G-FLOWS Stage 3:

Anangu Pitjantjatjara Yankunytjatjara (APY) Lands Drilling Program, north-western South Australia

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Executive summary

The scarcity of reliable and useable water resources is one of the most significant limitations on health, wellbeing and economic development in the semi-arid and arid regions of South Australia. The Anangu Pitjantjatjara Yankunytjatjara (APY) Lands in the north-western part of South Australia are an example where water supplies are almost entirely reliant on shallow, typically low yielding (and often saline) groundwater systems. Communities in this region rely upon these groundwater resources to supply water for their use (both non-potable and potable) and economic purposes including road building, pastoral, agriculture and mineral exploration.

There has been considerable investment in airborne electromagnetic (AEM) and other geophysical surveys in the region that are primarily used in mineral exploration. The data may help investigate, identify and target other aquifer systems (such as palaeovalleys).

The Goyder Institute for Water Research "Facilitating Long-term Outback Water Solutions" (G-FLOWS) project incorporates a suite of programs to specifically determine the usefulness of this geophysical data to provide information on groundwater resources.

This report documents the drilling program that was completed as part of the G-FLOWS Stage 3 program of works, which was designed to provide the necessary data required to ground-truth and validate the geophysics-based hydrogeological interpretation and help develop further understanding of the hydrogeology in the Musgrave Province, APY Lands.

The two primary objectives of the drilling program included:

1) Confirming the stratigraphy and depth of the Lindsay East Palaeovalley and to help validate the AEM geophysical data and geophysical model presented in Soerensen et al. (2017) including the identification of water bearing zones within the palaeovalley; and
2) Developing further understanding of the groundwater characteristics in the shallow groundwater system.

On-ground works for the drilling program were conducted from July to September 2018 in a location that was in close proximity to the community of Kaltjiti (Fregon) in the APY Lands.

To satisfy the key objectives, a number of drilling sites were chosen across the wider study area that extended from Amata in the north-west to Mimili in the south-east. Due to the challenges involved with clearances two sites were ultimately chosen for drilling and well installation works; namely site DH1 and site 22 (S22). DH1 centred on the Lindsay East Palaeovalley to help in understanding the hydrogeological and geophysical characteristic of the main palaeovalley. S22 was selected as a suitable drill site to examine the shallow, or phreatic, groundwater system outside the main palaeovalley systems; although S22 also incorporated a small-scale tributary to the palaeovalley. In total, 11 groundwater wells were constructed from 12 drillholes and two continuous drill core samples were collected.

Drilling near the centre of the Lindsay East Palaeovalley (DH1) suggests there are at least three groundwater bearing horizons:

i) the shallow phreatic watertable of calcareous mixed sand plain deposits,
ii) an interlayered coarse-grained sand and clay horizon and
iii) a very fine to coarse grained residual sand.

A saprolite/fractured rock aquifer underlays these palaeovalley sedimentary rocks. The coarse-grained sand (which overlays a lacustrine claystone and mudstone) shows promise as a productive aquifer, with development yields varying between 5 and 20 L/sec and salinities <1000 mg/L Total Dissolved Solids (TDS).

Only one aquifer was targeted at S22 by design, that of the phreatic watertable. Development yields were generally low (<1 L/sec) and salinity varied between 1000 and 1500 mg/L TDS.

Acknowledgments

We would like to acknowledge the traditional owners of the Anangu Pitjantjatjara Yankunytjatjara (APY) Lands, the Pitjantjatjara, Yankunytjatjara and Ngaanyatjarra people. In particular we would like to thank Mr Witjiti George, Mr Maxi Stevens, Mr Robert Stevens, Bruce, Frank, Lee, and many others for undertaking on-country site inspections.

We would also like to acknowledge the work undertaken by the APY Consultation, Land & Heritage Unit, including Ms Charmaine Jones, Ms Cecilia Tucker, Mr Noah Pleshet, and Mr Andrew Cawthorn, who facilitated the necessary clearance approval to undertake this program of works within the APY Lands.

Silver City Drilling are acknowledged for their drilling services to deliver this program as well as the staff of Regional Anangu Services Aboriginal Corporation (RASAC) in Umuwa for logistical support including accommodation.

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Finally, we would like to thank APY General Manager Mr Richard King and the entire APY Executive Board who were supportive of the G-FLOWS project.

1 Introduction

1.1 Project Background

The scarcity of reliable and useable water resources is one of the most significant limitations on health, wellbeing, social and economic development in the semi-arid and arid regions of South Australia. In such remote and regional areas, groundwater provides the primary and often only viable supply of water for community water supplies (both non-potable and potable) and industry development such as cattle, agriculture and mining.

This is particularly evident in the Anangu Pitjantjatjara Yankunytjatjara (APY) Lands, located in the north western region of South Australia, where water supplies are almost entirely reliant on shallow, typically low yielding and often saline groundwater systems. These water supplies are currently used for potable and non-potable community use, road building and economic development such as pastoral and agriculture industries. Additionally, although groundwater use for mining is currently restricted to aggregate quarrying for local use, groundwater supplies may potentially support an expanded mining industry. Consequently, a continuation of current economic activity, as well as any future development of current or greenfield-industries will require a greater understanding of groundwater flow systems and aquifer connectivity and yield.

Deep sedimentary cover, however, is a constraint to identifying water sources in the north-western parts of South Australia. To address this, the Goyder Institute for Water Research's "Facilitating Long-term Outback Water Solutions" (G-FLOWS) suite of research projects have developed new techniques to interpret airborne electromagnetic (AEM) geophysical data to identify groundwater resources buried by deep sediments.

Commencing in 2011 (with Stage 1), this project (Stage 3) is utilising new AEM data acquired in late 2016 under the Government of South Australia's Plan for Accelerating Exploration (PACE) program (co-funded by DEW). This projects involves a targeted program of data acquisition, interpretation and mapping of palaeovalley systems (potential groundwater resources) in the Musgrave Province, APY Lands. The research is applying new and innovative geophysical techniques developed in the previous G-FLOWS projects (Stages 1 and 2) combined with field evaluation techniques to potentially map and identify deep groundwater resources.

This project extends the AEM geophysical interpretation process by establishing hydrogeological control test sites. These sites are composed of a number of newly constructed water wells with the aim of reducing uncertainty in the interpretation of AEM data, thereby identifying deep potential groundwater resources in the palaeovalley system.

This report documents the drilling program that was conducted from July to September 2018, designed to provide the necessary data required to ground-truth and validate the hydrogeophysical interpretation and therefore aid in reducing uncertainty in geophysics-based outputs.

1.2 Drilling program objectives

The drilling program forms a key component of the on-ground works that extend the AEM geophysical interpretation process. This is achieved by establishing hydrogeological control test sites that are used to verify palaeovalley features. These hydrogeological control sites were composed of a number of newly constructed groundwater wells.

In addition to mapping the hydrogeological system of the main palaeovalley, drilling works were also designed to provide further understanding of the shallow groundwater system that is used extensively in the region for community supply.

In the initial stages of the project, two primary hydrogeological control test sites were identified. Drill site DH1 (specifically DH1a, b, c, d, e, f, g, a2) centred on the Lindsay East (Mermangye) Palaeovalley. This was selected to help understand the hydrogeological and geophysical characteristics of the main palaeovalley. Site 22 (S22) was selected as a suitable drill site to examine the shallow, or phreatic, groundwater system outside of the palaeovalley; however S22 also incorporated a small-scale tributary to the palaeovalley (Figure 1-1).

The primary objectives of the drilling program were to:

1) Confirm the stratigraphy and depth of the Lindsay East Palaeovalley and to help validate the AEM geophysical data and geophysical model presented in Soerensen et al. (2017) including the identification of water bearing zones within the palaeovalley; and
2) Develop further understanding of the groundwater characteristics in the shallow groundwater system.

Knowledge generated from fulfilling these objectives will be used to inform the conceptual understanding of the groundwater system including the (deep) palaeovalley system as part of the G-FLOWS Stage 3 project.

1.3 Study area

The regional study area for G-FLOWS Stage 3 is centred on the indigenous APY Lands located approximately 1,100 kilometres north-west of Adelaide, in the far north western corner of South Australia. The project focus area (or local study area) covers approximately 26,600 km^2 within the central region of the APY Lands. It encompasses a number of communities and homelands including Amata, Pukatja (Ernabella), Yunyarinyi (Kenmore Park), Kaltjiti (Fregon), Mimili and the administrative centre of Umuwa (Figure 1-1).

The 2016 census reported that 2,276 people live in the APY Lands, with 83.6% being Aboriginal and/or Torres Strait Islander descent (ABS, 2018). According to ABS (2017), the main industry and biggest employer in the APY Lands is education and training, although with respect to income generation, the pastoral industry is of highest importance. Retail trade, arts and recreation are also notable employers and generators of income.

The climate of the region is arid to semi-arid, with mean rainfall generally below 300 mm/yr. The community of Pukatja reports an annual mean rainfall of 282 mm (BoM, 2018a), and a mean annual temperature of 27.5°C (BoM, 2018b). Vegetation comprises predominantly grassland, shrub land, and woodlands.

Topography in the local study area varies considerably. Mountainous regions associated with the Musgrave and Everard Ranges dominate the northern and southern margins of the study area respectively (Figure 1-1). The highest point in South Australia, Mt Woodroffe (1,435 mAHD), is located within the study area, approximately 40 kilometres west of Pukatja (Figure 1-1) in the Musgrave Ranges. Between the Musgrave and Everard Ranges are extensive plains and rangelands, dominated by sand aeolian dunes, sandplains and alluvial plains. A number of creeks drain the Musgrave Ranges to the north, with the most important being Officer Creek and its tributaries Currie Creek and Ernabella Creek, which flow through the centre of the study area (Figure 1-1).

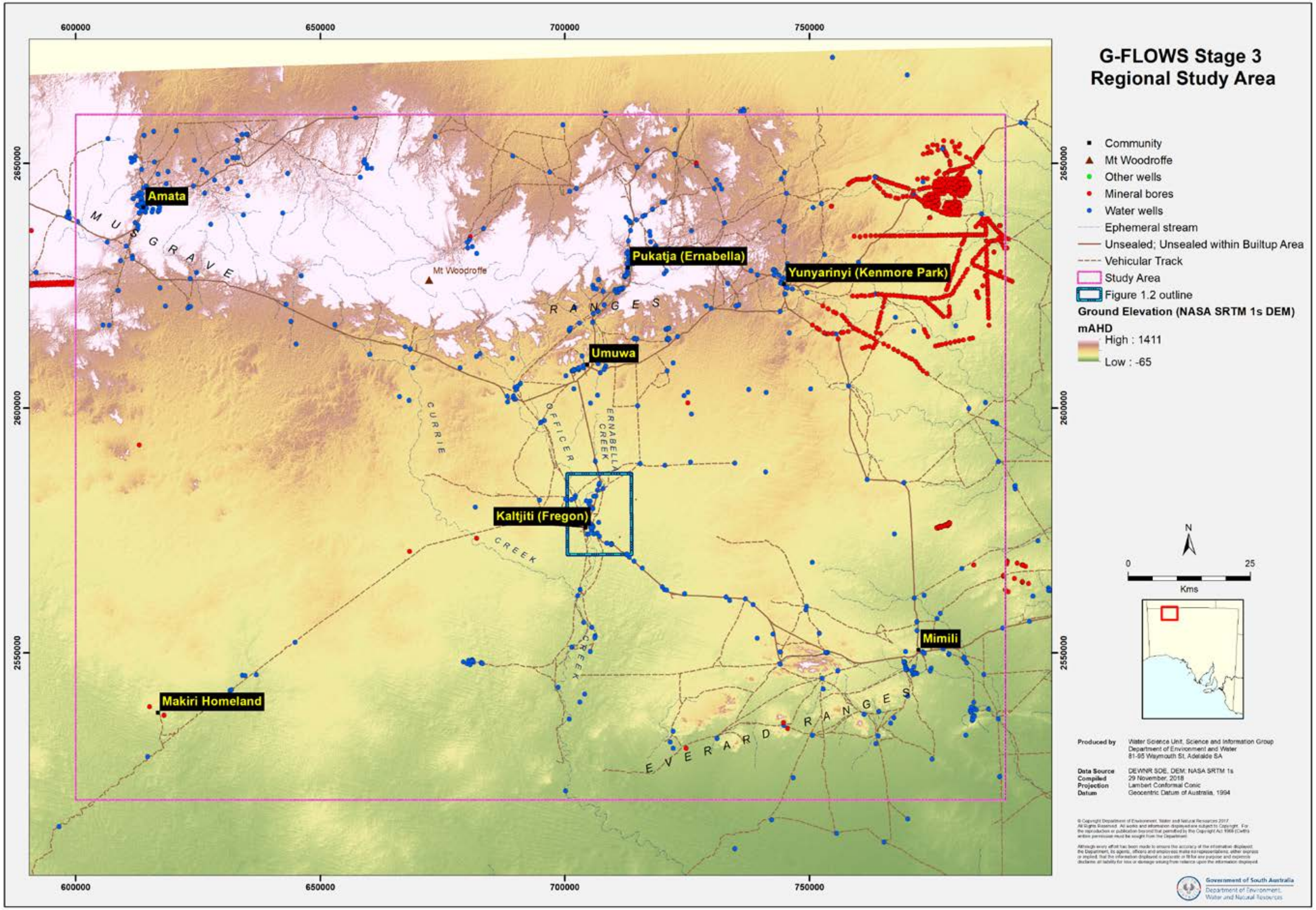

Figure 1-1. G-FLOWS Stage 3 study area.

1.3.1 DH1

Site DH1 is located on the Fregon-Mimili road approximately 6-7 kilometres southeast of Kaltjiti (Fregon). DH1 was selected due to its proximity to the mapped extent of the Lindsay East Palaeovalley (Figure 1-2) as depicted by the AEM geophysical data and its location adjacent to a main road, which aided site access and clearance. The topography at DH1 is generally flat, with relief primarily provided by sand dunes that were 3 to 5 metres in height. Vegetation largely consists of grassland and sparse woodland and soils are largely composed of aeolian sand and silt.

The well design and configuration for DH1 was based on potential future aquifer testing to help understand the hydraulics of the palaeovalley. While seven wells and one cored hole were initially planned for this location, an eighth well was installed providing a replacement for one of the initial wells which posed construction issues.

The DH1 site configuration incorporated the following:

1. The main site (south of Fregon-Mimili road) centred on the Lindsay East Palaeovalley with one cored hole (DH1a) and four completed wells (DH1a2, c, d and e). DH1a was plugged (no screen) and replaced with DH1a2.
2. A site located north of the Fregon-Mimili road with one completed well (DH1b) approximately 100 m north of the main site.
3. A site located approximately 1 kilometre from the main site adjacent to the Fregon-Mimili road with two completed wells (DH1f and g).

Drillholes at DH1 were designed to target the geological features and water bearing zones found within the palaeovalley sediment fill. Bores were designed to allow for aquifer testing of any encountered water bearing zones, with DH1c designed as a pumping well near the centre of the site, and DH1d and DH1b designed as observation wells 30 m and 100 m away respectively. DH1e and DH1a2 were designed as observation wells targeting water bearing sequences above (DH1e) and below (DH1a2) the main water bearing zone. Site DH1f and DH1g were designed to target the subsurface beyond the extent of the palaeovalley sediments. Table 4-1 summarises the basic well construction details.

1.3.2 S22

S22 is located adjacent to the Umuwa-Fregon road approximately 9 kilometres north of Kaltjiti (Fregon) (Figure 1-2). S22 was selected to aid the understanding of the phreatic (shallow) groundwater system. This is considered important for understanding its hydrodynamics with respect to the surrounding undulating topography, and the relationship with the shallow potentiometric surface (watertable). Additionally, S22 also spans part of a shallow palaeovalley tributary system.

One core hole and four wells were constructed at S22 namely S22a, S22b, S22c, and S22i (core and well).

Vegetation at S22 is similar to that found at DH1, consisting primarily of spinifex grasslands and open woodland, however riparian tree stands occur within the channel of Ernabella Creek and a reasonably thick stand of mulga occupies much of the southern portion of the study site.

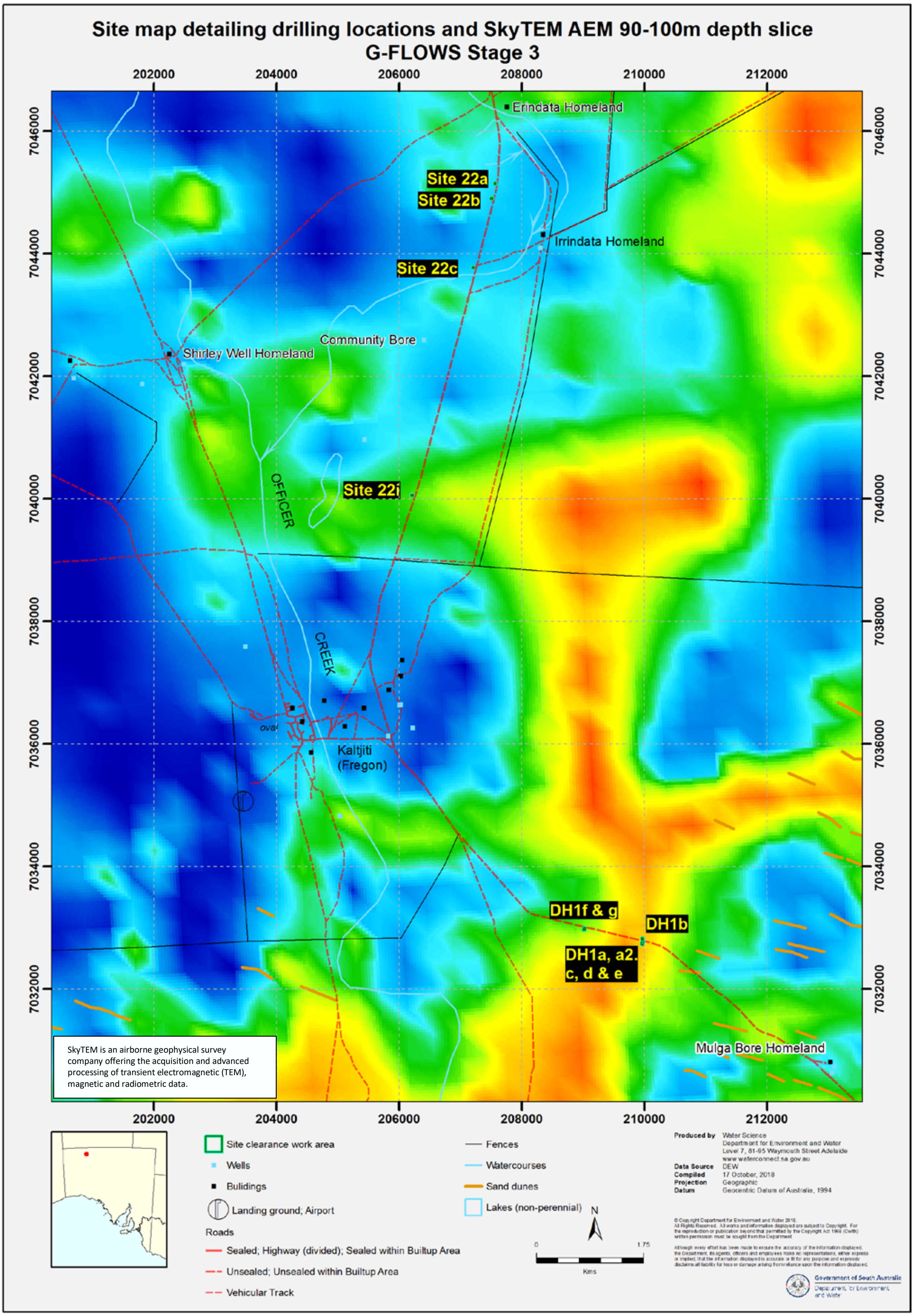

Figure 1-2. G FLOWS Stage 3 drilling program locality map overlaid on an airborne electromagnetic (AEM) data-set (warm colours signify more conductive material which is interpreted as paleovalley fill).

2 Regional geology and hydrogeology

2.1 Geology

The regional study area occurs within the south eastern portion of the Musgrave geological province (Musgrave Province). The Mesoproterozoic Musgrave Province is a Mesoproterozoic craton that is composed of granulite and amphibolite facies metamorphic rocks of the Birksgate Complex that granitoids of the Pitjantjatjara Supersuite, mafic and ultramafic rocks of the Giles Complex and mafic dykes of the Alcurra Dyke Swarm have subsequently intruded. The outcropping and sub-cropping region of the Musgrave Province abuts or is overlain by sediments and sedimentary rocks of a number of pericratonic, intracratonic and epicratonic depositional basins. These basins include the Neoproterozoic to Early Carboniferous Amadeus Basin to the north, the Ordovician to Early Cretaceous Canning Basin to the west and the Neoproterozoic to Late Devonian Officer Basin to the south (Figure 2-1). To the east, the Musgrave Province abuts a number of stacked basins. These eastern basins include the Cambro-Ordovician Warburton Basin, the Permo-carboniferous Arckaringa, and Pedirka basins, the Mesozoic Great Artesian Basin (Eromanga Basin) (Figure 2-1); major unconformities separate these basins from one another.

The region in general is highly deformed by a series of major east-west shear zone systems, the most important being the Hinckley, Mann-Ferdinand, Lindsay, Wintiginna and Woodroffe systems (Figure 2-1). Woodhouse and Gumm, (2003) interpreted metamorphic and initial structural deformation to have begun during the Musgravian Orogeny between 1220 and 1120 Ma, when intrusion of felsic magmas associated with the Pitjantjatjara Supersuite occurred. However, Woodhouse and Gumm, (2003) also suggested that the bulk of the high strain deformation occurred during the Late Neoproterozoic Petermann Orogeny (~550 Ma) when a number of mylonites and ultra-mylonites were formed. Between the Musgravian and Petermann Orogenies, the 1085-1040 Ma Giles Event resulted in the intrusion of mafic, ultra-mafic, and minor felsic igneous rocks as well as the deposition of bimodal volcanic rocks, followed by the intrusion of a number of dolerite dyke suites.

One of the most prominent geological features within the study area is the Woodroffe Thrust, which is a zone of sheared gneiss, mylonite, and pseudotachylite that occurs within the Musgrave Ranges (Figure 2-1). The Woodroffe Thrust demarcates the Musgrave Province into the northern Mulga Park Subdomain and the southern Fregon Subdomain (Pawley and Krapf, 2016). The thrust represents a major crustal discontinuity, in which Major and Conor (1993) postulated that a 15 m thick slab of granulitic basement (Fregon Subdomain) was thrust 24 kilometres over amphibolite facies rocks (Mulga Park Subdomain) during the Petermann Orogeny (~550 Ma). The dip of the thrusting is approximately 30° to the south. Another important related structural feature within the study area is the Levenger Graben, which represents a reactivation of the Mann Fault during the Cambrian (~542-488 Ma) (Figure 2-1). The Levenger Graben occurs south of the Musgrave Ranges, between Amata and Kaltjiti (Fregon). The shape and thick accumulation of clastic fill, called the Levenger Formation, within the Levenger Graben suggests this reactivation formed a wrench pull-apart basin (Major and Conor, 1993).

