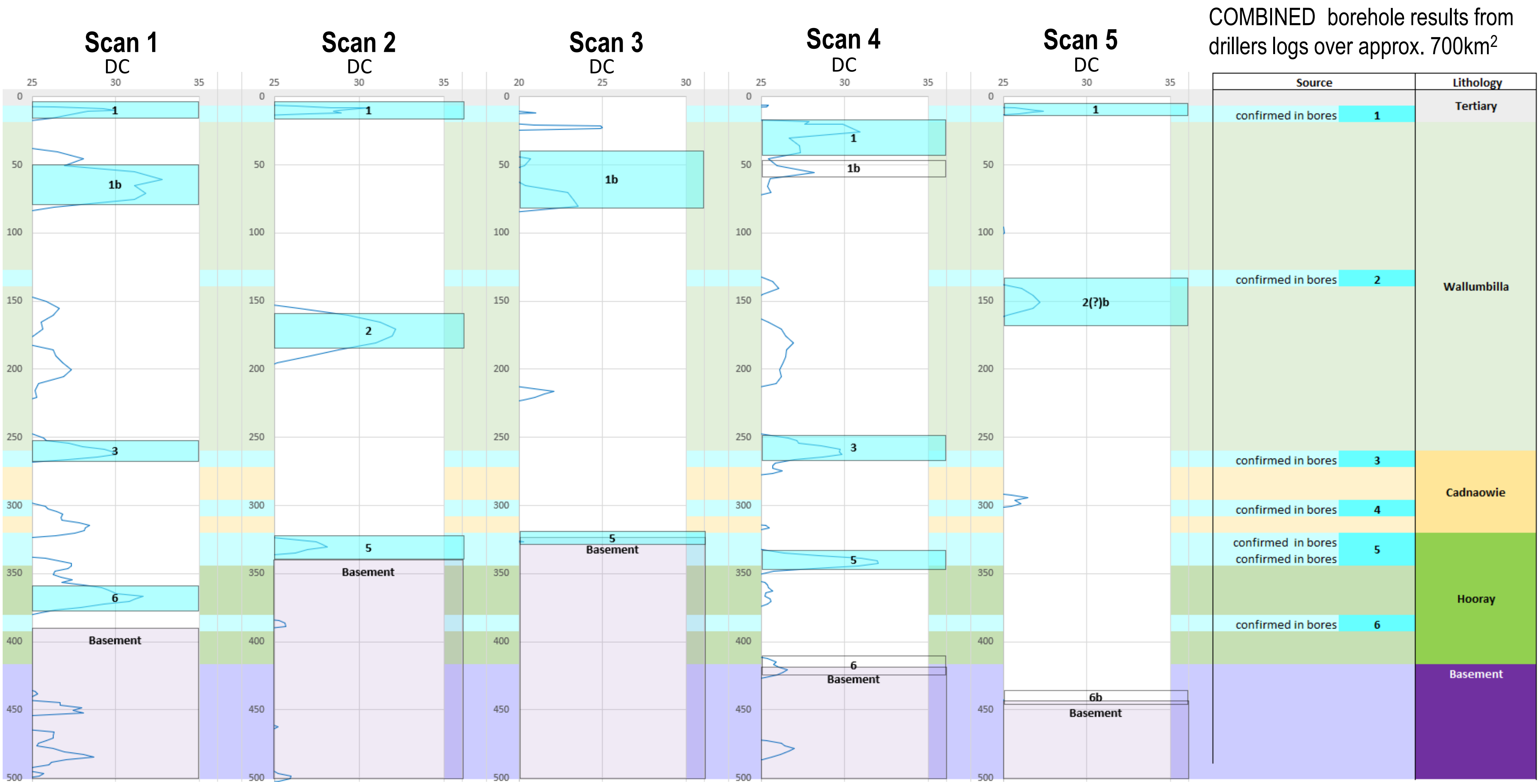
The technology could, however, replace a significant amount of physical drilling of boreholes and removes the documented uncertainty in borehole data as highlighted below in doi.org/10.1016/j.ejrh.2014.08.007

"Groundwater bores from the DNRM database were not incorporated in this study because of the **lack of reliable stratigraphic information**. For example, although more than 1600 bores are registered in the DNRM groundwater database (DNRM, 2012) within the 3D geological model domain, less than the 10% of these have available stratigraphic information. In addition, the data quality of these remaining 10% is often poor, or the stratigraphic data of these bores are already contained in the QDEX database, as many of the groundwater bores are old exploration wells registered in QDEX that were later converted to groundwater bores."



