

Groundwater Assessment



Chandler Facility

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Prepared for Tellus Holdings Limited
February 2017



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Chandler Facility

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Date 9 February 2017

Date 9 February 2017

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1 Introduction

1.1 Overview

Tellus Holdings (Tellus) is proposing to construct and operate the Chandler Facility (the Proposal) on the Maryvale pastoral lease (Northern Territory 810) approximately 120 kilometres (km) south of Alice Springs (see Figure 1.1).

Tellus is seeking development consent under the Northern Territory *Environmental Assessment Act* (EA Act) for the Proposal, broadly comprising:

- the mining of a high quality salt product at a depth of approximately 850 metres (m);
- provision for the permanent isolation of intractable waste or the temporary storage of materials in void spaces left from salt mining;
- the use of mining and waste emplacement methods that will replicate current global best practice techniques;
- haulage of salt and waste products via private haul roads;
- transportation of salt to port via rail;
- delivery of waste predominantly by rail; and
- transportation of workers via public and private roads.

A water assessment is required to assess potential impacts to water resources and water users from the construction and operation of the Proposal. The water assessment will address the requirements for major Proposal impact assessments.

1.2 Northern Territory Environment Protection Agency environmental assessment requirements

An environmental impact statement (EIS) has been prepared to address specific requirements provided in the *Final Guidelines for the Preparation of an Environmental Impact Statement* for the Proposal application, issued on September 2016.

This water assessment has been prepared as part of the EIS to address the specific groundwater and surface water requirements in the environmental assessment guidelines. Specifically, the water assessment addresses the key requirements of the Northern Territory EPA (NT EPA) and other NT Government agencies with jurisdiction over surface and groundwater management.

The relevant requirements in the *Final Terms of Reference* relating to water are listed in Table 1.1 and include the section of the report where they are addressed.

Table 1.1 Relevant guideline requirements

Requirement	Section addressed
Provide a detailed description of site and regional surface water catchments, waterways and swamps, including springs, in the vicinity of the proposed Project area and along access roads;	See Surface Water Assessment (Chandler Facility EIS)
Identify and assess risks to existing surface and groundwater quality and quantity as a result of the Project with specific reference to Project components.	Section 11 and Section 12
Identify and assess risks of potential discharge (i.e. spills, controlled/uncontrolled release, passive seepage) of contaminants (e.g. saline water, hydrocarbons, wastewater, hazardous materials) to surface and/or groundwater resources as a result of the Project components.	Section 4.1, Section 8.3 and Section 9
If groundwater extraction is proposed, outline potential impacts to vegetation and surface waterways (including any groundwater dependant ecosystems) from the drawdown of groundwater as a result of proposed extraction rates.	Section 9.4, Section 12.2 and 12.3
Identify and assess impacts of major weather events (e.g. 5 to 100 year average recurrence interval and extreme weather event (e.g. 100 year recurrence interval) on water management and infrastructure, including as relevant, flooding and/or storm surge.	Section 7.3
Associated with proposed infrastructure and disturbance of soils that may alter the hydrology, rates of erosion and sedimentation of surface waterways. Risk assessment should give consideration to the short, medium and long term timeframes of the Project.	Section 11.3, Section 13.1 and Section 13.2
A conceptual site model describing potential sources, pathways, receptors, and fate of any potentially contaminated waters from the Project is to be provided in the EIS. The model should be of sufficient detail for the general reader to understand the sources) of potential contaminants, the mechanism(s) of their release, the pathway(s) for transport, and the potential for human and ecological exposure to these potential contaminants.	Chapter 9
Describe proposed management of water for the Project for all mine-life stages and seasons, according to its source, quality, volume, end use or other parameters, including - Proposed management to contain contaminants on-site. - Water quality thresholds triggering management actions. - Description of any site surplus water volumes, and proposed management. - Management of stormwater, erosion and sediment loads during seasonal and extreme rainfall events.	See Water Management Plan and Erosions and Sediment Control Plan (Chandler Facility EIS)
Provide a draft Water Management Plan	See Water Management Plan (Chandler Facility EIS)
Discuss the sensitivity and significance of site and regional surface water resources from an ecological, public/social and economic perspective, including a description of water quality and flows, and any existing surface water users;	See Surface Water Assessment (Chandler Facility EIS)
Provide a description of site and regional groundwater resources, quality and significance in the vicinity of the proposed mining areas and their connectivity with surface waters;	Section 7.3 and Section 8
Describe site (and, if relevant, regional) hydrogeology to enable the prediction of potential impacts of the proposal on vegetation adjacent to mining areas, including drawdown cones and pollution pathways;	Section 8 and Section 10
Include a conceptual baseline groundwater model of regional aquifers investigating their size and location and the effect of drawdown on flow rate, water quality, recharge ability and any dewatering activity etc; and	Section 8
Include the location of groundwater bores for the project with respect to any groundwater dependent natural features.	Section 7.3

1.3 Objectives and scope of assessment

EMM Consulting Limited (EMM) was commissioned by Tellus to assess potential water impacts from the construction and operation of the Proposal. The key objectives of the assessment are to:

- identify and assess potential impacts on groundwater and surface water from the development of the Proposal;
- satisfy the *Final Terms of Reference* and other relevant agency requirements relevant to groundwater and surface water impact assessment; and
- inform the wider community about the Proposal and its potential impacts on the local and regional water environments.

To achieve these objectives, the water assessment:

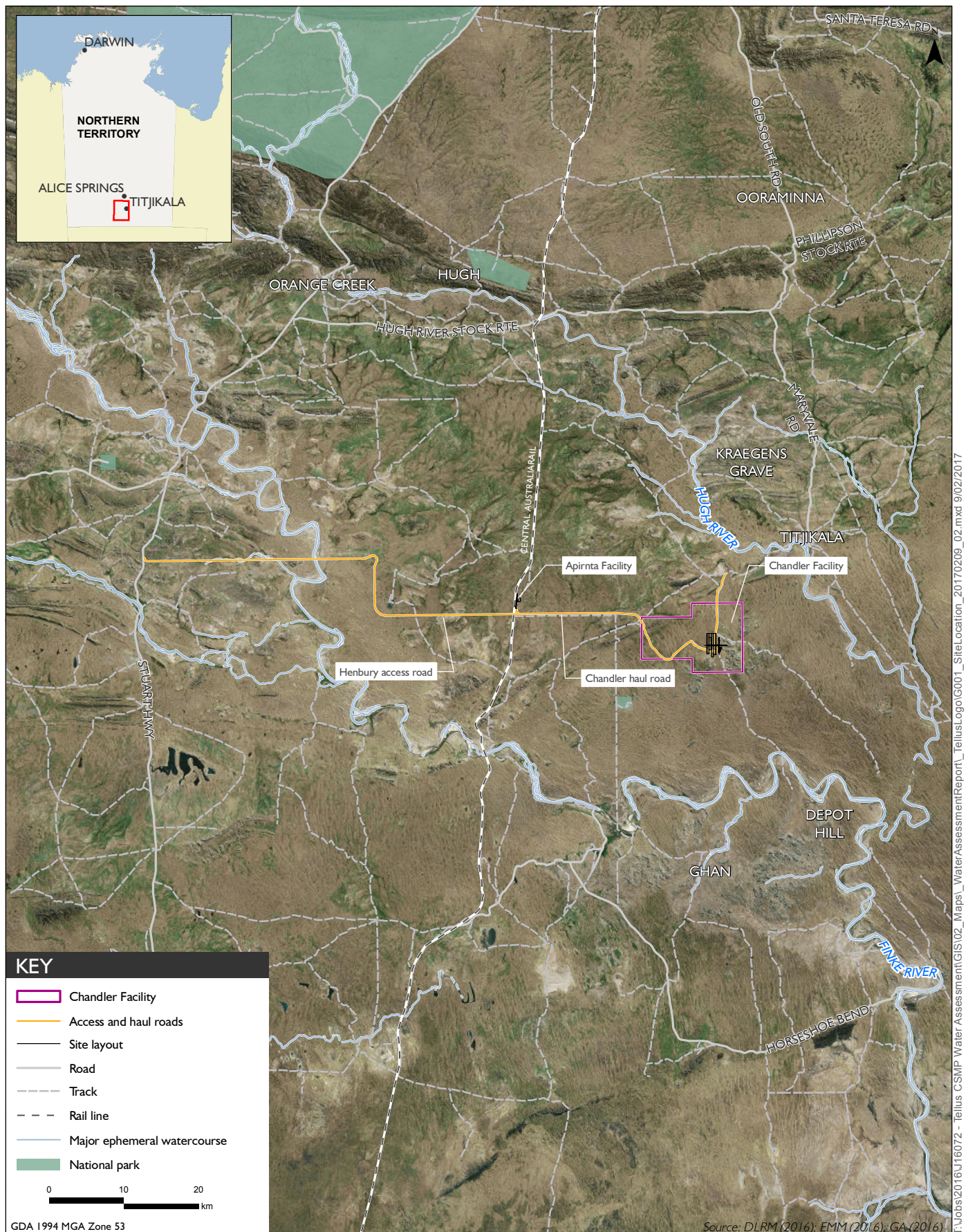
- assesses the existing hydrological and hydrogeological environments using a risk based approach, and baseline conditions within the Proposal area and its surrounding area;
- identifies and quantifies the potential risks and impacts of the Proposal on the current surface water and groundwater resources, and on the water users both environmental and extractive (including cumulative impacts);
- proposes mitigation and management measures, and monitoring requirements for surface water and groundwater; and
- discusses water licensing requirements in accordance with the relevant legislation.

1.4 Report structure

The structure of this report is as follows:

- Chapter 1 provides an introduction to the water assessment, including an overview of the Proposal, and the purpose and scope of the water assessment;
- Chapter 2 provides an overview of the relevant legislation, policies and guidelines to the Proposal area;
- Chapter 3 provides a description of the Proposal, including site water management;
- Chapter 4 outlines an overview of the impacts assessment methodology;
- Chapter 5 describes the regional and local setting of the assessment area, including climate, topography, land use, surface water, geology, hydrogeology and water dependent ecosystems;
- Chapter 6 provides an overview of the field investigation programs;
- Chapter 7 describes the regional and Proposal area surface water resources in detail, including surface water levels and quality;

- Chapter 8 describes the regional and Proposal area groundwater resources in detail, including hydrogeological units, groundwater levels, head pressure gradients, hydraulic conductivity and geochemistry;
- Chapter 9 outlines the site conceptual model for surface water and groundwater;
- Chapter 10 provides an overview of the site water balance and the water budget;
- Chapter 11 discusses the Proposals potential impacts on local and regional surface water resources, surface water users and potential surface water availability to ecosystems;
- Chapter 12 discusses the Proposals potential impacts on local and regional groundwater resources, groundwater users and potential groundwater availability to ecosystems;
- Chapter 13 outlines the mitigation and management measures, and monitoring requirements for surface water and groundwater, including a water management plan; and
- Chapter 14 provides the conclusions of the water assessment.



Location of the project area

Chandler Facility
Water Assessment

Figure 1.1

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2 Approval framework/Regulations, policies and guidelines

This Chapter outlines relevant Northern Territory (NT) and Commonwealth environmental legislation regarding management of surface and groundwater resources in relation to the Proposal.

2.1 Northern Territory legislation

2.1.1 Water Act

The NT *Water Act* 2013 (*Water Act*) is the primary legislation regulating groundwater and surface water resources in the NT and is administered by the Department of Environment and Natural Resources (DENR). The *Water Act* provides the legislative framework for water planning and entitlements for most water resources in the NT, and for the investigation, allocation, use, control, protection, management and administration of surface water and groundwater resources.

Mining activities (as defined by the *Mining Management Act* 2001) are, however, exempt from the requirements of the *Water Act*. The take of groundwater and/or surface water for mining activities or the discharge of water within mining tenements are authorised under the *Mining Management Act*. It is understood that changes to the *Water Act* were proposed by the NT government to remove the exemption of mining activities located within declared or proposed Water Allocation Plan areas. These changes have not yet been enacted. Water Allocation Plan areas can be developed within the defined Water Control Districts.

There is currently no declared or proposed Water Allocation Plan or a Water Control District over the Proposal area. As such, it is understood that the Proposal would be exempt from the *Water Act* and no licences or authorisation relating to groundwater or surface water management under the *Water Act* would be required.

The exception to the rule is in a case where water pollution emanates from a mining operation onto land that is not part of the mining title. This would be regulated under the *Water Act* and a waste discharge licence, with set water quality requirements, would be required. The Proposal will not be discharging waste water and therefore will not require a waste discharge licence.

2.1.2 Mining Management Act

The *Mining Management Act* 2001 was established to ensure the development of the NT's mineral resources in accordance with environmental standards consistent with best practice in the mining industry (*Mining Management Act*, Section 3(a)). The *Mining Management Act* aims to protect the environment by establishing a system whereby mining activities that will result in a substantial disturbance of the ground require an Authorisation. This act is administered by the Department of Mines and Energy (DME).

Activities authorised with a mining title under the *Mining Management Act* that are exempt from the *Water Act* are authorised to use water in the title area. This includes the right to take or divert naturally occurring surface water and extract groundwater. In these cases, there are no restrictions on the amount of water that can be used.