Within the study area and relevant to this study are a number of more recent sedimentary formations, most notable being the palaeovalleys (Figure 2-1), which have their headwaters in the Musgrave Ranges and generally flow to the south. These palaeovalleys can typically reach up to 70 m deep (Pawley and Krapf, 2016). Palaeovalleys of note within or near the study area include the Lindsay, Serpentine, Lindsay East and Hamilton palaeovalleys. These palaeovalleys largely formed during the Neogene (~23-2.6 Ma) during tropical and sub-tropical climatic periods. They are filled with alluvial, fluvial, and lacustrine sediments composed of clay, sandy clay, mixed-sand plain deposits, and lenses of coarse sand and gravel. Preceding the palaeovalley development was a period of intense chemical weathering that resulted in the development of a deep weathering profile of up to 90 m that affected Proterozoic and existing Phanerozoic rocks (Pawley and Krapf, 2016). Weathering caused kaolinisation, mottled or pallid saprolite development and the formation of ferruginous duricrust and silcrete. Recent aridity has led to a surficial geology dominated by aeolian and ephemeral alluvial processes, leading to a landscape of aeolian sand plains, alluvial plains and dunefields.

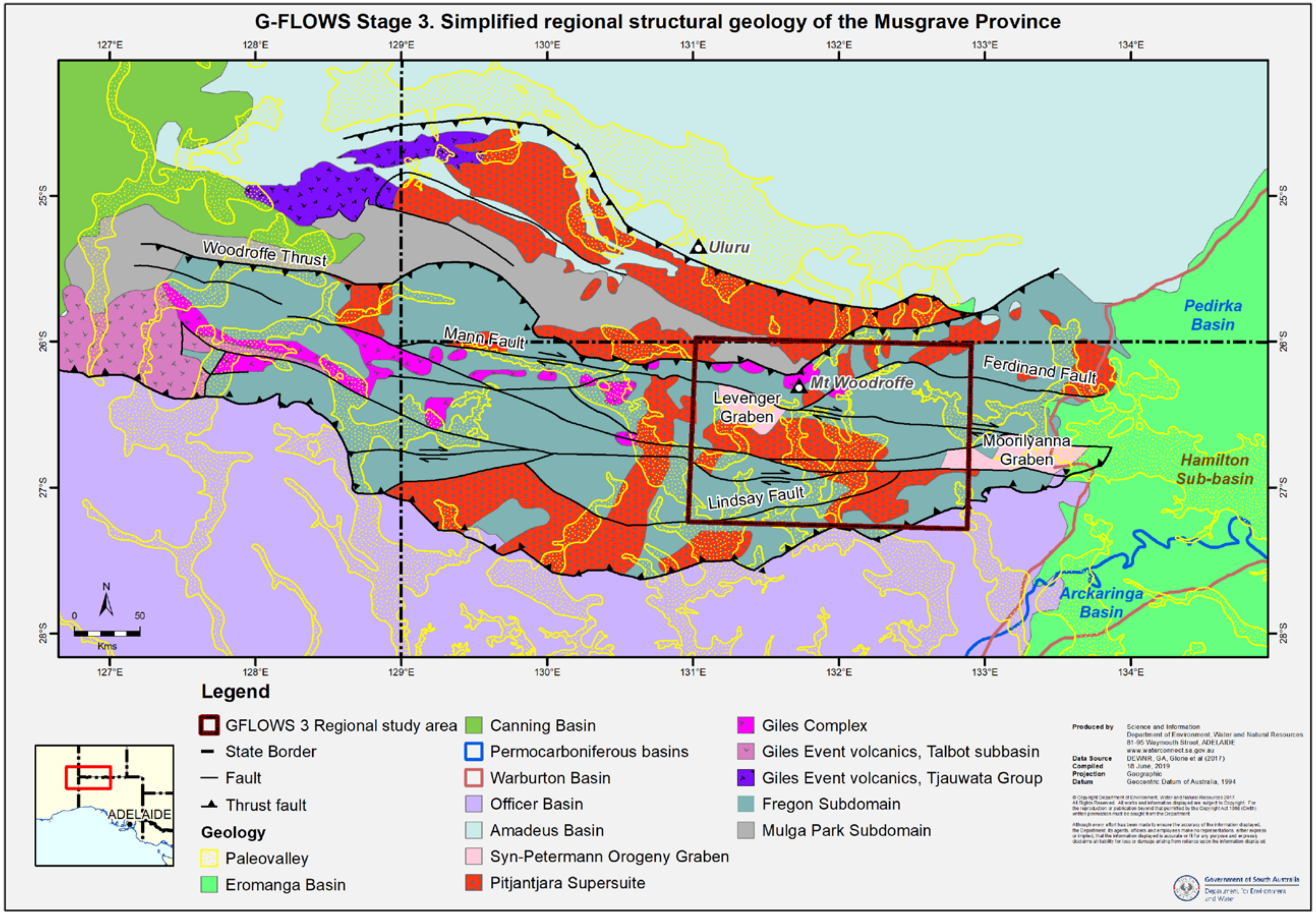

Figure 2-1. Simplified regional structural geology of the Musgrave Province, surrounding sedimentary basins and location of palaeovalleys. Developed after Glorie et al. (2017), and Geoscience Australia (2012).

2.2 Hydrogeology

The hydrogeology of the region is extremely complex in terms of both the hydrostratigraphy and the groundwater flow systems. Despite large knowledge gaps, a preliminary understanding of the system is presented below based on available information.

The broad scale geology of the region is relatively well known (Pawley and Krapf, 2016); however the hydrostratigraphy is not well known. Based on the mapped distribution of the Quaternary and Tertiary system and a number of geological logs throughout the region, the hydrostratigraphy has been broadly divided into four units:

- Unit 1: Quaternary and Tertiary units. This layer consists of sands, clays, and silts. The distribution of any inter-beds of this horizon is unknown with any certainty within the overall depositional sequence. Based purely on the observed lithology, it is estimated that the hydraulic conductivity varies by 3-5 orders of magnitude.
- Unit 2: Weathered fractured rock aquifer. This layer comprises highly weathered saprolite and less weathered saprock horizons of crystalline basement units such as the Birksgate Complex, Pitjantjatjara Supersuite and others. Recent drilling into this unit have obtained yields of up to 10 L/s (Howles et al., 2017).
- Unit 3: Fractured rock aquifer. The fractured rock aquifer is regarded as fresh metamorphic and igneous basement rocks that contain water-bearing fractures (Howles et al., 2017). The distribution and orientation of these fractures at local and subregional scales is unknown, however the orientation of regional faults may provide insights (Pawley and Krapf, 2016). For instance, the dextral strike-slip interpreted movement along major east-west faulting (Figure 2-2) might imply secondary tensional deformation in the northeast-southwest orientation, with antithetic and synthetic strike–slip movement in the north-south and east-southeast- west-northwest orientations respectively. It is anticipated that hydraulic conductivities will be generally low but with an inherent heterogeneity that may lead to localised zones of high hydraulic conductivity associated with concentrated fracturing.
- Unit 4: Deep unfractured basement. This layer is part of the fractured rock aquifer but is likely to have a lower hydraulic conductivity than the layer immediately above.

Groundwater level data and a newly interpreted potentiometric surface appears to indicate that groundwater flow generally follows topography. At a study area scale (Figure 2-2), watertable contours indicate groundwater flow direction as having a south east flow-path emanating from the Amata area. However directly north of Kaltjiti (Fregon), the flow direction is almost directly north-south.

Water levels vary from approximately 800 mAHD near Mt Woodroffe in the Musgrave Ranges to approximately 320 mAHD south of the Everard Ranges (Figure 2-2). The topographic highs (Musgrave and Everard Ranges) appear to be the largest influence on the potentiometric surface.

The Lindsay East Palaeovalley also appears to be an important influence on groundwater flow since potentiometric contours display a low regional hydraulic gradient between the two ranges where a spur separating the Lindsay East and Hamilton palaeovalleys forms a groundwater divide (Hou et al., 2012). As well as the ranges, the potentiometric contours display preferential flow along the Lindsay East Palaeovalley.

Leaney et al (2013) suggested that the Musgrave Ranges and the headwaters of drainage channels emanating from these ranges are an important recharge area. Keppel et al (in prep.) also suggested that the Everard Ranges may also form an area of recharge to either the unconsolidated Quaternary and Tertiary sediment aquifers that abut the ranges, or to the fractured rock aquifer via basement outcrop within the ranges themselves.

The range front region on the southern margins of the Musgrave Ranges contain alluvial fan deposits, which may form localised aquifers. Furthermore, the Levenger Graben, which lies in close proximity to the southern range front and south of the Amata-Umuwa road, is filled with clastic sedimentary rocks of Cambrian age, known as the Levenger Formation. Although modern day drainage features appear to flow toward this area, the current watertable does not suggest that the alluvial fan deposits or the Levenger Graben have any particular influence on groundwater flow. This interpretation may be highly influenced by a lack of data, as there is very little drilling south of the Musgrave Ranges between Amata and Kaltjiti (Fregon).

The specific impact of faulting on localised groundwater flow patterns within the study area (secondary porosity and permeability influence aside), is currently difficult to discern given the lack of data. However given the prevalence of deformation, it is likely to be important. The general east-west strike of structural deformation, which is perpendicular to the north to south or northwest-southeast direction of palaeovalley development, regional surface drainage and groundwater flow, suggests that tectonic uplift or sagging is generally more important than the influence of shearing on the groundwater system. However, this perpendicular relationship also indicates a potential for localised development of lateral flow barriers, or preferential flow pathways. Additionally, reactivation of structures may have important influence on the architecture of current-day drainage and palaeovalleys. Such an architecture is interpreted between Pukatja and Kaltjiti (Fregon) where the accumulation and thickness of Quaternary and Tertiary alluvial sediments appears to be impacted by dip-slip movement along fault planes (Figures 2-1 and 2-2).

Structural influence on groundwater flow is not evident in current groundwater level data, however such evidence might be found at more localised scales than what is currently permitted by the existing well network.

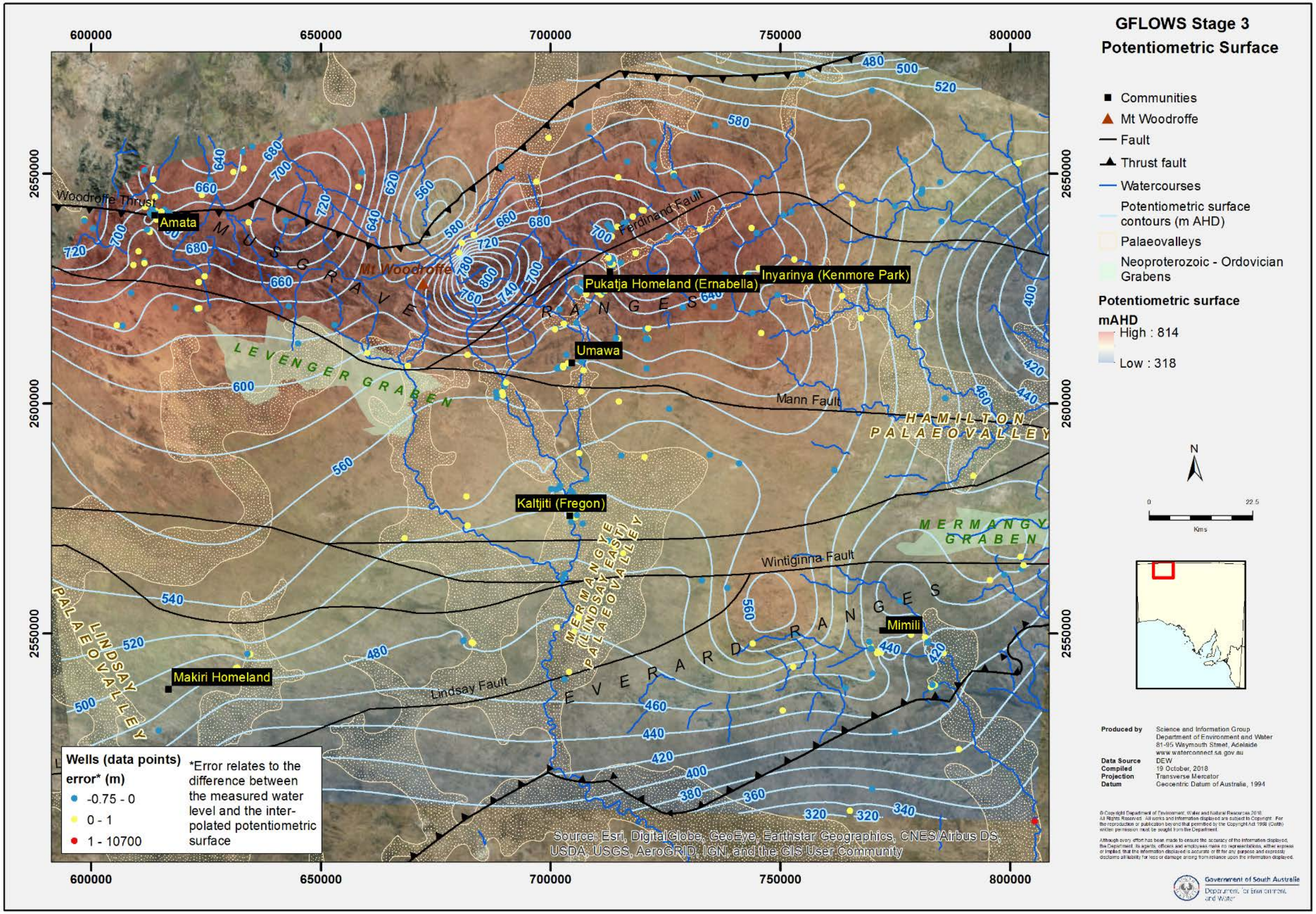

Figure 2-2. Interpreted potentiometric surface, G-FLOWS 3 study area.

3 General work program design

Drilling at DH1 included the drilling of a cored hole through the entire depth of the Lindsay East Palaeovalley and the installation of seven wells targeting shallow and deep aquifers found within the palaeovalley for the purposes of hydrochemical sampling and aquifer test analysis. Drilling at S22 included drilling of a cored hole through the entire depth of a tributary to the Lindsay East Palaeovalley (Figure 2-2) and the installation of four wells targeting the phreatic groundwater system. Table 4-1 presents a summary of basic well construction details and Figure 3-1, Figure 3-2, and Figure 3-3 present drillhole and well locations.

3.1 Pre-drilling approvals and procurement

Prior to commencement of drilling, cultural heritage clearance and consent from the Traditional Owners of the proposed drill sites and endorsement of the APY Executive was required. To facilitate this process, on 8 September 2017 DEW submitted a Heritage Impact Assessment (HIA) to the APY Consultation, Land & Heritage Unit through the APY Executive, describing the on-ground works (drilling program) and the potential impacts.

Representatives from DEW also presented details of proposed drilling works at a number of APY Executive meetings, including one hosted on the APY Lands on 8 November 2017, giving the APY Executive the opportunity to discuss the program in person.

Field trips conducted in October 2017 and May 2018 incorporated drill site location clearances with anthropologists from the APY Consultation, Land & Heritage Unit. The APY Executive granted official approval for drilling works on 28 May 2018. Official approval was accompanied by a draft preliminary advice report that received a final sign-off from the APY Executive during a meeting held on 23 May 2018.

DEW arranged Dial Before You Dig (DBYD) clearances for all drill sites. This included engaging a qualified underground cable-locating contractor to identify underground cables (if any) at each drill site. Site visits were undertaken with DEW in late June 2018. Subsequent to cable locating works, the approved drilling site area DH1 required expansion to accommodate the presence of a telecommunications fibre optic cable (Figure 3-1 and Figure 3-2) and the drillers' campsite.

Well permits applications were submitted to DEW and permits were granted prior to drilling.

DEW initiated procurement for the drilling program in late 2017 and a contractor was engaged in mid-2018. The contractor evaluation team included representatives from DEW, Geological Survey South Australia (GSSA), Flinders University and CSIRO. DEW awarded the final contract to Silver City Drilling Pty Ltd on 21 June 2018.

3.2 Drilling and well construction

The initial design of the drilling program incorporated a number of different cored drillhole sites, as well as sites for water well construction. This was later narrowed down to 17 wells; seven wells located near the Lindsay East Palaeovalley (DH1), six wells in the shallow groundwater system and palaeovalley tributary system (S22) and 4 wells in the shallow groundwater system on the foothills of the Musgrave Ranges (Figure 2-2).

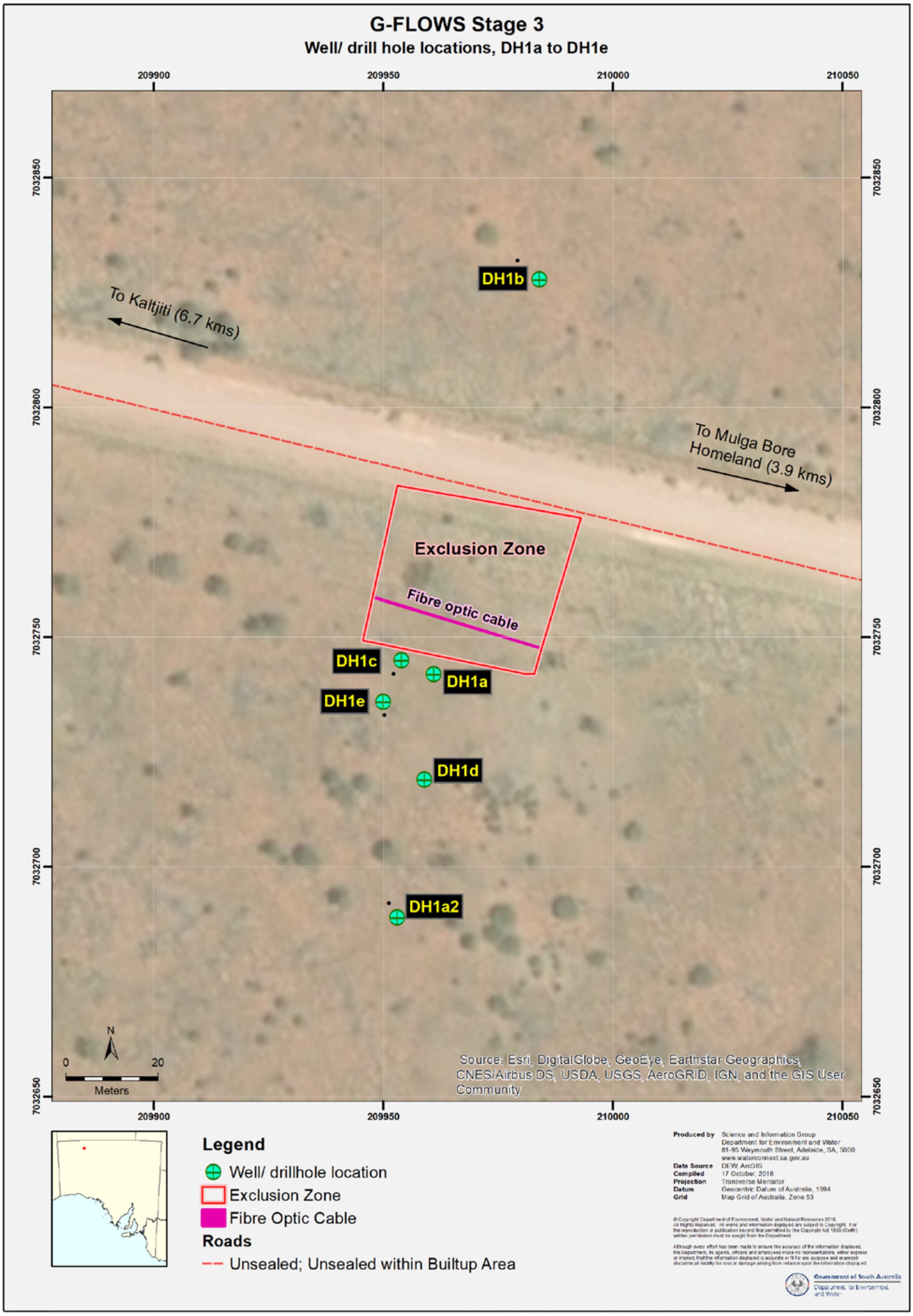

Figure 3-1. Drillhole site locations and exclusion zone at DH1 (DH1a, b, c, d, e, a2).

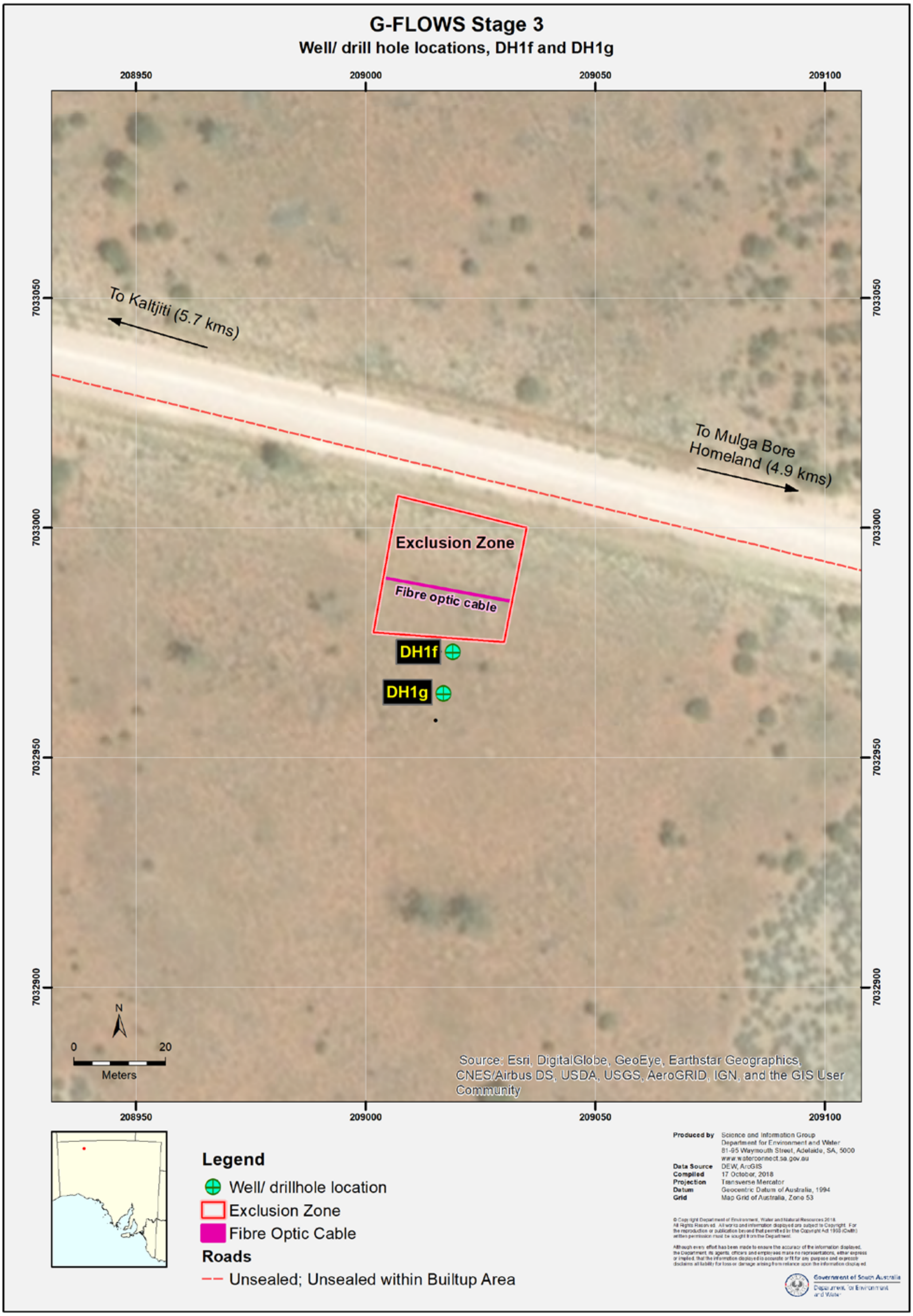

Figure 3-2. Drillhole site locations and exclusion zone at an extension of (DH1f and g).

