# ADVANCING WATER EXPLORATION FOR THE FUTURE

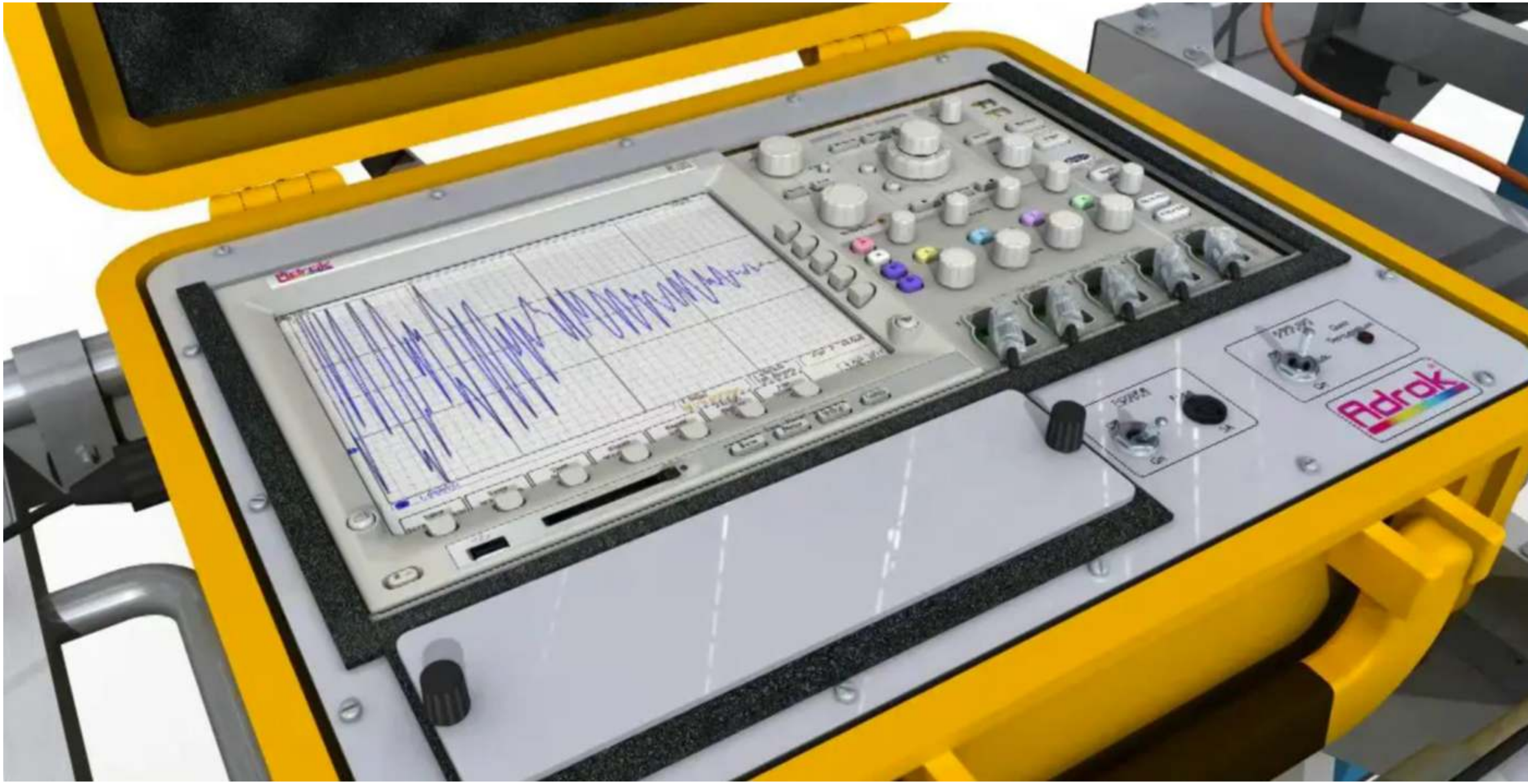
## New technology for identifying deep aquifers

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.

# THE ADROK ADVANTAGE

## A faster, cheaper and greener way to achieving water security

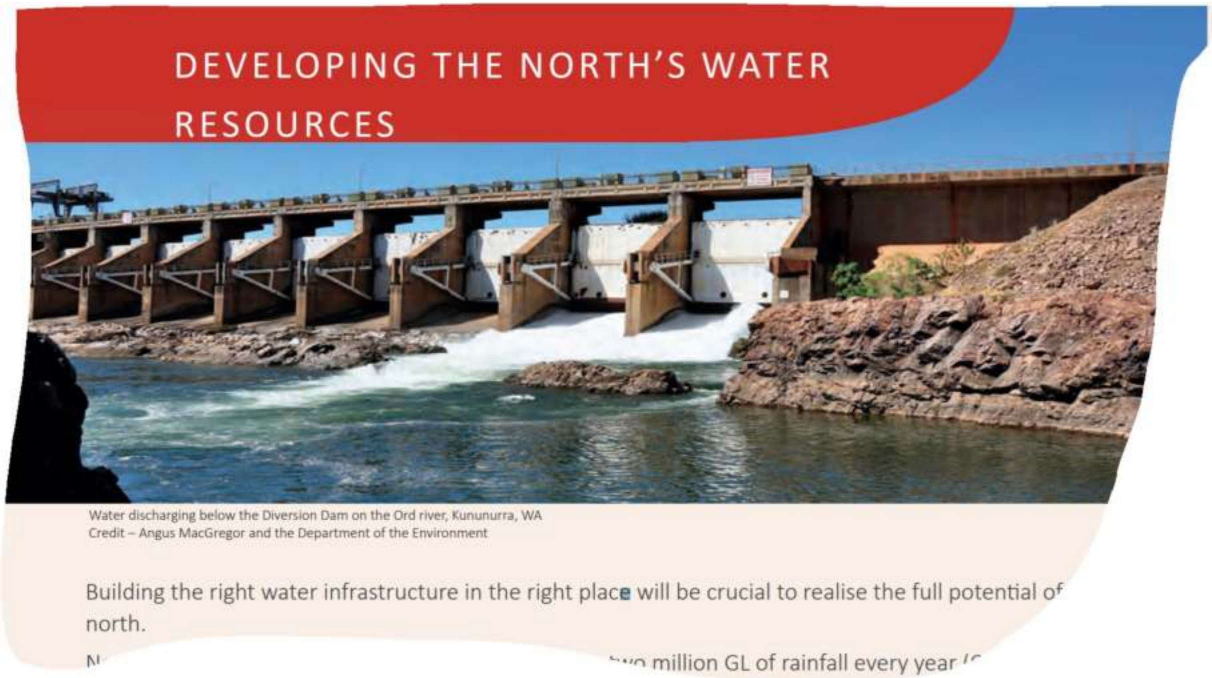
Adrok is a geophysics technology development company set out to create a technique that could "virtually see" different materials at great depths beneath the surface. Adrok's pulsed radar/Atomic Dielectric Resonance (ADR) scanner has been tested in many countries and for different commodities. Adrok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

Adrok is positioned to align with key stakeholders in the field of groundwater targeting and management in Australia and overseas.

The **aim** is to help ensure the future of water security for Australia by helping governments, private organisations and individuals to meet strategic outcomes for the future development of regional Australia.

Australia is the driest continent in the world, yet we also consume 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 Australia must act quickly 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.

As part of a strategic economic development plan, Australia has embarked on a very large-scale program to develop Australia's north. The details of the program are presented in "Our North, Our Future: White Paper on Developing Northern Australia (https://www.industry.gov.au/data-and publications/our-north-our-future-white-paper-on-developing-northern-australia). The program to develop northern Australia has already achieved major milestones, including but certainly not limited to the drilling of tens of water bores, the completion and ongoing processing of the worlds largest airborne EM survey and extensive community and industry consultation. Adrok has a key role to play by providing cutting edge technology to save both time and money during the groundwater targeting phase.


DEVELOPING THE NORTH'S WATER RESOURCES

Water discharging below the Diversion Dam on the Ord river, Kununurra, WA
Credit – Angus MacGregor and the Department of the Environment

Building the right water infrastructure in the right place will be crucial to realise the full potential of north.

million GL of rainfall every year

**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 across Australia in regions that have been identified as high potential areas for aquifers but where drilling is required to prove their existence.**

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

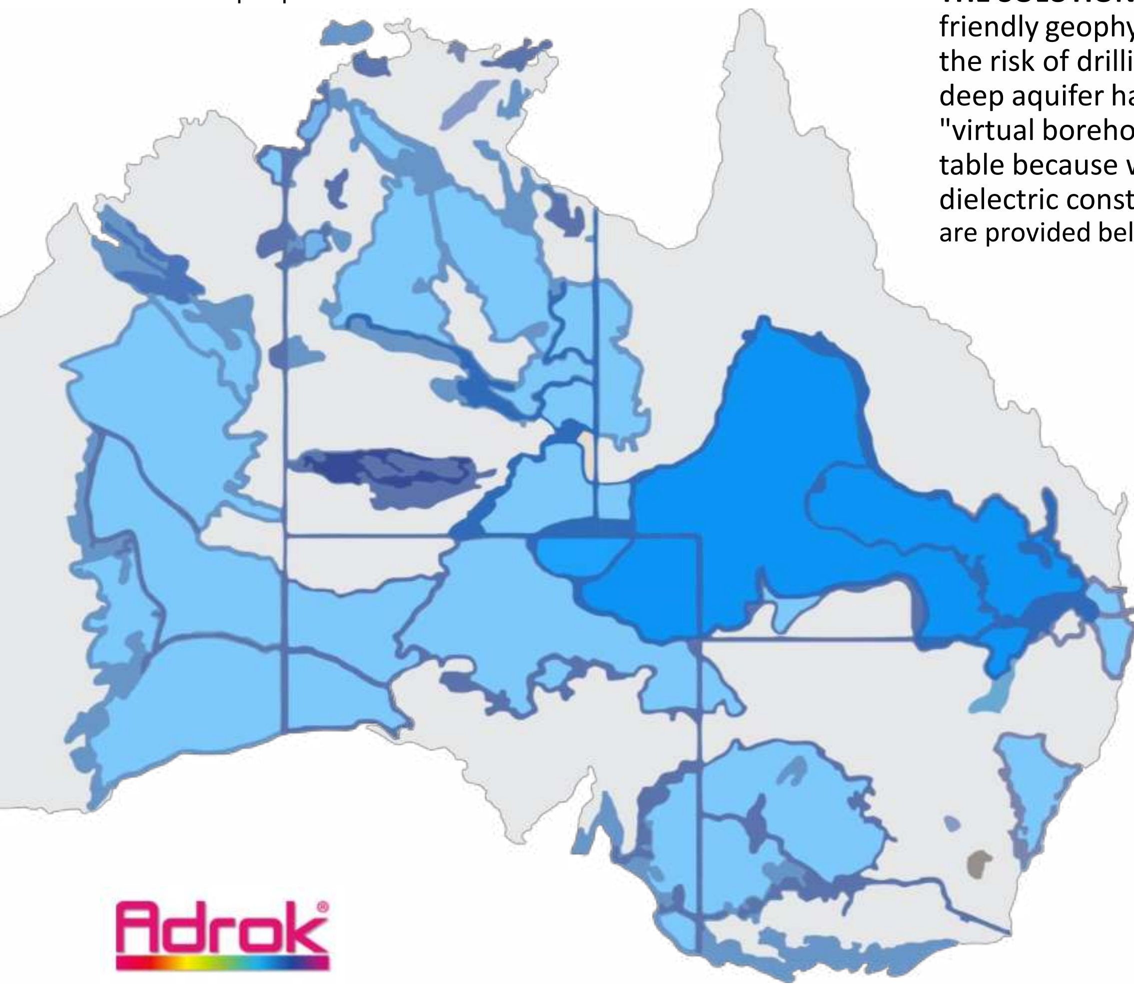
The scanner can be used almost anywhere regardless of how remote, dry, cold, hilly or flat

# Australia'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:** Australia has a lack of water, yet development in the north 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 Australia where drill-rig access can be limited by terrain.