Under the *Mining Management Act*, operators of mines are also required to implement and maintain a management system for the site (as described in a Mining Management Plan). The Mining Management Plan describes the environmental management structure, environmental commitments, monitoring programs, rehabilitation and closure planning, and includes water management requirements.

The *Mining Management Act* also requires payment of security to provide for the rehabilitation of Mineral Leases or to rectify environmental harm caused by mining activities.

The project will be assessed under the *Mining Management Act*.

2.1.3 Northern Territory Environment Protection Authority Act

The *Northern Territory Environment Protection Authority Act* establishes the NT EPA as an independent authority with duties and functions under the *Waste Management and Pollution Control Act 1994* and the *Environmental Assessment Act*.

2.1.4 Environmental Assessment Act

The *Environmental Assessment Act* and the *Environmental Assessment Administrative Procedures* establish the framework for the assessment of potential or anticipated environmental impacts of development, and provide for protection of the environment, including water resources, water quality and resource management.

In March 2013, following determination by the Australian Government under the *Environment Protection and Biodiversity Conservation Act 1999*, the Northern Territory Environment Protection Authority (NT EPA) decided that the project requires assessment under the NT *Environmental Assessment Act* at the level of EIS. In 2016, a variation to the 2013 Notice of Intent was reviewed by the two levels of government. The variation did not alter the level of assessment required for the Proposal.

2.1.5 Waste Management and Pollution Control Act

The *Waste Management and Pollution Control Act* was established to ensure the protection, and where practicable to restore and enhance the quality of, the Northern Territory environment. The Act is the primary piece of environmental protection legislation in the Northern Territory and is administered by the NT EPA. The Act:

- imposes general environmental duties;
- requires the licensing of certain activities;
- establishes offences relating to the environment; and
- contains material enforcement, penalty and extension of liability provisions.

The Act does not apply to a contaminant or waste resulting from a mining activity (covered in Mining Management Act) that is confined within the land on which the mining activity is being carried out.

2.2 Australian Government legislation

2.2.1 Environment Protection and Biodiversity Conservation Act 1999

Under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), actions that are likely to have a significant impact on a matter of national environmental significance are assessed. The Australian Government Department of the Environment and Energy (DoEE) is responsible for administering the Act. Matters considered to be of national environmental significance include World Heritage properties, National Heritage places, threatened species and ecological communities, migratory species, wetlands of international importance ('Ramsar' wetlands), and water resources, in relation to coal seam gas development and large coal mining development.

A referral and assessment process determines the application of the EPBC Act. The first step in this process is referral of the project to DoEE. The project is then assessed for the potential for impacts upon matters of national environmental significance, and if this is likely, to establish the significance of these impacts. If it is determined that there will be, or there is likely to be, a significant impact to a matter of national environmental significance the project is declared to be a controlled action and will require formal assessment under the EPBC Act.

As there are no Ramsar wetlands in the region of the project nor is it a coal seam gas or large coal mining development, assessment under the EPBC Act is therefore not required in relation to impacts to water resources.

On 17 December 2012, the project was referred to the Australian Government for consideration under the EPBC Act. On 21 February 2012, a delegate for the Minister for Sustainability, Environment, Water, Population and Communities determined that the project is a controlled action for impacts on listed threatened species and communities, not specifically in relation to water resources. The project will be assessed by an EIS in accordance with the bilateral agreement between the NT and Australian governments.

2.3 Commonwealth policies and guidelines

2.3.1 Australian Groundwater Modelling Guidelines

The *Australian Groundwater Modelling Guidelines* (NWC 2012) were developed to provide a consistent and sound approach for the development of numerical groundwater flow modelling in Australia. The importance of developing a robust conceptual model is a key aspect of modelling and measured groundwater data is used to conceptualise and describe both quantitatively and qualitatively all observed groundwater behaviour in the region. Groundwater level data is used to calibrate a numerical groundwater model, until there is acceptable agreement between model estimated and actual groundwater levels.

The guidelines provide a confidence-based classification system which defines three different classes of model. Class 1 has limited confidence in model estimates while Class 3 has high confidence. The guidelines provide information on the data requirements for each model class, such as spatial distribution of bores and temporal groundwater level data.

As per the Terms of Reference, a site conceptual model has instead been developed and is presented in Section 8. The site conceptual model has been developed in accordance with the Australian Modelling Guidelines (NWC 2012). A numerical groundwater model has not been developed in support of this EIS as water impacts are not likely to occur and such a model was required under the Terms of Reference.

2.3.2 Australian and New Zealand guidelines for fresh and marine water quality

The Australian and New Zealand guidelines for fresh and marine water quality (ANZECC/ARMCANZ 2000) set out the framework for the application of water quality guidelines. These guidelines describe requirements over a variety of marine and freshwater environments, aquatic ecosystems, primary industries, recreational water, drinking water and monitoring and assessment. The guidelines provide an authoritative guide for setting water quality objectives for natural and semi-natural water resources in Australian and New Zealand sustaining current or likely future environmental values (uses).

The guidelines were used when assessing the baseline groundwater quality for the Proposal (see Section 7.2.4).

3 Proposal description

3.1 Proposal schedule

The Proposal will comprise a three-year construction period and a subsequent one-year commissioning period. Following this period Tellus is seeking approval and an operating licence for the project for a 25-year period (although it is likely this period of time will extend well beyond 25 years). Following the cessation of mining and waste disposal, rehabilitation and institutional control would follow for a period of time. A conceptual Proposal operational life-cycle has several key milestones as described in Table 3.1.

Table 3.1 Proposal life-cycle

Year	Activity
1	At the conclusion of Year one, the completion of enabling works will allow for the establishment of the mine camp. In addition, preparations for the construction of the Apirnta Facility will begin.
5	Transportation of waste by rail to the Apirnta Facility will commence. Waste will be temporarily stored at the Apirnta Facility during the construction of the Chandler Facility. During this period, run-of-mine (ROM) salt will be brought to surface and temporarily stockpiled at the Chandler Facility. Once the Chandler Facility achieves adequate capacity for waste storage, waste will be transferred by road from the Apirnta Facility to the Chandler Facility and emplaced into specially designed waste rooms.
10	Salt mining continues at an average rate of 500,000 tonnes per annum (t/yr). Waste emplacement averages 340,000 T/yr.
25	At the completion of year 25, an upper limit of 12,500,000 T of salt will have been mined, and up to 8,500,000 T of hazardous, intractable waste would have been permanently isolated within the Chandler Facility. In the event that Tellus discontinue operations, the shaft and decline will be backfilled and sealed in accordance with the Mine Closure Plan. Following closure, the post-closure monitoring requirements will commence. Alternatively, Tellus will apply for an extension to the existing approval and, if approved will continue mining and waste storage operations.
35	Post-closure environmental monitoring ceases.
45	Relinquishment of tenements under the Mine Management Act. All mining-related infrastructure will be decommissioned and surfaces revegetated in accordance with the Mine Closure Plan and Rehabilitation Plan. Transfer of the management of the Chandler Facility and Apirnta Facility to the NT Government along with financial provision for the management of the Facility's during the institutional control period.
45+	NT Government controls the Facility for the institutional control period.

3.2 Proposal area

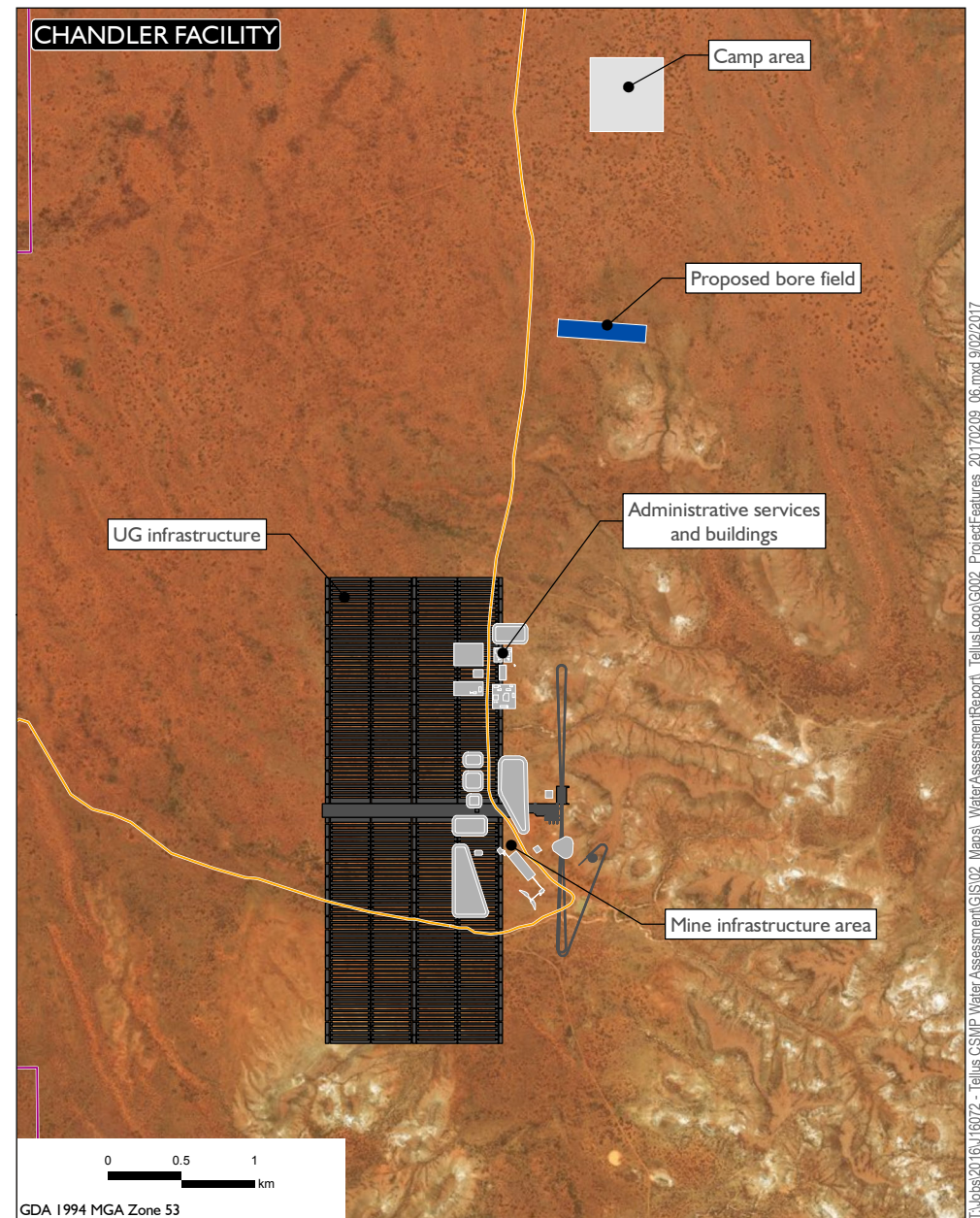
The above ground and below ground Proposal area is approximately 405 and 1,162 hectares (ha) respectively, and includes the following key Proposal features (see Table 3.2 and Figure 3.1).

The land directly disturbed by the Proposal is referred to as the disturbance area. For some Proposal features in the Proposal area (ie haulage and access roads), a larger area has been surveyed than would actually be disturbed. This enables some flexibility to account for changes to the design plans that may occur during detailed design. The Proposal area and disturbance area for each Proposal feature are included in Table 3.2.

Table 3.2 Proposal area and disturbance area

Proposal element	Proposal area (ha) ¹	Disturbance area (ha)
Chandler Facility (underground infrastructure)		
ROM ² salt surface conveyors	1	1
Room and pillar excavation	361	361
Ventilation and access shafts	41.1	41.1
Reclaimer system	2.5	2.5
Sub-total	405.6	405.6
Chandler Facility (above ground infrastructure)		
Mine infrastructure	163.8	163.8
Mine accommodation camp	0.5	0.5
ROM salt stockpile	25	25
Power generation (diesel/gas/solar field)	4	4
Spoil storage piles	5	5
Fire break	15	15
Sub-total	213.3	213.3
Apirnta Facility		
Rail siding	9	9
Storage and transfer facility	30	30
Sub-total	39	39
Road infrastructure		
Henbury Access Road	180	600
Chandler Haul Road	93	310
Sub-total	273	910
Total land requirements (above/below ground)	930.9	1,567.9

Notes: 1. ha=hectares.
2. ROM=Run of mine.



3.3 Proposal features

An overview of the key Proposal features with water demand requirements have been summarised in the sections below.

3.3.1 Chandler Facility – surface infrastructure

The surface infrastructure area will include the following key areas;

- soil and overburden stockpiles;
- salt stockpiles;
- a dry processing area, maintenance areas and workshops, truck load-out area, administration offices and amenities;
- groundwater management infrastructure, including raw/potable water supply borefields, monitoring bores and associated pumps, pipelines and a water treatment plant;
- surface water management infrastructure;
- services and utilities infrastructure (eg solar infrastructure);
- internal paved access roads; and
- other ancillary equipment and infrastructure.