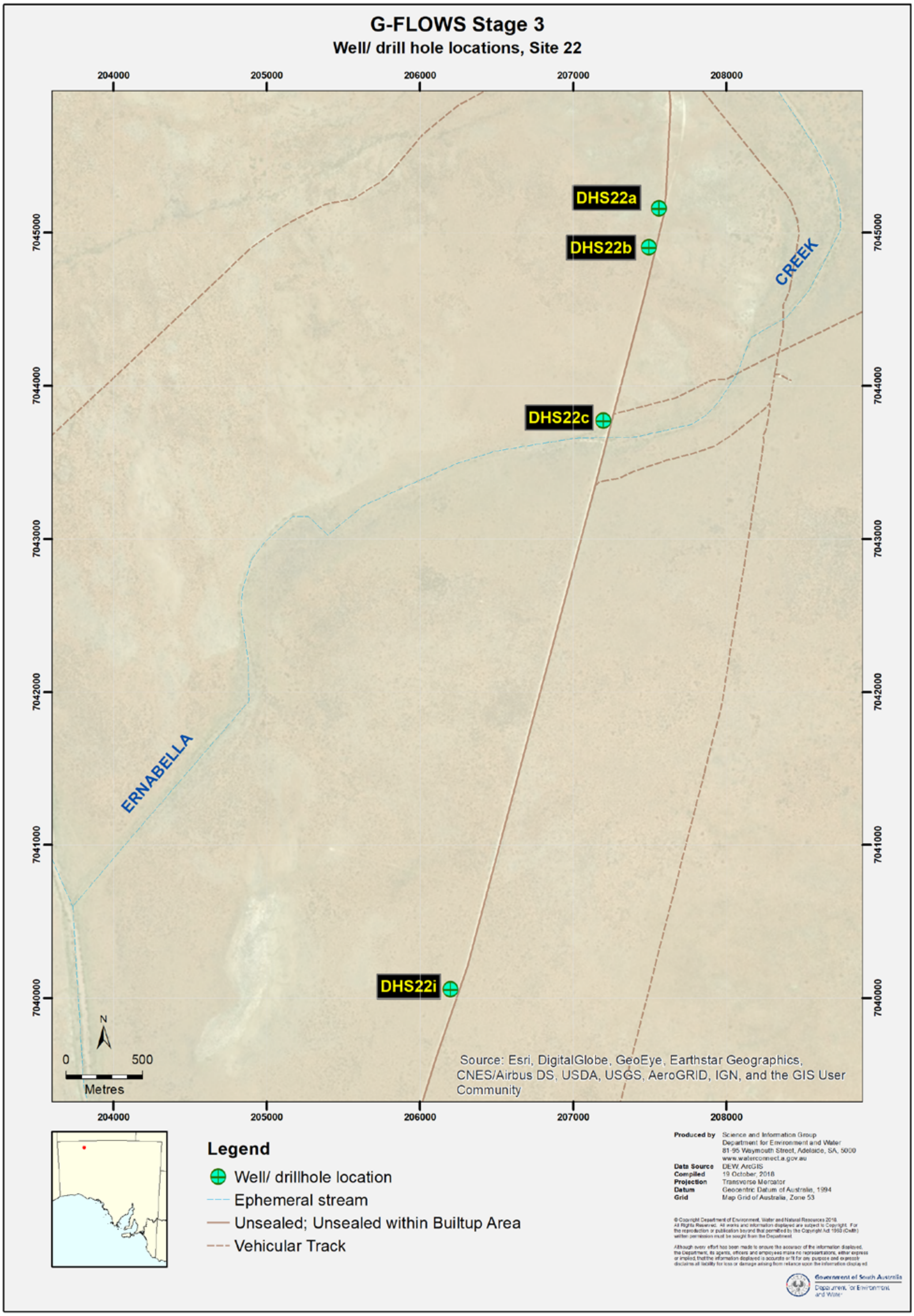

Figure 3-3. Drillhole site locations and exclusion zone at S22 (S22a, b, c, i).

3.2.1 GENERAL DRILLING METHODOLOGY

The program employed three drilling techniques:

- Shallow drillholes (< 35 m) targeting the watertable employed compressed air rotary drilling. This method enables real-time water cut identification.
- Deeper drillholes (> 35 m) located in the palaeovalley used mud rotary drilling methodology. This technique is an ideal drilling method for unconsolidated formations, such as the palaeovalley sediments, since the drilling mud stabilises the formation and maintains the integrity of the drillhole for well construction and/or running of downhole geophysical tooling. A compressed air rotary technique was employed for the first two drillholes (DH1a and DH1d). However, issues related to containing airlifted water and collapse of the hole-wall meant that drilling converted to a mud rotary methodology for the remainder of the deep palaeovalley drillholes.
- Finally, the drilling contractor used a triple-tube wire-line diamond coring technique to collect core samples ("HQ" bit size which produces a 98mm diameter drillhole).

Three types of wells were installed following the specifications described in Table 3-1.

Table 3-1: Nominal well specification types.

WELL TYPE	CASING MATERIAL	NOMINAL CASING DIAMETER (MM)	AQUIFER MONITORED	SCREEN TYPE	SCREEN APERTURE (MM)	NOMINAL SCREEN DIAMETER (MM)	SCREEN LENGTH (M)	SUMP (M)
Shallow well (< 35 m)	C12 PVC	155	Shallow sediments (water-table)	Machine slotted C12 PVC	0.5-0.7	155	3	1
Deep well (> 35 m)	C12 PVC	177	Palaeovalley water bearing zone sediments	Wire- wound Stainless Steel	0.5	141	3-6	1
Deep basement well (DH1a2)	C12 PVC	177/100	Weathered basement	Hand slotted CLU PVC	1.0	100	3	1

4 Drilling program on-ground works and findings

Drilling commenced on 11 July 2018 with DH1a and was effectively completed on 5 September 2018 at DH1a2 (replacement/re-drill of DH1a).

Two cored holes were drilled and 11 wells completed. Additionally, DH1a was completed as a partially constructed well with no screen and a grout cap emplaced at depth at the completion of the program.

A Boart Longyear KWL 1600H drill rig with KWL rod handler was used for the entire program. The rig also accommodated an air compressor booster and was capable of both air and mud rotary drilling. The same rig was used for the core extraction using a HQ (96 mm) core-barrel.

The basic work method for each of the shallow wells included installation of surface control casing and drilling of a 304 mm diameter drillhole using air until groundwater was intersected. Drilling ceased when a sufficient depth to accommodate the well screen (slotted PVC with gravel pack as par an in-line construction) and sump was achieved. A 150 mm outside diameter (OD) PVC casing was used during well construction.

The work method for a number of the deep palaeovalley holes drilled early in the program varied slightly as the drilling contractors encountered and addressed issues. In general, each hole commenced with a 304 mm diameter drillhole to accommodate a 6 m surface control casing. A 102 mm or 127 mm pilot hole was drilled to a point just above the target aquifer before being reamed out using a 225 mm bit. A variation to this general plan was DH1a2, which was drilled with a 225 mm bit from the beginning. A 177 mm (outer diameter) PVC casing was installed and pressure grouted in place. Drilling was then completed after a 24 hour curing time using a 146 mm or 150 mm bit to drill out the grout plug within the annulus and then into the target aquifer to depth and a stainless steel screen installed as per a telescopic construction.

Drilling and well construction details are summarised in Table 4-1 with the construction of wells varying depending upon the targeted aquifer.

Cuttings were buried in place in the local vicinity for all wells, in many cases being utilised as backfill material for the mud pits that were constructed while mud drilling.

Table 4-1: Basic well construction details

UNIT NO.	NAME	PERMIT NO.	CONSTRUCT-ION DATE	FINAL DEPTH (M)	ZONE	EASTING	NORTHING	STUDY SITE	SCREEN LENGTH (M)	AQUIFER MONITORED	WELL DESIGN
5344-87	DH1a	294909	1-Sep-18	117	53	209961	7032742	DH1	No screen	NA	Deep Observation/ Production Well
5344-78	DH1a2	330199	3-Sep-18	112.7	53	209953	7032689	DH1	3	Fractured Rock	DH1a2 Observation Well
5344-89	DH1b	294912	28-Aug-18	59.9	53	209984	7032828	DH1	3	Palaeovalley	Deep Observation/ Production Well
5344-80	DH1c	294911	13-Aug-18	57.5	53	209954	7032745	DH1	6	Palaeovalley	Deep Observation/ Production Well
5344-82	DH1d	294910	28-Jul-18	61.4	53	209959	7032719	DH1	6	Palaeovalley	Deep Observation/ Production Well
5344-83	DH1e	294914	29-Jul-18	14.5	53	209950	7032736	DH1	3	Phreatic	Shallow Observation Well
5344-85	DH1f	294913	11-Aug-18	77.35	53	209019	7032973	DH1	6	Fractured Rock	Deep Observation/ Production Well
5344-86	DH1g	294915	12-Aug-18	15.61	53	209017	7032964	DH1	3	Phreatic	Shallow Observation Well
5344-79	S22a	294916	17-Aug-18	35.3	53	207562	7045160	S22	3	Phreatic	Shallow Observation Well
5344-84	S22b	294918	20-Aug-18	35.5	53	207495	7044907	S22	3	Phreatic	Shallow Observation Well
5344-81	S22c	294917	18-Aug-18	20.2	53	207198	7043773	S22	3	Phreatic	Shallow Observation Well
5344-88	S22i	330198	25-Aug-18	51.8	53	206201	7040059	S22	3	Phreatic	Shallow Observation Well

4.1.1 WELL DESIGN AND CONSTRUCTION

The well designs incorporated a number of different elements depending on the target formation, i.e. the phreatic watertable or water bearing units within the deep palaeovalley. Key elements included:

- Shallow wells (< 35 m)
    - 304 mm steel surface control casing (2-3 m)
    - 155 mm PVC casing
    - 155 mm slotted PVC 3 m in-line screen with gravel pack (aperture 0.5-0.7 mm)
    - 155 mm PVC 1 m sump
    - Tremmie grouted casing
- Palaeovalley wells (> 35 m)
    - 304 mm steel surface control casing (6 m)
    - 177 mm PVC casing
    - 141 mm stainless steel 3-6 m telescopic screen (aperture 0.5 mm)
    - 141 mm stainless steel 1 m sump
    - Pressure grouted casing

At the DH1 palaeovalley site, well construction and well configurations were designed to accommodate future aquifer testing on water bearing units found within the palaeovalley. This design would enable hydraulic testing of both vertical and lateral conductivity and transmissivity as well as lateral connectivity outside of the palaeovalley. This also enabled hydrogeological sampling and analysis on various sequences within (and outside) of the palaeovalley sediments. Although the hydrogeological environment was largely unknown until observed while drilling, the final well installation accommodated:

- One primary production well in the centre of the palaeovalley targeting the main water bearing zone (target aquifer) within palaeovalley sediments (DH1c, Unit No. 5344-80).
- One observation well located along the length of the palaeovalley approximately 30 m away from the primary production well completed within the target aquifer (DH1d, Unit No. 5344-82).
- One observation well located along the length of the palaeovalley approximately 90-100 m from the primary production well completed within the target aquifer (DH1b, Unit No. 5344-89).
- One observation well completed below the palaeovalley sediments (DH1a2, note: replacement Unit No. 5344-78; DH1a replacement).
- One shallow observation well targeting the phreatic water-table and located in close proximity of the primary production well (DH1e, Unit No. 5344-83).
- One observation well completed within the weathered basement outside the palaeovalley located approximately 1 kilometre away from the primary production well (DH1f, Unit No. 5344-85).
- One shallow observation well targeting the phreatic water-table outside the palaeovalley located approximately 1 kilometre away from the primary production well (DH1g, Unit No. 5344-86).

While well design at DH1 was to help characterise the palaeovalley, the primary objective of wells constructed at S22 was to capture any variability of the watertable and its possible dependence on the topography (Figure 3-3). Consequently, well locations incorporated:

- One observation well located on a topographic high (S22a).
- One observation well located mid-way between the topographic high and topographic low (S22b).
- One observation well located at a topographic low (Ernabella Creek) (S22c).

- One additional observation well located within an AEM feature and thought to be a smaller palaeovalley tributary (S22i).

Appendix A provides diagrams summarising the well construction and geological logs for each well installed during the drilling program. Additionally, Table 4-1 and Table 4-1 provide a summary of well construction and specification details.

Casing lengths were glued and tek screwed at the bell join using stainless steel screws that were of a length that did not breach the inner diameter of the casing. Centralisers were also installed every 6 m to ensure the casing was centred in the drillhole.

Deep observation/production wells

After pressure-grouting of the casing, grout was allowed to cure for 24 hours. Following drilling to depth, the screen assemblage was fitted with a K-packer and lowered into place using the assistance of the drilling rods. In some cases there was difficulty experienced lowering the screen assemblage to depth and in the cases of DH1b and DH1c, a second attempt at lowering the screen was required after the first screen assemblage was removed.

Shallow observation wells

For shallow wells, the drilling contractor inserted a gravel pack around the slotted screen to filter groundwater flowing into the well and to provide a platform for the grout mix and bentonite seal. The gravel pack extended between 0.5 m and 1.0 m above the top of the slotted screen to prevent either grout or bentonite from entering the screen. The depth of gravel pack was confirmed from surface during installation.

A 0.5 m thick pack of hydrated medium bentonite chips was placed above the gravel pack as a seal. The annulus of the drillhole between the bentonite and the surface was then fully grouted. The grout mix consisted of a 20 kg/15 L Portland cement/water grout mix.

Well development

Upon completion of the constructed well, development of the well was undertaken using air jetted through drilling rods. This process cleaned the well of any drilling fluids and fines and to establish the gravel pack (natural or otherwise) adjacent to the screen. Wells were developed in-line with the agreement specification, i.e. nominally 1 hour for slotted PVC screens and up to 3 hours for stainless steel screens or until drilling fluids were removed, fines clearly reduced and water was relatively clear. The wells were sterilised using a minimum of two well volumes of water containing 100 mg/L free available chlorine. The chlorine solution was left in the well undisturbed (no air) for a minimum of approximately 15 minutes. The drilling contractor then continued development until discharge was clean and effectively sand-free.

Well headworks

Wells were fitted with either a PVC or steel flange and flange plate then secured with bolts and locks.

Cultural heritage monitors

As outlined in the preliminary advice report, cultural heritage monitors (Traditional Owners) were present during any clearance or ground-disturbing activities conducted during on-ground works of the drilling program.

4.2 Downhole geophysics

DEW's Water Resource Monitoring Unit (WRMU) ran downhole geophysical tooling on a selected number of drillholes prior to well construction and at critical stages of the drilling program. Results from downhole geophysics are presented as part of the graphical drilling log diagrams in Appendix A and Table 4-2 presents a summary of the wells where downhole geophysics was carried out, the method of collection and the stage of well-construction when downhole geophysics was undertaken.

WRMU also collected downhole geophysical data and downhole camera imagery on certain wells to confirm well construction, since a number of wells encountered some issues during installation. This data proved useful in the successful completion of these wells.

Table 4-2: Summary of downhole geophysical logging.

WELL NAME	UNIT NO.	DIAMETER [1]	GAMMA [2]	GR TOTAL [3]	K [3]	U [3]	TH [3]	FLUID TEMP. [4]	FLUID COND. [4]	INDUCTION COND. [5]	INDUCTION COND. [6]	RESISTIVITY [7]	NEUTRON [8]	LOGGED OPEN HOLE	LOGGED CASED
		mm	API	cps	cps	cps	cps	°C	uS/cm	mS/m	mS/m	ohm.m			
DH1a	5344-87	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
DH1a2	5344-78														
DH1b	5344-89		✓	✓	✓	✓	✓			✓		✓		✓	✓
DH1c	5344-80														✓
DH1d	5344-82		✓	✓	✓	✓	✓	✓	✓	✓					✓
DH1e	5344-83		✓	✓	✓	✓	✓	✓	✓	✓					✓
DH1f	5344-85		✓	✓	✓	✓	✓			✓		✓		✓	
DH1g	5344-86														
S22a	5344-79														
S22b	5344-84														
S22c	5344-81														
S22i	534-88	✓	✓							✓		✓	✓	✓	

[1]DGRT 3-arm caliper tool
[2]DEW total count gamma tool; standard units set by the American Petroleum Institute (API)
[3]Mount Sopris spectral gamma tool; “GR” = gamma ray, “K” = potassium , “U” = uranium, “TH” =thorium; units of counts per second (cps)
[4]ALT FTC fluid temperature & EC tool
[5]DGRT A085 (HI-327F) focused induction conductivity probe
[6]Mount Sopris combination magnetic susceptibility / induction probe (2HMC453)
[7]ALT DLL3 dual spacing focused resistivity laterolog tool
[8]DEW single spaced neutron probe

4.3 Lithology and hydrogeology

Drillhole cores were collected at both DH1a and S22i. Below is a summary of the geology and hydrogeology encountered in these cored holes as well as other bores.

4.3.1 SITE DH1

Lithology

Table 4-3 provides a summary of the lithology encountered and Figure 4-1 presents an interpreted cross-section through DH1 based on drilling and AEM data (Soerensen et al., 2017).

Table 4-3: Summary of lithology encountered at site DH1.

DEPTH (m)	UNIT	DESCRIPTION	COMMENTS
0 to 3	Present day surficial sand profile	Fine to medium grained, dark red-brown mixed sandplain sand	Deposited in a an arid-zone mixed aeolian, fluvial and sheet-wash environment
~3 to 5	Duricrust (calcrete or silcrete)	Well-developed duricrust. Vuggy, massive calcrete or a massive pallid silcrete.	Silcrete found at DH1b
~5 to 60	Partly calcareous mixed sand plain deposits	Variably calcreted, silicified and/or consolidated red-brown fine- to coarse-sands. Minor silts, clays and gravels. interlayered fluvial, sheet-wash and aeolian-deposited or reworked sediments	Close similarity to the surficial sand deposits, indicative of similar depositional environment. Variations in grain size and 'crete development describe variations in sediment profile or depositional environment.
~60 to 65	Main target aquifer	Interbedded clay and coarse sand	This unit may be included with other near surface sedimentary rocks as part of the arid-zone mixed sand plain depositional environment. However, the interbedded clay and lack of duricrusts point to a predominantly fluvial depositional environment.
~65 to 74	Oxidised claystone and mudstone	Claystone and mudstone deposited in a quiescent, ephemeral (playa) lacustrine environment	Notably conductive zone in AEM datasets (Soerensen et al., 2017).
~75 to 76	Gypsum	Gypsum horizon after exposure and oxidation of sulphides within unit below	Marks point in time the lacustrine environment changed from permanent (anoxic) to ephemeral (oxic).
~76 to 85	Black claystone and mudstone	Claystone and mudstone deposited in a quiescent, permanent lacustrine environment. Black colour due to sulphide and organic matter deposited in anoxic conditions.	Notably conductive zone in AEM datasets (Soerensen et al., 2017).
85 to 95	Sands, silts and clays	Very fine to coarse-grained quartz sands, silts and clays that grade into underlying saprolite.	May be either a palaeovalley sand or a reworked residual sand after saprolite.
~ 95 to >113	Saprolite	Fine to coarse grained angular to sub angular quartz grains in a clay matrix.	After gneissic granite (Pitjantjatjara Supersuite)

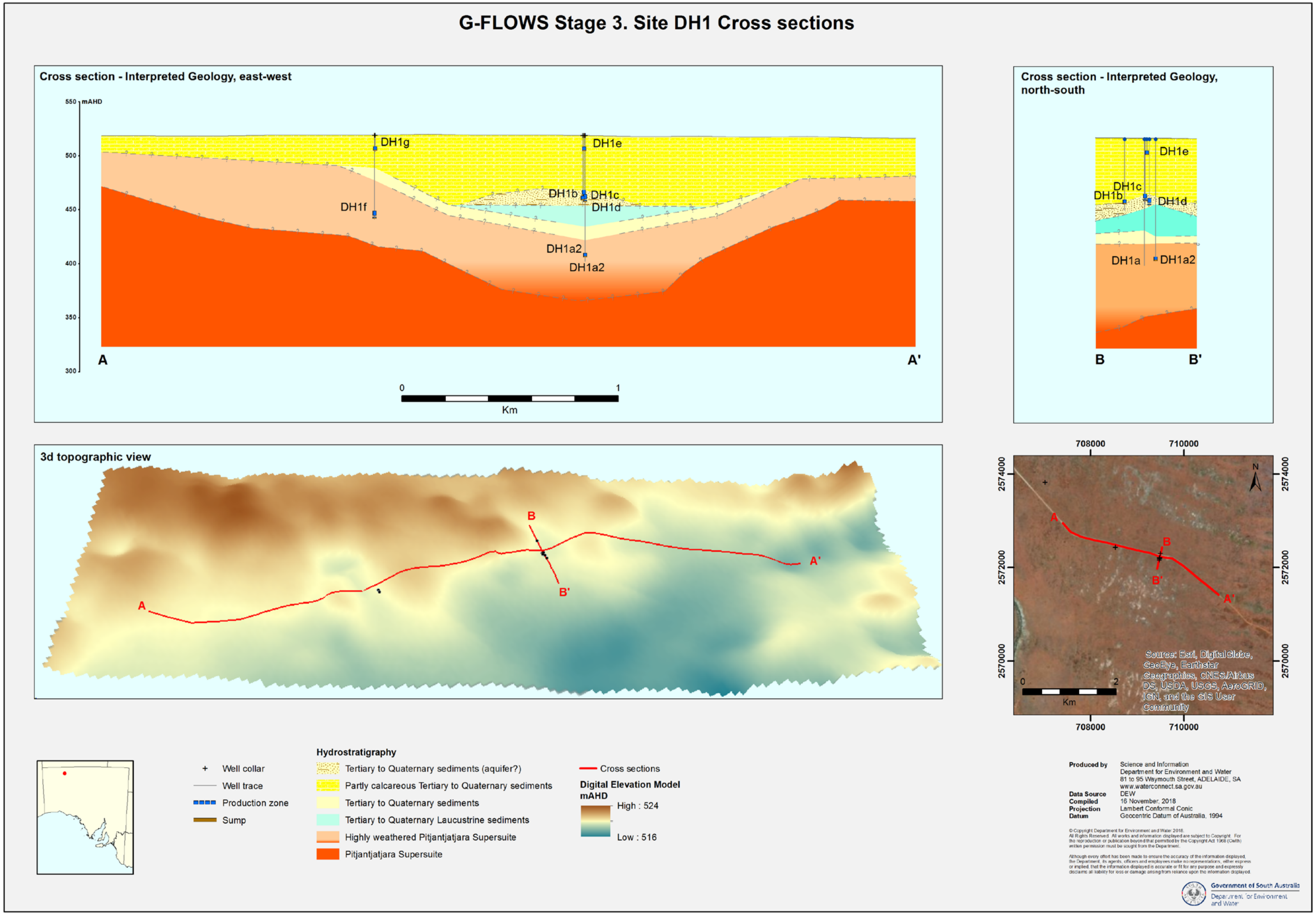

Figure 4-1. Cross sectional interpretation through DH1.

Hydrogeology

Table 4-4 below presents a summary of the hydrogeology of encountered water bearing units at DH1. Additionally, Table 4-5 presents water quality results from installed wells.