**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.

* The number of scans completed is dependent upon factors including the distance between sites, types of 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)

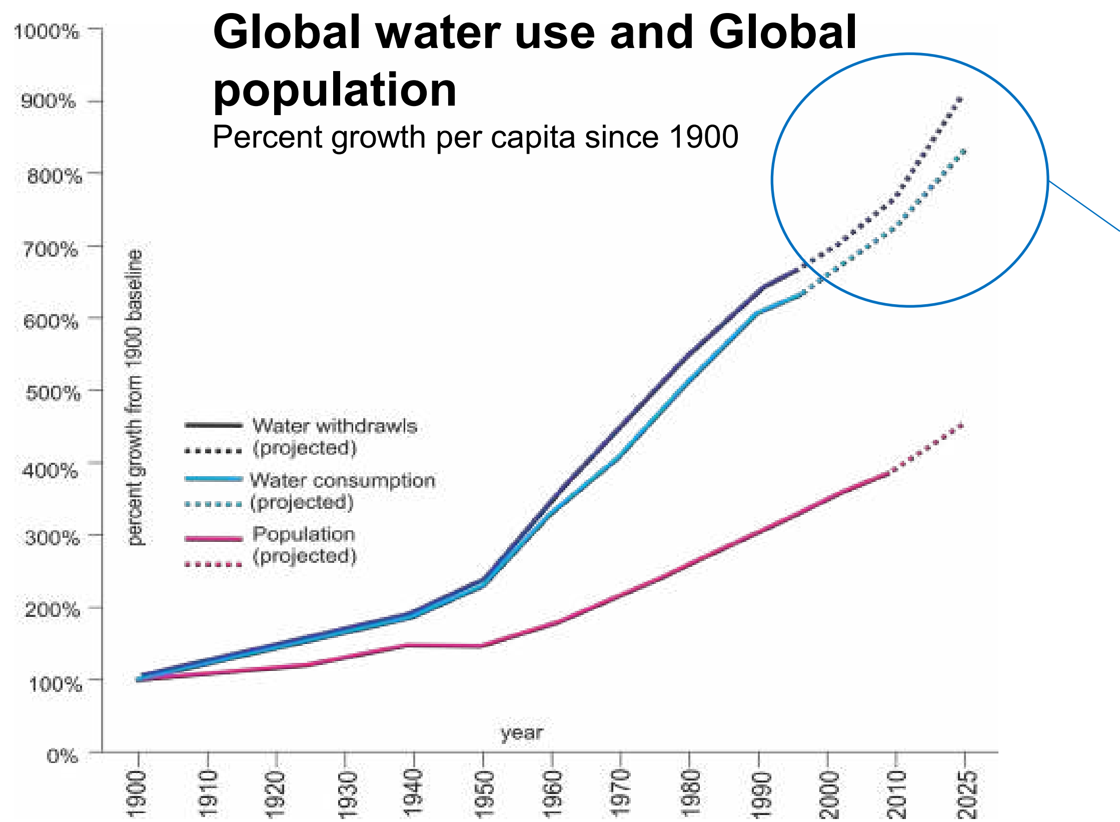
Nearly half the global population are already living in potential water scarce areas at least one month per year and this could increase to some 4.8 – 5.7 billion in 2050. About 73% of the affected people live in Asia (69% by 2050) (Burek et al., 2016).

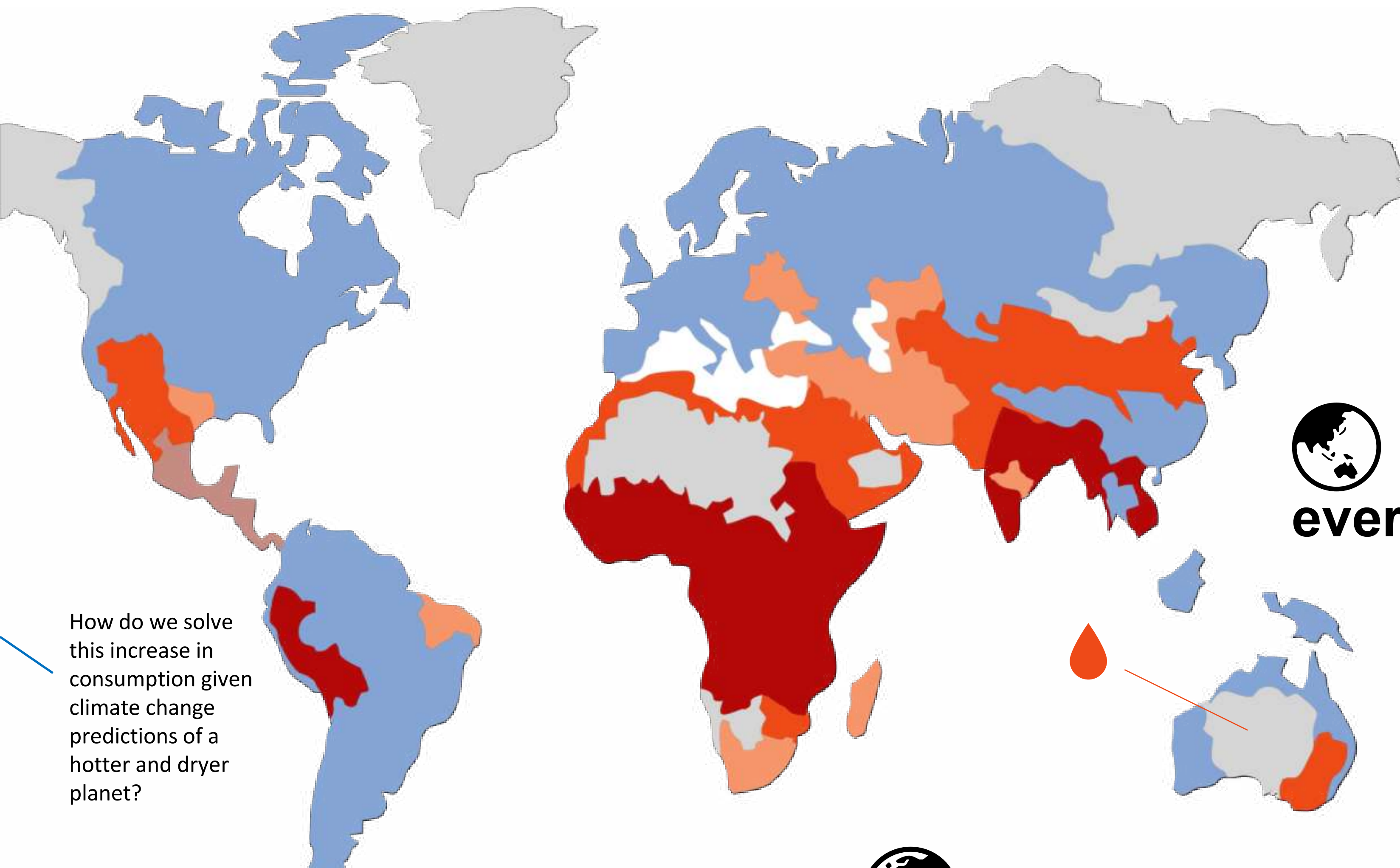
A third of the worlds biggest groundwater systems are already in distress (Richey et al., 2015).

**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.





Not estimated

Little or no water scarcity water scarcity

Approaching economic water scarcity

Physical water scarcity

Economic water scarcity

Water scarcity already affects
**every continent**

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.

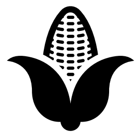
**1/2**

**of the world's largest cities** experience water scarcity.

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

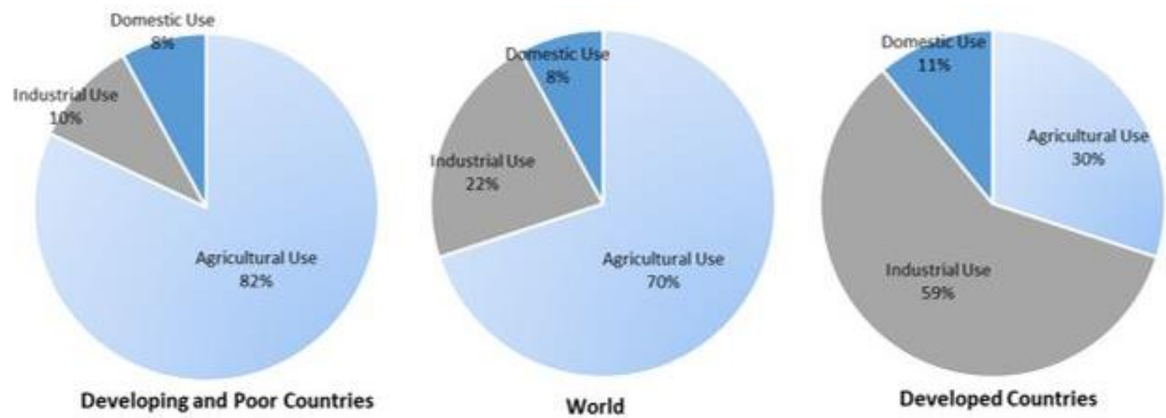
# WHY IS WATER SECURITY SO IMPORTANT?

"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".