A water supply borefield will be constructed to facilitate the construction of the surface infrastructure area, decline and ventilation shafts. The borefield will initially consist of two to four production bores (likely targeting the Langra Formation) at a depth of approximately 150 m Below Ground Level (BGL). Untreated water will be pumped to storage retention dams and used for grout mixing, drill operations and dust suppression activities. A second borefield (of up to four bores) may be constructed closer to the mine camp and will provide a potable water supply for drinking and ablution. The potable water supply borefield will target shallow alluvial/colluvial deposits and/or the Upper Langra groundwater system. Water will then undergo treatment prior to storage in above-ground tanks.

3.3.2 Chandler Facility – underground infrastructure

i Underground mine

The underground mine will be excavated to the target salt bed at an approximate depth of 800 m BGL. The mine will be a conventional room and pillar design, and composed of multiple passages running in parallel along a horizontal plane and separated by pillars of unmined material. Each passage will be nominally 250 m long, 15 m wide and 6 m high. Each passage will be subdivided into rooms that would allow separation of waste types according to zoning criteria.

The underground mine will be fitted with a conveyor system to transfer ROM salt to the surface. The underground mine will also be fitted with amenity services (see sections below).

A dedicated underground services area will also be established near the bottom of the mine vertical shafts. The services provided in this area will include personal amenities, lunch room, maintenance services and storage areas including a 5.5 kilolitre fuel storage bay.

ii Mine access decline

Construction of the decline will commence by drill and blasting into an existing rock outcrop on Maryvale Hills. This technique will effectively create what is known as a *portal entrance* from where the decline would commence.

The mine access decline will comprise a sloped tunnel approximately six km in length connecting the surface to the underground mine. The mine access decline will be the main transport route for waste containers entering the underground mine and waste rock leaving the underground mine.

The mine access decline will also host fans and coolers to bring fresh air to the underground mine.

iii Mine vertical shafts

The vertical shafts will include a main shaft and a secondary shaft. The shafts would intersect the mine access decline and terminate at the underground mine (see Figure 3.2).

The main shaft will be divided into three vertical compartments: a main compartment, counterweight compartment and auxiliary compartment.

The main compartment will hold a container used to convey ROM salt, while the counterweight compartment will regulate its movement. The auxiliary compartment will be used to transport workers to the underground mine. The compartment will split into two floors that could transport up to six workers per floor.

The main shaft will also reticulate utilities and services such as raw water, power and communications and would provide fresh air to the underground mine. The secondary shaft will draw dirty air from the underground mine to the surface.

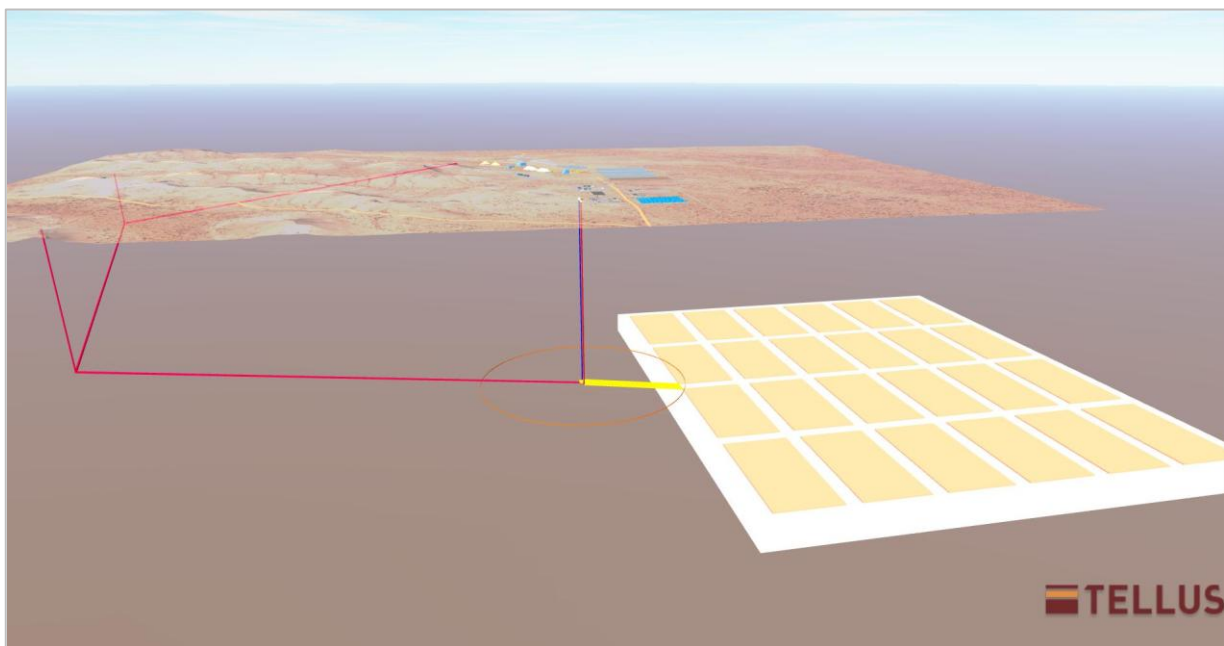


Figure 3.2 Proposed underground layout of the Chandler Facility

3.3.3 Apirnta Facility

The Apirnta Facility will be located on Henbury Estate approximately 31 km west of the Chandler Facility. The temporary storage facility will occupy an area of approximately 30 ha. At capacity, the Apirnta Facility will be able to be loaded with approximately 400,000 T of waste material.

The Apirnta Facility will be used to temporarily store waste material prior to transportation via the Chandler Haul Road.

The Apirnta Facility will include a number of key infrastructure components, including:

- rail siding;
- loading bays;
- vehicle weighbridge;
- storage warehouse;
- open storage yard;
- liquid waste tank;
- quarantine area;
- laboratory;
- office buildings;
- maintenance shed; and
- access road.

The facility will also be appropriately design with stormwater drainage and will be connected to essential services including electricity, water and sewerage.

3.3.4 Transport infrastructure

The transport of product, supplies and workers to and from the Chandler Facility during the construction and operations stages of the Proposal will be facilitated through enhanced road and rail improvements. Two haulage/access roads are proposed for the Proposal; Chandler Haul Road and Henbury Access Road. These are described below and shown on Figure 3.1.

i Road access/haulage

The Chandler Haul Road will be approximately 31 km long and 30 m wide and connect the Apirnta Facility to the Chandler Facility. The proposed Chandler Haul Road will be upgraded during the construction phase of the Proposal to enable the safe and controlled transportation of salt and waste product to and from the Chandler and Apirnta Facilities. Five groundwater production bores will be located along the haulage road and will supply water for dust suppression demands during construction and operation.

The Henbury Access Road will be approximately 60 km long and 30 m wide and connect the Apirnta Facility to the Stuart Highway to the west and through to the Chandler Facility via the Chandler Haul Road. The proposed Henbury Access Road will be upgraded during the construction phase of the Proposal to enable the safe and controlled transportation of works travelling to and from site.

In addition to the external haul and access roads there will be a network of smaller internal access roads within the bounds of the Chandler Facility. The access roads will be paved and approximately 10 m wide.

ii Rail siding

The rail siding (Apirnta Siding) will be a private 1.8 km rail siding and constructed adjacent to the existing Adelaide to Darwin railway. The siding will act as a transshipment point for outgoing salt and incoming waste.

Incoming materials will be transported in sealed shipping containers and off-loaded from rail wagons at the Apirnta Siding for transfer to the Apirnta Facility.

Outgoing salt stored and shipping containers and received from the Chandler Facility will be loaded onto empty rail wagons for transportation to Adelaide Port.

3.4 Site water management

Site water management is necessary during all phases of the Proposal construction and operation and will encompass:

- meeting site water demands for mining and processing operations, and potable needs;
- storage and containment of runoff from disturbed areas;
- management of intercepted groundwater during construction of the decline and ventilation shafts; and
- water related infrastructure, including pumps and pipes.

The water management system for the Proposal includes the management of both site surface water and extracted groundwater. The surface water management system will be designed to manage surface water flows on site according to catchment areas and associated water quality. The groundwater management system forms part of the overall site water balance, and inputs into the surface water management system.

3.4.1 Water sources

The proposed strategy for the management of water is based on the separation of water from different sources based on anticipated water quality, as follows:

Water sources would include:

- surface water generated by direct rainfall within the surface water catchment areas in the Chandler Facility surface infrastructure area, transport and water storage facility areas. This will be separated into mine affected water and sediment laden water;

- saline groundwater will be captured, contained and will enter into the mine water management system for reuse and or treatment. This water will be sourced from:
 - groundwater inflows collected during the construction of the decline/ventilation shafts; and
 - groundwater extracted as a water supply source from deep bores.
- fresh-brackish groundwater abstracted from shallow groundwater systems will be contained and managed to be used as a potable supply.

Surface water runoff from undisturbed areas will be diverted, wherever possible, around areas disturbed by mining and released from the site, minimising the capture of clean surface runoff.

Sewage at the Proposal area will be managed in two ways:

- for areas with high density of personnel (ie process plant area and accommodation facility), a package waste treatment system will be used, which will require occasional pumping out of sludge; and
- for ablutions located in areas with low or infrequent use, untreated waste will be collected in septic tanks which will be emptied by tanker as required.

3.4.2 Groundwater abstraction

Groundwater will be abstracted for two purposes:

- raw water supply; and
- potable water supply.

i Raw water supply

Raw water will be abstracted to service three key Proposal activities:

- Mining operations;
- Chandler Facility dust suppression, drilling and construction demands; and
- Chandler Haul Road/Apirnta Facility dust suppression, wash-down and construction demands.

A borefield will be sited to the north-east of the decline entrance and will target the Langra groundwater system at a depth of approximately 150 m BGL. Bores will be spaced at a distance of approximately 200 m and connected to electro-submersible pumps. Abstracted water will be gravity fed to a water storage retention dam.

A series of production bores will be sited at approximately eight km intervals along the Chandler Haul Road, with two additional production bores, one at each end of the Chandler Haul Road. Bore depths will vary between 50-150 m BGL and will target a combination of the Langra and Stairway Sandstone groundwater systems. Bores will be operated on a throttled float system to pump groundwater to above-ground storage tanks when the water level in the storage tanks drops below 50% capacity. Water carts will connect to the storage tanks as required along the Chandler Haul Road.

ii Potable water supply

To meet the camp accommodation and drinking water demand, two large diameter (approximately ≥ 250 mm diameter) production bores will be constructed to the north-east of the mine decline, nearby to the proposed camp accommodation site.

Extracted groundwater will be piped to a site water treatment plant. Water will then be treated to Australian Drinking Water Guidelines (NHMRC 2011). The system will likely comprise the following treatment processes:

- staged microfiltration;
- reverse osmosis (or dilution);
- carbon filtration;
- chlorination;
- water softening; and
- ultra violet disinfection.

Treated water will then be stored in two enclosed steel tanks with a combined capacity of 40,000 litres (L).

Following use, grey water will be reticulated back through the water treatment plant. Tellus have set a 50% recycled water target.

3.4.3 Water storage infrastructure

The proposed water storage infrastructure included in the Water Management System (WMS) are listed in Table 3.3. All dams will be clay lined to prevent leakage.

Table 3.3 Water storage infrastructure

Dam	Description
Setting dam	Two settling dams will be constructed in the south and north of the Chandler Facility's surface infrastructure area. Excess water collected during runoff will be directed to the sedimentation dams to allow sediment to settle out of solution.
Main water storage dam	The main dam will store a component of dewatered saline groundwater for use in dust suppression.
Evaporation pond	Dewatered saline groundwater will be directed to the evaporation pond. The evaporation pond will be clay lined to reduce infiltration.
Water treatment storage tanks	Two 20,000 L water storage holding tanks will collect treated water. One tank will be located adjacent to the Administration and Maintenance area, the other will be located adjacent to the accommodation facility.
Runoff collection drains	A series of runoff collection drains will be constructed around the Chandler Facility to ensure surface water runoff is appropriately controlled and prevented from interacting with surface infrastructure. Drains will direct runoff to one of the two sedimentation dams.

3.4.4 Water demands

The operational water demands for the Proposal are summarised in Table 3.4.

Table 3.4 **Operation phase water demands**

Demand	Water type	Average volume (ML/year) ¹	Source
Dust suppression			
Overburden/ore removal	Saline	43	Saline groundwater
Chandler haul roads, service roads			
Light vehicle roads			
Process water			
Process plant demand	Saline	46.9	Saline groundwater
Wash down bays	Non-saline	2	Potable groundwater
Workforce consumption			
Personnel – potable	Potable	14	Potable groundwater
Personnel – toilet and non-drinking	Non-saline	Reticulated	Reticulated from potable groundwater
TOTAL DEMAND	Saline	89.9	Saline groundwater
	Potable	16	Potable groundwater

Notes: 1.ML/year=megalitres per year.

4 Assessment of risks

This water assessment examines the construction and use of site infrastructure, dewatering, mining, and on-site water storage.

4.1 Risk register

The Chandler Water Assessment operates a risk assessment approach throughout the document and is designed to assess all potentially direct and indirect impacts to water resources through the construction and operation of the Proposal.

A list of potential risks arising from the construction and operation of the Proposal has been provided below.