Table 4-4: Hydrogeology of site DH1

AQUIFER	DEPTH (m below ground surface)	YIELD (l/sec)	QUALITY (mg/L)	DESCRIPTION
Shallow (phreatic)	~13	<1	880-1350	The variable development of duricrust and other calcareous horizons within the top 60 m suggests that the upper aquifer may be described as having a grossly bimodal porosity. As well as a small-scale primary porosity controlled by grainsize and grain distribution, a larger scale secondary "mega"-porosity controlled by zones of duricrust development may have an important influence on localized aquifer hydrodynamics. Such zones are likely to have much of their primary porosity destroyed by duricrust development but may well have a secondary porosity controlled by solution cavity (vugs) or micro-fracture development. Consequently, the hydrogeological properties of this unit and by extension the capacity of the unit to be a productive aquifer may be highly variable and dependent on the heterogeneous distribution of secondary porosity formation.
Target Aquifer	~60-65	5-20	740-790	Most productive aquifer encountered at study site. Consists of a zone of interlayered non-to-poorly calcareous sands and clays between 60 and 65 m overlying a lacustrine claystone and mudstone.
Saprolite/ fractured rock aquifer	~95-120	2-5	~1000	This unit has potential as a productive aquifer. The problem with this horizon as a groundwater resource from a practical point of view is that the combination of anoxic clays and unconsolidated coarse sand horizons make for difficult drilling conditions. Consequently, well design, drilling methodology and cost are important considerations when attempting to access any groundwater in this particular aquifer.

Table 4-5: Field-based water quality at site DH1. Parameters include: dissolved oxygen (DO), specific conductance (SP.EC), electrical conductivity (EC), total dissolved solids (TDS), oxidation-reduction potential (ORP or redox), alkalinity (ALK).

WELL NAME	UNIT NO.	DATE/TIME	TEMP. °C	DO mg/L	SP. EC µs/cm	EC µs/cm	TDS mg/L	pH	ORP mV	ALK mg/L
DH1a	5344-87	NA	NA	NA	NA	NA	NA	NA	NA	NA
DH1a[2]	5344-78	3/09/2018 17:30	23.2	0.05	1675	1616	1086	8.24	35.5	226
DH1b	5344-89	28/08/2018 9:10	23.4	1.49	1207	1169	787	8.14	77.5	212
DH1c	5344-80	13/08/2018 7:50	18.9	0.05	1147	1013	748	8.40	87.6	294
DH1d	5344-82	28/07/2018 12:05	24.1	0.80	1200	1180	780	8.31	126.7	218
DH1e	5344-83	29/07/2018 12:05	19.5	0.08	1362	1221	884	8.60	158.9	212
DH1f	5344-85	11/08/2018 10:48	19.7	0.07[1]	1655	1502	1072	8.80	17.7	222
DH1g	5344-86	12/08/2018 12:05	23.3	9.04[1]	2072	2005	1345	9.48	27.7	146

[1]unstable

[2]well construction issues and well replaced; no water during drilling therefore no field parameters

4.3.2 SITE S22

Lithology

The geology of S22 is highly variable and encompasses silcrete and calcrete duricrusts, fluvial sediments associated with Ernabella Creek (Figure 1-1), saprolite and weathered granite. Table 4-6 provides a summary of the lithology encountered and Figure 4-2 presents an interpreted cross-section through S22 based on drilling and AEM data (Soerensen et al., 2017).

Table 4-6: Summary of lithology encountered at site S22.

DEPTH (m)	UNIT	DESCRIPTION	COMMENTS
0 to 1	Surficial sands	Thin veneer of sandy red-brown mixed sandplain soils	At DHS22c and DHS22i.
1-6 to 9	Duricrust (calcrete or silcrete)	Well-developed duricrust. Vuggy, massive calcrete or a massive pallid silcrete.	Elevated topography at the study site is associated with silcrete (in the form of chalcedony) and is consequently indicative of topographic inversion.
6 - 9 to 30 - 45 (S22a and S22i)	Partly calcareous mixed-sandplain deposits	Variably calcreted, silicified and/or consolidated red-brown fine- to coarse-sands. Minor silts, clays and gravels. interlayered fluvial, sheet-wash and aeolian-deposited or reworked sediments	Close similarity to the surficial sand deposits, indicative of similar deposition environment. Variations in grain size and 'crete development describe variations in sediment profile or depositional environment.
6 - >20 (S22c)	Fluvial sediments	Red-brown silty fine sands and mud. Inter-bedded with bands of sandy gravel.	Found near Ernabella Creek.
9 - 45 to >55	Saprolite/ Granite	Clayey fine to coarse grained angular to sub angular grains. Dark purple mega-mottle development. May be underlying re-worked residual sands	Granite (Pitjantjatjara Supersuite). Mega-mottle development may be associated with a fault.

Hydrogeology

Table 4-7 below presents a summary of the hydrogeology of encountered water bearing units at S22. Additionally, Table 4-8 presents water quality results from installed wells.

Table 4-7: Hydrogeology of S22.

AQUIFER	DEPTH m below ground surface	YIELD L/sec	TDS mg/L	DESCRIPTION
Saprolite/ fractured rock aquifer	~95-120	2-5	~1000	This unit has potential as a productive aquifer. The problem with this horizon as a groundwater resource from a practical point of view is that the combination of anoxic clays and unconsolidated coarse sand horizons make for difficult drilling conditions. Consequently, well design, drilling methodology and cost are important considerations when attempting to access any groundwater in this particular aquifer.

Table 4-8: Field-based water quality at site S22. Parameters include: dissolved oxygen (DO), specific conductance (SP.EC), electrical conductivity (EC), total dissolved solids (TDS), oxidation-reduction potential (ORP or redox), alkalinity (ALK).

WELL NAME	UNIT NO.	DATE/TIME	TEMP. °C	DO mg/L	SP. EC µs/cm	EC µs/cm	TDS mg/L	pH	ORP mV	ALK mg/L
S22a	5344-79	17/08/2018 10:30	23.9	6.20	3080	3016	2002	11.7	281	376[1]
S22b	5344-84[2]	NA	NA	NA	NA	NA	NA	NA	NA	NA
S22c	5344-81	18/08/2018 11:40	21.9	5.63	1652	1554	1073	8.28	98.7	264
S22i	5344-88	25/05/2018 11:15	23.8	0.04	2144	2094	1391	7.91	87.4	172

[1]alkalinity measured at earlier time due to indicator issues
[2]no water during drilling therefore no field parameters

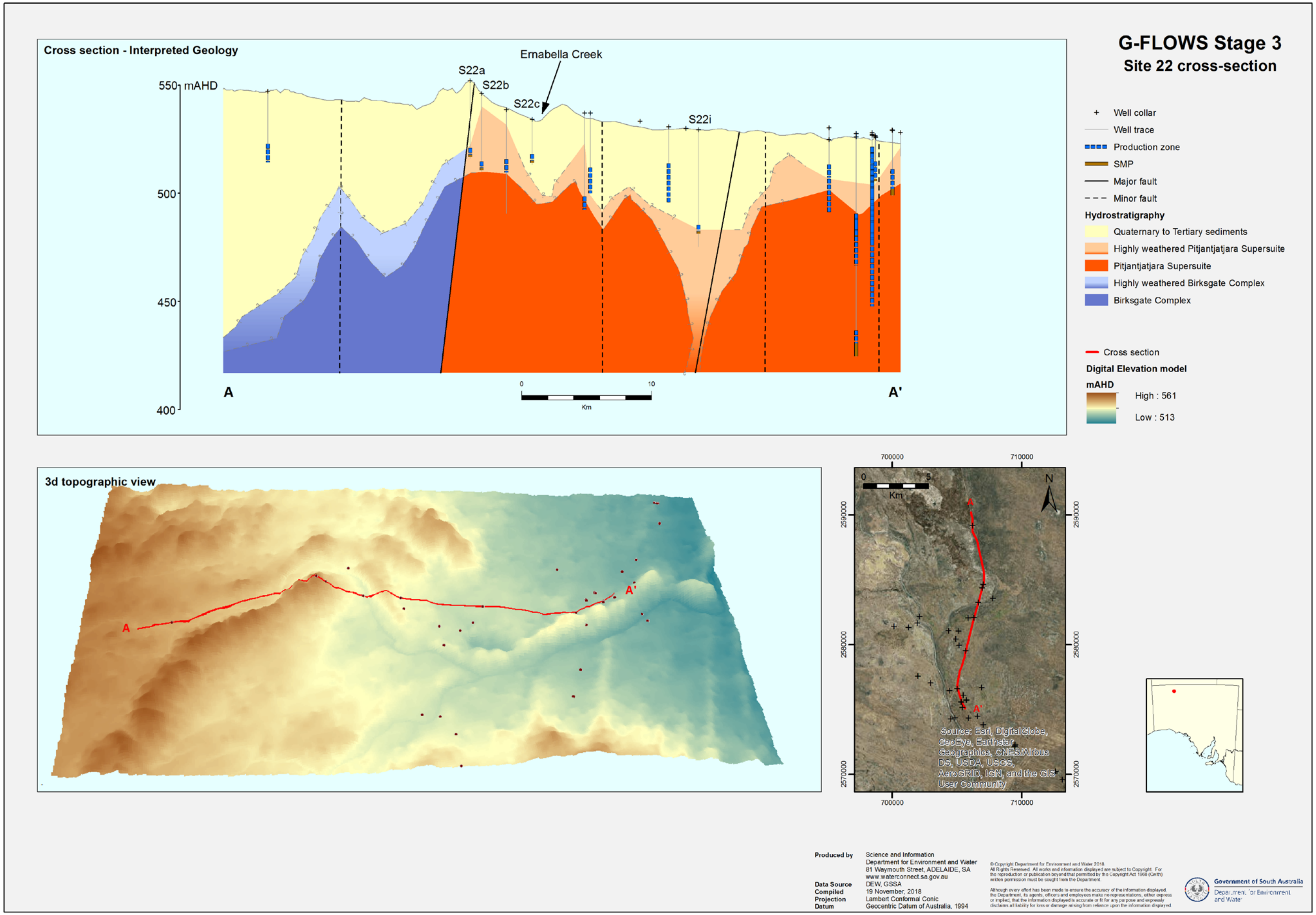

Figure 4-2. Cross sectional interpretation through S22.

5 Summary of drilling program

On-site drilling works were conducted between 10 July and 5 September 2018 in the APY Lands (Musgrave Province), north western South Australia. In total, 11 groundwater wells (including one replacement well) were constructed including two cored drillholes at two hydrogeological control sites namely DH1 and S22.

DH1 was centred on the main Lindsay East Palaeovalley, located approximately five kilometres east of Kaltjiti (Fregon). This site was targeted using the 2016 AEM survey data (Soerensen et al., 2017) that located the nominal location of the main palaeovalley in the area. In choosing this site, consideration was given to the proximity of other historical wells and road access.

Centred on the palaeovalley at DH1, one cored drillhole (DH1a) and seven wells were constructed; five centred within the lateral extent of the palaeovalley and two located outside the palaeovalley (lateral) extent. Drillhole locations were configured to allow for future aquifer testing and hydrochemical sampling of the groundwater in the palaeovalley sediments.

A further four observation wells were completed at S22, together with one cored drillhole (S22i). This site is located approximately nine kilometres north of Kaltjiti (Fregon) and was designed to examine the shallow watertable (or phreatic groundwater surface) and its dependence on topographic features. At this location, the cored hole (S22i) was located adjacent to a smaller “tributary” of the main palaeovalley system.

Drilling methodologies included a combination of air and mud rotary with mud used for deeper palaeovalley wells (including S22i) where deeper unconsolidated formations needed to be stabilised to enable downhole geophysical surveys in the open hole and well construction. Air was used for shallower wells (< 35 m) targeting the watertable.

Close to the centre of the Lindsay East Palaeovalley (DH1) at least three groundwater bearing sequences (or aquifers) were encountered: i) the shallow phreatic watertable of calcareous mixed sand plain deposits, ii) an interlayered coarse-grained sand and clay horizon and a very fine to coarse grained residual sand; iii) a saprolite/fractured rock aquifer that underlays these palaeovalley sedimentary rocks. While data is preliminary and based on air development (which can be subjective), the coarse-grained sands (which overlays a lacustrine claystone and mudstone) shows promise as a productive aquifer, with development yields varying between 5 and 20 L/sec and salinities <1000 mg/L TDS.

By design, the target at S22 was the phreatic watertable aquifer and as such, development yields were generally low (<1 L/sec) and salinities were generally between 1000 and 1500 mg/L; although it should be noted that S22i (located near a palaeovalley tributary feature) appears to have slightly higher yields.

Palaeovalley systems can be delineated using AEM surveys by identifying conductivity variations at depth over large areas, however to date, there has been limited verification of AEM data, and their ability to delineate groundwater horizons. The recently acquired 2016 AEM data (Soerensen et al., 2017) proved useful with respect to identifying the location of the main Lindsay East Palaeovalley for drilling targets. According to the preliminary results of the drilling program, these palaeovalley sediments appear to be viable groundwater resources for remote and arid regions such as the APY Lands where water is a limiting factor to community wellbeing and economic growth of the area. This drilling data will help to further ground-truth the AEM data and enable it to be upscaled to the wider APY region where an AEM footprint exists.

The successful completion of this drilling program has not only enabled further AEM verification but also allowed for the establishment of important groundwater data points to help further characterise the palaeovalley and shallow groundwater systems through future hydraulic testing and hydrochemical sampling of the groundwater resource.

6 Units of measurement

6.1 Units of measurement commonly used (SI and non-SI Australian legal)

NAME OF UNIT	SYMBOL	DEFINITION IN TERMS OF OTHER METRIC UNITS	QUANTITY
Day	d	24 h	time interval
gigalitre	GL	10^6 m^3	volume
Gram	g	10^{-3} kg	mass
hectare	ha	10^4 m^2	area
Hour	h	60 min	time interval
kilogram	kg	base unit	mass
kilolitre	kL	1 m^3	volume
kilometre	km	10^3 m	length
Litre	L	10^{-3} m^3	volume
megalitre	ML	10^3 m^3	volume
metre	m	base unit	length
microgram	µg	10^{-6} g	mass
microlitre	µL	10^{-9} m^3	volume
milligram	mg	10^{-3} g	mass
millilitre	mL	10^{-6} m^3	volume
millimetre	mm	10-3 m	length
minute	min	60 s	time interval
second	s	base unit	time interval
tonne	t	1000 kg	mass
Year	y	365 or 366 days	time interval
Day	d	24 h	time interval

7 References

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8 Appendix A – Well and drillhole log diagrams

A.1 Well Construction Diagrams

GFLOWS Stage 3 Drilling Program

Site:	DH1	**SWL (▼):**	7.91 mtoc	**Driller:**	J.Paech/ H.Beach
Permit No.:	330199	**Water Cut ( ):**		**Drilling Company:**	Silver City Drilling
Unit No.:	534400078			**Rig:**	KWL 1600H
Borehole Name:	DH1a2	**Datum:**	GDA94	**Status of Well:**	Operational
Date Drilled:	03/09/2018	**Easting:**	209953	**Purpose:**	Production
Date Reworked:		**Northing:**	7032689	**Logged by:**	M.Keppel
Depth:	112.7m	**Zone:**	53	**Geophy. by:**	

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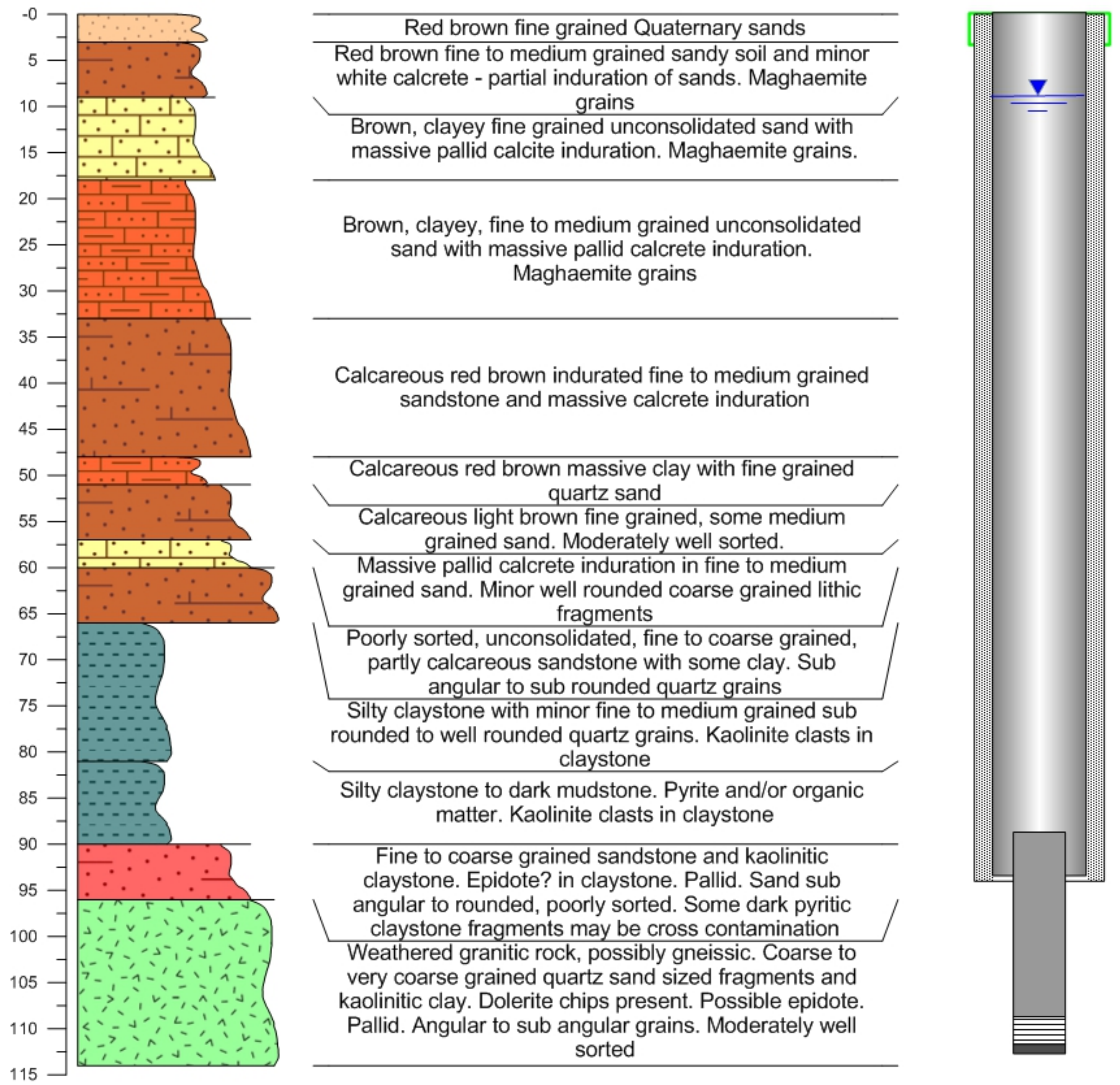

	Type	Int. Diam.	Interval	Cement	Apeture
Surface Casing Details:	Steel	247mm	+0.10 - 3.3m	0 - 3.3m	
Casing details:	PVC	157mm	+0.15 - 93.4m	0 - 94m	
Prod. Zone Details:	PVC	100mm	108.7 - 111.7m		~1 mm
Sump:	PVC	100mm	111.7 - 112.7m		

Well Construction

Casing, Cement, Control Casing, Sump, Screen, Riser

Geology

- Calcareous clayey sandstone
- Calcareous sand /sandstone
- Calcrete
- Clayey sand /sandstone
- Sand /sandstone
- Saprolite
- Silty claystone

Page 1 of 1

GFLOWS Stage 3 Drilling Program

Site:	DH1	**SWL (▼):**	8.25 mbgs	**Driller:**	J.Paech/ H.Beach
Permit No.:	294912	**Water Cut ( ):**		**Drilling Company:**	Silver City Drilling
Unit No.:	534400089			**Rig:**	KWL 1600H
Borehole Name:	DH1b	**Datum:**	GDA94	**Status of Well:**	Operational
Date Drilled:	3/08/2018	**Easting:**	209984	**Purpose:**	Production
Date Reworked:		**Northing:**	7032828	**Logged by:**	M.Keppel
Depth:	59.9m	**Zone:**	53	**Geophy. by:**	N.Vasilic

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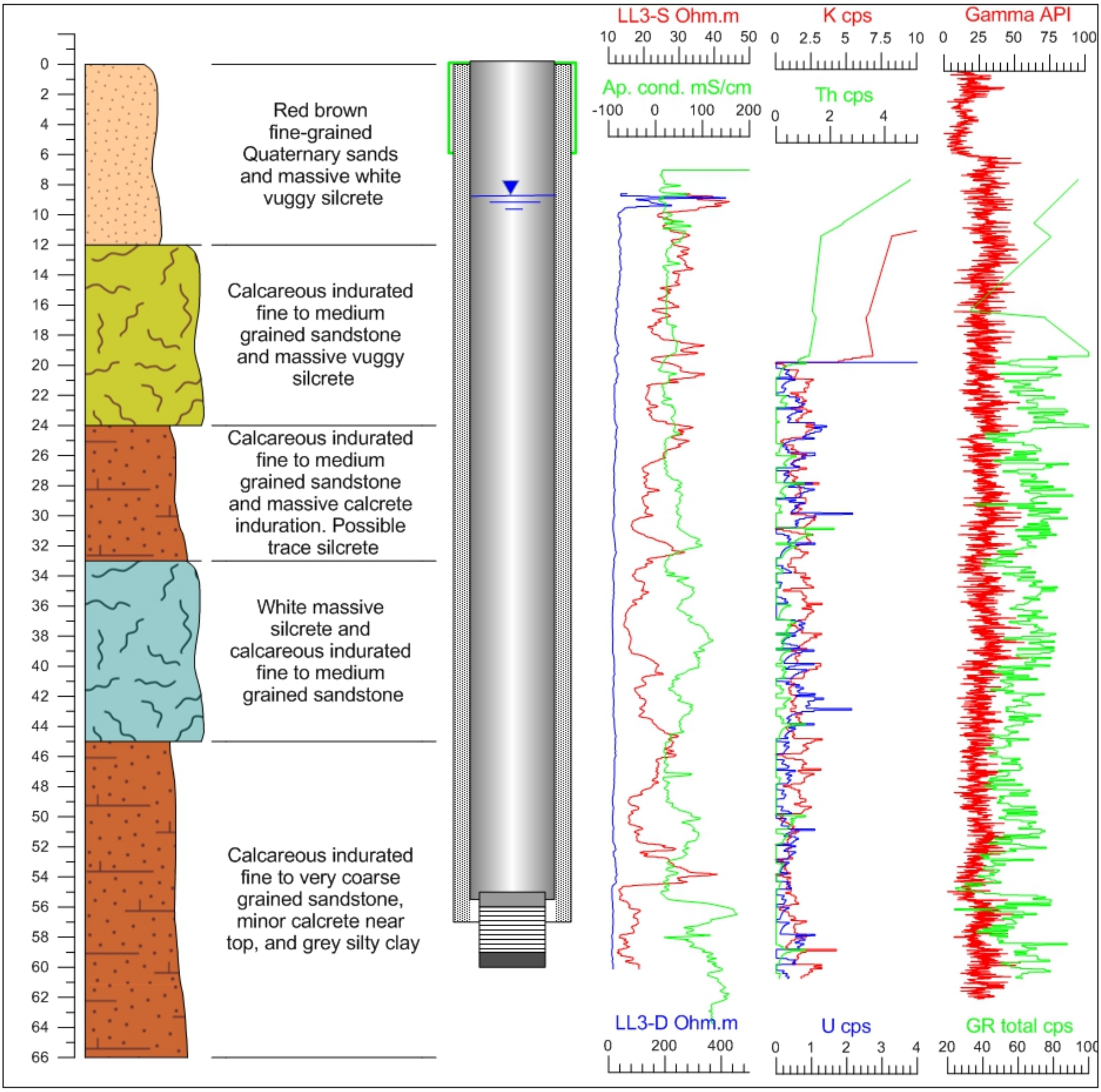

	Type	Int. Diam.	Interval	Cement	Apeture
Surface Casing Details:	Steel	247mm	+0.12 - 5.88m	0 - 5.88m	
Casing details:	PVC	157mm	+0.15 - 55.5m	0 - 57m	
Prod. Zone Details:	Steel	128mm	57 - 60.4m		0.5mm
Sump:	Steel	128mm	60.4 - 61.4m		

Geology

- Calcareous sand /sandstone
- Calcareous sandstone and silcrete
- Sand /sandstone
- Chalcendony/ silcrete

Well Construction

Casing · Cement · Control Casing · Sump · Screen · Riser

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GFLOWS Stage 3 Drilling Program

Site: DH1	**SWL (▼):**	7.51 mtoc	**Driller:**	J.Paech/ H.Beach
Permit No.: 294911	**Water Cut ( ):**		**Drilling Company:**	Silver City Drilling
Unit No.: 534400080			**Rig:**	KWL 1600H
Borehole Name: DH1c	**Datum:**	GDA94	**Status of Well:**	Operational
Date Drilled: 30/07/2018	**Easting:**	209954	**Purpose:**	Production
Date Reworked:	**Northing:**	7032745	**Logged by:**	M.Keppel
Depth: 57.5m	**Zone:**	53	**Geophy. by:**	

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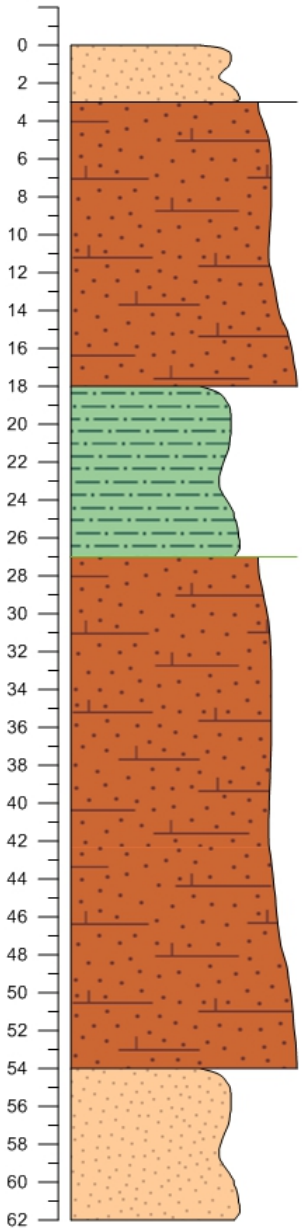


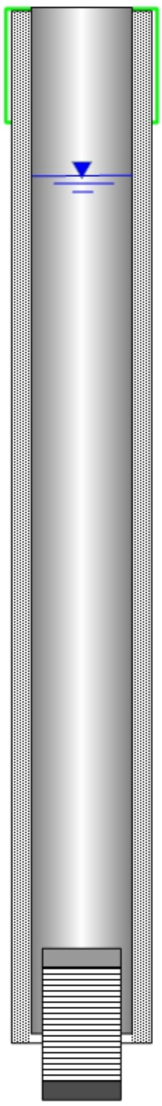
Indurated Quaternary Sands. Fine to medium grained, massive. Calcretised at 3m.