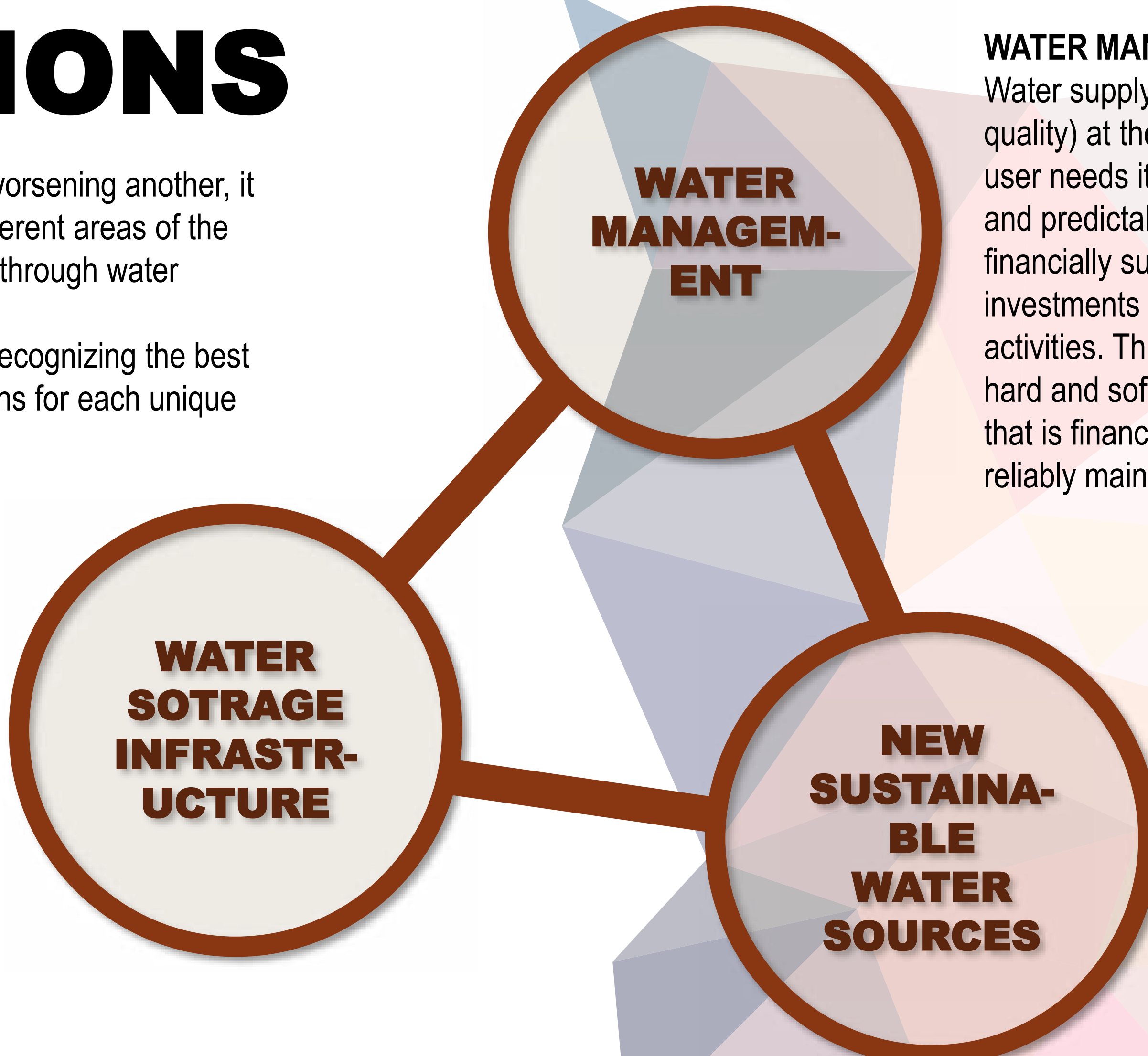
**"Water supply (quantity and quality) at the place where the user needs it must be reliable and predictable to support financially sustainable investments in economic activities**."
(UNWATER WWDR2015)

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 recognizing 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, Australia needs to embark on new programs to define **new water resources** to ensure that these two critical sectors of the Australian economy are sustainable.

**AQUIFERS, natures water storage facility**

→ **DISCOVERY**

→ **ESTIMATION**

→ **MONITORING**

→ **MANAGEMENT**

## WHY AQUIFERS FOR A SUSTAINABLE WATER FUTURE FOR AUSTRALIA

Extremely high evaporation rates in Australia 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 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?

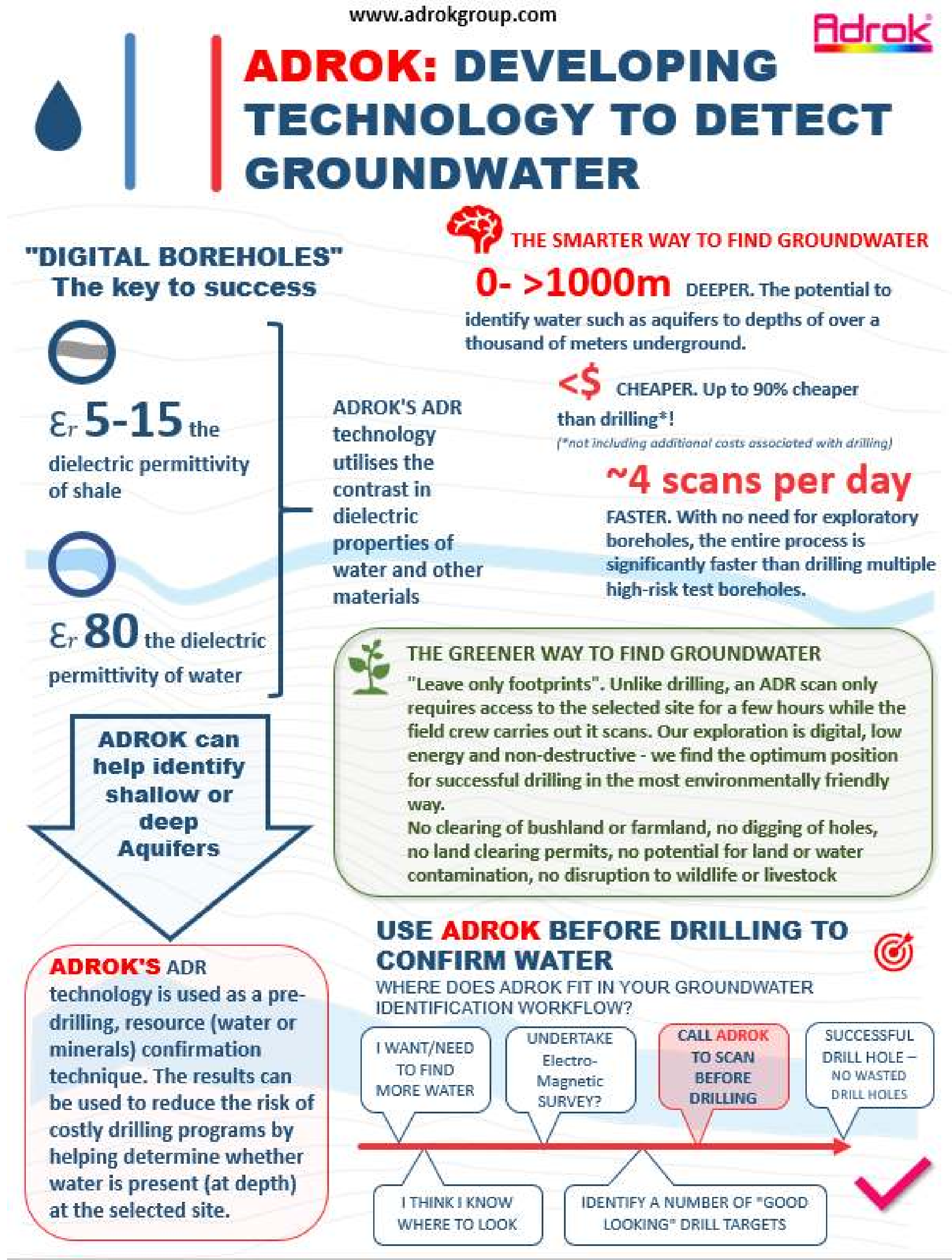
This ‘**echo**’ is as unique as a fingerprint and can then be analyzed to reveal detailed information on the characteristics of the material that has been discovered.

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



# 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:

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

# MINING





**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 waster 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)

# Australia is the driest inhabited continent and the highest per capita user of water!

The Groundwater Sector plays a critical role in national water security, **contributing an $6.8bn/per annum to Gross Domestic Product (GDP).**

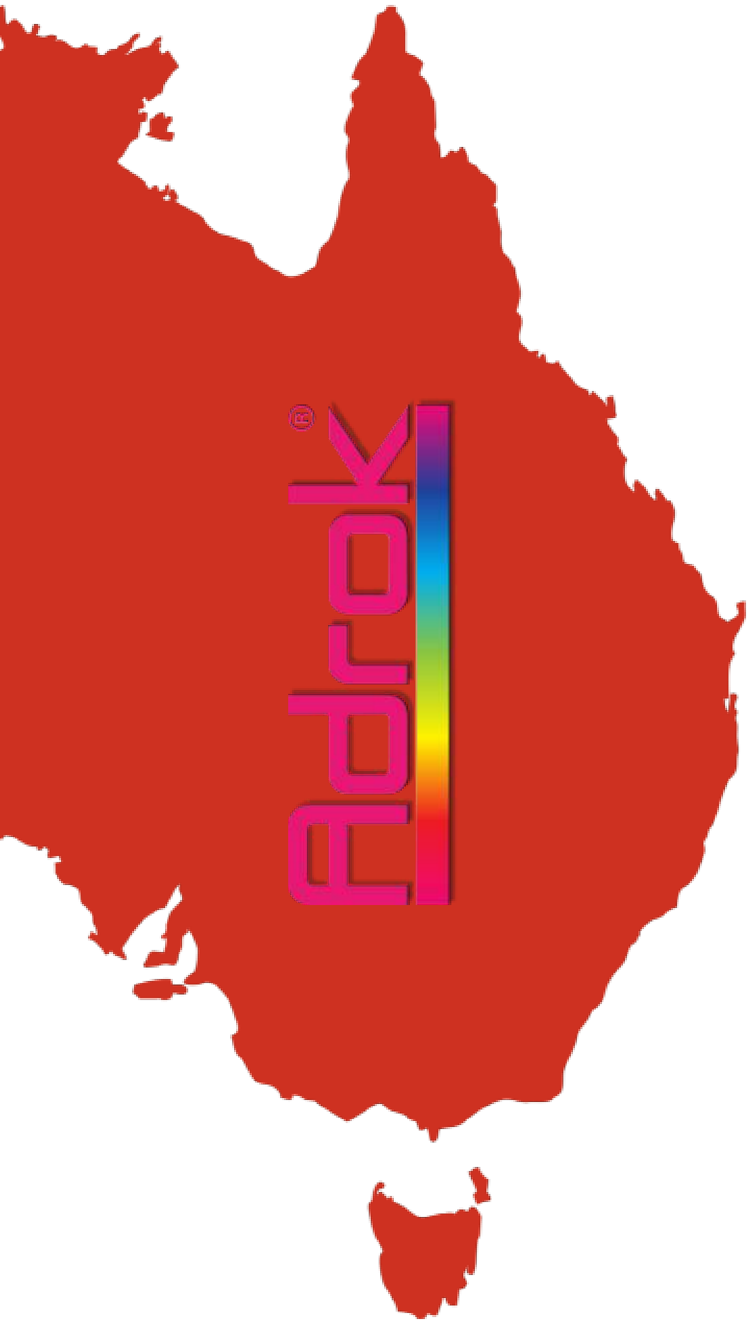
**Groundwater represents 17% of available fresh water within Australia** and is essential for providing increased supply during periods of drought for agriculture and community consumption in many parts of the country.

In addition, many mineral and energy deposits occur in remote areas where groundwater is the only secure local water source.