Table 4.1 Chandler risk register

Hazard	Aspect/Descriptor	Proposal stage
Surface water	Surface water ingress to mine decline and ventilation shafts	Construction, operation, closure
Surface water	Contaminated surface water runoff	Construction, operation, closure
Surface water	Livestock contamination	Construction, operation
Surface water	Salt dissolution	Construction, operation
Surface water	Flooding	Construction, operation, closure
Surface water	Surface erosion	Construction, operation
Surface water	Reduction in ecosystem health	Construction, operation
Surface water	Dilution of solar evaporation ponds	Construction
Groundwater	Contamination of alluvium and Horseshoe Bend Shale groundwater system	Construction, operation
Groundwater	Contamination of Langra groundwater system	Construction, operation
Groundwater	Contamination of Stairway Sandstone groundwater system	Construction, operation
Groundwater	Contamination of Jay Creek Limestone groundwater system	Construction, operation
Groundwater	Contamination of Titjikala water supply	Construction, operation
Groundwater	Contamination of Arafura water supply	Construction, operation
Groundwater	Contamination of Alice Springs water supply	Construction, operation, closure
Groundwater	Contamination of Horseshoe Bend Spring	Construction, operation
Groundwater	Groundwater inflows to ventilation shaft, decline and mine	Construction, operation
Groundwater	Groundwater inflow during exploration drilling	Construction
Groundwater	Over abstraction arising from construction and operational water demands	Construction, operation
Groundwater	Reduced baseflow arising from Proposal dewatering and groundwater abstraction	Construction, operation
Groundwater	Dissolution of Chandler Formation	Construction, operation, closure
Groundwater	Reduction in ecosystem health	Construction, operation
Groundwater	Dewatering of regional groundwater systems	Construction, operation

4.1.1 Sensitive receptors

A complete list of key sensitive receivers, their source of water and the potential impact has been listed in Table 4.2 and are discussed in Sections 7 and 8.

Table 4.2 Key sensitive receptors

Receptor	Water source	Potential impact	
Key surface water features			
Finke River	Rainfall-catchment runoff	a)	reduction in flow arising from drainage diversions;
Hugh River		b)	contaminated surface water runoff.
Cox Creek			
Groundwater supplies			
Rocky Hill borefield	Mereenie Aquifer System	a)	contamination of water supply due to derailment of waste designated for mine storage; and
Roe Creek borefield	Mereenie Aquifer System	b)	impact to water supply.
Titjikala water supply	Titjikala groundwater system	a)	impact to water supply.
Idracowra stock water supply	Alluvium		
Surface water supplies			
Halfway Dam	Rainfall-catchment runoff	a)	destruction of dam during construction of Chandler Facility.
Springs			
Pascoes Spring	Amadeus Basin	a)	reduced flow due to construction and operation dewatering impacts; and
Horseshoe Bend Spring		b)	contamination arising from waste storage leakage.
Polly’s Spring			
Black Hill Spring			
Micks Spring	Eromanga Basin	a)	reduced recharge to Pedirka and/or Eromanga Basin from Finke River arising from surface erosion and flow diversions; and
Dalhousie Spring complex		b)	contaminated surface water runoff to Finke River discharging to Pedirka and/or Eromanga Basin.
Riparian vegetation			
River Red Gum woodland (<i>Eucalyptus camaldulensis</i> var. <i>obtusa</i>)	Alluvium – combination of interflow and perched groundwater	a)	contamination of alluvial groundwater systems via infiltration of mine surface water runoff; and
Coolabah woodland (<i>Eucalyptus coolabah</i> subsp. <i>arida</i>)		b)	dewatering of shallow groundwater systems.

5 Regional environment

5.1 Literature review

A literature review, drawing on a number of publicly available published geotechnical and hydrogeological reports has been undertaken to conceptualise the regional environment. The review has a particular focus on groundwater and surface water environments across the south-east of the Northern Territory and the north-west of South Australia. A summary of the critical information sources is included in Table 5.1.

Table 5.1 Summary of critical information sources

Reference	Subject	Location	Comments
Lloyd and Jacobson (1987)	The Hydrogeology of the Amadeus Basin, Central Australia	Amadeus Basin, Northern Territory	Conceptualises the hydrogeology of the Mereenie Aquifer System and its relationship with the fractured sandstone groundwater systems in the south-east of the Amadeus Basin
Wohling <i>et al</i> (2013)	Arckaringa Basin and Pedirka Basin, Groundwater Assessment Projects	Pedirka Basin, South Australia	Conceptualises the hydrogeology of the Pedirka Basin and its relationship with the Amadeus Basin and Finke River, and also the Eromanga Basin
Wells <i>et al</i> (1970)	Geology of the Amadeus Basin, Central Australia	Amadeus Basin, Northern Territory	Characterises the regional geology across the Amadeus Basin and postulates recharge mechanisms to the Mereenie Aquifer System and Permian deposits of the Pedirka Basin
Wolaver <i>et al</i> (2013)	Chapter 6: Hydrogeology of Dalhousie Springs	Western margin of the Pedirka Basin, South Australia	Presents hydrogeochemical evidence to suggest that spring water at Dalhousie Springs may be supplied in part by groundwater from the Eromanga Basin and the Pedirka Basin (but not the Amadeus Basin)
Duguid <i>et al</i> (2005)	Wetlands in Arid Northern Territory	Finke River catchment, Northern Territory	Describes the key surface water features across the Northern Territory, with a particular focus on the Finke River catchment. Details the geomorphological evolution of a number of major drainage basins across central and south-eastern Northern Territory
Jolly <i>et al</i> (1994)	Hydrogeology of the Roe Creek Borefield	Northern Amadeus Basin, Northern Territory	Characterises the hydrogeology of the Mereenie Aquifer System, with a focus on the Roe Creek Borefield
Read <i>et al</i> (1998)	Rocky Hill-Ooraminna Groundwater Investigation	Northern Amadeus Basin, Northern Territory	Describes the geometry of the northern Amadeus Basin and explores the significance of the Hermannsberg Sandstone groundwater system within the Mereenie Aquifer System
Jolly <i>et al</i> (2005)	Alice Springs Water Resource Strategy 2005	Northern Amadeus Basin, Northern Territory	Conceptualises the northern Amadeus Basin, providing groundwater storage estimates within the Mereenie Aquifer System

5.2 Topography

The southern region of the NT, where the Proposal is located, is characterised by rolling hills and dunes, and sand ridges. However, the general area of the Proposal is bisected by a number of orogenic mountain belts (ie created by tectonic activity) to the north, east and west.

The James Ranges and the Oliffe Ranges, a series of west-east trending ridgelines, rise to 788 m Australian Height Datum (AHD) and 428 m AHD respectively to the north of the Proposal area. These ridgelines lie at the southern edge of the Orange Creek Syncline and are predominantly composed of basement rock.

To the east of the Proposal area lies the Rodinga Ranges and the Pillar Range, a series of south-west to north-east trending ridgelines that rise to a maximum height of 350 m AHD.

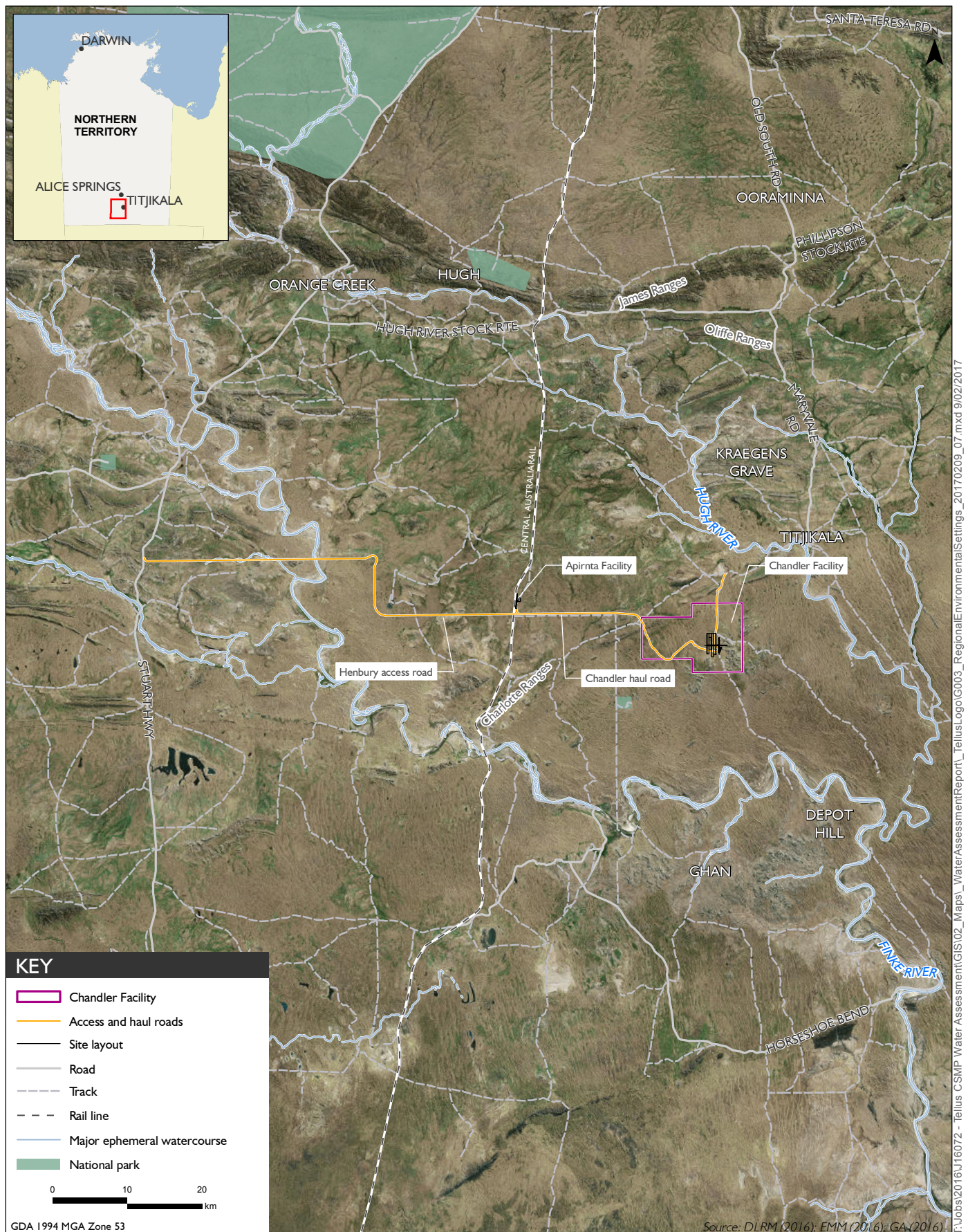
The Charlotte Range and the Maryvale Hills lie directly west of the Chandler Facility. These topographic highs interrupt the low lying areas dominated by sand dunes and flood plain deposits.

Plate 5.1 shows the low lying floodplain comprising alluvial and aeolian sediment, while the Maryvale Hills and the Charlotte Range may be distinguished in the distance.

Figure 5.1 shows the Proposal area and the local and key topographic ridgelines intersecting the local environment.



Plate 5.1 Vista from the Chandler Facility, facing west, toward the Maryvale Hills and Charlotte Range



Regional environmental setting

Chandler Facility
Water Assessment

Figure 5.1

5.3 Climate

Southern NT is characterised by a semi-arid to arid climate with hot dry summers and mild winters (Coffey 2012). Historic rainfall, temperature and evaporation data for the general area was acquired from the Bureau of Meteorology (BoM) for the Alice Springs Airport weather station (BoM: 015590), which is located approximately 113 km north of the Proposal area. The monthly rainfall and temperature dataset extends from January 1940 to July 2016. The mean daily evaporation record extends from 1959 to 2016.

Tellus Holdings also operate an automated weather station (AWS) at the proposed Chandler Facility. However, this meteorological dataset only extends from November 2015 and is, therefore, not used to define long term or seasonal climatic trends.

5.3.1 Rainfall

The BoM rainfall gauges in the general area are listed in Table 5.2. The nearest rainfall gauge to the Proposal area is located at Maryvale, approximately 21 km north-east of the Chandler Facility. Unfortunately, the record at Maryvale and adjacent sites contains a significant proportion of data gaps (>20% of missing data).

Data from BoM stations within 25 km of the mine site, namely Maryvale and Idracowra indicates that long term mean annual rainfall at the proposed mine site is likely to be approximately 204 millimetres (mm) (Table 5.3). Annual rainfall totals are highly variable from year to year and almost 50 percent of annual rainfall can occur within a single month, with rainfall greatest over the summer months and below regional averages during the winter months (see Figure 5.2).

The total annual rainfall recorded at the Alice Springs Airport weather station (BoM 015590) ranges from 76 mm to 782 mm (over the 74-year monitoring period), with an annual mean of 283.5 mm.

Table 5.2 Rainfall gauges

Gauge number	Name	Latitude	Longitude	Record start	Record end	Record length (years)	Distance from Chandler Facility (km) ¹	Mean Annual Rainfall (mm) ²
15519	Palmer Valley	24.75	133.23	1953	Open	63	74	253.5
15524	Idracowra	24.99	133.79	1950	Open	66	25	203.6
15536	Maryvale	24.67	134.07	1948	Open	68	21	205.3
15532	Henbury	24.55	134.25	1897	Open	129	77	224.2
15590	Alice Springs Airport	23.80	133.89	1940	Open	76	113	283.5

Source: Bureau of Meteorology, 2016.