Indurated calcareous sandstone. Red brown oxide staining. Fine to medium grained. Minor silty clay. Appears mottled near top

Silty plastic clay with indurated calcareous sandstone. Brown red oxide staining.

Indurated calcareous sandstone. Red brown Fe Oxide Staining. Fine to medium grained and minor silty clay.

Unconsolidated quartz sandstone, fine to medium grained, interbedded with grey silty massive clay. Brown grey.



	Type	Int. Diam.	Interval	Cement	Apeture
Surface Casing Details:	Steel	247mm	+0.12 - 5.88m	0 - 5.88m	
Casing details:	PVC	157mm	+0.15 - 54m	0 - 54.5m	
Prod. Zone Details:	Steel	128mm	56.5 - 57.5m		0.5mm
Sump:	Steel	128mm	56.5 - 57.5m		

Geology
- Calcareous sand /sandstone
- Sand /sandstone
- Sandy Clay

Well Construction
- Casing
- Cement
- Control Casing
- Sump
- Screen
- Riser

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GFLOWS Stage 3 Drilling Program

Site:	DH1	**SWL (▼):**	7.683 mbgs	**Driller:**	J.Paech/ H.Beach
Permit No.:	294910	**Water Cut (▽):**	11.5 mbgs (moist) 54mbgs (8L/sec)	**Drilling Company:**	Silver City Drilling
Unit No.:	534400082			**Rig:**	KWL 1600H
Borehole Name:	DH1d	**Datum:**	GDA94	**Status of Well:**	Operational
Date Drilled:	26/07/2018	**Easting:**	209959	**Purpose:**	Production
Date Reworked:		**Northing:**	7032719	**Logged by:**	M.Keppel
Depth:	61.4m	**Zone:**	53	**Geophy. by:**	N.Vasilic

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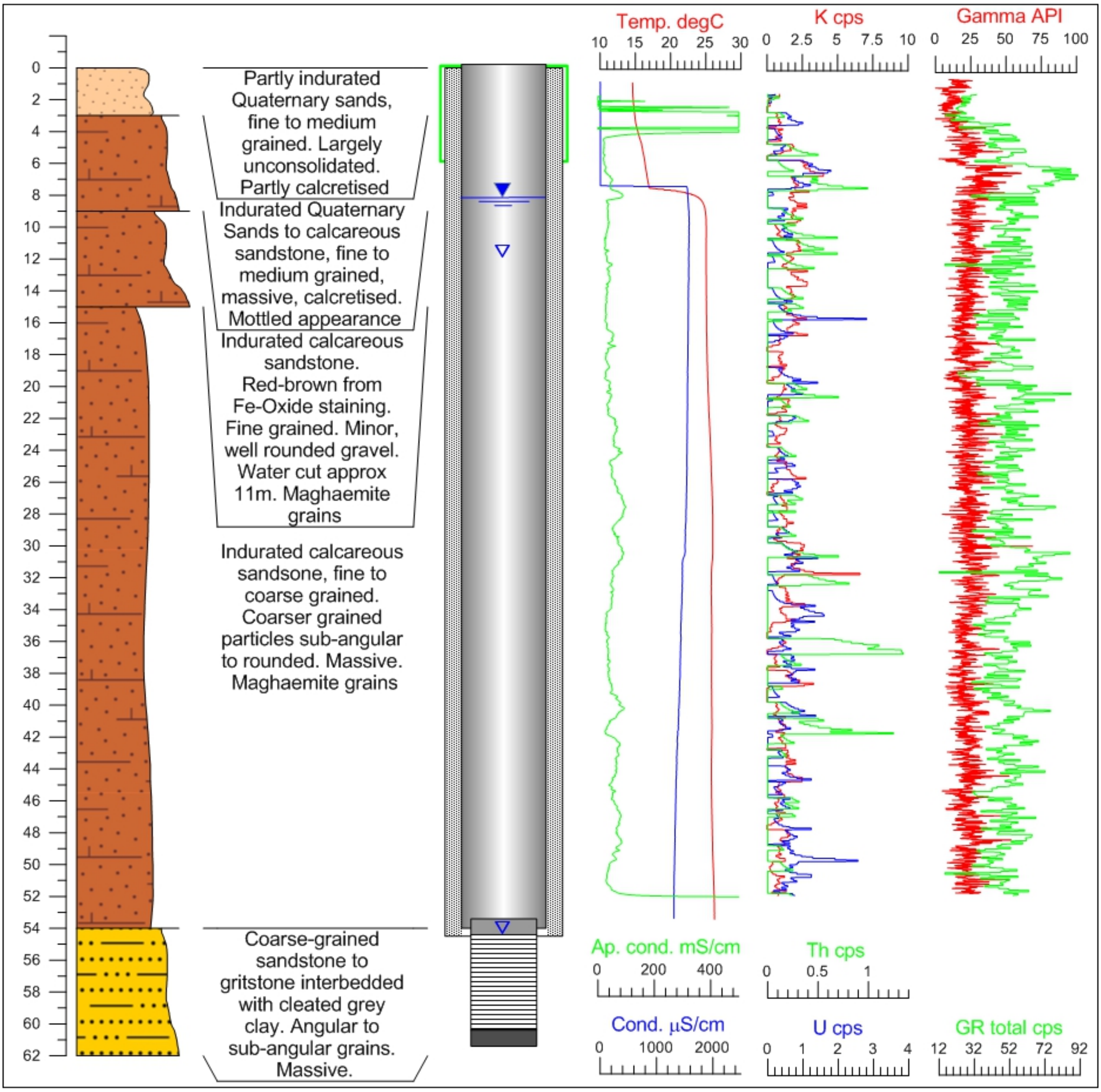

	Type	Int. Diam.	Interval	Cement	Apeture
Surface Casing Details:	Steel	247mm	+0.12 - 5.8m	0 - 5.8m	
Casing details:	PVC	157mm	+0.215 - 54m	0 - 54.5m	
Prod. Zone Details:	Steel	128mm	53.4 - 60.4m		0.5mm
Sump:	Steel	128mm	60.4 - 61.4m		

Geology
- Calcareous sand /sandstone
- Coarse grained sandstone and clay
- Sand /sandstone

Well Construction
Casing · Cement · Control Casing · Sump · Screen · Riser

GFLOWS Stage 3 Drilling Program

Site:	DH1	**SWL (▼):**	7.686 mbgs	**Driller:**	J.Paech/ H.Beach
Permit No.:	294914	**Water Cut (▽):**	11.5 mbgs	**Drilling Company:**	Silver City Drilling
Unit No.:	534400083			**Rig:**	KWL 1600H
Borehole Name:	DH1e	**Datum:**	GDA94	**Status of Well:**	Operational
Date Drilled:	28/07/2018	**Easting:**	209950	**Purpose:**	Production
Date Reworked:		**Northing:**	7032736	**Logged by:**	M.Keppel
Depth:	14.5m	**Zone:**	53	**Geophy. by:**	N.Vasilic

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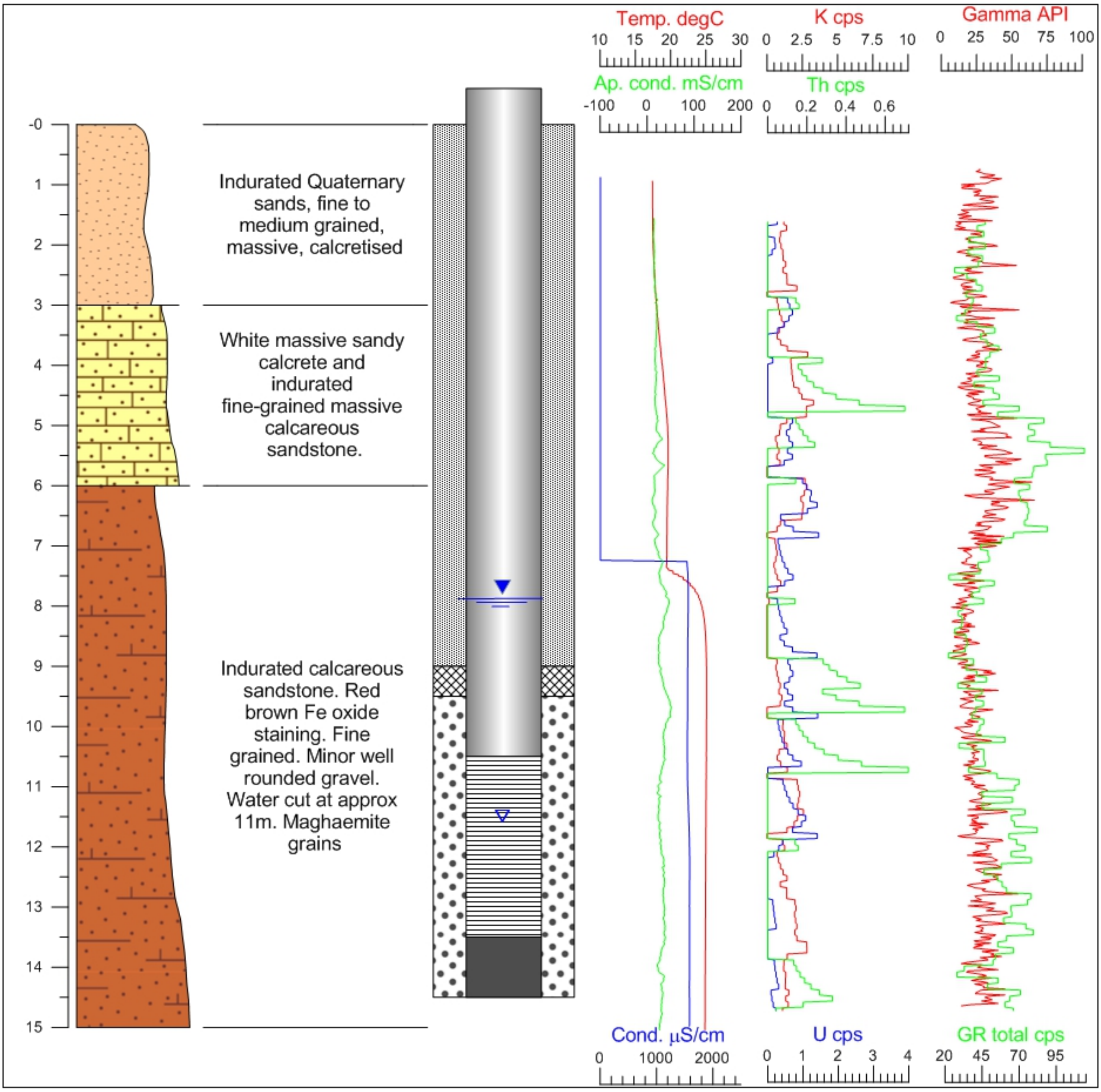

	Type	Int. Diam.	Interval	Cement	Apeture
Surface Casing Details:					
Casing details:	PVC	150mm	+0.15 - 10.5m	0 - 10.1m	
Prod. Zone Details:	PVC	150mm	10.5 - 13.5m		0.5mm
Sump:	PVC	150mm	13.5 - 14.5m		

Well Construction

Geology
- Calcareous sand /sandstone
- Calcrete
- Sand /sandstone

Casing · Cement · Control Casing · Sump · Screen · Gravel pack · Bentonite

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GFLOWS Stage 3 Drilling Program

Site: DH1	**SWL (▼):**	8.06 mtoc	**Driller:**	J.Paech/ H.Beach
Permit No.: 294913	**Water Cut (▽):**		**Drilling Company:**	Silver City Drilling
Unit No.: 534400085			**Rig:**	KWL 1600H
Borehole Name: DH1f	**Datum:**	GDA94	**Status of Well:**	Operational
Date Drilled: 7/08/2018	**Easting:**	209019	**Purpose:**	Production
Date Reworked:	**Northing:**	7032973	**Logged by:**	M.Keppel
Depth: 77.35m	**Zone:**	53	**Geophy. by:**	N.Vasilic

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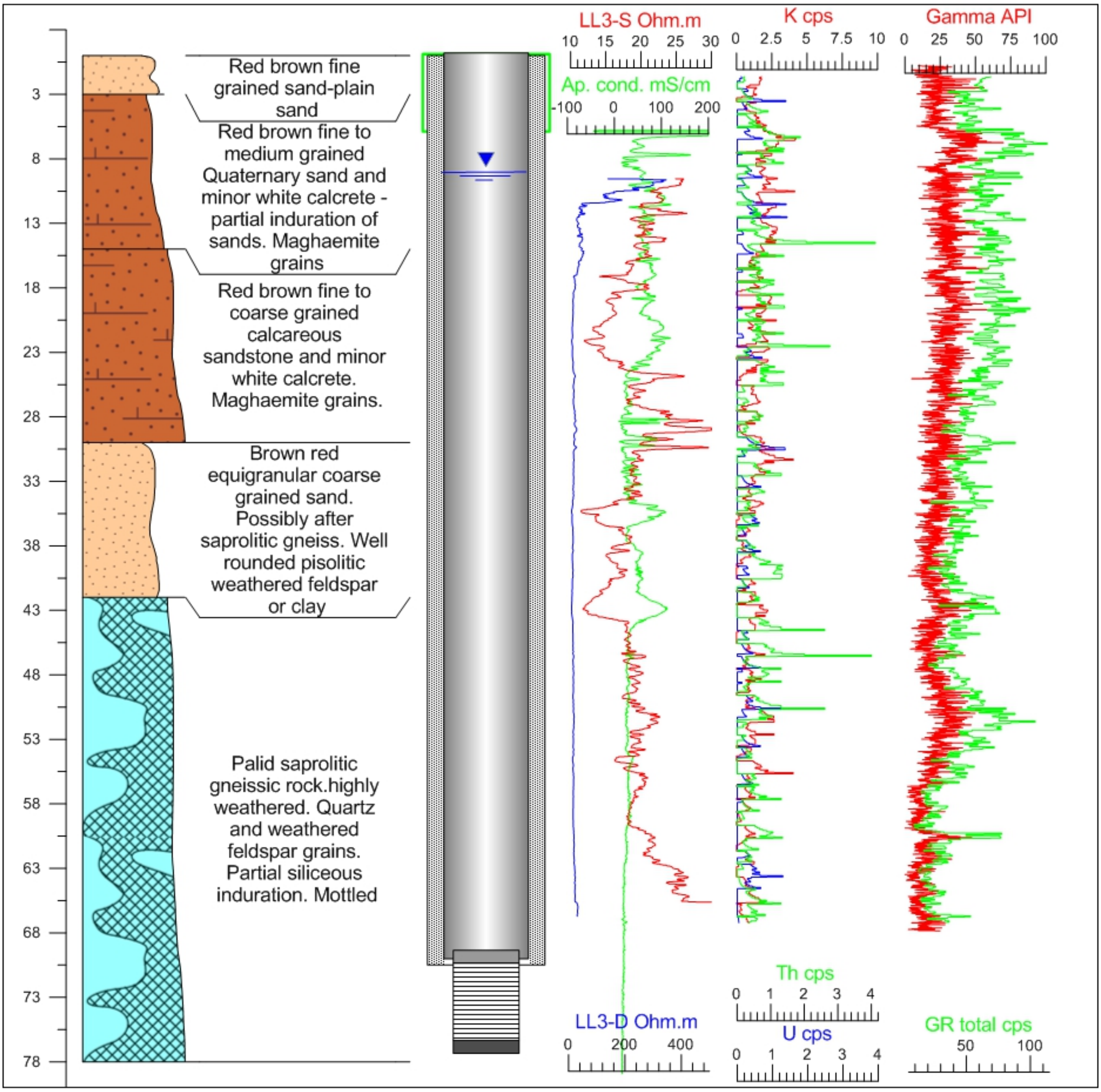

	Type	Int. Diam.	Interval	Cement	Apeture
Surface Casing Details:	Steel	247mm	+0.12 - 5.8m	0 - 5.8m	
Casing details:	PVC	157mm	+0.215 - 69m	0 - 54.5m	
Prod. Zone Details:	Steel	128mm	70.35 - 76.35m		0.5mm
Sump:	Steel	128mm	76.35 - 77.35m		

Geology
- Calcareous sand /sandstone
- Sand /sandstone
- Mottled saprolite

Well Construction
Casing | Cement | Control Casing | Sump | Screen | Riser

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GFLOWS Stage 3 Drilling Program

Site:	DH1	**SWL (▼):**	7.88 mtoc	**Driller:**	J.Paech/ H.Beach
Permit No.:	294915	**Water Cut (▽):**		**Drilling Company:**	Silver City Drilling
Unit No.:	534400086			**Rig:**	KWL 1600H
Borehole Name:	DH1g	**Datum:**	GDA94	**Status of Well:**	Operational
Date Drilled:	09/082018	**Easting:**	209017	**Purpose:**	Monitoring
Date Reworked:		**Northing:**	7032964	**Logged by:**	N.Statton
Depth:	15.61m	**Zone:**	53	**Geophy. by:**	

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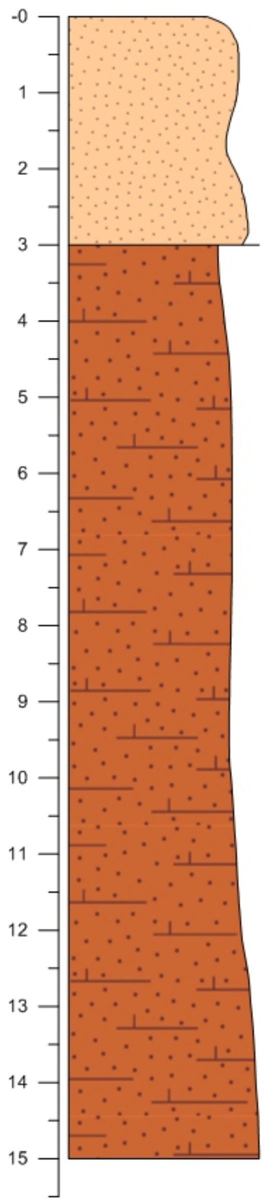
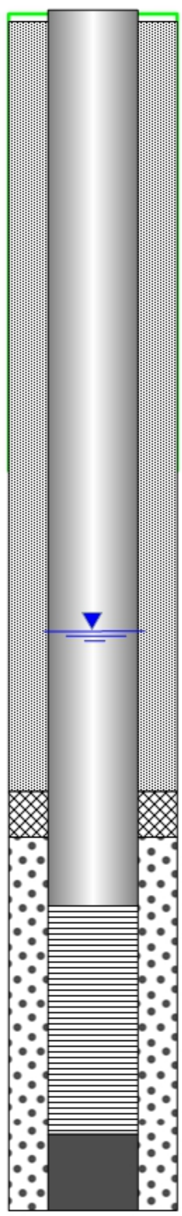


Red brown fine grained Quaternary sands

Red brown fine to medium grained Quaternary sand and minor white calcrete - partial induration of sands. Maghaemite grains



	Type	Int. Diam.	Interval	Cement	Apeture
Surface Casing Details:		320mm	+0.1 - 6.0m		
Casing details:	PVC	150mm	+0.15 - 11.61m	0 - 10.1m	
Prod. Zone Details:	PVC	150mm	11.61 - 14.61m		0.5mm
Sump:	PVC	150mm	14.61 - 15.61m		

Well Construction

Geology
- Calcareous sand /sandstone
- Sand /sandstone

Casing | Cement | Control Casing | Sump | Screen | Gravel pack | Bentonite

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GFLOWS Stage 3 Drilling Program

Site:	S22	**SWL (▼):** 27.05 mbgs		**Driller:**	J.Paech/ H.Beach	
Permit No.:	294916	**Water Cut (▽):** ~33 mbgs		**Drilling Company:**	Silver City Drilling	
Unit No.:	534400079			**Rig:**	KWL 1600H	
Borehole Name:	DH-S22a	**Datum:**	GDA94	**Status of Well:**	Operational	
Date Drilled:	17/08/2018	**Easting:**	207562	**Purpose:**	Monitoring	
Date Reworked:		**Northing:**	7045160	**Logged by:**	C.Krapf	
Depth:	35.3m	**Zone:**	53	**Geophy. by:**		