GAB AQUIFER IDENTIFICATION

Preliminary results from an Adrok pulsed radar study in a structurally complex part of the GAB where nearby water bores are very different to one another suggesting complex vertical interaction between aquifers



Blue line on all charts shows DC measurements with increasing depth

DEEP AQUIFERS

The future of water security. How Australia could learn from other countries

The importance of Deep Aquifers in Qatar

DOI: 10.13140/2.1.3191.5521

"Qatar is known for its scarcity of renewable water resources. In addition, expanding agricultural activities are highly dependent upon this limited resource for irrigation. **Deep aquifer in Qatar might be a valuable source for groundwater** to be considered. Therefore, much attention has been directed to investigate this source allover Qatar. The objective of the current work is the characterization of hydrogeological setting within Aruma Formation, which is of Upper Cretaceous age. Aruma Formation is located in the southwest part of Qatar near Saudi Arabia with its top of 450 m below ground surface. In this work, four deep wells were drilled and tested to evaluate Aruma aquifer. Those new four wells were drilled to final depth ranging between 630 and 730 m penetrating Aruma aquifer at each location".

The importance of Deep Aquifers in Somali

doi.org/10.3390/w11081735

"Between 2015 and 2018, the Horn of Africa was affected by a series of climatic-induced events, namely El Nino, La Nina, and the Indian Ocean Dipole. These events modified the variability of rainfall patterns and resulted in extended periods of low rainfall, low recharge, and high evapotranspiration. That situation prompted humanitarian water professionals to finance the transportation of water from selected locations with high groundwater potential through water trucks to areas facing groundwater depletion and drought. To mitigate this, UNICEF identified alternative water supplies by **exploring sustainable deeper groundwater sources**. This paper describes a three-phase methodology of deep groundwater development of wells in the Ogaden Jesoma sandstone aquifers of the Somali region of the Horn of Africa, to a depth of 600 m below ground level. The methodology included the development of groundwater suitability maps using geological and remote sensing data, hydrogeological ground truthing of the maps, and then test drilling at the selected locations. The results concluded that the deep sandstone aquifer of Jesoma can provide fresh water with yields of 15 L/s to the local population of the Somali region. The study provided insights into deep groundwater identification and development as well as adaptive deep borehole drilling as a source for **climate-resilient water supplies"**.