In northern Australia, groundwater resources and water banking/aquifer storage provide significant opportunity to **underpin economic expansion** due to the limitations posed by the seasonal nature of surface water, the limited availability of surface dam sites, and high evaporation rates that rapidly deplete surface storages.

**There are major gaps in our knowledge of groundwater systems and resources in northern Australia.** The groundwater component of the "Exploring for the Future" program will therefore focus on addressing these knowledge gaps, to support future opportunities for irrigated agriculture, mineral and energy development, and community water supply.

In Australia, groundwater makes up approximately **17%** of accessible water resources and accounts for over 30% of our total water consumption.




**GEOSCIENCE AUSTRLIA IS SUPPORTING 5 NEW GROUNDWATER DEVELOPMENT AREAS**
(https://www.ga.gov.au/eftf/groundwater/east-kimberly)

These are:
1) East Kimberly (NW-Western Australia)
2) Northern Sturt Corridor (Daly River Basin, NT)
3) Southern Sturt Corridor (Tennant Creek Region, NT)
4) Upper Burdekin (Charters Towers Region, QLD)
5) Surat and Galilee Basins (SE QLD)

The main **OBJECTIVES** of the project are to:

1) Identify the location, quantity and quality of new and existing groundwater resources in sedimentary basin and palaeo-valley aquifers;
2) Assess the potential for managed aquifer recharge (MAR) options to provide local storage and to manage salinity and seawater intrusion; and
3) De-risk resource and agricultural investment, and inform water management options, including infrastructure development and water banking based on baseline hydrogeological data.

The groundwater investigations will involve the collection, interpretation and delivery of a range of new pre-competitive hydrogeological, geophysical, geospatial and remote sensing datasets to map the near-surface geology and groundwater systems in selected regions, as well as assessing any potential salinity hazards associated with resource development.

1. Deloitee Access Economics, National Centre for Groundwater Research and Training, October 2013, Economic Value of Groundwater in Australia, Accessed 6 November 2017.

# WATER PRIORITIES

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 may 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 FINDING GROUNDWATER**

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.

# EXPANDING THE NORTH

## Adding value in untapped areas

The East Kimberley region is prospective for future development of agriculture, conventional and unconventional energy, and mineral resources. The region is endowed with good road, port and energy infrastructure, with a local labour force based in Kununurra. LOCAL water security is provided by Australia's second largest surface dam (Lake Argyle). However,

**"additional water security is required, particularly in upland areas where the costs are high"**.

Groundwater investigations will focus on the Keep and Ord Valleys and upland areas in the Northern Territory and Western Australia. The project will map groundwater prospectivity, and the potential impacts associated with groundwater and agriculture in this region.

# 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

### 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.

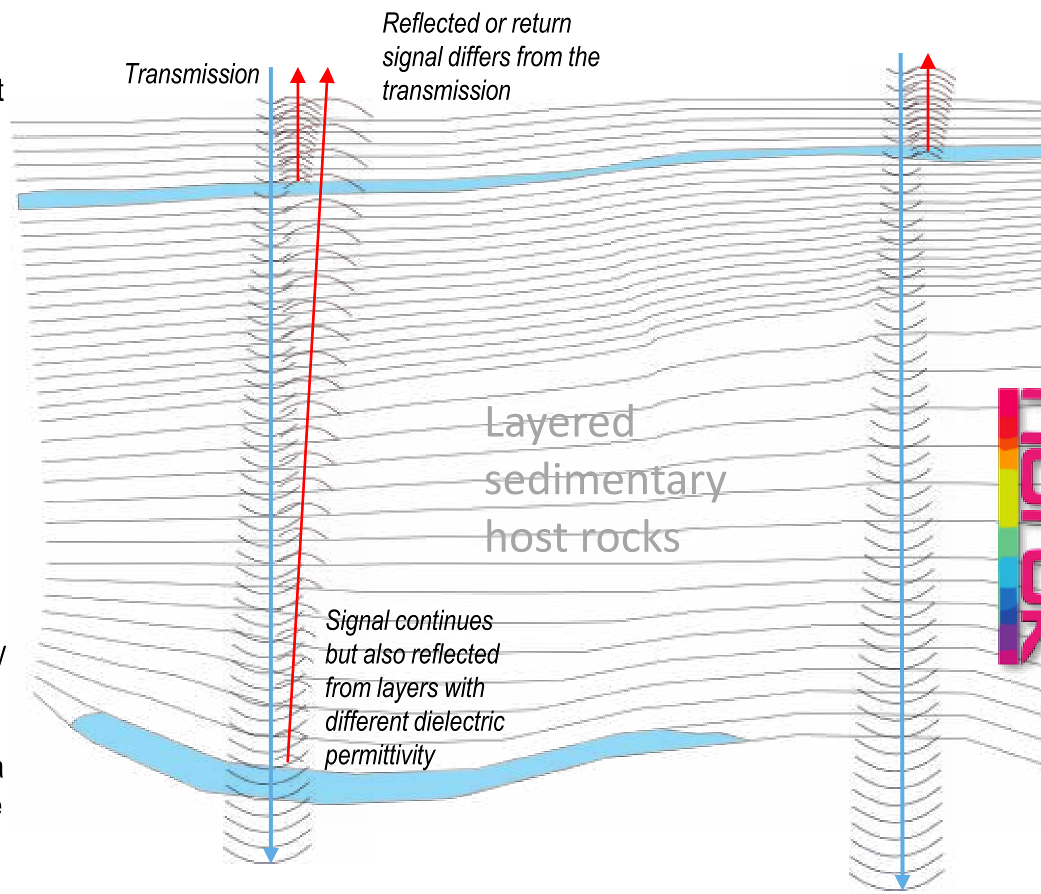
### Defining materials

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.

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.

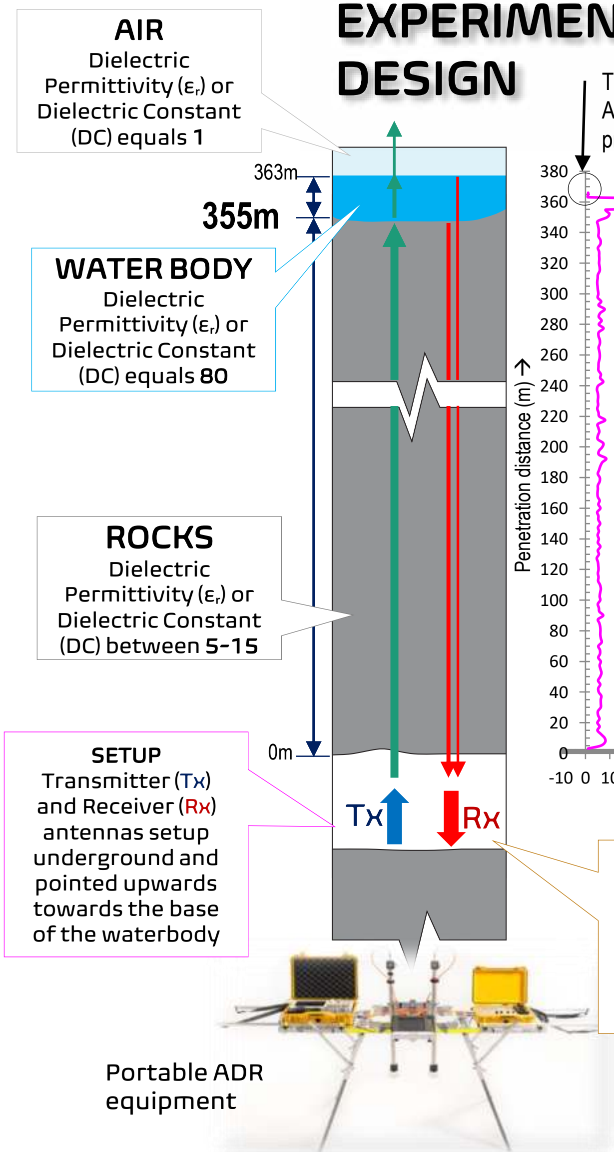


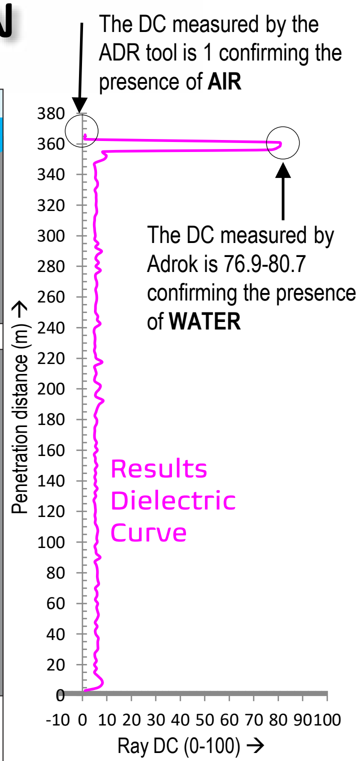
# DEPTH-OF-PENTRATION TEST by TECK RESOURCES

## 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



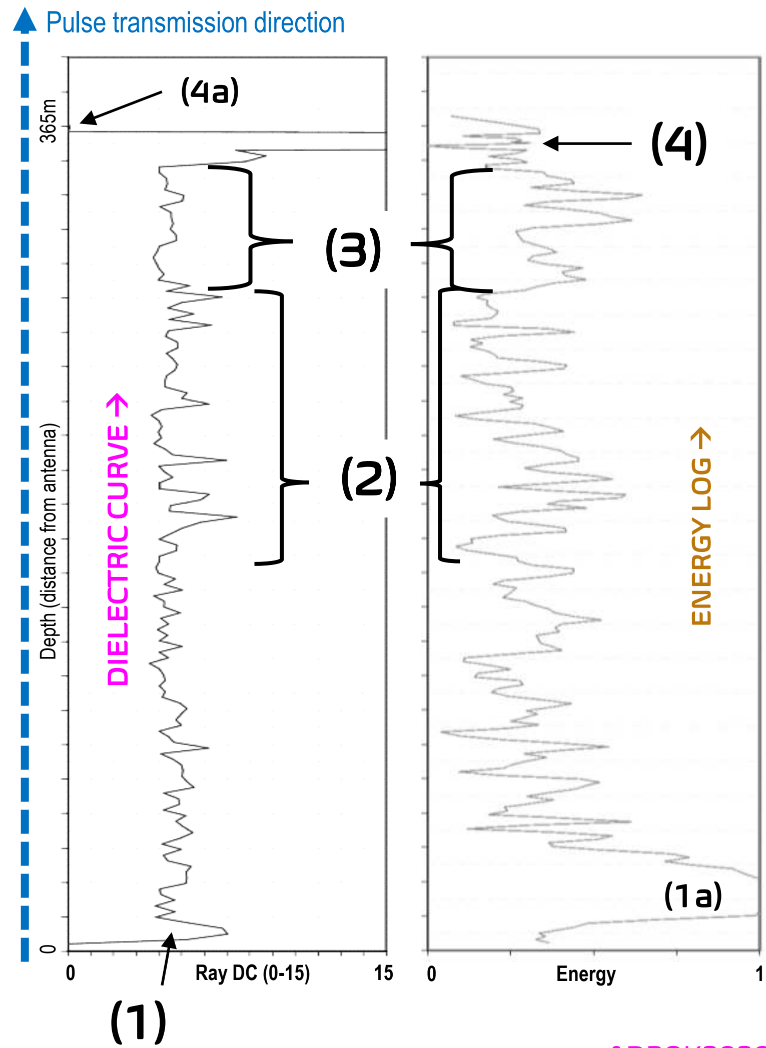




**(4) (water-rock interface)** The lowest energy (strongest relative energy return) is recorded at the boundary between rock (DC=3-12) and the overlying waterbody (DC=80). The sharp boundary between rocks with contrasting DC acts as a strong reflector at the 1-70MHz range (refer to GPR overleaf). The 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 ($\varepsilon_r$).