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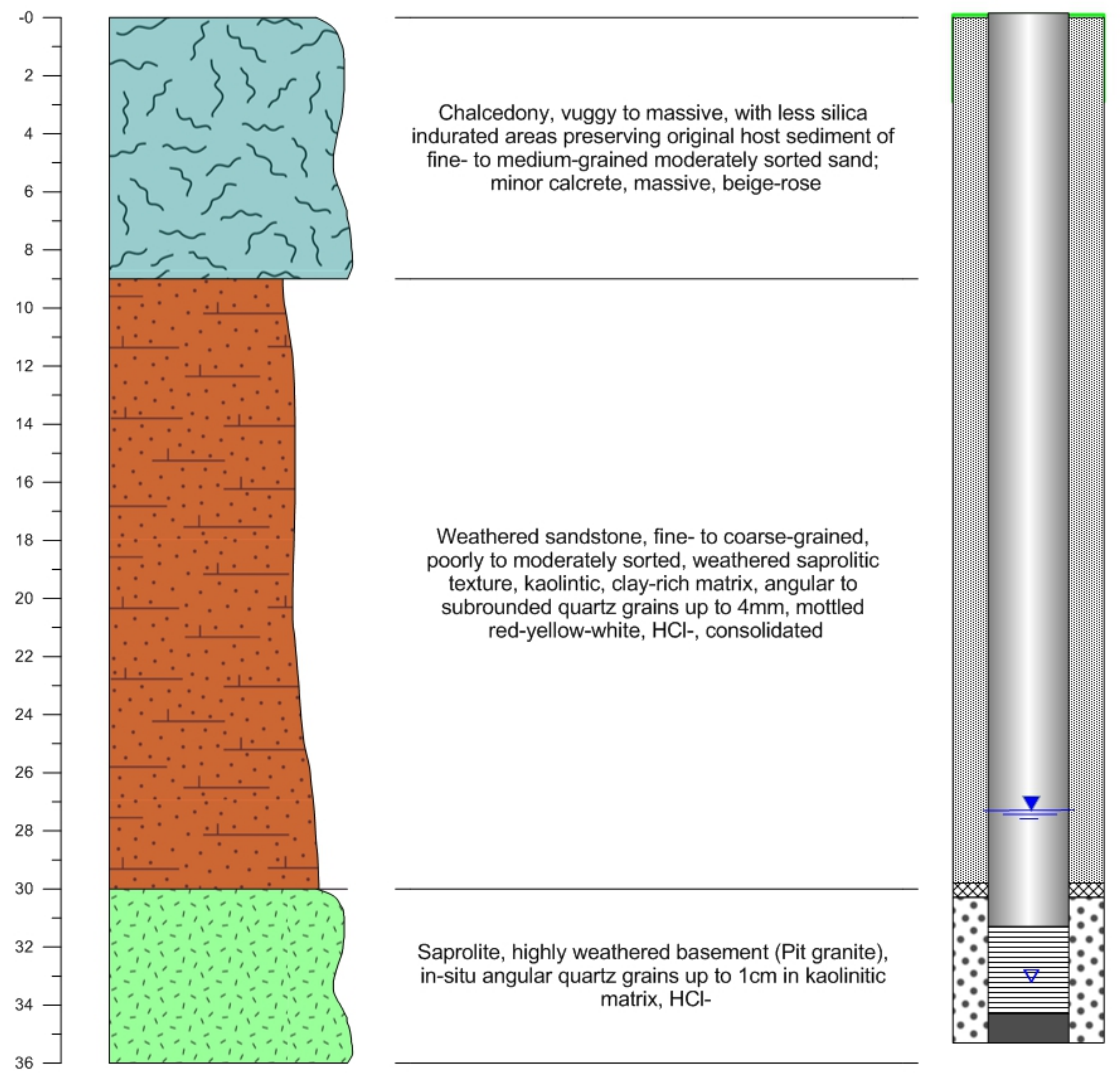

	Type	Int. Diam.	Interval	Cement	Apeture
Surface Casing Details:		320mm	+0.1 - 2.9m		
Casing details:	PVC	150mm	+0.10 - 31.3m	0 - 29.8m	
Prod. Zone Details:	PVC	150mm	31.3 - 34.3m		0.5mm
Sump:	PVC	150mm	34.3 - 35.3m		

Well Construction

Geology
- Calcareous sand /sandstone
- Chalcendony/ silcrete
- Saprolite

Casing | Cement | Control Casing | Sump | Screen | Gravel pack | Bentonite

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GFLOWS Stage 3 Drilling Program

Site:	S22	**SWL (▼):**	31 mtoc	**Driller:**	J.Paech/ H.Beach
Permit No.:	294918	**Water Cut (▽):**	~33.5 mbgs	**Drilling Company:**	Silver City Drilling
Unit No.:	534400084			**Rig:**	KWL 1600H
Borehole Name:	DH-S22b	**Datum:**	GDA94	**Status of Well:**	Operational
Date Drilled:	20/08/2018	**Easting:**	207495	**Purpose:**	Monitoring
Date Reworked:		**Northing:**	7044907	**Logged by:**	C.Krapf
Depth:	36m	**Zone:**	53	**Geophy. by:**	

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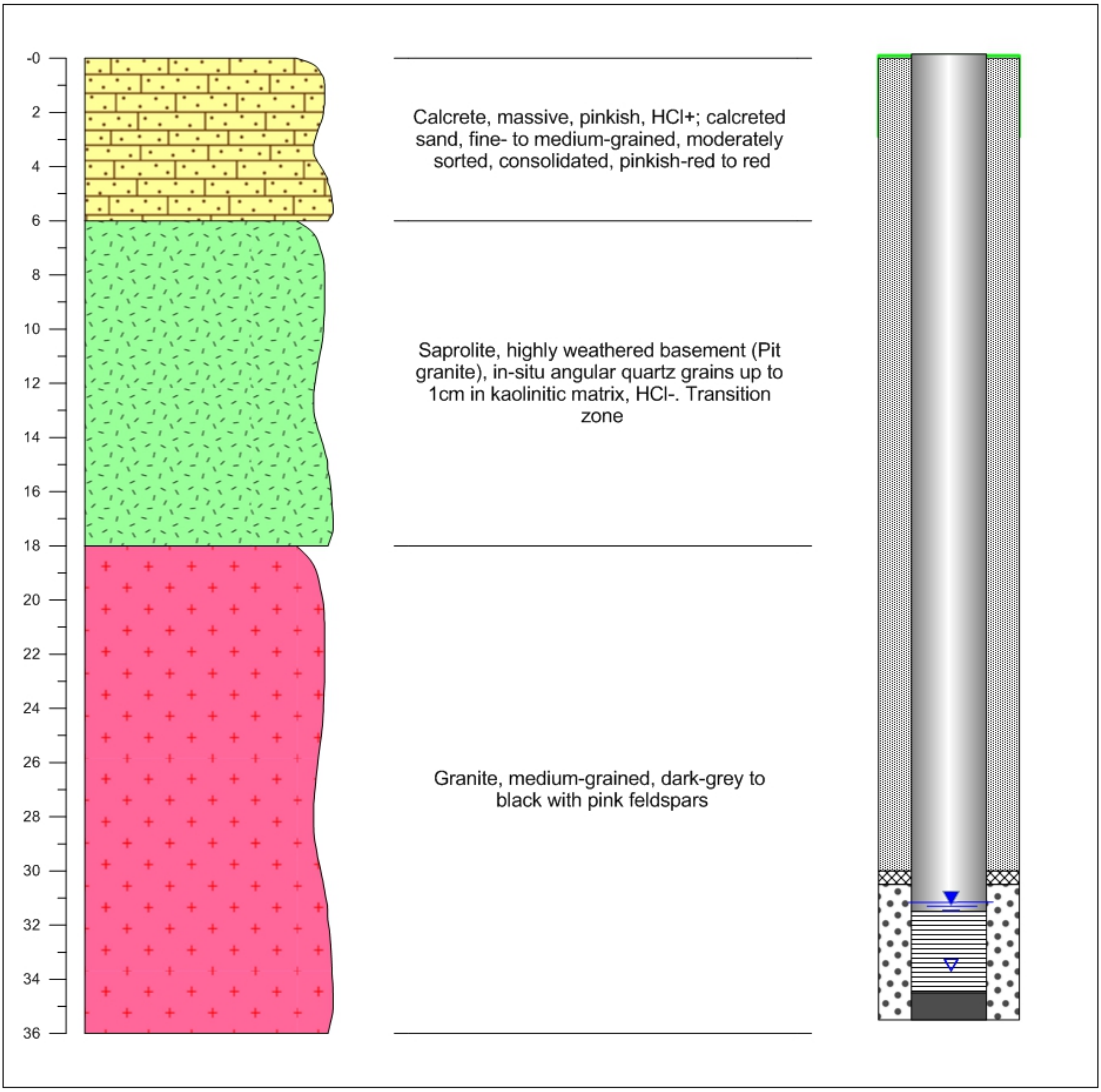

	Type	Int. Diam.	Interval	Cement	Apeture
Surface Casing Details:		320mm	+0.1 - 2.9m		
Casing details:	PVC	150mm	+0.10 - 31.5m	0 - 30m	
Prod. Zone Details:	PVC	150mm	31.5 - 34.5m		0.5mm
Sump:	PVC	150mm	34.5 - 35.5m		

Geology: Calcrete, Granite, Saprolite

Well Construction: Casing, Cement, Control Casing, Sump, Screen, Gravel pack, Bentonite

GFLOWS Stage 3 Drilling Program

Site:	S22	**SWL (▼):**	12.19 mbgs	**Driller:**	J.Paech/ H.Beach
Permit No.:	294917	**Water Cut (▽):**	~18 mbgs	**Drilling Company:**	Silver City Drilling
Unit No.:	534400081			**Rig:**	KWL 1600H
Borehole Name:	DH-S22c	**Datum:**	GDA94	**Status of Well:**	Operational
Date Drilled:	18/08/2018	**Easting:**	207198	**Purpose:**	Monitoring
Date Reworked:		**Northing:**	7043773	**Logged by:**	C.Krapf
Depth:	20.2m	**Zone:**	53	**Geophy. by:**	

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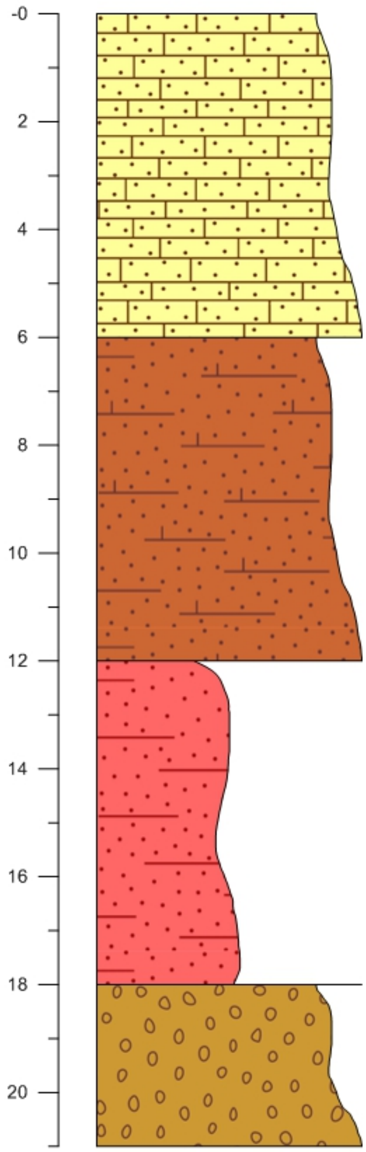
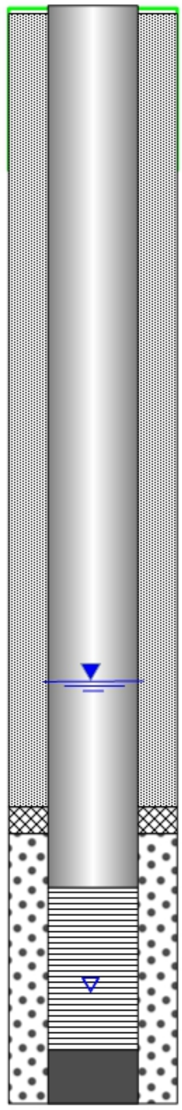


Calcrete with chalcedony overprint in patches, calcrete formed in fine to medium-grained, moderately sorted sand, red-brown-orange; interp: pedogenic calcrete with chalcedony overprint formed within sand plain deposits

Sand, silt- to medium-grianed, poorly to moderately sorted, red-orange-brown, clay-rich with angular to subrounded quartz grains

Mud, clay to fine-grained silty sand, moderately to well sorted, orange-red to choclate brown, HCl-; minor calcrete. Floodplain deposits with pedogenic calcrete overprint

Gravel (?), fine- to coarse-grained, poorly to moderately sorted, clay-rich, broken up ravels 0.3-1.5cm, HCl-



	Type	Int. Diam.	Interval	Cement	Apeture
Surface Casing Details:		320mm	+0.1 - 2.9m		
Casing details:	PVC	150mm	+0.10 - 31.5m	0 - 30m	
Prod. Zone Details:	PVC	150mm	31.5 - 34.5m		0.5mm
Sump:	PVC	150mm	34.5 - 35.5m		

Well Construction

Geology
- Calcareous sand /sandstone
- Calcareous gravel
- Calcrete
- Clayey sand /sandstone

Casing   Cement   Control Casing   Sump   Screen   Gravel pack   Bentonite

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GFLOWS Stage 3 Drilling Program

Site:	S22	**SWL (▼):**	13.2 mbgs	**Driller:**	J.Paech/ H.Beach
Permit No.:	330198	**Water Cut (▽):**	~45 mbgs	**Drilling Company:**	Silver City Drilling
Unit No.:	534400088			**Rig:**	KWL 1600H
Borehole Name:	DH-S22i	**Datum:**	GDA94	**Status of Well:**	Operational
Date Drilled:	25/08/2018	**Easting:**	206201	**Purpose:**	Monitoring
Date Reworked:		**Northing:**	7040059	**Logged by:**	C.Krapf
Depth:	48m	**Zone:**	53	**Geophy. by:**	K.inverarity

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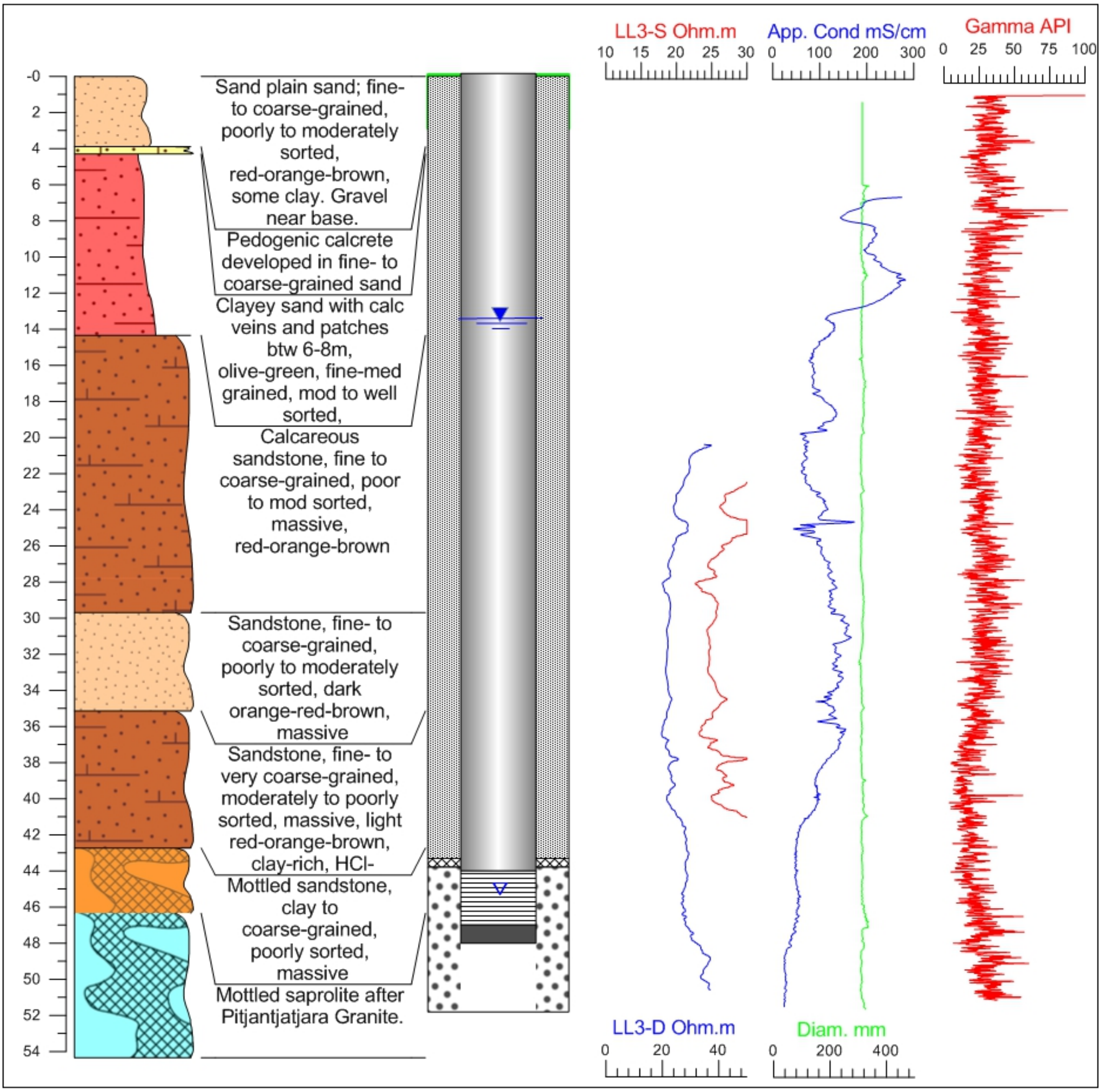

	Type	Int. Diam.	Interval	Cement	Apeture
Surface Casing Details:		320mm	+0.1 - 2.9m		
Casing details:	PVC	150mm	+0.10 - 47.8m	0 - 46.3m	
Prod. Zone Details:	PVC	150mm	44.0 - 47.0m		0.5mm
Sump:	PVC	150mm	47.0 - 48.0m		

Well Construction

Casing | Cement | Control Casing | Sump | Screen | Gravel pack | Bentonite

Geology
- Calcareous sand /sandstone
- Calcrete
- Clayey sand /sandstone
- Mottled sand /sandstone
- Mottled saprolite
- Sand /sandstone

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A.2 Detailed geology diagrams (cored drillholes)

GFLOWS Stage 3 Drilling Program

Site:	DH1	**SWL ( ):**		**Driller:**	H.Beach
Permit No.:	294909	**Water Cut ( ):**		**Drilling Company:**	Silver City Drilling
Unit No.:	534400087			**Rig:**	KWL 1600H
Borehole Name:	DH1a	**Datum:**	GDA94	**Status of Well:**	Not operational
Date Drilled:	14/07/2018	**Easting:**	209961	**Purpose:**	Observation
Date Reworked:		**Northing:**	7032732	**Logged by:**	C.Krapf
Depth:	93.4m	**Zone:**	53	**Geophy. by:**	N.Vasilic

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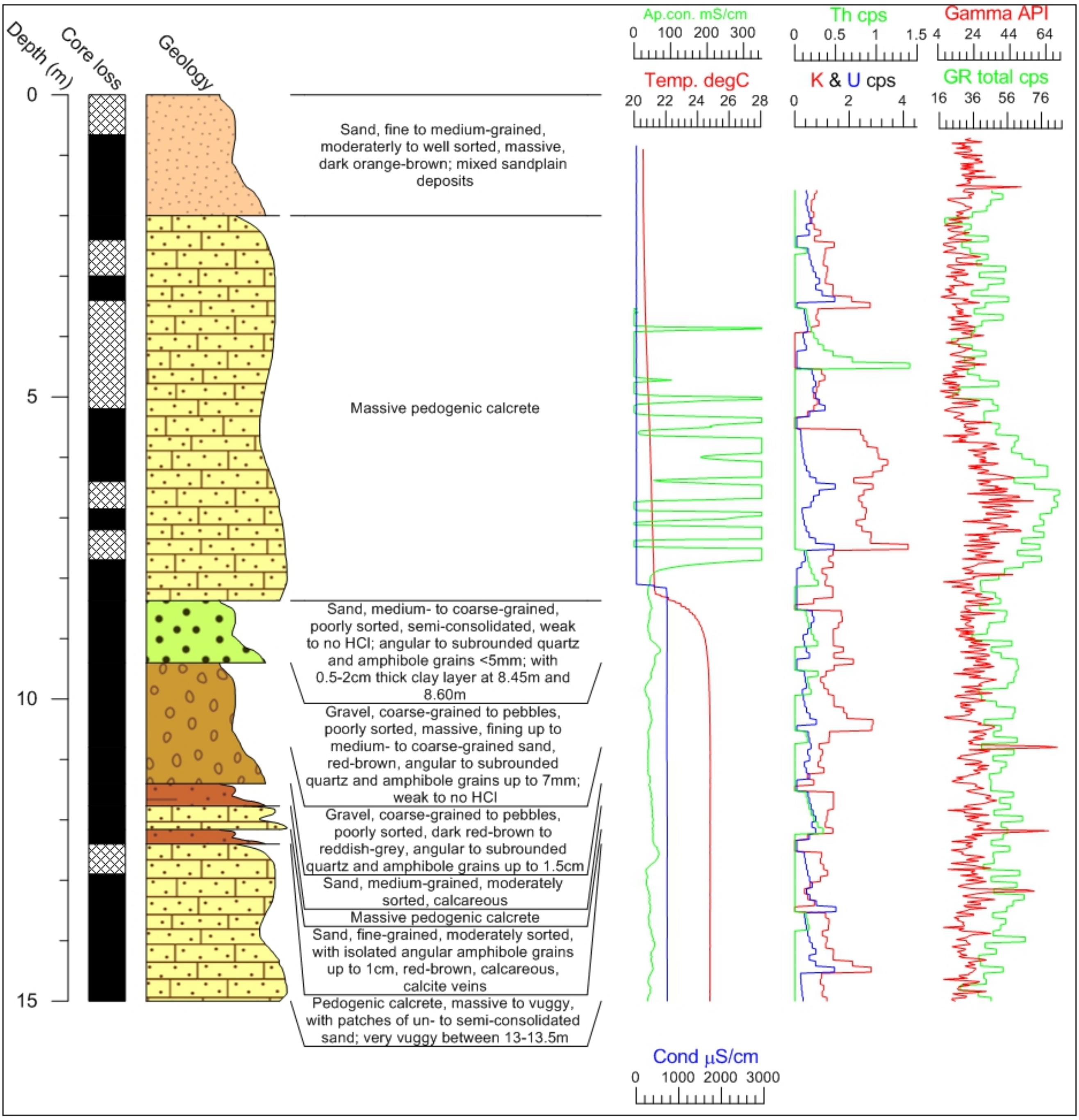

Geology

- Core recovered
- Core loss
- Calcareous clayey sand/ sandstone
- Calcareous sand/ sandstone
- Calcrete
- Clay/ claystone
- Clayey sand/ sandstone
- Coarse calcareous sand/ sandstone
- Coarse sand/ sandstone
- Gravel
- Gypsum
- Mottled sandstone
- Mottled saprolite
- Mud/ mudstone
- Sand/ sandstone
- Sandy clay/ sandy claystone
- Sandy siltstone/ silty sandstone

GFLOWS Stage 3 Drilling Program

Site:	DH1	**SWL ( ):**		**Driller:**	H.Beach
Permit No.:	294909	**Water Cut ( ):**		**Drilling Company:**	Silver City Drilling
Unit No.:	534400087			**Rig:**	KWL 1600H
Borehole Name:	DH1a	**Datum:**	GDA94	**Status of Well:**	Not operational
Date Drilled:	14/07/2018	**Easting:**	209961	**Purpose:**	Observation
Date Reworked:		**Northing:**	7032742	**Logged by:**	C.Krapf
Depth:	93.4m	**Zone:**	53	**Geophy. by:**	N.Vasilic