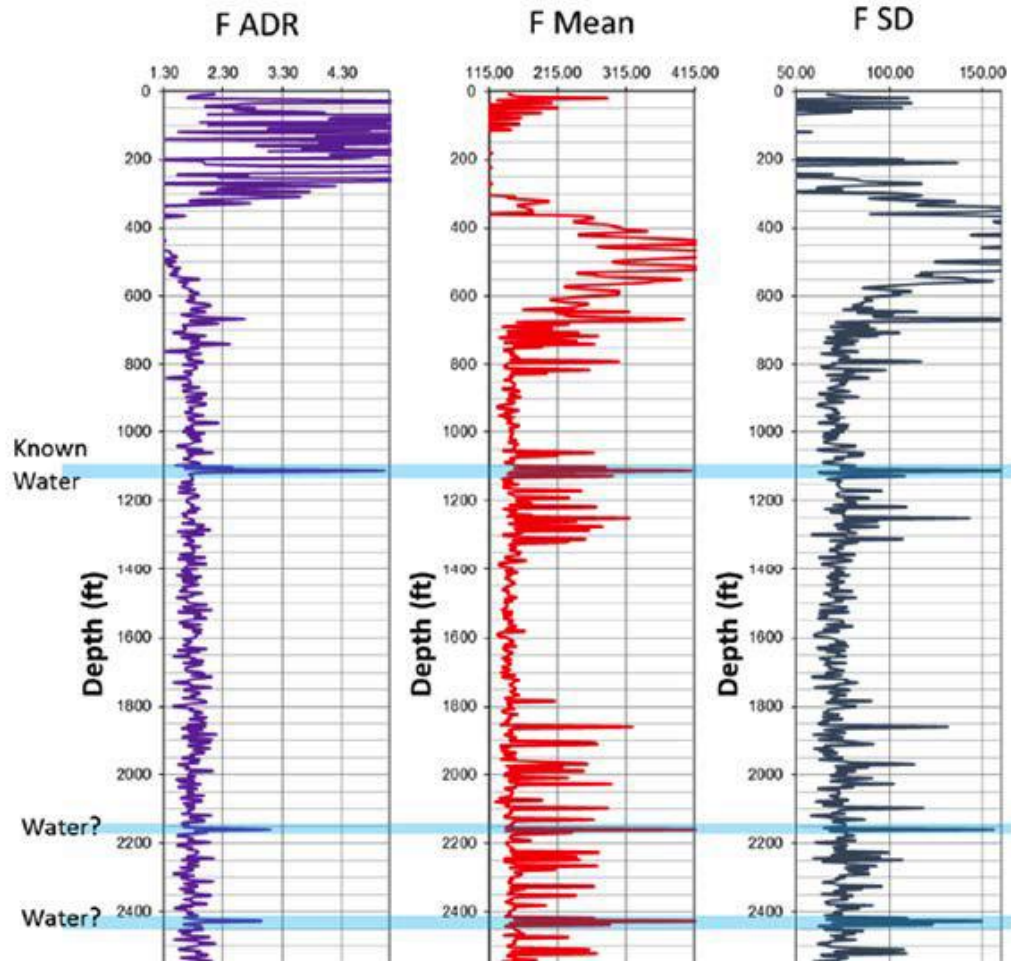
CASE STUDY: OKLAHOMA water and oil

Oklahoma water and hydrocarbons - Identifying water (aquifers) in hydrocarbon-bearing sediments to >1200ft depth

For more information see www.adrokgroup.com – "Together we rock" Volume 3, Case Study 7

Identification of a deep aquifer while looking for oil

Adrok were able to pinpoint water layer (aquifer) at approximately 1260 ft (384m) deep below the surface. The water is confirmed in borehole data.