Notes: 1.km=kilometres.

2.mm=millimetres.

Table 5.3 Mean monthly rainfall

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Alice Springs Airport (015590)												
40.7	43	31.2	17.2	18.9	13.5	15.3	8.8	8.1	20.5	28.4	37.9	283.5
Palmer Valley (015519)												
31.7	36.8	20.5	20.8	15.4	13	18.1	7.8	10.7	20.8	27.6	30.3	253.5
Idracowra (015524)												
25.4	26.1	20.6	13.9	16.7	12.8	12	7.9	7.6	15.8	19.4	25.4	203.6
Maryvale (015536)												
25.9	24.3	21.6	12.1	17.5	13.1	12.5	8.3	8	17	18	27	205.3
Henbury (015532)												
29.9	30.6	24.5	11.1	17.2	13.7	11	7.3	9.1	18	23.9	27.9	224.2

Source: Bureau of Meteorology, 2016.

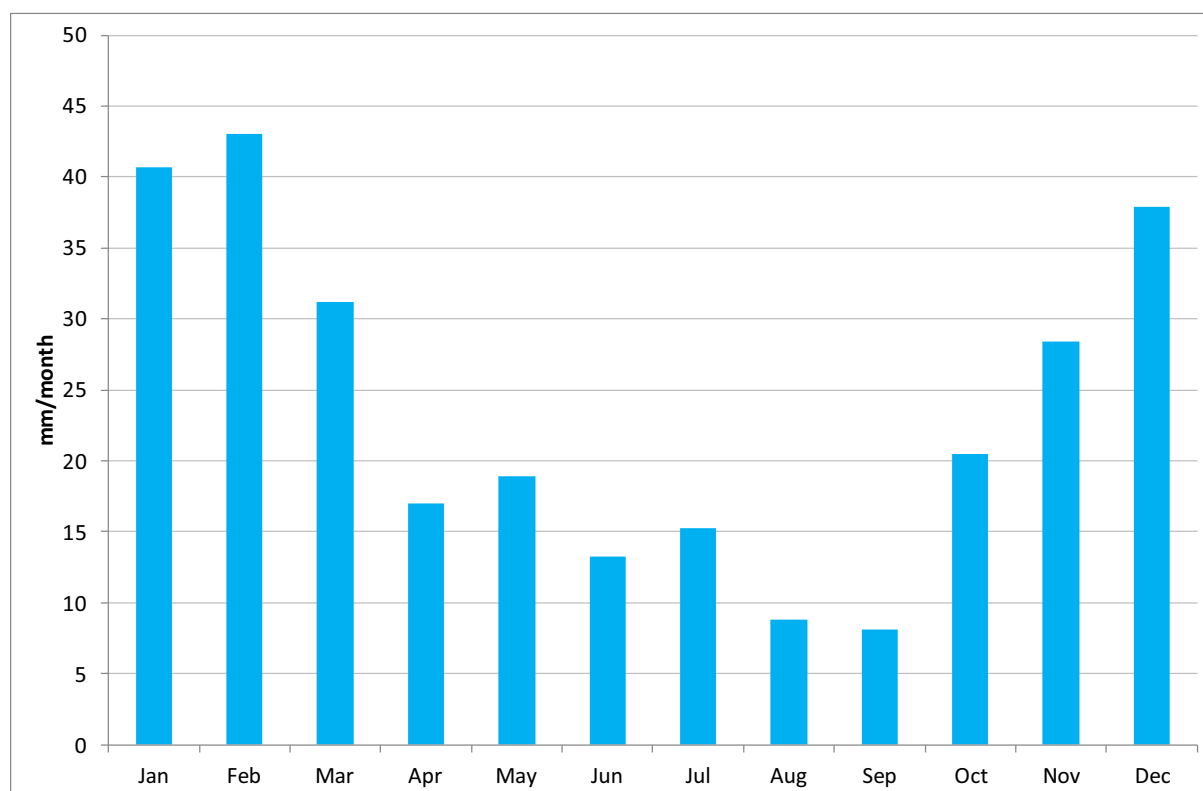


Figure 5.2 Monthly mean rainfall distribution Alice Springs Airport, Northern Territory (BoM: 015590)

5.3.2 Rainfall intensity

Average Recurrence Intervals (ARIs) have been determined by the BoM (Table 5.4). ARIs show predicted rainfall intensities for a range of storm durations and average recurrence intervals. For example, a 100-year ARI 24-hour rainfall intensity (7.4 mm/hr) is almost twice the 10-year ARI 24-hour rainfall intensity (3.87 mm/hr) and one eighth of the 100-year ARI 1-hour rainfall intensity (55.7 mm/hr). In general, higher rainfall intensity occurs over short durations, also higher rainfall intensity events are a less frequent occurrence than lower intensity rainfall events.

Table 5.4 Rainfall intensity – frequency – duration data

Units mm/hr	Frequency as an Average Recurrence Interval						
Duration	1 year (mm) ¹	2 year (mm)	5 year (mm)	10 year (mm)	20 year (mm)	50 year (mm)	100 year (mm)
5 mins	41.8	56.5	82.7	99.9	122	152	176
6 mins	39.0	52.7	77.2	93.2	114	142	164
10 mins	32.2	43.4	63.6	76.8	93.6	117	135
20 mins	24.1	32.5	47.4	57.2	69.4	86.5	100
30 mins	19.8	26.7	38.8	46.8	56.8	70.7	81.8
1 hr	13.3	18.0	46.3	31.7	38.6	48.1	55.7
2 hrs	8.37	11.3	16.9	20.5	25.1	31.5	36.7
3 hrs	6.25	8.51	12.8	15.7	19.3	24.4	28.5
6 hrs	3.75	5.15	7.93	9.83	12.2	15.6	18.4
12 hrs	2.28	3.15	4.93	6.17	7.72	9.94	11.8
24 hrs	1.42	1.97	3.08	3.87	4.84	6.24	7.4
48 hrs	0.885	1.22	1.89	2.36	2.94	3.78	4.47
72 hrs	0.639	0.879	1.37	1.71	2.13	2.74	3.24

Source: Bureau of Meteorology, 2016.

Notes: 1.mm=millimetres.

5.3.3 Evaporation

Characterising evaporative losses is important to understanding the mechanisms for groundwater recharge and the regional climatic conditions. Daily mean pan evaporation data is available from the Alice Springs Airport weather station (BoM 015590). Pan evaporation is a measurement that integrates several climatic elements, including temperature, humidity, rainfall, solar radiation, and wind. The Alice Springs Airport weather station has a reliable pan evaporation dataset extending from 1959 to 2016 (approximately 57 years) for comparison with historic rainfall for the area.

The annual average pan evaporation measured at the station is approximately 3,147 mm, more than ten times the annual average rainfall (see Figure 5.3).

The greatest evaporation rates occur from October through to March, as evaporation is significantly influenced by temperature and solar radiation over the summer period. On average, evaporation exceeds rainfall in each month of the year.

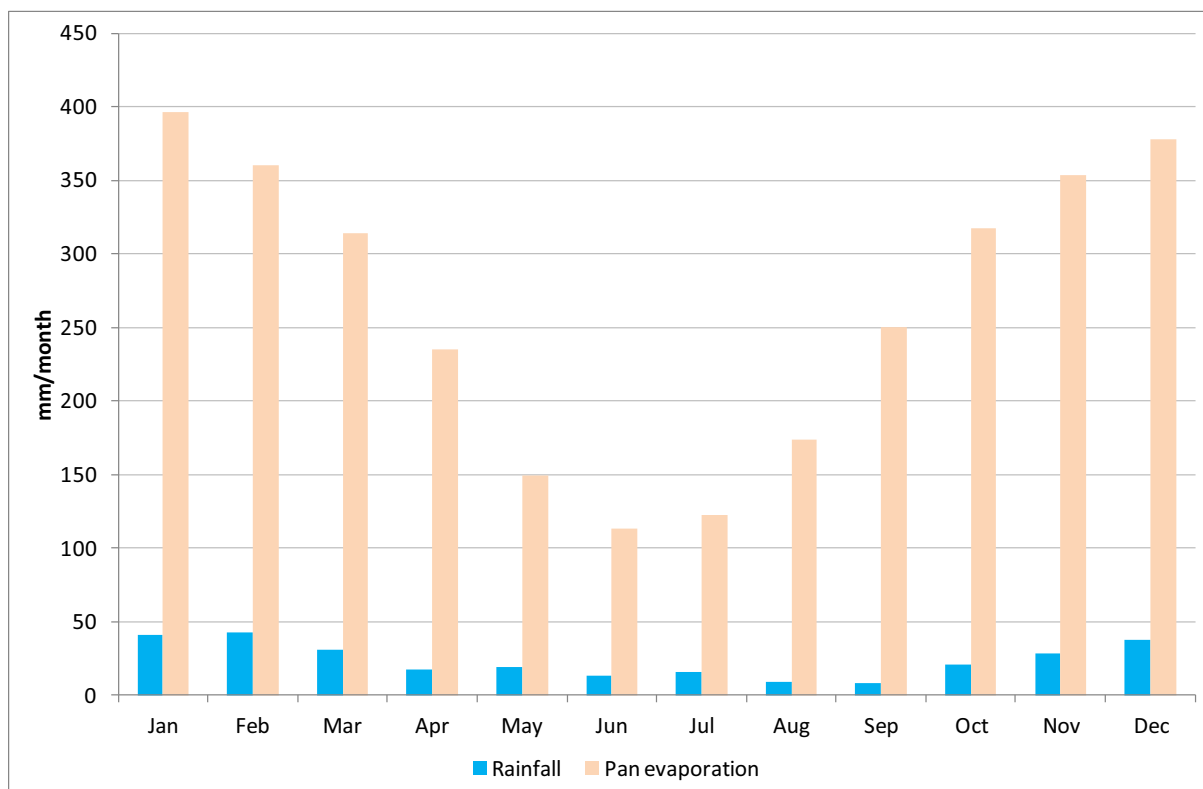


Figure 5.3 Average monthly rainfall and evaporation (BoM 015590)

5.3.4 Rainfall recharge

Analysis of wet and dry periods is important to appropriately characterise seasons and climatic variability. This information can be used to analyse groundwater recharge responses and consider potential impacts.

Analysis of dry and wet periods can be completed using the statistical technique of cumulative deviation from the mean (CDFM). CDFM is commonly used to relate groundwater level fluctuations to trends in rainfall and can also be used to assess trends in long-term monthly and annual rainfall fluctuations. The CDFM method subtracts the actual rainfall over a defined period from the long-term mean rainfall of the same period (Ferdowsian and McCarron 2001; Yesertener 2007).

Figure 5.4 presents the cumulative departures from the mean for the Alice Springs Airport weather station (BoM). The upward or downward trend in the curve indicates a period of above or below average rainfall respectively; these are marked on the graph as wet or dry periods.

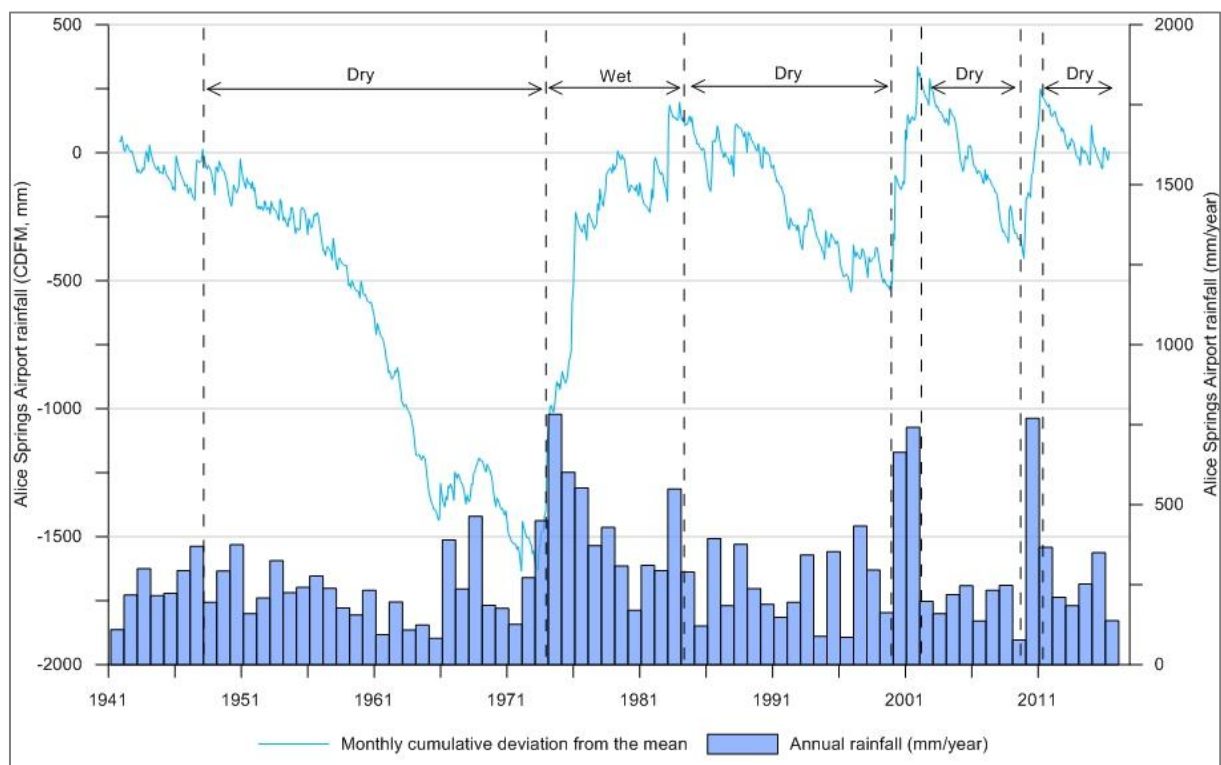


Figure 5.4 Rainfall: Monthly cumulative deviation from the mean

Figure 5.4 shows defined wet and dry periods over the 65-year rainfall record. Four apparent dry periods with below average rainfall are observed over this period (1948-1973; 1983-1999; 2001-2009; 2011-current). Conversely, three defined wet periods are visible within the dataset (1973-1983; 1999-2001; 2009-2011).