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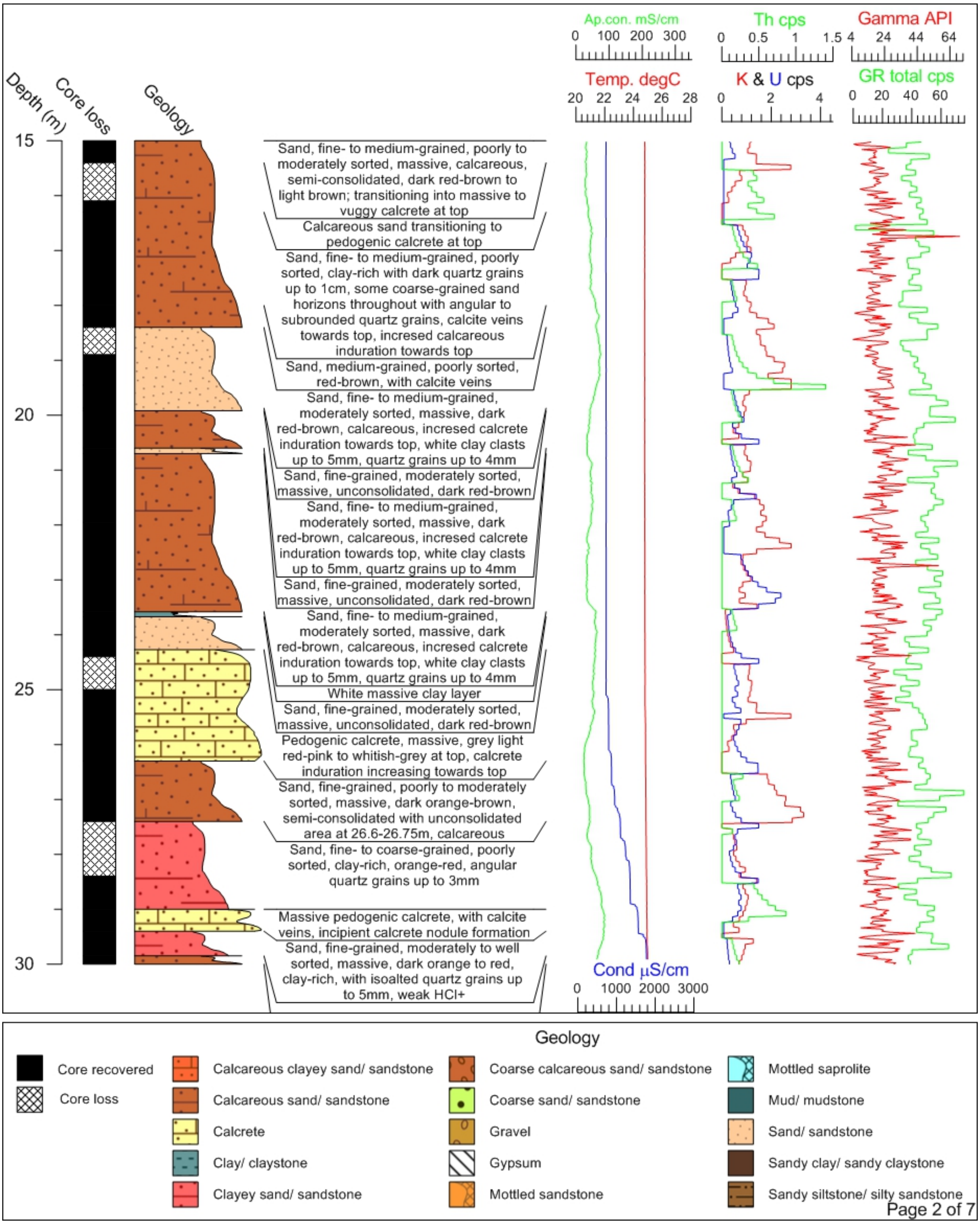

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GFLOWS Stage 3 Drilling Program

Site:	DH1	**SWL ( ):**		**Driller:**	H.Beach
Permit No.:	294909	**Water Cut ( ):**		**Drilling Company:**	Silver City Drilling
Unit No.:	534400087			**Rig:**	KWL 1600H
Borehole Name:	DH1a	**Datum:**	GDA94	**Status of Well:**	Not operational
Date Drilled:	14/07/2018	**Easting:**	209961	**Purpose:**	Observation
Date Reworked:		**Northing:**	7032742	**Logged by:**	C.Krapf
Depth:	93.4m	**Zone:**	53	**Geophy. by:**	N.Vasilic

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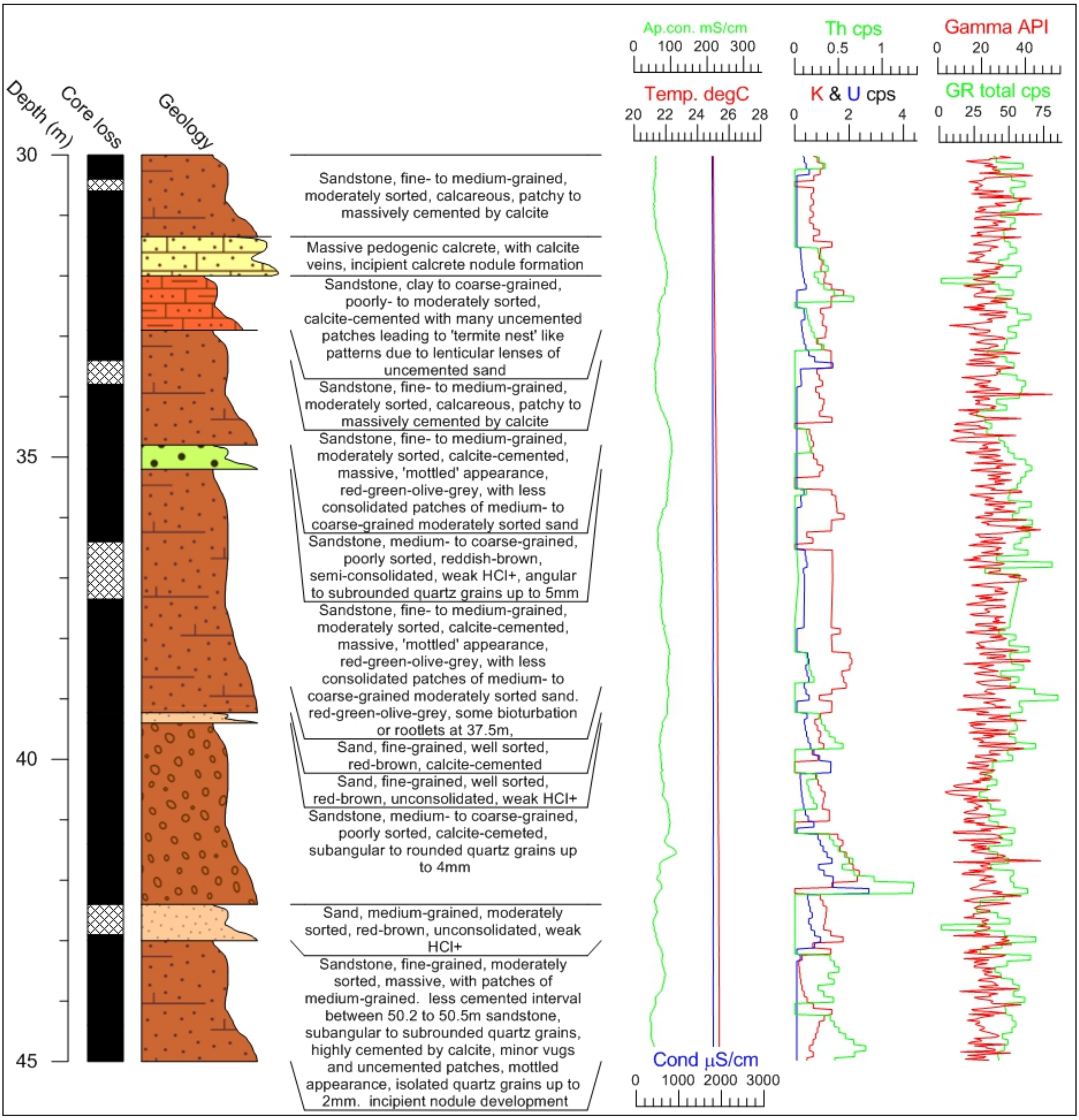


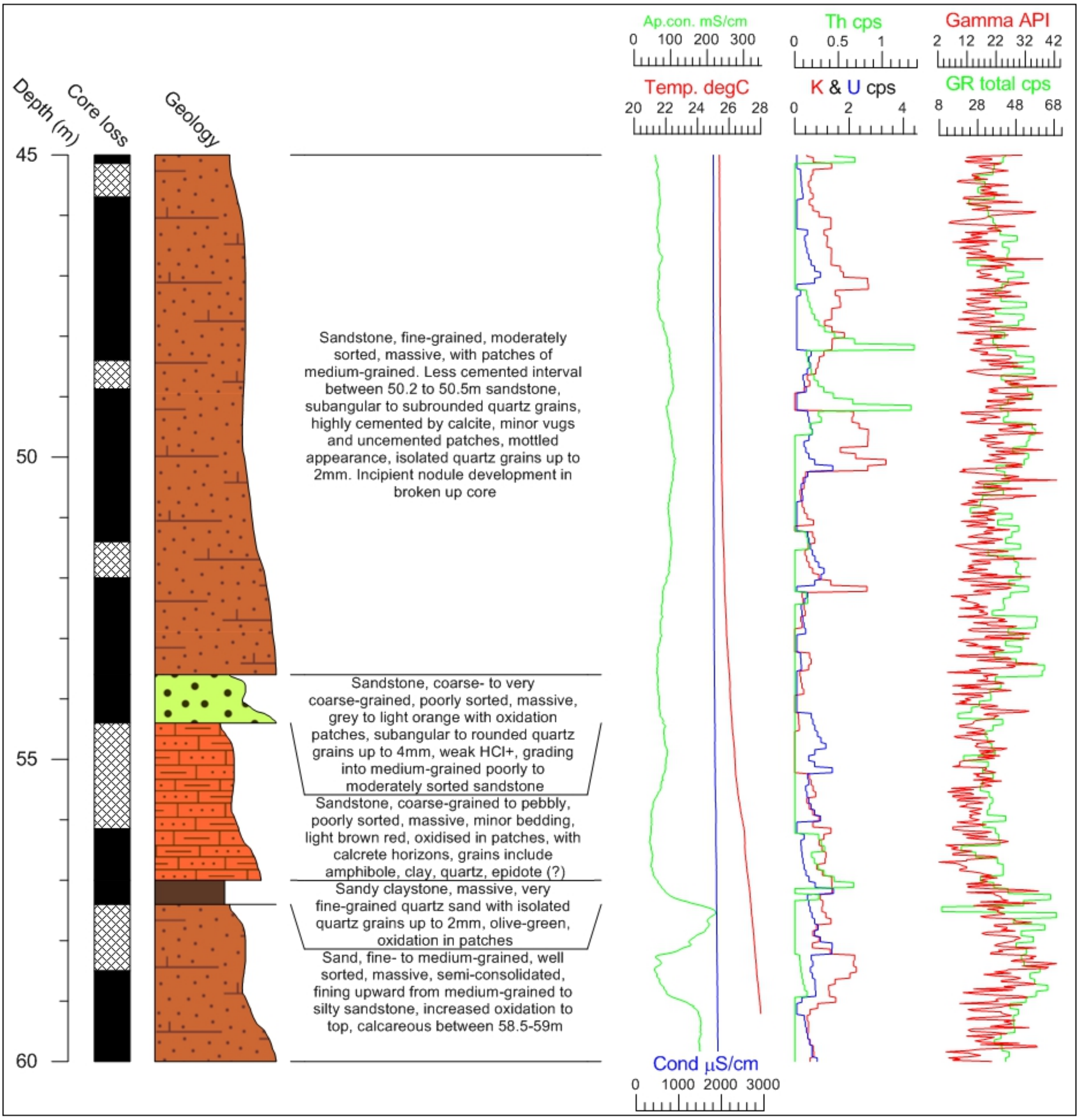
Geology

- Core recovered
- Core loss
- Calcareous clayey sand/ sandstone
- Calcareous sand/ sandstone
- Calcrete
- Clay/ claystone
- Clayey sand/ sandstone
- Coarse calcareous sand/ sandstone
- Coarse sand/ sandstone
- Gravel
- Gypsum
- Mottled sandstone
- Mottled saprolite
- Mud/ mudstone
- Sand/ sandstone
- Sandy clay/ sandy claystone
- Sandy siltstone/ silty sandstone

GFLOWS Stage 3 Drilling Program

Site:	DH1	**SWL ( ):**		**Driller:**	H.Beach
Permit No.:	294909	**Water Cut ( ):**		**Drilling Company:**	Silver City Drilling
Unit No.:	534400087			**Rig:**	KWL 1600H
Borehole Name:	DH1a	**Datum:**	GDA94	**Status of Well:**	Not operational
Date Drilled:	14/07/2018	**Easting:**	209961	**Purpose:**	Observation
Date Reworked:		**Northing:**	7032742	**Logged by:**	C.Krapf
Depth:	93.4m	**Zone:**	53	**Geophy. by:**	N.Vasilic

Government of South Australia
Department for Environment and Water



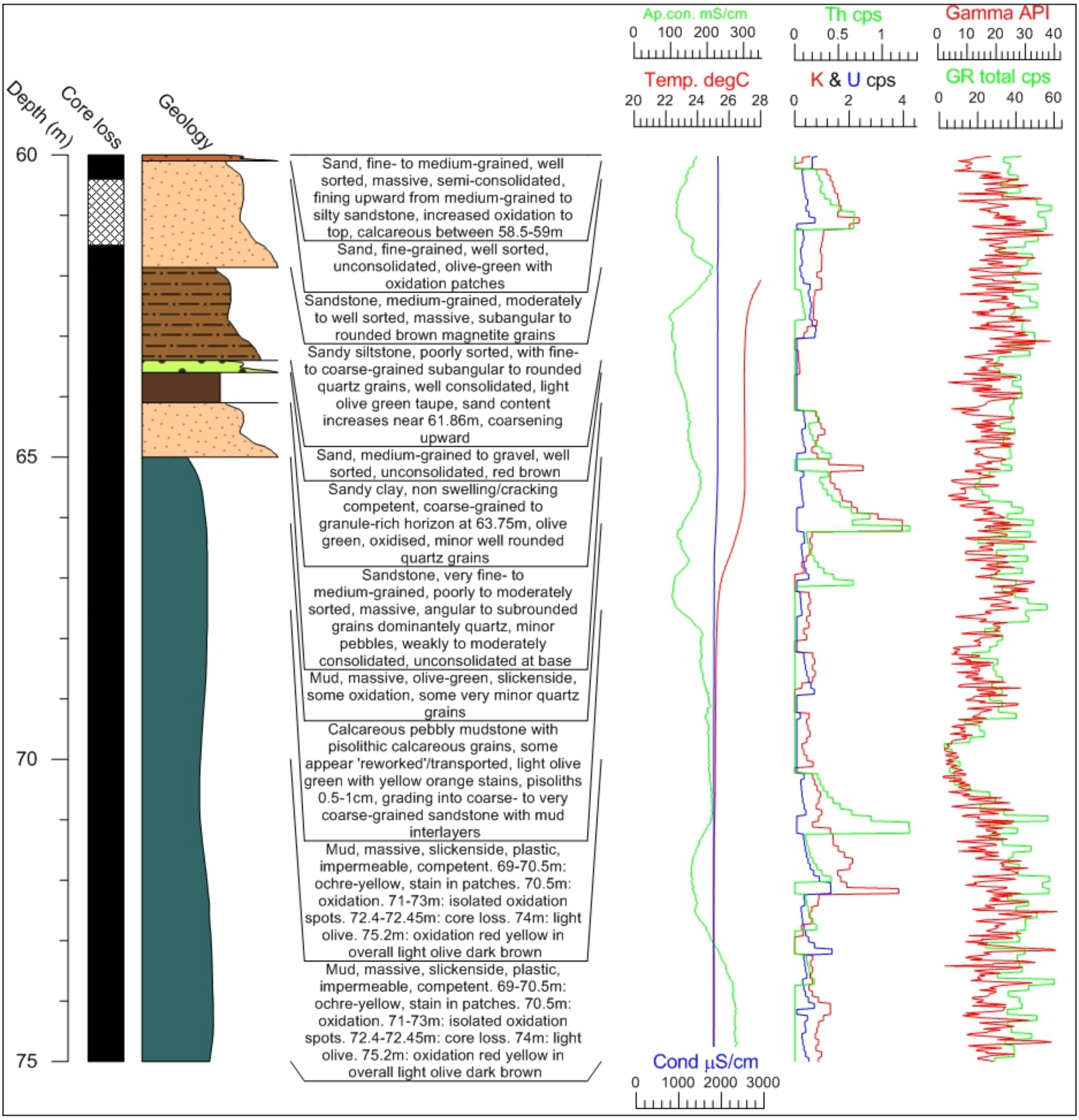
Geology

- Core recovered
- Core loss
- Calcareous clayey sand/ sandstone
- Calcareous sand/ sandstone
- Calcrete
- Clay/ claystone
- Clayey sand/ sandstone
- Coarse calcareous sand/ sandstone
- Coarse sand/ sandstone
- Gravel
- Gypsum
- Mottled sandstone
- Mottled saprolite
- Mud/ mudstone
- Sand/ sandstone
- Sandy clay/ sandy claystone
- Sandy siltstone/ silty sandstone

GFLOWS Stage 3 Drilling Program

Site:	DH1	**SWL ( ):**		**Driller:**	H.Beach
Permit No.:	294909	**Water Cut ( ):**		**Drilling Company:**	Silver City Drilling
Unit No.:	534400087			**Rig:**	KWL 1600H
Borehole Name:	DH1a	**Datum:**	GDA94	**Status of Well:**	Not operational
Date Drilled:	14/07/2018	**Easting:**	209961	**Purpose:**	Observation
Date Reworked:		**Northing:**	7032732	**Logged by:**	C.Krapf
Depth:	93.4m	**Zone:**	53	**Geophy. by:**	N.Vasilic

Government of South Australia
Department for Environment and Water



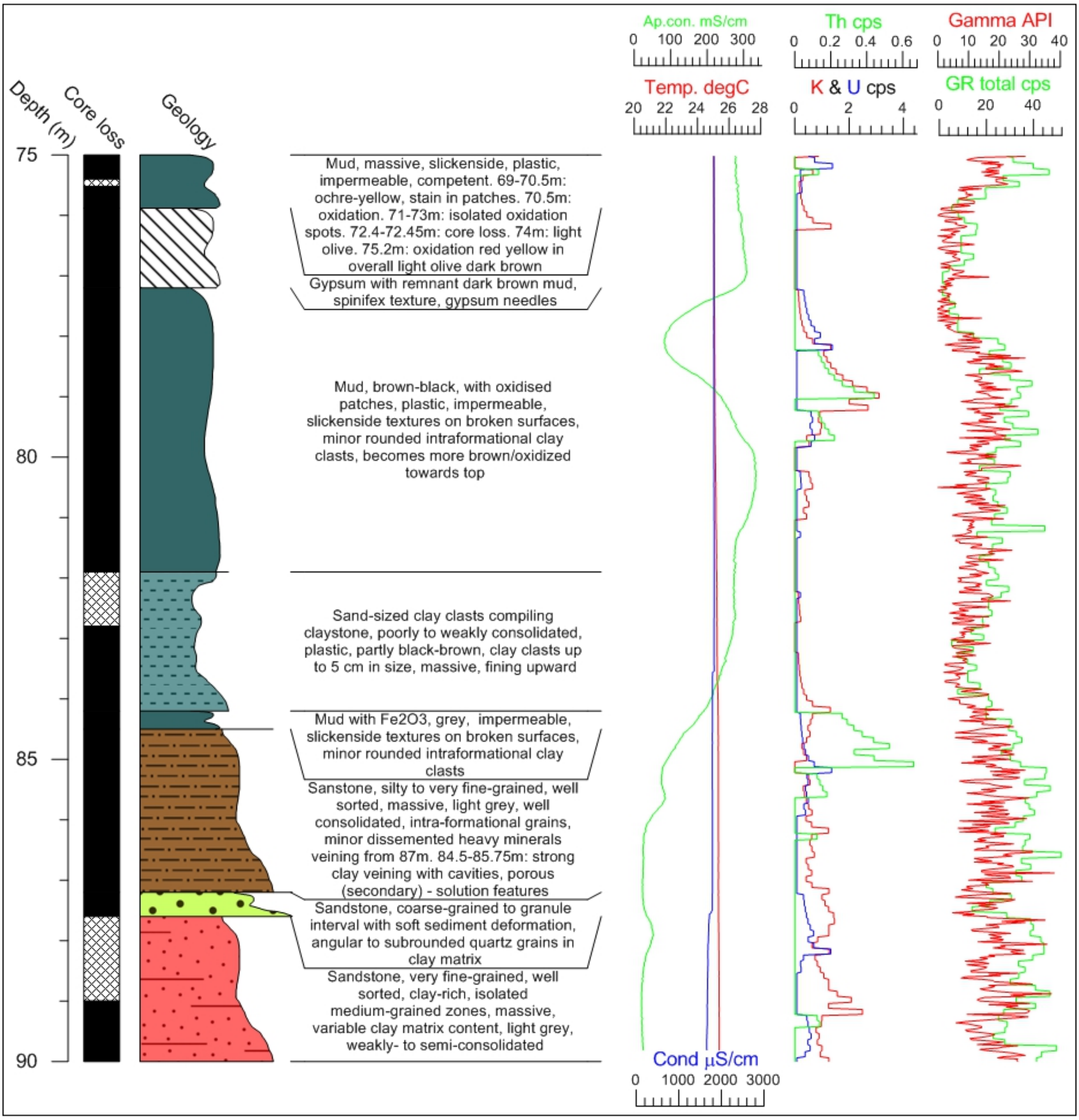
Geology

Core recovered	Calcareous clayey sand/ sandstone	Coarse calcareous sand/ sandstone	Mottled saprolite
Core loss	Calcareous sand/ sandstone	Coarse sand/ sandstone	Mud/ mudstone
	Calcrete	Gravel	Sand/ sandstone
	Clay/ claystone	Gypsum	Sandy clay/ sandy claystone
	Clayey sand/ sandstone	Mottled sandstone	Sandy siltstone/ silty sandstone

GFLOWS Stage 3 Drilling Program

Site:	DH1	**SWL ( ):**		**Driller:**	H.Beach
Permit No.:	294909	**Water Cut ( ):**		**Drilling Company:**	Silver City Drilling
Unit No.:	534400087			**Rig:**	KWL 1600H
Borehole Name:	DH1a	**Datum:**	GDA94	**Status of Well:**	Not operational
Date Drilled:	14/07/2018	**Easting:**	209961	**Purpose:**	Observation
Date Reworked:		**Northing:**	7032742	**Logged by:**	C.Krapf
Depth:	93.4m	**Zone:**	53	**Geophy. by:**	N.Vasilic

Government of South Australia
Department for Environment and Water



Geology

Core recovered	Calcareous clayey sand/ sandstone	Coarse calcareous sand/ sandstone	Mottled saprolite
Core loss	Calcareous sand/ sandstone	Coarse sand/ sandstone	Mud/ mudstone
	Calcrete	Gravel	Sand/ sandstone
	Clay/ claystone	Gypsum	Sandy clay/ sandy claystone
	Clayey sand/ sandstone	Mottled sandstone	Sandy siltstone/ silty sandstone