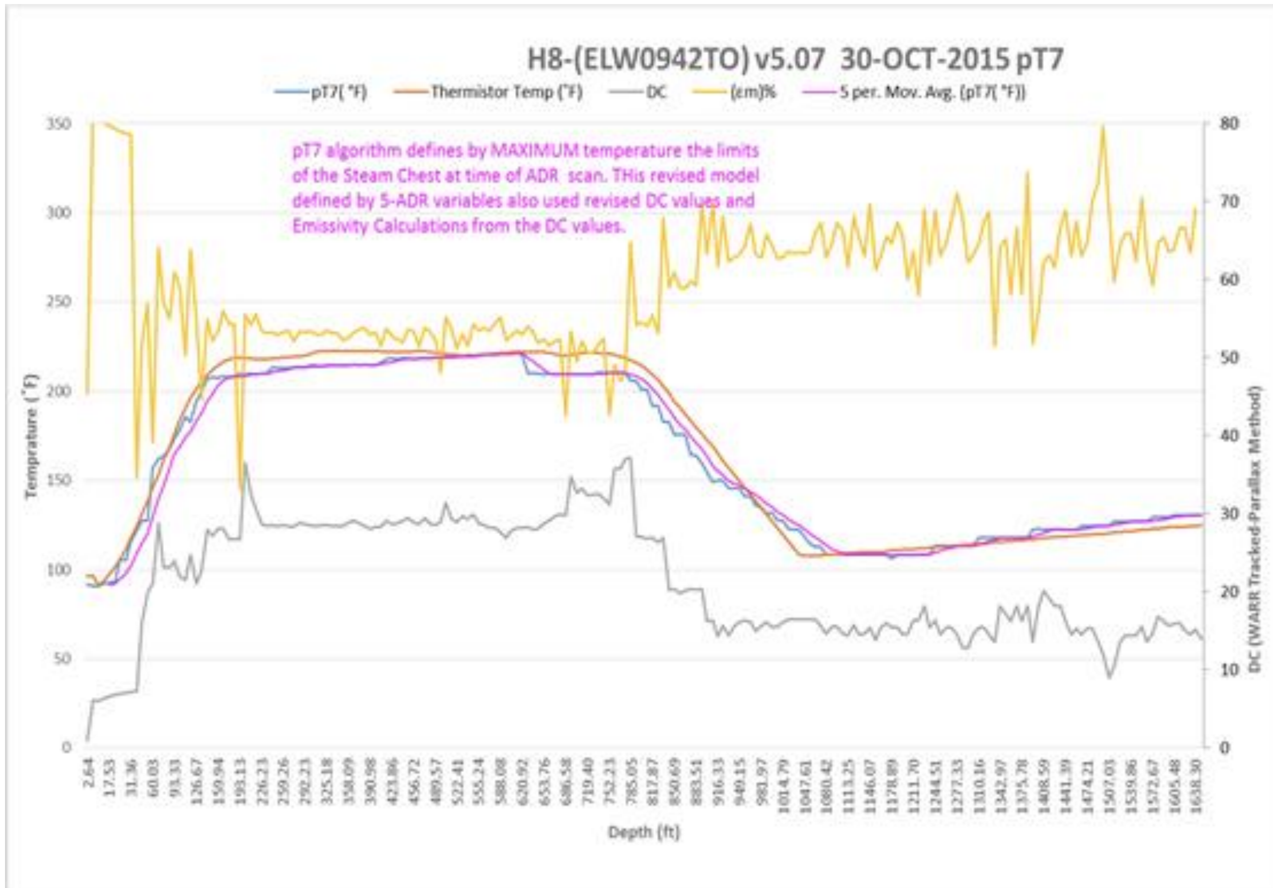
CASE STUDY: **TEMPERATURE**

Monitoring test case: Efficacy test of the application of ADR technology to commercial measurement of hot and cold subsurface regions and of temperature for Enhanced Oil Recovery applications onshore USA. For more information see **www.adrokgroup.com** "Together We Rock", V.2, Cases study 3.1

Adrok's ADR temperature measurements were significantly reliable and of a Technology Readiness Level (TRL) 6. The client is now working with Adrok to increase the TRL to 9 (commercially operational).

Benefits for this client

On this oilfield, the client currently takes temperature measurements once every 90 days for each of their 75,000 well locations. The cost of conducting this invasive, downhole thermometer measurement is around US$5,000 per well. During measurement, the wells are not in production and there is an additional cost associated with this downtime. Adrok has the potential to reduce the costs associated with downhole thermometer measurements, as ADR can measure temperature from ground level without the need of an expensive borehole.



GROUNDWATER DEFINITION WORKFLOW

Areas of high-water priority are identified. Arid regions of the world are identified as a high priority area. A sustainable source of water is required for ongoing social, agricultural or industrial development

Geology model generate to identify areas of high aquifer potential. 3D GIS models of sub-surface geology can be used to rank particular areas as high-, medium- or low-potential for aquifer development. The type, geometry and paleoenvironment of formation of the host unit (e.g. paleo braided sand channel) is critical to targeting the aquifer but determining this for deep aquifers (below the limits of LIDAR) are extremely difficult.

PRELIMENARY regional geophysical surveys. A critical step in the discovery process is to fly regional airborne geophysical surveys, in particular LIDAR and Electromagnetics (EM). These geophysical datasets provide a good indication of potential shallow aquifers (LIDAR) or, in the case of EM, a useful but relatively non-specific and relatively shallow indication of where groundwater might exist at depth based on conductivity and resistivity. Neither of the techniques can pinpoint deep aquifers, thickness of aquifers and other key features

Phases 1-3 are often already completed

HERE IS WHERE ADROK CAN HELP

Adrok is developing a geophysical solution for targeting groundwater without the need for drilling. The technique is more specific than regional surveys in that it can potentially (through proposed development) provide a confirmation of water at depth below a point on the Earth's surface. The technique can be considered as a "virtual" or "digital" borehole but, unlike drilling, is entirely no-impact as it requires no digging, no surface disturbance.

Drill aquifer defined using ADR. ADROK will not completely replace drilling as it does not allow users to physically test or sample the water at depth*. However, it is a geophysical technique that is used prior to drilling to ensure that the water exists at the target depth and/or to explore for water below the limits of traditional geophysics. ADR is a confirmation tool thereby removing the risk of "dry" or unsuccessful drill holes which can be extremely costly and time consuming

Successful drilling of aquifers and deep aquifers defined by ADROK's ADR. ADR will aim to identify aquifers to over 1000m deep beneath the surface, but it will also define shallow aquifers with the same precision. Only one drill hole is required.