**(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.

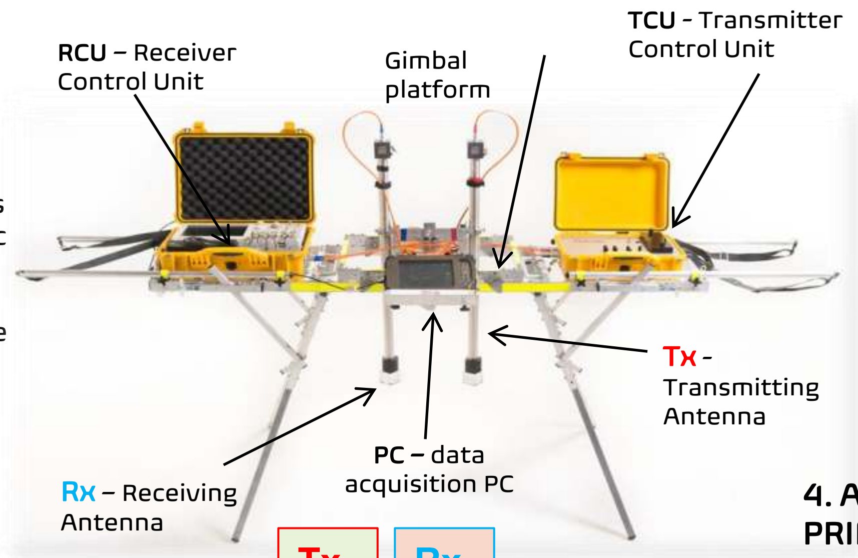


Adrok®

# 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 ($\varepsilon_r$). 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

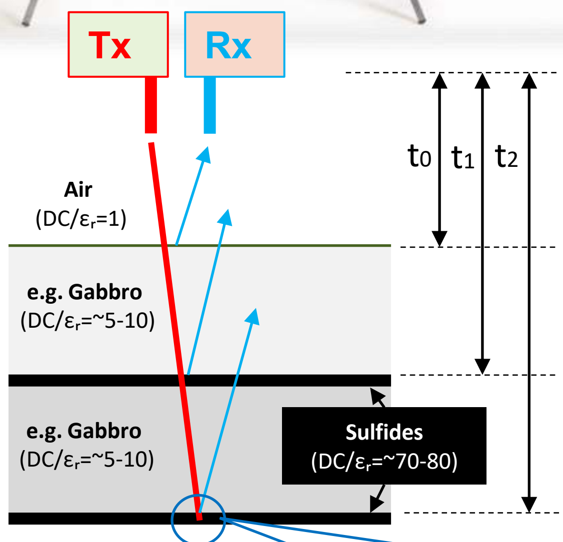
## 3. BORROWING SOME PRINCIPALS FROM GROUND PENETRATING RADAR (GPR):

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

**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.




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 ($\varepsilon_r$) 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

# 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.

# CASE STUDIES

## Some background information of GEOTHERMAL

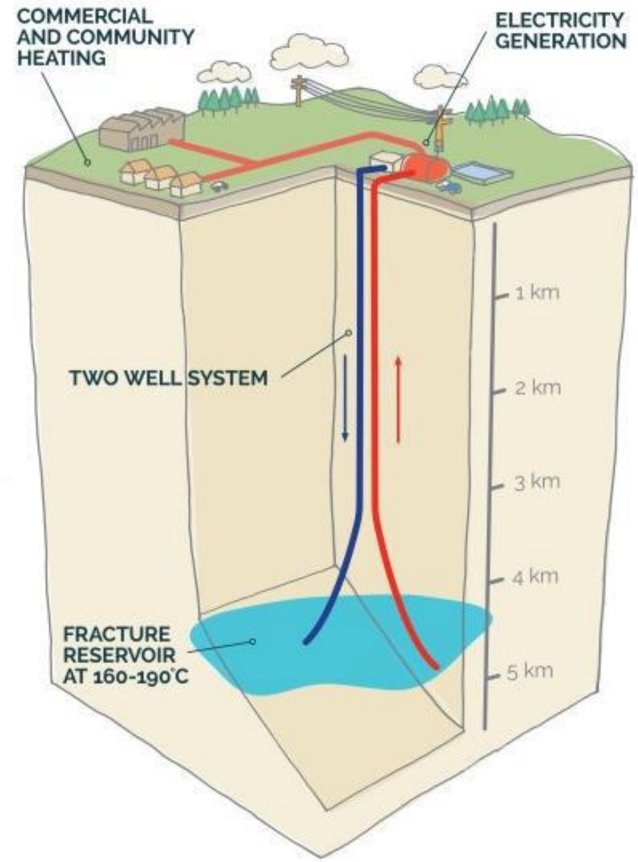
**Info from: Clean Energy Council of Australia**

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%**

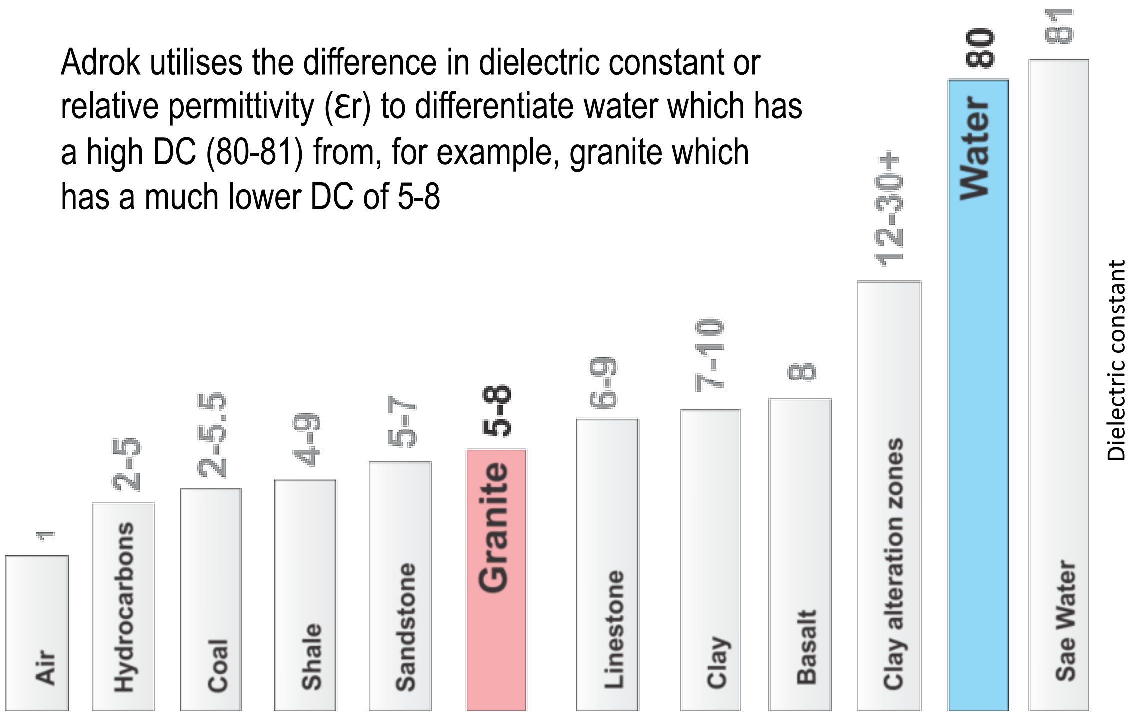
The amount of electricity generated by AUSTRALIA from geothermal sources

# ADROK RESULTS CORNWALL GEOTHERMAL

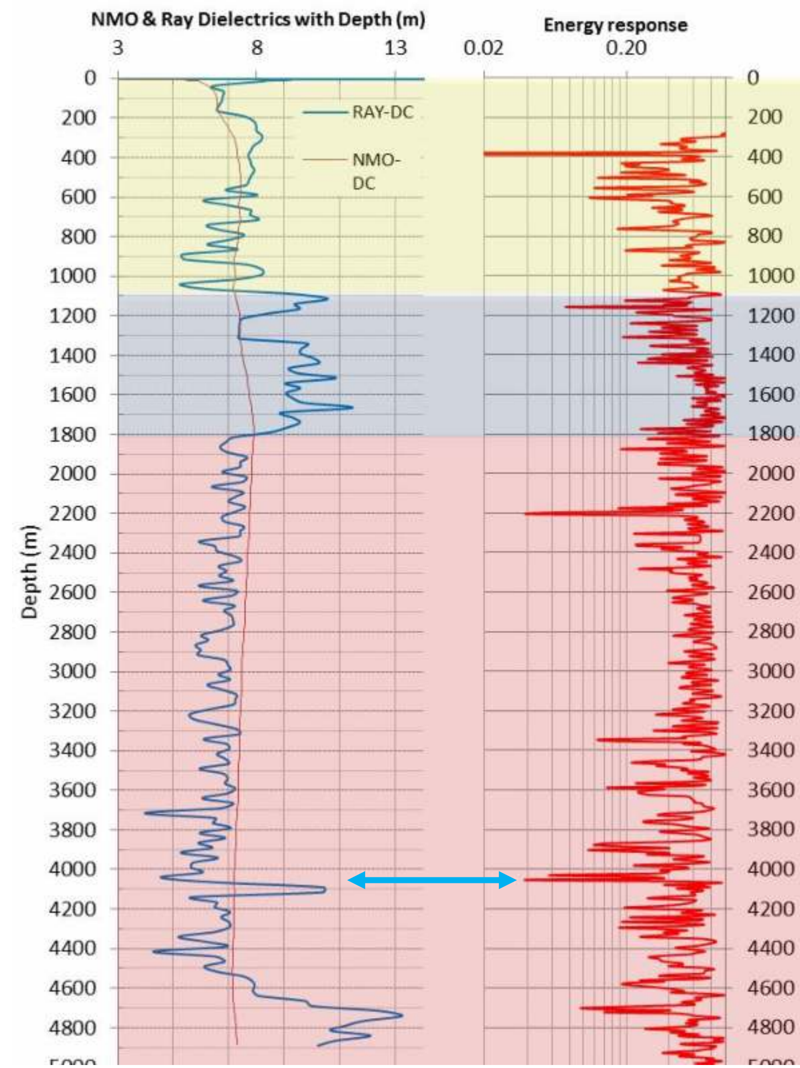
## Cornwall Geothermal - Identifying hydrated fracture in granite at >4000m depth