The bulk of the monitoring period shows below average, or dry, conditions. This suggests that the above average, or wetter periods, comprise significant rainfall events such that the mean is skewed to portray average rainfall as 'dry'.

Section 7 presents monitoring data indicating muted or negligible groundwater level responses to rainfall across the Proposal groundwater monitoring bores over the 14-month monitoring period, indicating a very low rainfall recharge rate.

5.4 Land use

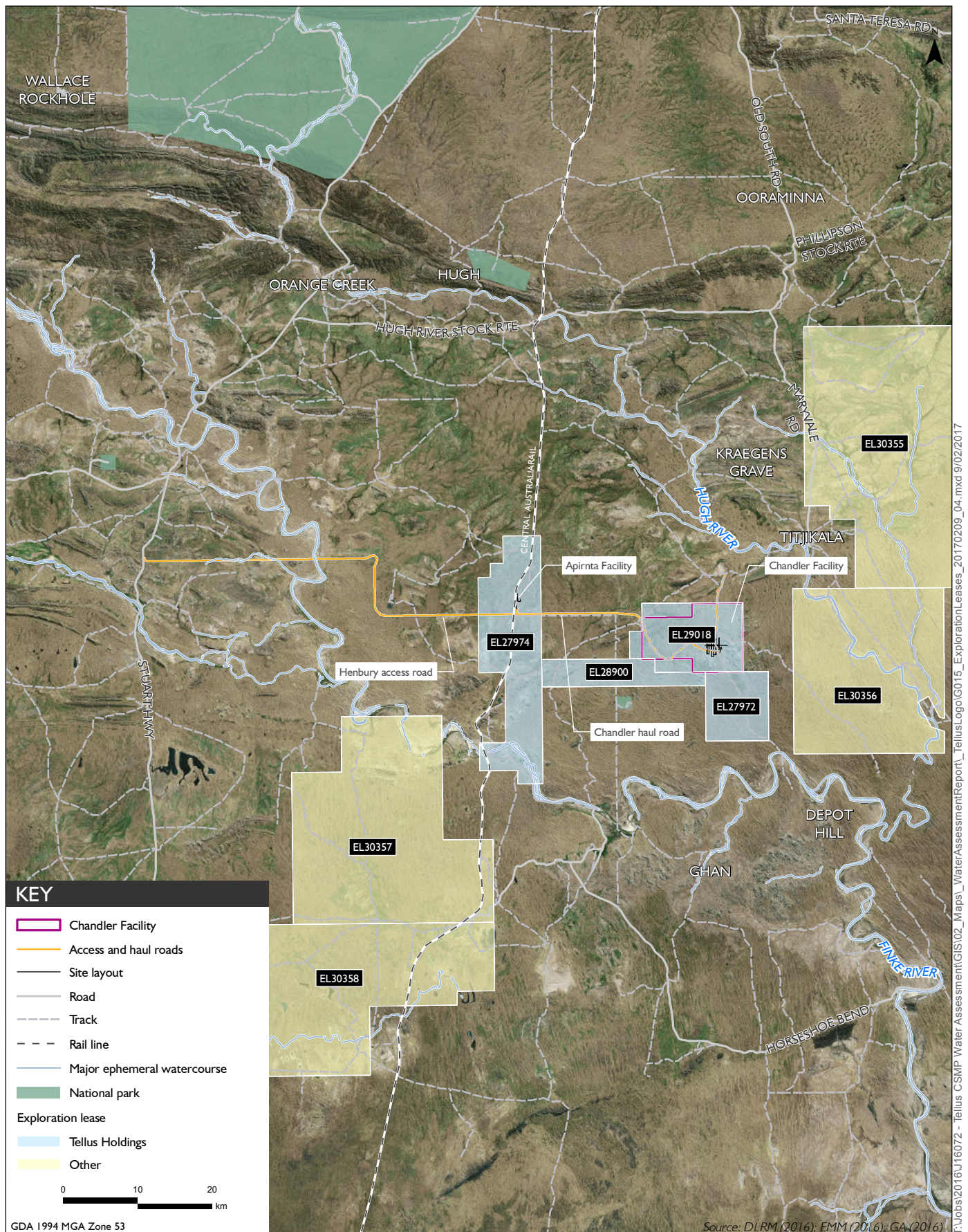
The Proposal area is in the locality of Titjikala in the Rodinga ward of the MacDonnell Shire Council that provides municipal services to the community. Titjikala is home to Arrernte, Luritja and Pitjantjatjara people (Coffey 2012).

Adjacent land is associated with pastoral leases PPL1094 (Henbury), PPL1063 (Maryvale) and PPL1090 (Idracowra). Chambers Pillar and Titjikala attract a small number of tourists (approximately 6500 people a year) (Coffey 2012).

Tellus holds exploration leases over the entire Chandler Facility area, comprising the following exploration leases:

- EL29018;
- EL28900;
- EL27974; and
- EL27972.

The Tellus exploration leases are shown on Figure 5.5. Elsewhere, major land uses are recorded as cattle grazing and Aboriginal land management.



Tellus exploration leases

Chandler Facility
Water Assessment

Figure 5.5

5.5 Vegetation

The Proposal area contains 17 different vegetation formations, including forests, woodlands, shrublands, palmlands, grasslands, forblands and an inland salt lake. Forty-two different vegetation types occur across the 17 vegetation formations (DLRM 2011). The dominant vegetation type across much of the Proposal area is Hard Spinifex (*Trioda basedowii*), Low Open Hummock Grassland with an open shrubland of Desert Cassia (*Senna artemisioides* subsp. *filifolia*), Mulga (*Acacia aneura*), Witchetty Bush (*Acacia kempeana*), *Aristida holathera* and *Allocasuarina decaisneana* (DLRM 2011) (see Plate 5.2 and Plate 5.3).



Plate 5.2 *Trioda basedowii*



Plate 5.3 *Acacia aneura*

Several ephemeral creeks intersect the Proposal area and are lined by riparian woodlands, comprising:

- River Red Gum (*Eucalyptus camaldulensis* var. *obtusa*) Woodland, containing Coolabah (*Eucalyptus coolabah* subsp. *arida*) with an understorey of Couch (*Cynodon dactylon*), Silky Browntop (*Eulalia aurea*) and Spiny Sedge (*Cyperus gymnocaulos*); and
- Coolabah Woodland, with an understorey of Lignum (*Muehlenbeckia florulenta*), Mulga, Desert Cassia, Water Clover (*Marsiliea spp.*), Couch and Buffel Grass (*Cenchrus ciliaris*).

Given their proximity to waterways, and the presence of River Red Gum and Coolabah, it is likely that these vegetation communities could be partially dependent on the subsurface presence of shallow groundwater.

The mapped ecological communities across the Proposal area are shown on Figure 5.6.

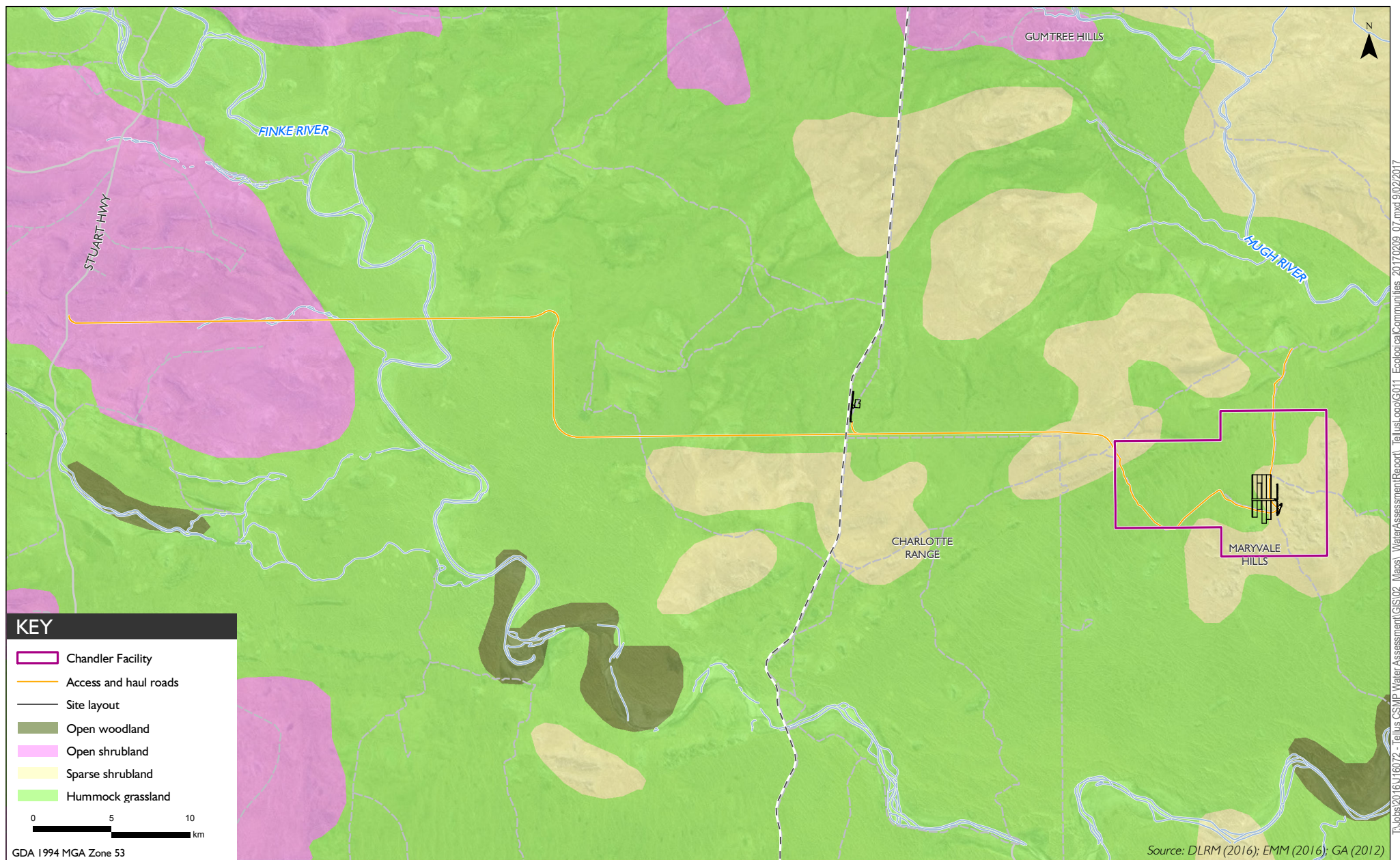
5.5.1 Threatened species

A number of near threatened flora species listed under the *Territory Parks and Wildlife Conservation Act 2014* (TPWC Act) have been recorded in the Proposal area, comprising *Tecticornia triandra*, *Tecticornia disarticulata*, *Atriplex fissivalis*, *Atriplex stuartii*, *Sclerolaena paralellicrispus*, *Sclerolaena longicrispus*, *Lepidium strongyphyllum*, *Goodenia havilandii*, *Acacia grosbyi*, *Sida calyxhymania*, *Sida intricata*, *Potamogeton crispus*, *Pimelia simplex* subsp. *continua*, *Ruppia tuberosa*, *Gilesia bineflora*, *Dodonaea microzyga* var. *microzyga* and *Zygophyllum crassissimum* (DPE 2012).

Two vulnerable flora species listed under the Commonwealth EPBC Act have also been recorded in the Proposal area, namely *Eremophila prostrata* and *Acacia latzii*.

Several near threatened fauna species listed under the TPWC Act have also been recorded in the Proposal area, comprising Adriana's Ctenotus, Australian Bustard, Australian Reed-Warbler, Australian Shelduck, Black-footed Rock-wallaby, Bush Stone-curler, Chestnut Quail-thrush, Emu, Flock Bronzewing, King Brown Snake, Kultarr, Letter-winged Kite, Long-haired Rat, Red-tailed Black-cockatoo, Redthroat, Scarlet-chested Parrot, Square-tailed Kite and Striated Grasswren (DPE 2012). The Black-footed Rock-wallaby is also listed as a vulnerable species under the EPBC Act.

As mentioned in Section 2, the Proposal has been determined by the Commonwealth Government to be a controlled action for impacts on listed threatened species and communities under the EPBC Act.