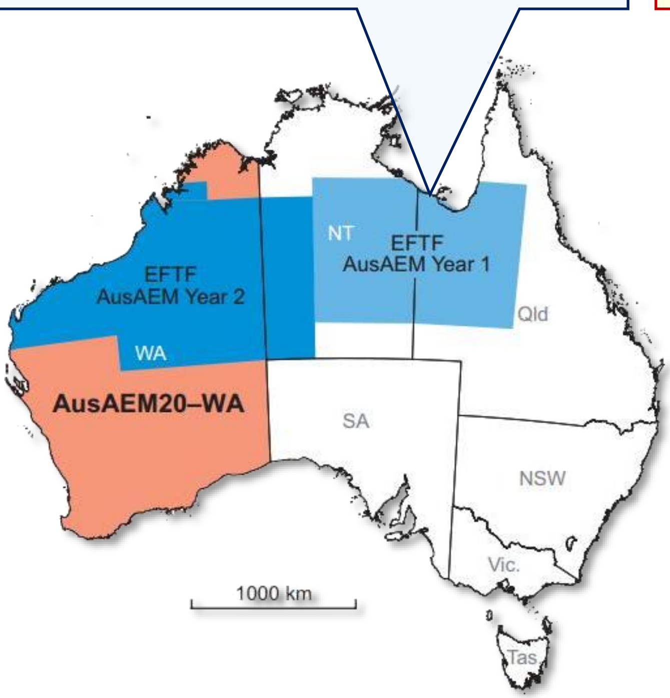
IDENTIFY + MANAGE

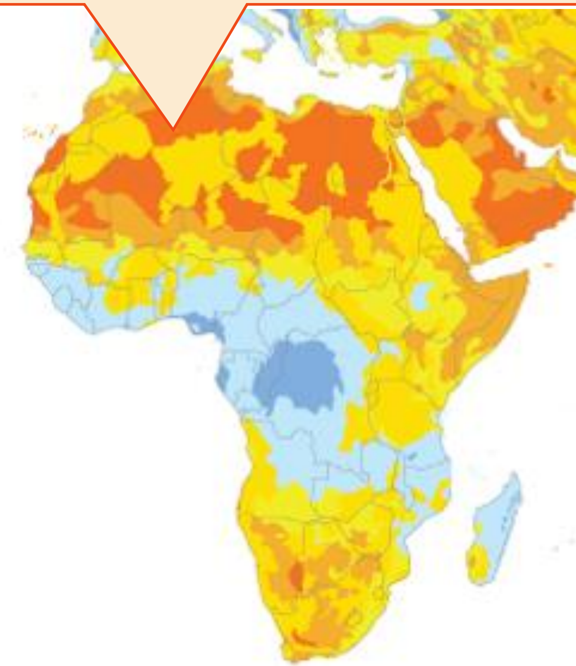
Some examples of where geophysics, specifically ADR can assist in either targeting aquifer delineation or can contribute to the equally important management of aquifers and groundwater

Adrok can add value to the recently completed AusAEM by working together with government bodies &/or organisations to develop the pulsed radar technology to explore for aquifers in areas where the AEM has been interpreted as presenting for water.

PROVIDE ADDTITIONAL DATAPOINTS
Adrok can add value to the current almost complete lack of reliable groundwater data in northern Africa for example.