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GFLOWS Stage 3 Drilling Program

Site:	DH1	**SWL ( ):**		**Driller:**	H.Beach
Permit No.:	294909	**Water Cut ( ):**		**Drilling Company:**	Silver City Drilling
Unit No.:	534400087			**Rig:**	KWL 1600H
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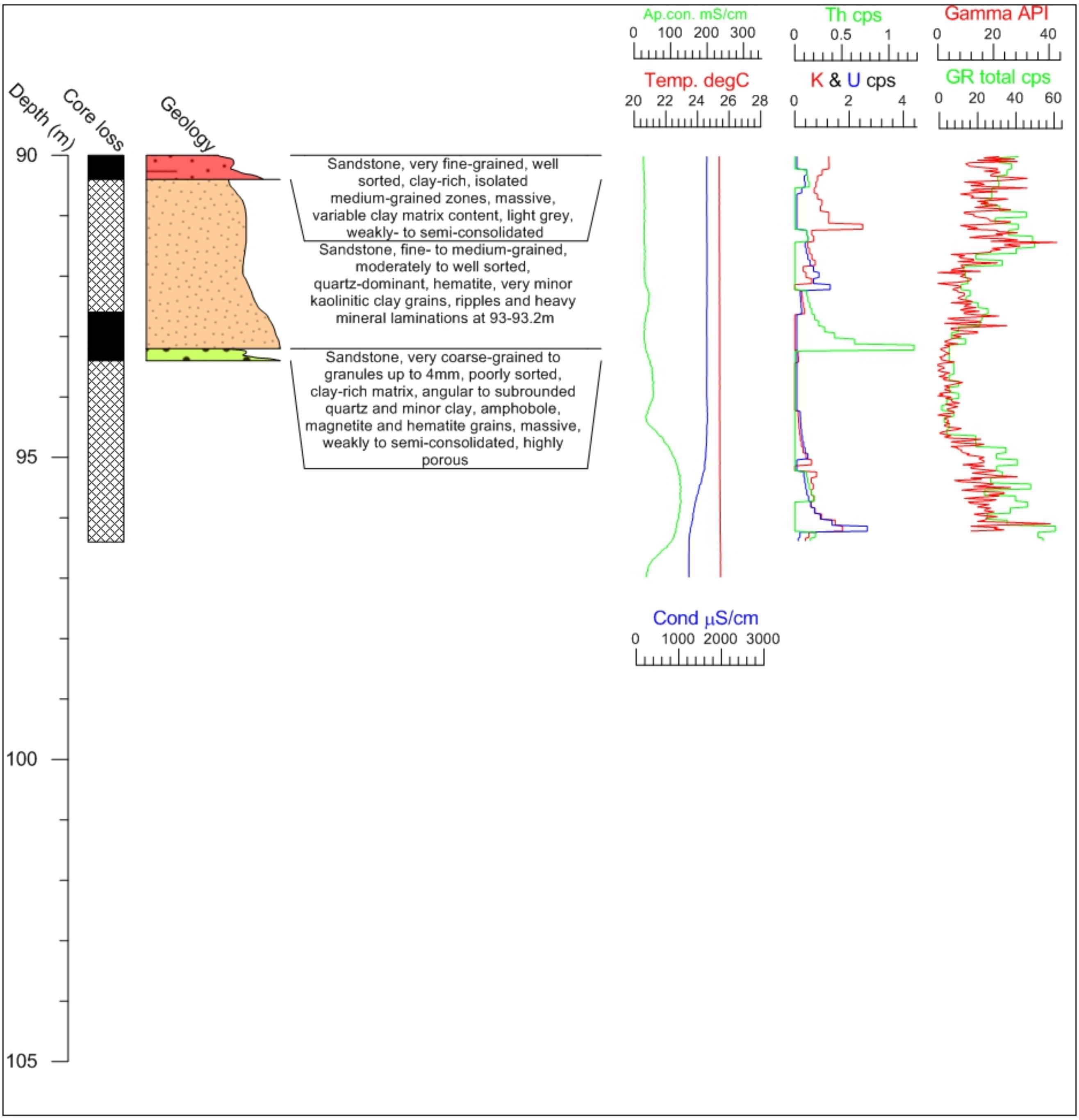

Geology

Core recovered	Calcareous clayey sand/ sandstone	Coarse calcareous sand/ sandstone	Mottled saprolite
Core loss	Calcareous sand/ sandstone	Coarse sand/ sandstone	Mud/ mudstone
	Calcrete	Gravel	Sand/ sandstone
	Clay/ claystone	Gypsum	Sandy clay/ sandy claystone
	Clayey sand/ sandstone	Mottled sandstone	Sandy siltstone/ silty sandstone

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GFLOWS Stage 3 Drilling Program

Site:	Site 22	**SWL ( ):**		**Driller:**	H.Beach/ J.Paech
Permit No.:	330198	**Water Cut ( ):**		**Drilling Company:**	Silver City Drilling
Unit No.:	534400088			**Rig:**	KWL 1600H
Borehole Name:	S22i	**Datum:**	GDA94	**Status of Well:**	Not operational
Date Drilled:	21/08/2018	**Easting:**	206195	**Purpose:**	Observation
Date Reworked:		**Northing:**	7040080	**Logged by:**	C.Krapf
Depth:	54.34m	**Zone:**	53	**Geophy. by:**	K. Inverarity

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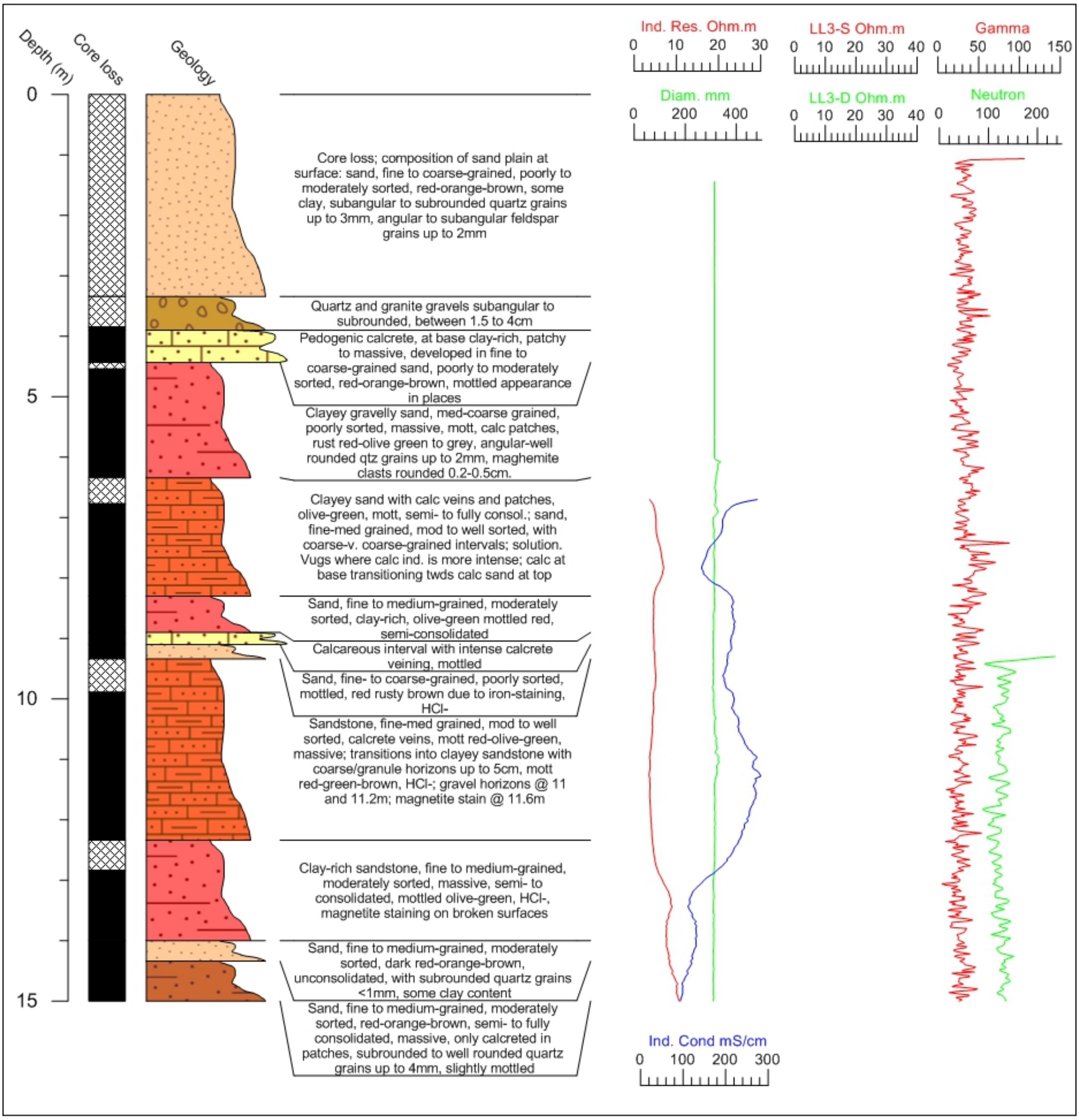

Geology

Core recovered	Calcareous clayey sand/ sandstone	Coarse calcareous sand/ sandstone	Mottled saprolite
Core loss	Calcareous sand/ sandstone	Coarse sand/ sandstone	Mud/ mudstone
	Calcrete	Gravel	Sand/ sandstone
	Clay/ claystone	Gypsum	Sandy clay/ sandy claystone
	Clayey sand/ sandstone	Mottled sandstone	Sandy siltstone/ silty sandstone

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GFLOWS Stage 3 Drilling Program

Site:	Site 22	**SWL ( ):**		**Driller:**	H.Beach/ J.Paech
Permit No.:	330198	**Water Cut ( ):**		**Drilling Company:**	Silver City Drilling
Unit No.:	534400088			**Rig:**	KWL 1600H
Borehole Name:	S22i	**Datum:**	GDA94	**Status of Well:**	Not operational
Date Drilled:	21/08/2018	**Easting:**	206195	**Purpose:**	Observation
Date Reworked:		**Northing:**	7040080	**Logged by:**	C.Krapf
Depth:	54.34m	**Zone:**	53	**Geophy. by:**	K. Inverarity

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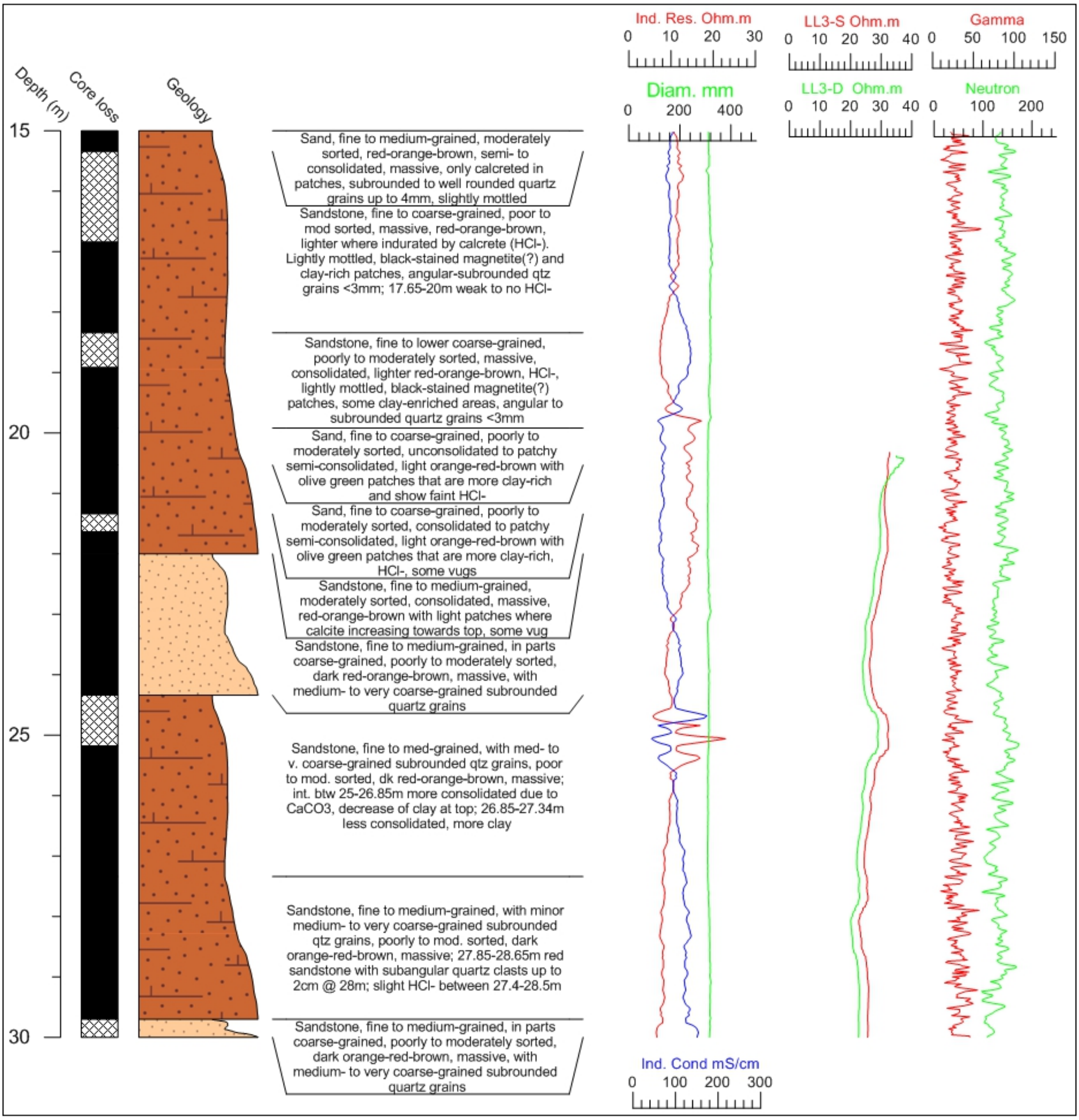

Geology

- Core recovered
- Core loss
- Calcareous clayey sand/ sandstone
- Calcareous sand/ sandstone
- Calcrete
- Clay/ claystone
- Clayey sand/ sandstone
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- Coarse sand/ sandstone
- Gravel
- Gypsum
- Mottled sandstone
- Mottled saprolite
- Mud/ mudstone
- Sand/ sandstone
- Sandy clay/ sandy claystone
- Sandy siltstone/ silty sandstone

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GFLOWS Stage 3 Drilling Program

Site:	Site 22	**SWL ( ):**		**Driller:**	H.Beach/ J.Paech
Permit No.:	330198	**Water Cut ( ):**		**Drilling Company:**	Silver City Drilling
Unit No.:	534400088			**Rig:**	KWL 1600H
Borehole Name:	S22i	**Datum:**	GDA94	**Status of Well:**	Not operational
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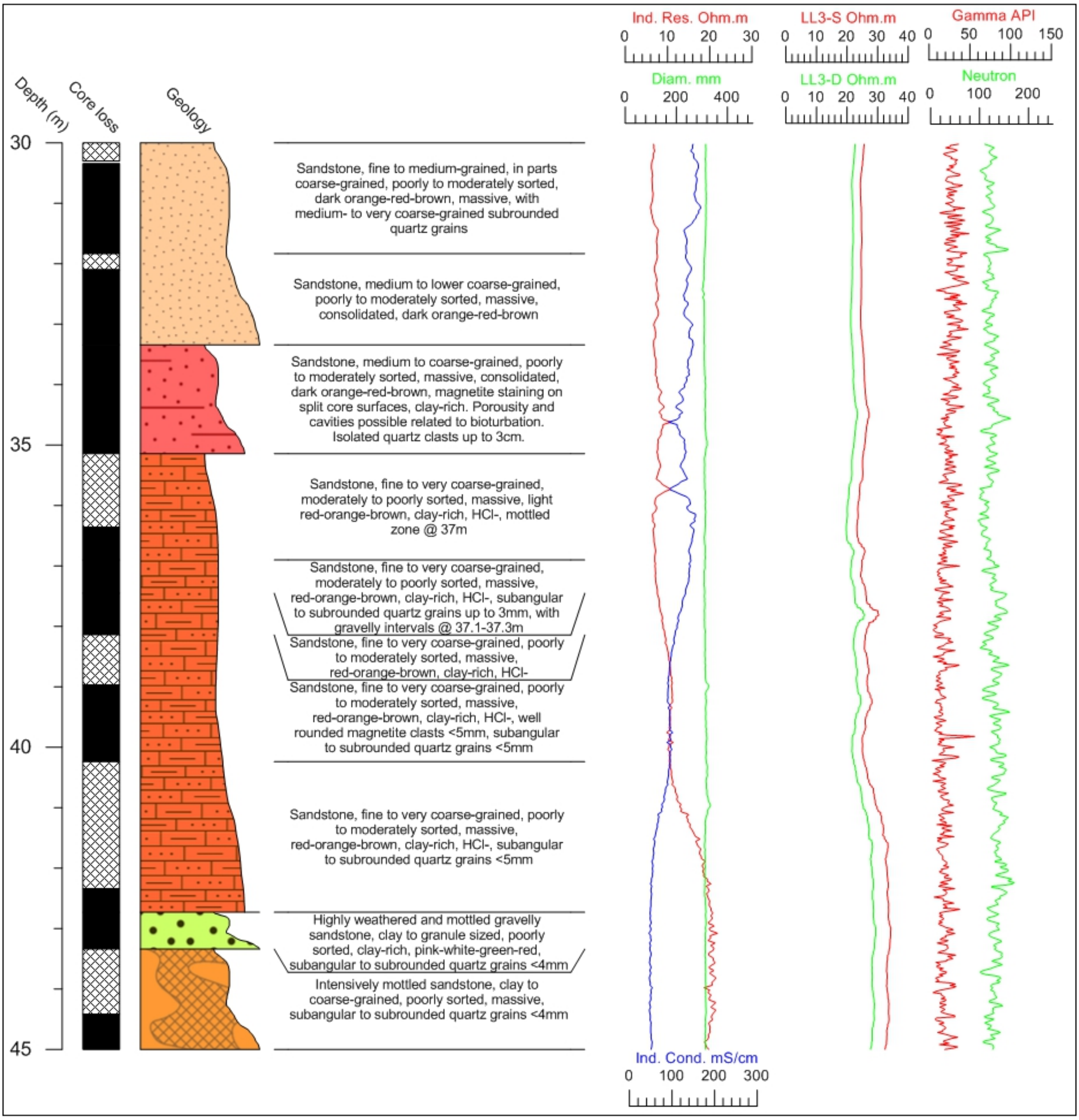
Government of South Australia
Department for Environment and Water



Geology

- Core recovered
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- Calcareous clayey sand/ sandstone
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GFLOWS Stage 3 Drilling Program

Site:	Site 22	**SWL ( ):**		**Driller:**	H.Beach/ J.Paech
Permit No.:	330198	**Water Cut ( ):**		**Drilling Company:**	Silver City Drilling
Unit No.:	534400088			**Rig:**	KWL 1600H
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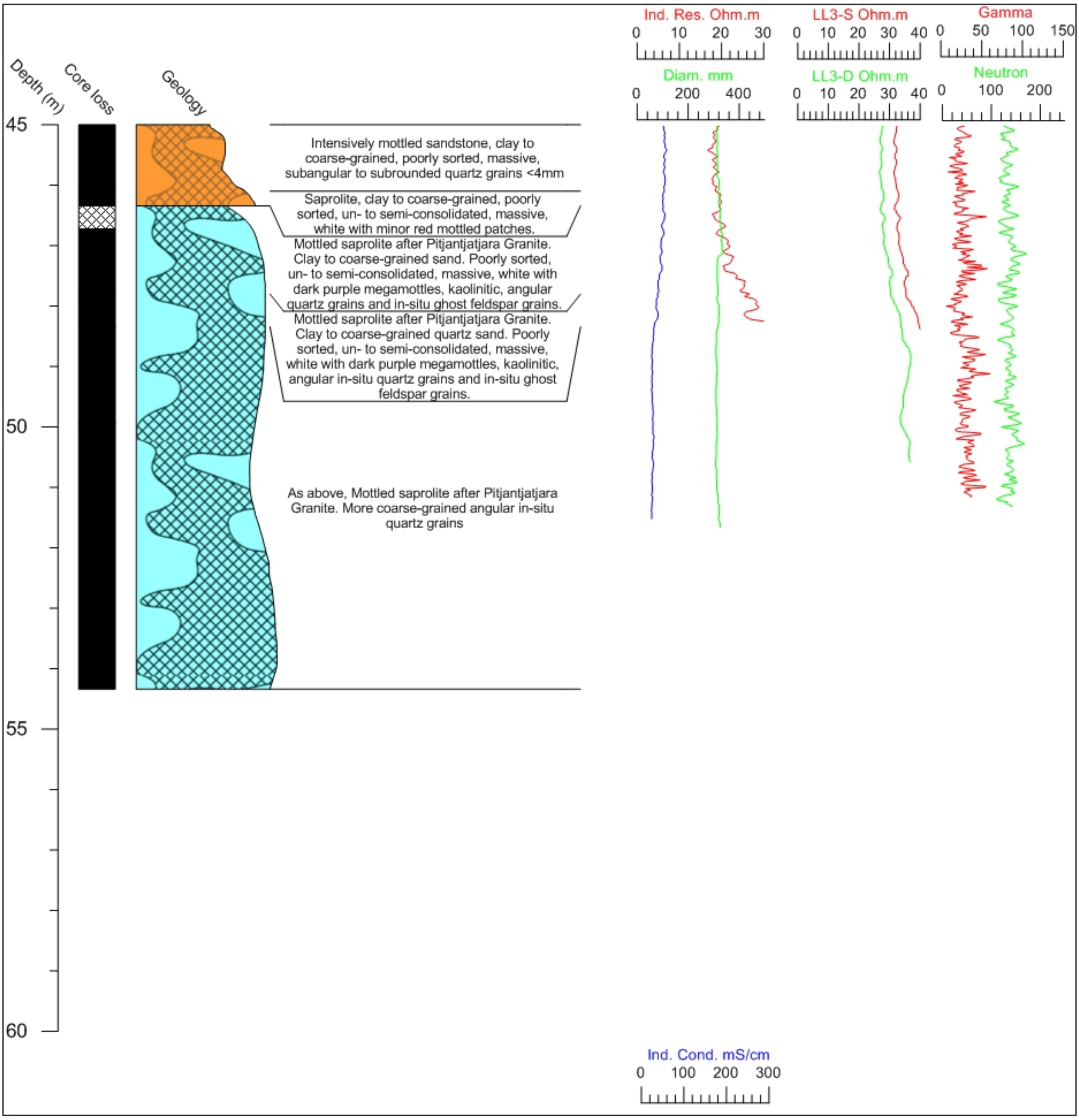

Geology

Core recovered	Calcareous clayey sand/ sandstone	Coarse calcareous sand/ sandstone	Mottled saprolite
Core loss	Calcareous sand/ sandstone	Coarse sand/ sandstone	Mud/ mudstone
	Calcrete	Gravel	Sand/ sandstone
	Clay/ claystone	Gypsum	Sandy clay/ sandy claystone
	Clayey sand/ sandstone	Mottled sandstone	Sandy siltstone/ silty sandstone

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The Goyder Institute for Water Research is a partnership between the South Australian Government through the Department for Environment and Water, CSIRO, Flinders University, the University of Adelaide, the University of South Australia, and the International Centre of Excellence in Water Resource Management.