Mapped ecological communities across the project area

Chandler Facility
Water Assessment

Figure 5.6

5.6 Surface water

5.6.1 Regional setting

Most surface water is derived from rainfall runoff from the surrounding land area or catchment. Three categories of surface water systems exist across the NT:

- Permanent or perennial surface water systems—these are ever-present and are typically observed as rivers, lakes, springs and swamps.
- Semi-permanent or ephemeral surface water systems—these systems hold water for part of the year and are typically observed as small creeks, lagoons, waterholes or low lying areas across arid zones.
- Engineered surface water systems—these systems are widespread across the NT and typically consist of dams, turkey nests or engineered swamps that provide a source of water for stock and domestic purposes.

The NT is represented by four major drainage divisions. Drainage divisions are topographically controlled and direct regional surface water flows to either a major sea or inland basin. Each drainage division has numerous river basins, which form the catchment areas for major surface water systems. There are 35 river basins represented across the NT. The Proposal lies within the Finke River Basin within the Lake Eyre Drainage Division.

The low average rainfall and extensive aridity in southern NT contributes to a lack of permanent watercourses in the vast majority of the land surface. Most watercourses are ephemeral with particularly infrequent flows, reflecting the rainfall distribution. Clay pans, salt pans, rivers and flood outs are dry for the majority of the year, flooding during irregular intense rainfall events. When flowing, rivers drain inland (athalassic) rather than to the sea. Watercourses originate where surface runoff discharges into defined channels, converging to form ephemeral rivers.

Despite their variable flow regimes, these ephemeral surface water systems provide a crucial source of water for arid landscapes. They support significant aquatic and terrestrial biodiversity, including many unique species.

5.6.2 Local setting

The Hugh and Finke rivers are the key ephemeral surface water features in the vicinity of the Proposal area. These watercourses are considered to be drainage channels that convey surface water flows to discharge areas. Flow events in these rivers are characteristically infrequent, however when flowing, they support permanent wetlands and waterholes that provide internationally significant habitats for waterbirds and aquatic flora and fauna (Miles *et al* 2015). Dryland rivers, such as the Fink River and Hugh River, also support consumptive and recreational water users and are widely used for agricultural and town supplies in inland Australia. These rivers are usually also important to Indigenous peoples with sacred sites and other culturally important requirements (Robson 2008).

Several ephemeral drainage lines discharge to the Finke River and Hugh River along the reaches adjacent to the Proposal area. These are predominantly topographical controlled by various sand dunes, ranges and outcropping basement rock visible across the Proposal area. The Charlotte Ranges to the west of the Proposal are a source of ephemeral drainage for the Finke River, while the ranges to the north of the Proposal (Olliffe Range and James Ranges) drain to the Hugh River.

5.7 Geological setting

A number of major geological basins extend across Central Australia. This section describes the regional geological setting in relation to the three key geological basins in south-east NT and northern SA; Amadeus Basin, Pedirka Basin, and the Eromanga Basin. The extent, depositional context and structure of the three key geological basins are described in the sections below and shown on Figure 5.7 and Figure 5.8.

5.7.1 Amadeus Basin

The Proposal area lies in the Amadeus Basin, an extensive asymmetrical east-west trending, elongate intracratonic sedimentary basin with an area of approximately 155,000 square kilometres (km²) (Lloyd and Jacobson 1987). The south-eastern extent of the Amadeus Basin abuts the north-western extent of the Pedirka Basin about 80 km south-east of the Proposal area (and close to the north-western extent of the Eromanga Basin—Figure 5.7). The land surface is structurally controlled to the north, east and west by a series of extensive Palaeozoic orogenies. Alluvial sediments dominate low lying areas.

The sedimentary sequences in the basin reach a maximum thickness of approximately 8 km, but in the Northern Amadeus sub-basin (north of the Proposal area), the depth extends to only about 3 km. The sedimentary sequences are bounded to the north and south by Precambrian intrusive and metamorphic rocks (Lloyd and Jacobson 1987). The basin has been affected by intraplate tectonics, and has numerous folds and thrust belts (NT Department of Mines and Energy 2016).

The predominant marine and terrestrial sedimentary sequences that form the basin were deposited between the Neoproterozoic and Early Carboniferous periods, and are primarily composed of siliciclastic and carbonate units (Alley and Gravestock 1995). These include: dolostone, limestone, shale, sandstone, siltstone, quartzite, evaporite, diamictite and conglomerate (NT Department of Mines and Energy 2016).

Several significant geological events have influenced the structure and geological composition within the basin. Sedimentation of dolomitic siltstones and sandstones in the Late Proterozoic was terminated by a period of mountain building, salt diapirism, folding and northward overthrusting associated with the Petermann Ranges (in the north-western area of the basin) (Wells et al. 1970). During the Cambrian, continental sedimentation persisted in the north-west, while shallow marine shales, carbonates and evaporates were deposited in the north-east (Lloyd and Jacobson 1987). Ocean regression terminated marine deposition in the Late Ordovician (Coffey 2012). The Alice Springs Orogeny, in the Carboniferous, was a major intraplate mountain building period resulting in extensive associated folding and faulting in the Amadeus Basin (Lloyd and Jacobson 1987).

The stratigraphic summary and associated orogenies of the south-eastern extent of the Amadeus Basin observed across the Proposal area is shown in Table 5.5. The key geological units intercepted by the Proposal are identified in bold.

Table 5.5 **Stratigraphic summary of the south-eastern extent of the Amadeus Basin**

Period	Group	Formation	Orogenies
Quaternary		Alluvium	
		Aeolian sand	
Tertiary		Conglomerate	
		Silcrete (grey billy)	
		Sandstone/siltstone conglomerate	
Cretaceous		Rumbalara Shale	
Jurassic		De Souza Sandstone	
Carboniferous		Idracowra Sandstone	Alice Springs Orogeny
Devonian	Finke Group	Horseshoe Bend Shale	
		Langra Formation	
	Pertnjara Group	Undifferentiated sandstone	
		Brewer Conglomerate	
		Hermannsberg Sandstone	
		Parke Siltstone	
		Mereenie Sandstone	
Ordovician	Larapinta Group	Undifferentiated sandstone, siltstone and limestone	
		Stokes Siltstone	
		Stairway Sandstone	
		Horn Valley Siltstone	
		Pacoota Sandstone	
Cambrian	Pertaoorrtta Group	Undifferentiated sandstone, siltstone and limestone	Unnamed ('Bloodwood') Orogeny
		Goyder	
		Jay Creek Sandstone	Petermann Range Orogeny
		Shannon	
		Giles Creek	
		Chandler	
		Todd River Dolomite	
		Arumbera Sandstone	
		Pertatataka	
		Julie Member	
		Waldo-Pedlar Member	
Proterozoic		Olympic Member	
		Limbla Member	
		Ringwood Member	
		Areyonga	
		Bitter Springs	

5.7.2 Pedirka Basin

The Pedirka Basin abuts the Amadeus Basin at its north-western boundary (also near to the north-western boundary of the overlying Eromanga Basin—Figure 5.7), about 80 km south-east of the Proposal area. The Pedirka Basin is located at the SA/NT border, about 860 km north-north-west of Adelaide and 160 km south of Alice Springs. The Pedirka basin is understood to cover an area of about 60,000 km² and is overlain by the western lobe of the Eromanga Basin (Wohling *et al.*, 2013).

The Pedirka basin is bound to the south-west by the Musgrave Ranges. The northern boundary is defined by the Arunta Block and a complex fault block consisting of Mesoproterozoic to Cambrian metasedimentary and volcanic rocks called the Hale River High, the location of which is controlled by the Pellinor Fault Zone (Munson and Ahmad, 2012). A major north-west structural feature referred to as the Dalhousie-McDills Ridge dissects the basin into eastern (Madigan and Poolowanna Troughs) and western (Eringa Trough) portions. A thin deposit of Permian sediment over the ridge connects the two halves. The basin reaches a thickness of up to 1,525 m within the Eringa Trough, located west of the Dalhousie-McDills Ridge (Giuliano, 1988). The Poolowanna Trough occupies the far eastern portion of the basin and is separated from the Madigan Trough by the Colson Shelf, upon which only about 135 m of Permian sediments have been deposited (Munson and Ahmad, 2012, after Central Petroleum, 2011). Sediments within the Poolowanna Trough are largely of Triassic age (Simpson Basin), with Permian sediments only occurring along the western flank of the trough.

5.7.3 Eromanga Basin

The Eromanga Basin covers an area of approximately 1,000,000 km² of central eastern Australia and unconformably overlies the Pedirka Basin. At its north-western boundary (about 80 km south-east from the Chandler site), there is a transition zone from the western Eromanga Basin to the south-eastern boundary of the Amadeus Basin across a narrow intervening outcrop of the Pedirka Basin (Figure 5.7). In this area, the infiltration of intermittent flows in Finke River has been identified as a significant source of recharge to Pedirka Basin and to western Eromanga Basin outcropping units, which forms the main contribution of groundwater flows to the Dalhousie Spring complex located at about 230 km south-east of the Chandler site.

The depositional history of the Eromanga Basin can be broken up into three sequences; lower non-marine, marine and upper marine. The lowermost unit was deposited in the Jurassic Period, and consists of interbedded siltstone, sandstone and coal (Poolowanna Formation), deposited in high sinuosity fluvial and flood plain environments (Elinor Alexander Petroleum Group, 1998). The Poolowanna Formation underlies the Algebuckina Formation along the western margins of the basin. The middle marine and upper marine deposits are absent at the western margin of the Eromanga Basin, west of the Dalhousie-McDills Ridge. The Algebuckina Formation is unconformably overlain by the rapidly deposited upper non-marine sequences (Winton Formation), consisting of coal, floodplain and low sinuosity channel deposits.

Following the deposition of Permian and Triassic sediment, a period of erosion and deep weathering in the Late Cretaceous associated with the formation of the Lake Eyre Basin, resulted in the deposition of non-marine Cainozoic sediment. With the modern landscape formed during the Pliocene-Quaternary.

5.8 Geomorphological setting

The first mountain building phase, the Petermann Orogeny, affected the southern part of the Amadeus Basin via the uplift, folding and faulting of basement rock and sediments. During the Alice Springs Orogeny significant sections of the West MacDonnell Ranges were uplifted and compression forces to the south caused present day folding. This formed the following synclines in the southern Amadeus Basin: the Missionary Syncline and the Orange Creek Syncline, both north of the Proposal, and the shallower Chandler Syncline, targeted by the Chandler Facility.

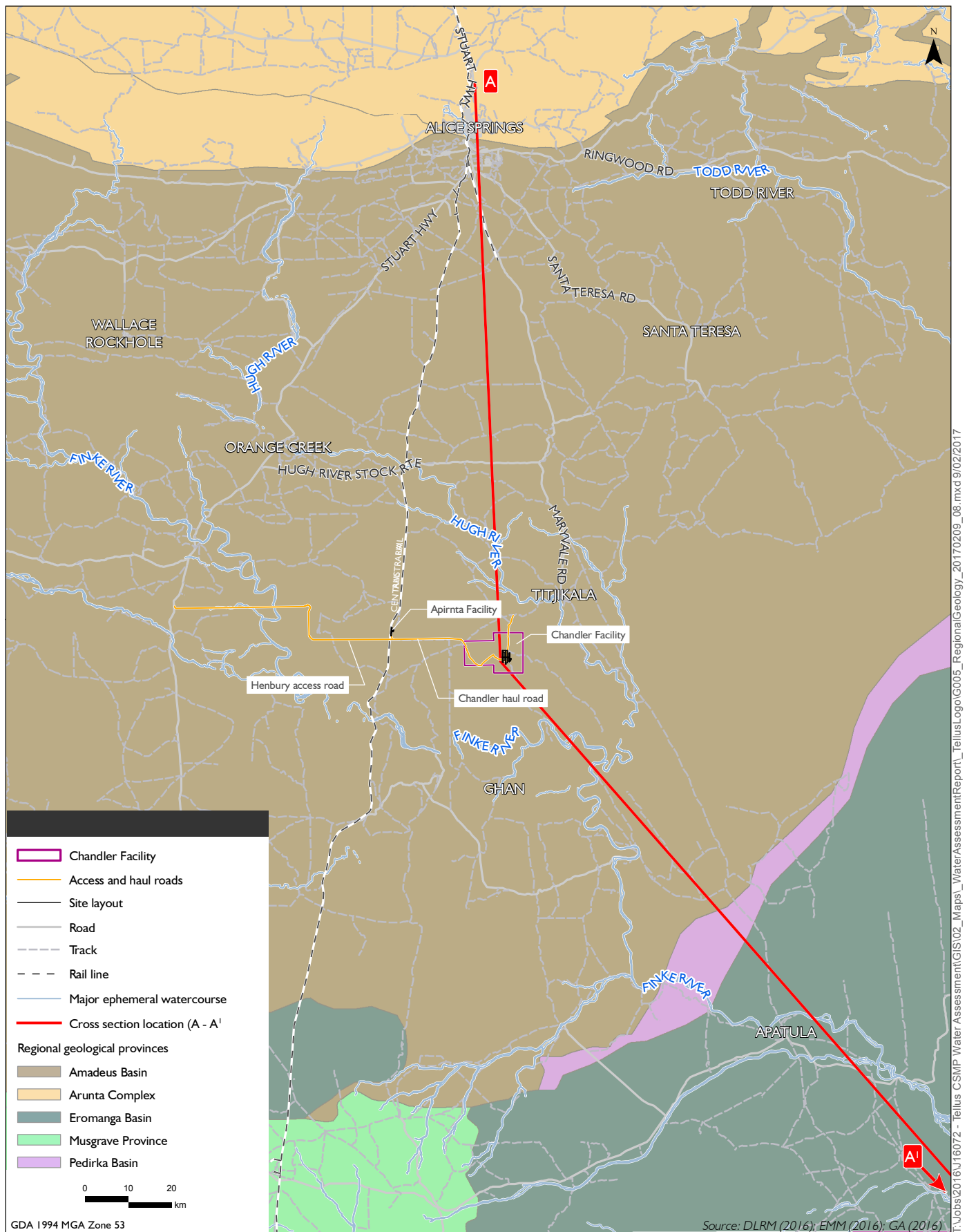
Deposition of the alluvium is likely to have occurred in the early to mid-Cainozoic with the development of various fluvial systems, notably the Finke and Hugh Rivers (see Plate 5.4). During the Tertiary, a period of persistent aridity was established across Central Australia, prompting the development of extensive duricrusts, consisting of ferricretes, silcrete and calcrete (see Plate 5.5). Ongoing aridity into the Quaternary lead to the development of sand dunes across the south-eastern extent of the Amadeus Basin and ultimately the modern day environment (Lloyd and Jacobson 1987).