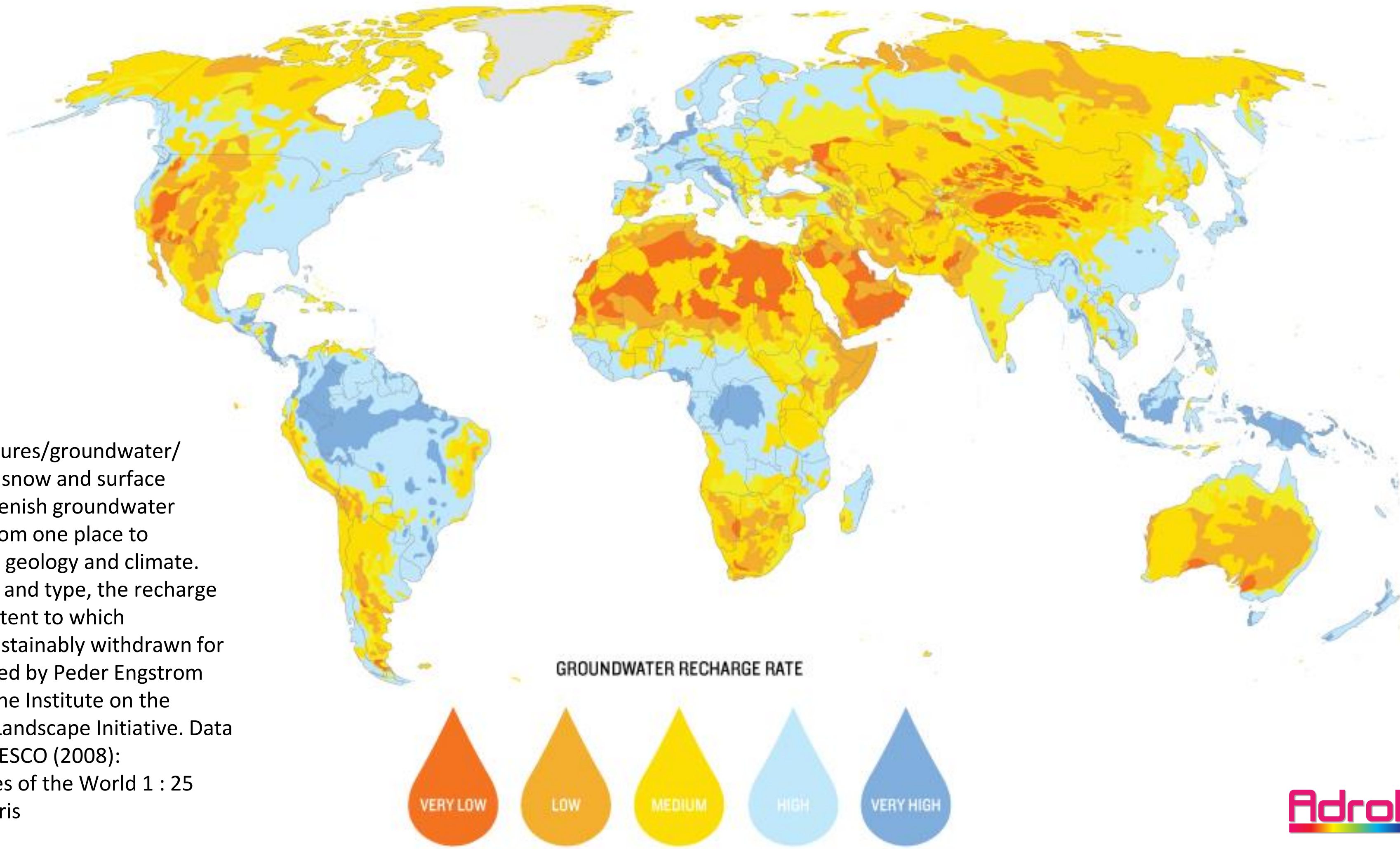
GROUND TRUTH data collected via remote sensing. Satellite-based models showing aquifer drainage require on-the-ground testing. Drilling numerous boreholes is an unreliable, costly and environmentally degrading means of testing.





IDENTIFY + MANAGE

By adopting some of the processing techniques developed in collaboration with the oil industry, and now being trialed in some minerals industries, Adrok can help provide additional on-the-ground monitoring data in order to help manage aquifers. While deep aquifers may present a useful resource as proposed globally, management of these water resource is also critical. Models such as presented below are based on inversions of satellite gravity data which require quick and precise ground-truthing. It is highly plausible that Adrok will, through some rigorous testing proposed here, have the technology to be able to carry out non-invasive checks of this style of management data.



https://ensia.com/features/groundwater/
The rate at which rain, snow and surface waters are able to replenish groundwater varies tremendously from one place to another, mostly due to geology and climate. Along with aquifer size and type, the recharge rate determines the extent to which groundwater can be sustainably withdrawn for human use. Map created by Peder Engstrom and Kate Brauman of the Institute on the Environment's Global Landscape Initiative. Data provided by BGR & UNESCO (2008): Groundwater Resources of the World 1 : 25 000 000. Hannover, Paris

INNOVATION FOR A CHANGING WORLD

CONTACT US

WEB:	ADROKGROUP.COM
ADDRESS:	49-1 West Bowling Green Street Edinburgh, EH6 5NX Scotland
PHONE:	+44 (0) 131 555 6662
EMAIL:	info@adrokgroup.com
AUSTRALIA	srichards@adrokgroup.com