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




Water-rich fractures in granite are characterised by Low Energy but expectedly high DC




Exert from processed scan

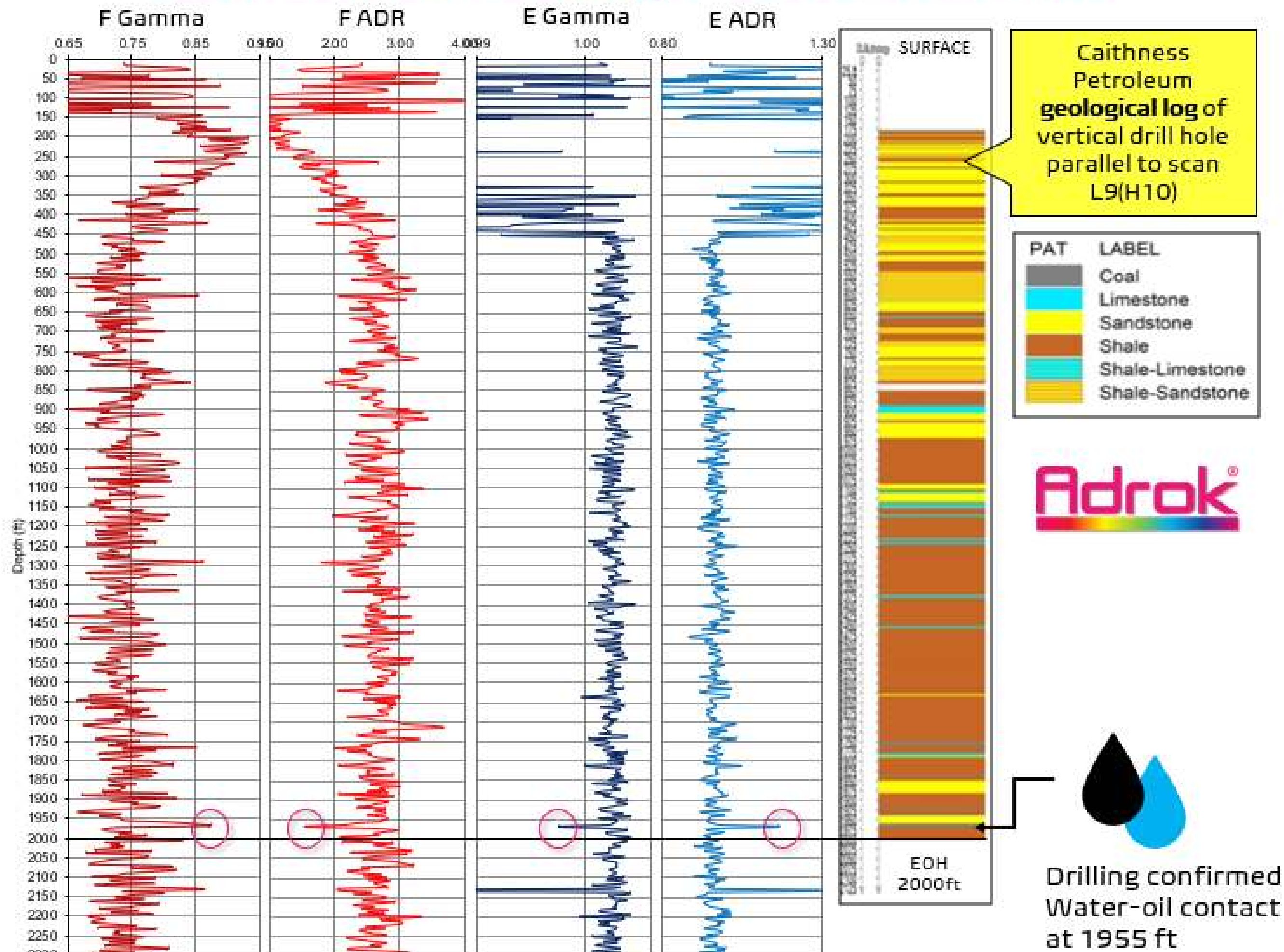
# CASE STUDY

**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 ft below surface**

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



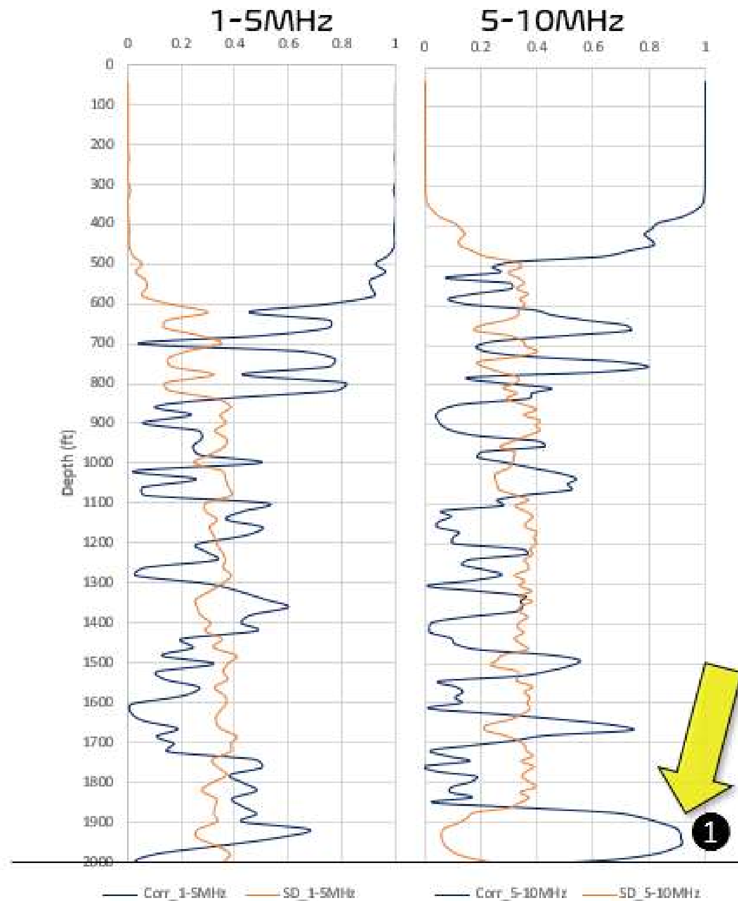

CAITHNESS PETROLEUM LIMITED

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.

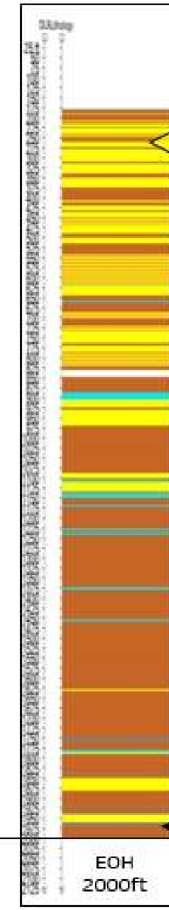
# Deep (2000ft) Petroleum and Water detection using Pulsed Radar

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

**Water-oil boundary at 1967 ft below surface**




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




Adrok

Drilling confirmed Water-oil contact at 1955 ft

CAITHNESS PETROLEUM LIMITED

Very high values for correlation in 5-10MHz bandwidth (❶ 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.

# GAB BACKGROUND

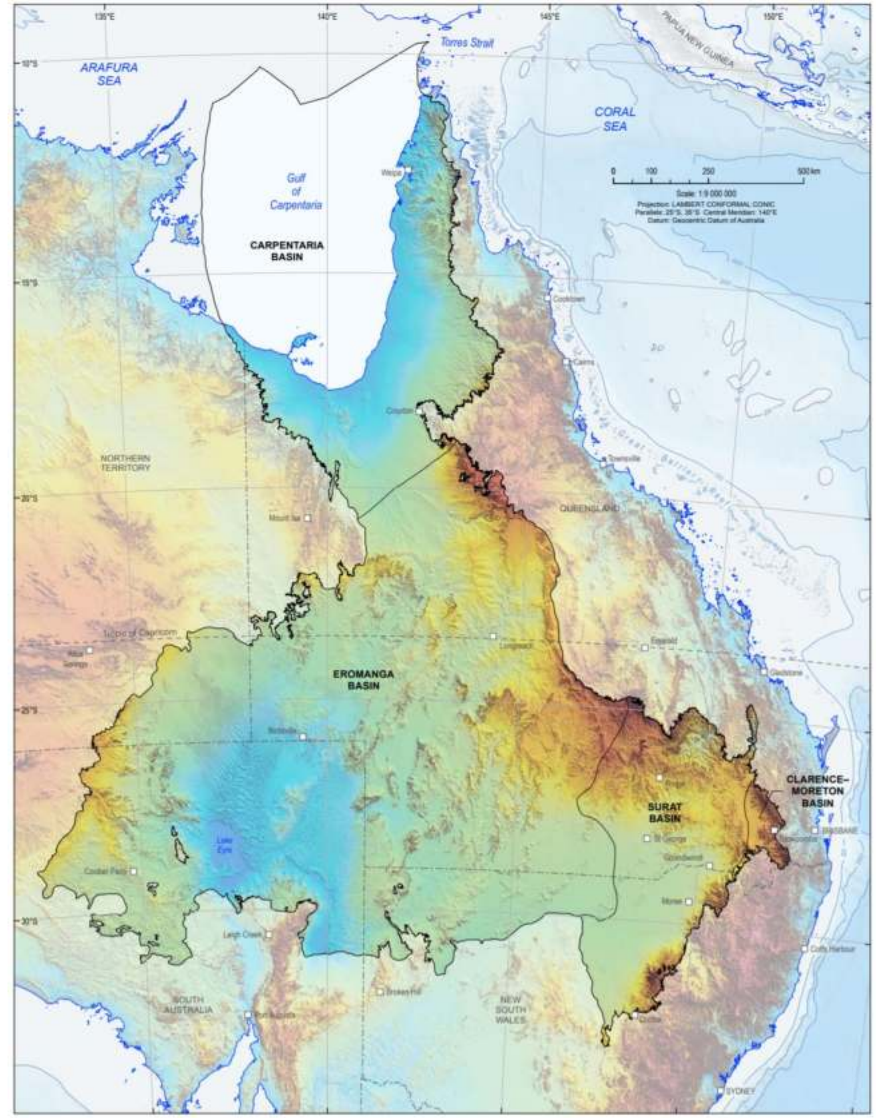
## Geoscience Australia – Summary of the Great Artesian Basin Research Priorities Workshop

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.

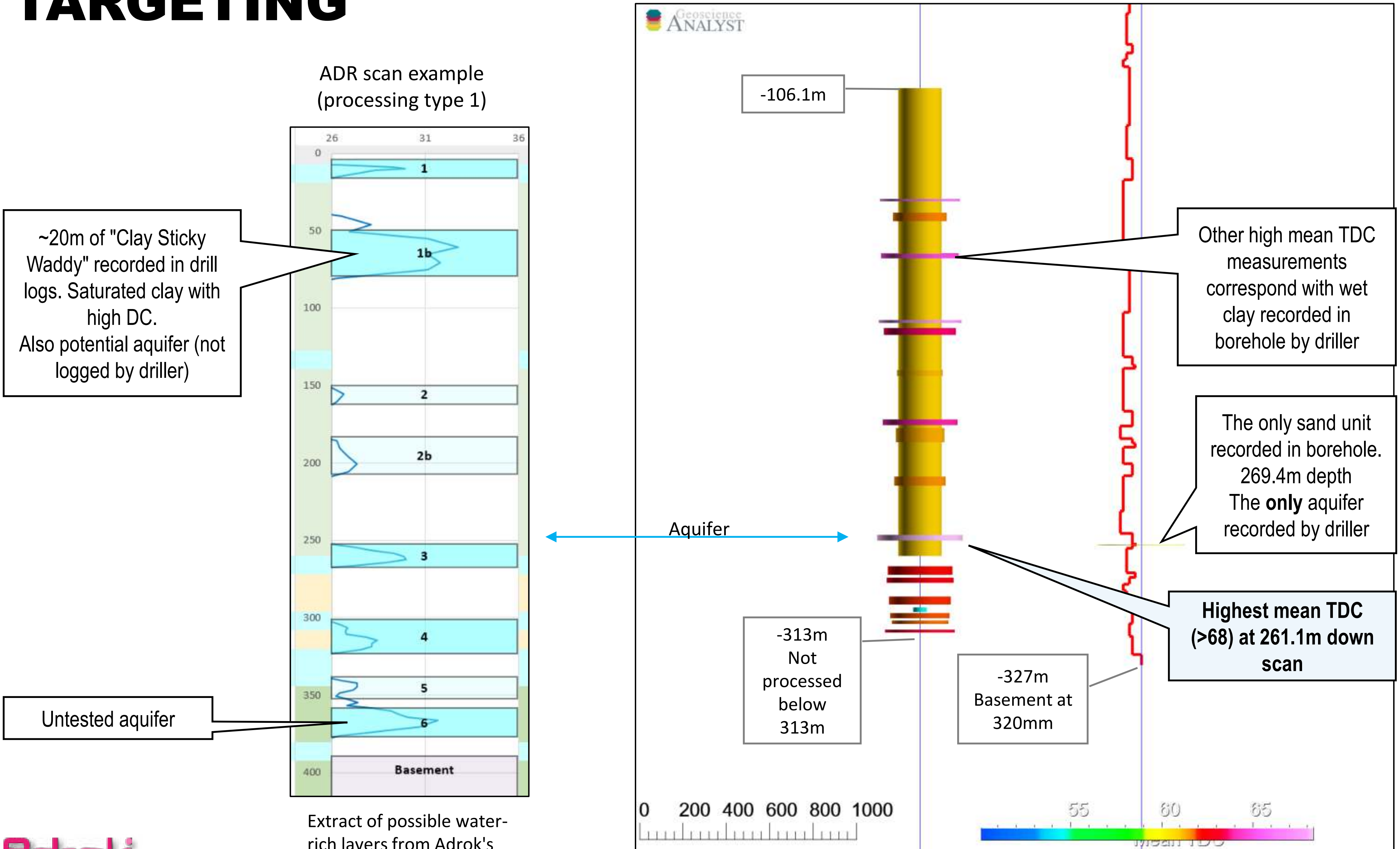
***New information is required*** as new challenges arise; this knowledge evolution leads to a recognition that current key science issues exist that need to be explored. It is essential to share information about GAB water policy, management and research activities with relevant stakeholders and decision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



# ADROK AQUIFER TARGETING

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

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




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

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

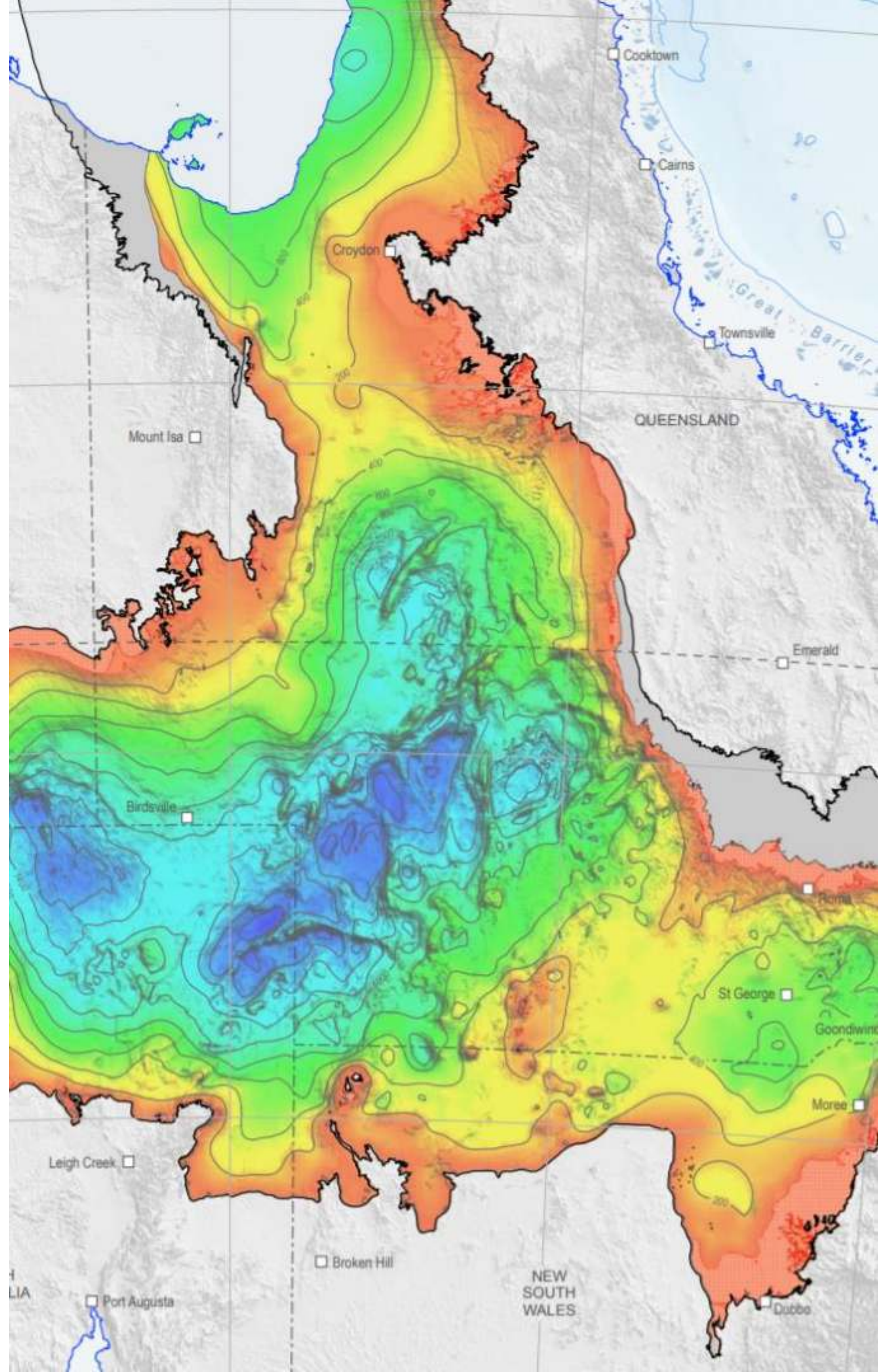
# FUTURISING WATER EXPLORATION

**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".**

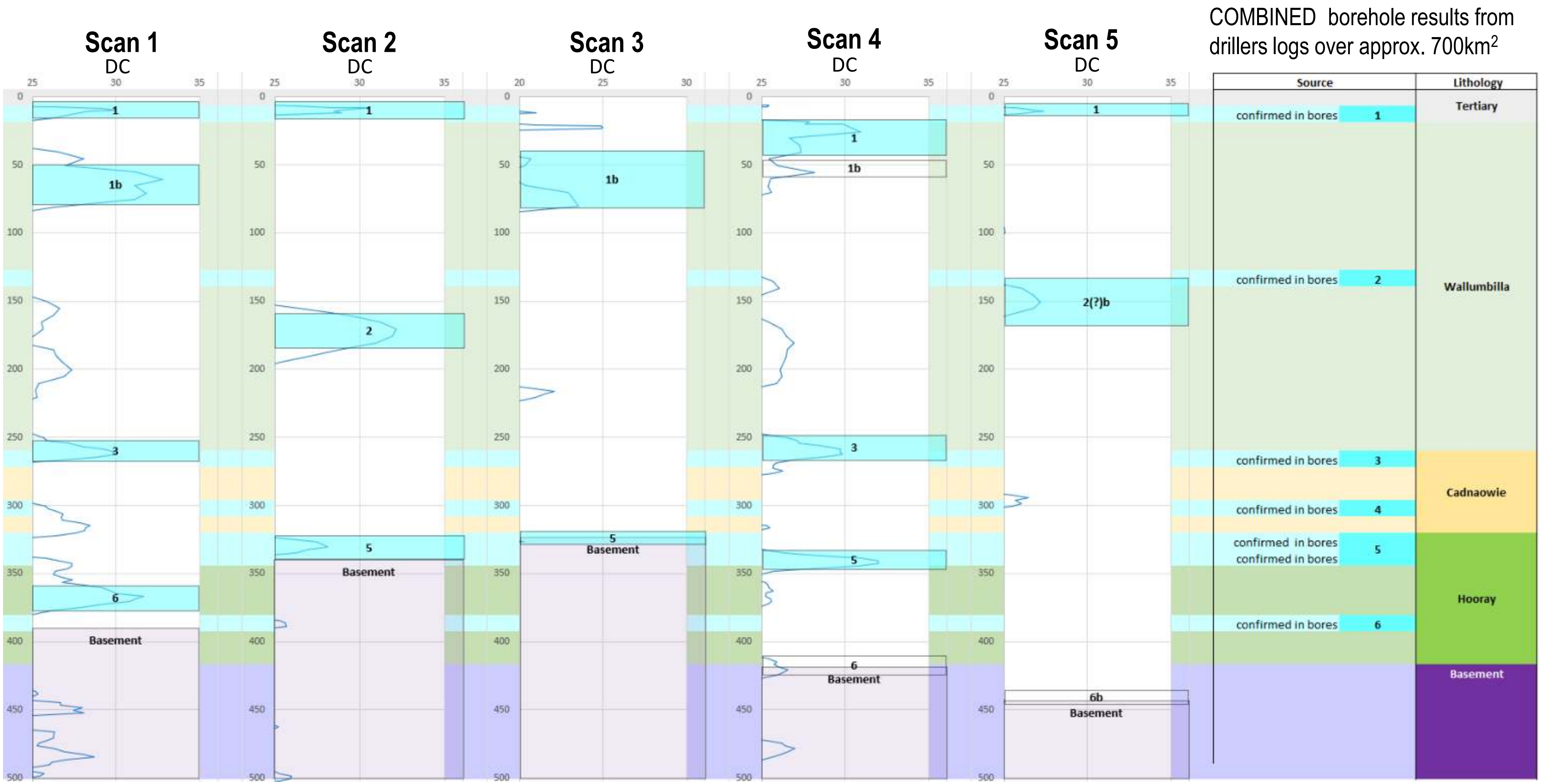
**The technology could, however, replace a significant amount of physical drilling of boreholes and removes the documented uncertainty in borehole data as highlighted below in**
doi.org/10.1016/j.ejrh.2014.08.007

"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.

GAB = Great Artesian Basin, Australia

# 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"**.

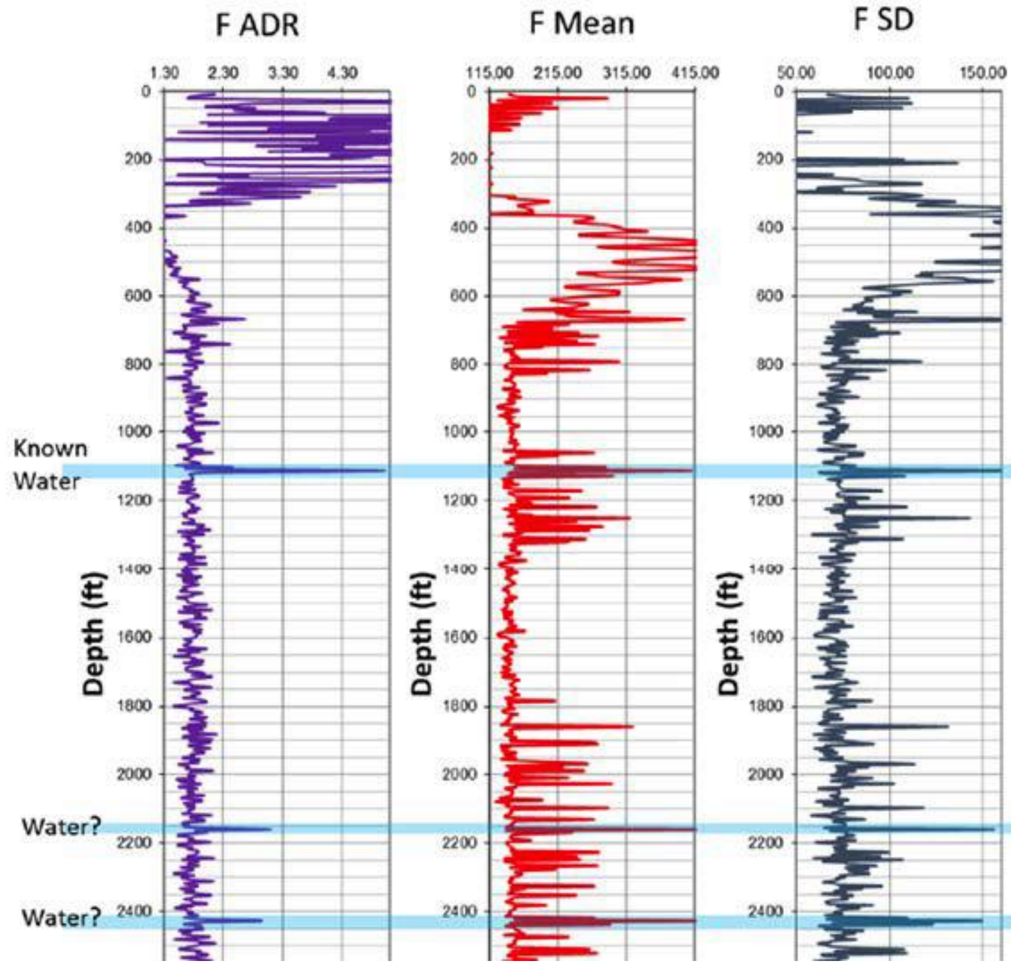
# OKLAHOMA water and oil

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.



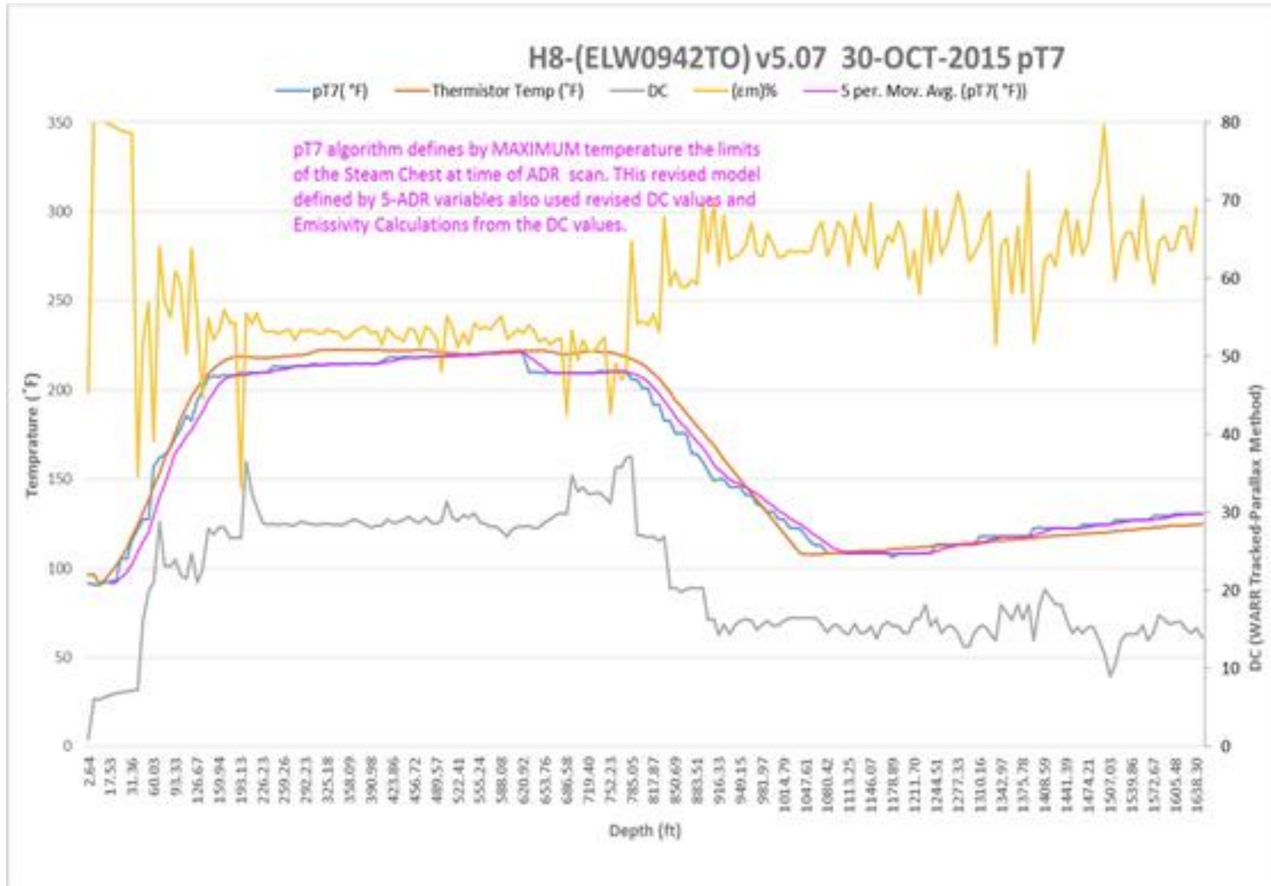
# TEMPERATURE

## 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

*Phases 1-3 are often already completed*

**Areas of high water priority are identified.** Australia has defined the north as a high priority area. A sustainable source of water is required for planned expansion of the mining and agriculture sector

**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

## 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 Earths 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.

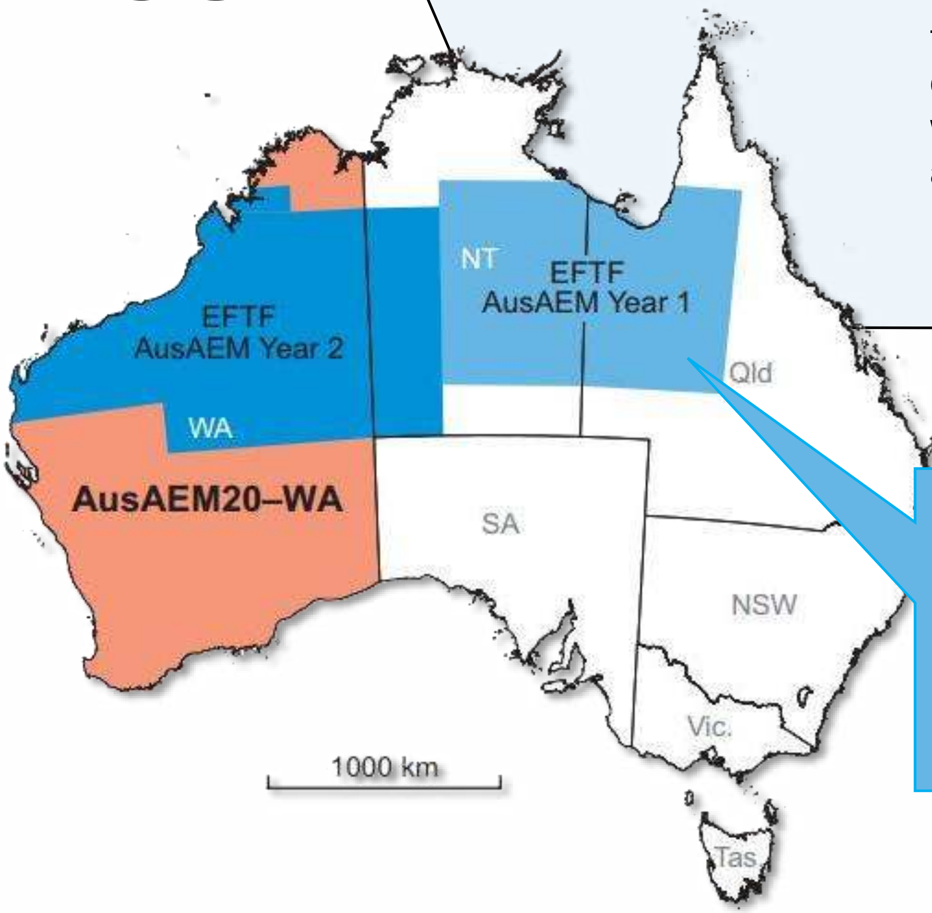
**Drill aquifer defined using ADR.** ADROK will not completely replace drilling as it does not allow users to physically test or sample the water at depth*. However, it is a geophysical technique that is used prior to drilling to ensure that the water exists at the target depth and/or to explore for 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.

# PROPOSAL

Adrok are proposing a collaborative project in an area where the results can be tested by drilling for groundwater in the near future. Northern Australia, where the AusAEM survey has been completed and water targets generated would be a perfect test bed for the ADR scanner.

Many areas in northern Australia exhibit high potential for deep aquifers, but the cost of accessing with drill equipment is beyond the scope of the project. Adrok will aim to run trials to tests for difficult-to-access aquifers.




**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.**

# INNOVATION FOR A CHANGING WORLD

**CONTACT US**

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