Plate 5.4 **Hugh River-facing west**



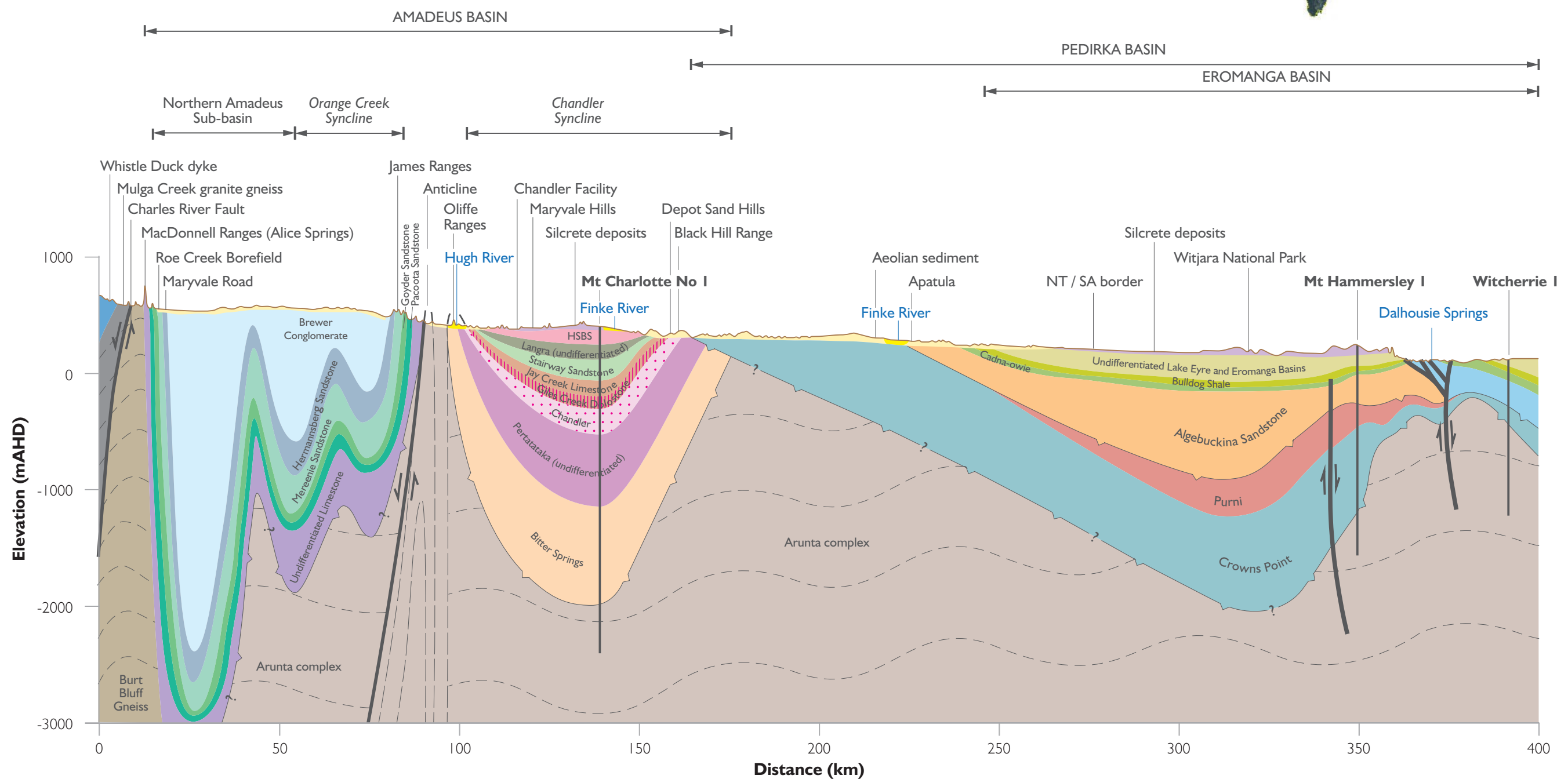
Plate 5.5 **Silcrete deposit–Maryvale Hills**



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A
north-west

A'
south-east



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5.9 Hydrogeological setting

The geological composition and structure of the Amadeus Basin is highly complex, with the development of local and regional groundwater systems influenced by the complex depositional environment (see Section 5.7) and structure of the area, namely the Alice Springs, James Ranges and Petterman Orogenies.

5.9.1 Groundwater systems

There are three main groundwater system types associated with central and south-eastern NT across the Amadeus Basin, these are the:

1. Mereenie Aquifer System;
2. fractured rock groundwater systems; and
3. near surface sediment groundwater systems.

The following sections describe the extent, groundwater flow and recharge/discharge characteristics of each of these systems.

i Mereenie Aquifer System

In the northern-central part of the basin toward Alice Springs broad folds define three key aquifer systems, the Hermannsberg Sandstone, Mereenie Sandstone and the Pacoota Sandstone systems (Lloyd and Jacobson 1987). These aquifers are collectively termed the *Mereenie Aquifer System* (MAS) (Jolly et al, 2005), and are associated with sediments deposited in the Carboniferous, Devonian and Early Ordovician periods. The MAS units occur within the Northern Amadeus sub-basin and Orange Creek Syncline, but do not occur within the Chandler Syncline (also refer to cross-section A in Figure 5.8, and cross-section C presented later in Figure 7.3).

Secondary porosity (or fracture flow) is the primary pathway for groundwater movement through the MAS, with permeability and porosity highly variable between the key lithological units represented across the MAS. Recharge to the MAS occurs through runoff infiltration via alluvial stream beds during major flood events. The magnitude of this recharge is generally thought to only have local significance due to the complex structure of the system (Jolly *et al.*, 1994). Recharge to the MAS is estimated at around 100 megalitres (ML) per year across the Roe Creek area (Jolly *et al.*, 1994), whereas recharge across the Rocky Hill/Ooraminna area is estimated to be up to 3,000 ML/year.

Annual average discharge via natural processes from the MAS is estimated at 2,000-4,000 ML/year, and to primarily occur via evapotranspiration and spring discharge (Read and Paul 2002). Evapotranspiration is postulated to dominate total discharge from the MAS, however spring discharge along the Orange Creek Anticline within the Deep Well Homestead is also thought to be an important discharge area from the system, with an estimated average annual discharge of 900 ML/year (Macqueen and Knott 1982).

Groundwater quality within the MAS is generally considered to be potable, suitable for both domestic and stock purposes. Total dissolved solids (TDS) across the system range from between 260 milligrams per litre (mg/L) immediately east of Roe Creek to 640 mg/L across the Pine Gap area.

ii Fractured rock groundwater systems

South of the Orange Creek/Missionary syncline and the Central Ridge, a series of intense folding and faulting generated by the James Ranges and Ollife Range has given rise to the deposition of a series of fractured rock systems of primarily Devonian to Ordovician age. These systems extend to the south-east and dip steeply below the Pedirka Basin and eventually the Eromanga Basin.

Groundwater within the fractured rock systems is unlikely to be extensive, unlike the MAS to the north. Localised faulting and the deposition of claystones and siltstones form leaky aquitards throughout the area, likely to have resulted in the development of less extensive and more localised groundwater systems.

Groundwater storage and flow within these localised systems is likely to be restricted by their thickness and the permeability of the geology. Recharge is thought to occur through infiltration of overlying alluvial stream beds during flood events however, the reduced permeability influenced by the claystone aquitards is likely to restrict recharge to these deeper systems.

Discharge is understood to occur primarily via evapotranspiration and at springs along the Finke River to the south-east of the Chandler Facility.

Water quality within the localised groundwater systems is highly variable and generally considered to be brackish to saline (TDS>1,500 mg/L). The limited permeability and recharge to the system is thought to contribute to long groundwater residence time, greater mineralisation of the local groundwater systems, and therefore reduced water quality.

iii Near surface sediment groundwater systems

The local near-surface sediment groundwater systems support the various ephemeral surface drainage features bisecting the Proposal. These surface drainage channels incise the bedrock, allowing the development of sediment to partly fill the channel void and provide a medium for groundwater and groundwater flow. Sediment is typically characterised as moderately porous, poorly sorted and unconsolidated.

The main developed alluvial systems located across the south-eastern extent of the Amadeus Basin are the Hugh River and Finke River. Recharge to these shallow systems primarily occurs during major flooding events.

Due to the shallow nature of these systems, the majority of natural discharge occurs via evapotranspiration. However, leakage to the underlying weathered bedrock is also expected to occur.

6 Field investigation program

Groundwater monitoring is an essential components in characterising the Proposal area baseline, pre-mining hydrogeological and hydrologic environments. Baseline water level and quality data collected from the various aquifers and watercourses is used to understand flow paths, recharge and discharge characteristics, and groundwater–surface water connectivity. The collection of field data is important for the accurate representation of the hydrogeological and hydraulic conceptual model.

A monitoring network has been established by the proponent which forms the basis for field testing and monitoring. Monitoring of groundwater for the Proposal commenced in May 2015. This chapter provides an overview of the field investigation techniques, with results presented in subsequent chapters.

6.1 Groundwater monitoring

6.1.1 Groundwater monitoring network

A dedicated project groundwater monitoring network was designed, installed and monitored by Ride Consulting to investigate hydrogeological conditions across the Chandler Facility area. 14 months of baseline groundwater level data has been collected at monthly intervals and is supplemented by groundwater quality data.

The groundwater monitoring network has been designed to provide reasonable spatial coverage and investigate the main hydrogeological systems. The Horseshoe Bend Shale Formation, Langra Formation, which both overlie the Chandler Formation (salt deposit), are the key water bearing formations across the Chandler Facility area.

Specifically, the groundwater network was designed to:

- identify and characterise water bearing units and aquitards in the Chandler Facility area, with particular focus on characterising groundwater flow and quality within the main groundwater bearing units, the Horseshoe Bend Shale Formation and the Langra Formation; and
- provide spatial representation of pressure heads across the Chandler Facility area to investigate potential vertical hydraulic gradients and connectivity between water bearing units.

6.1.2 Groundwater monitoring bore drilling program

The drilling and installation of all groundwater monitoring bores was undertaken by Diverse Group Pty Limited under the supervision of Ride Consulting hydrogeologists in May 2015. Drilling was mostly undertaken using open hole rotary drilling techniques with compressed air.

Groundwater monitoring bores were drilled and installed in accordance with the *Minimum Construction Requirements for Water Bores in Australia* (NUDLC 2012). Most groundwater monitoring bores, with the exception of WT5 were installed to target the most productive water bearing zones and were effectively sealed from overlying formations.

The supervising hydrogeologist undertook the following during drilling:

- geological appraisal at 1 m intervals, based on visual inspection of drill cuttings or drill core, with collation of this information into a bore log;
- recording of water interceptions and airlift yields at each water bearing zone intersected;
- measurement of water quality for all key water bearing zones intersected; this typically involved measurement of field physio-chemical parameters with select samples undergoing more detailed laboratory analysis; and
- specific design of a targeted, monitoring installation.

Registration of monitoring bores was obtained from the Water Resources division within the Department of Land Resource Management following the completion of drilling works.

6.1.3 Monitoring installations

Installation of the groundwater monitoring network commenced in May 2015. The network comprises:

- six groundwater monitoring bores, consisting of four nested sites; a nested location is where multiple monitoring bores are installed at the same location which target different depths in the geological profile; nested sites provide information on the vertical hydraulic gradients and inferred connectivity at the location; and
- two drill holes converted to production bores.

Table 6.1 provides an overview of the groundwater monitoring bore installations, while Figure 6.1 shows the locations of the groundwater monitoring bores. Summary bore logs are included in Appendix A.

Table 6.1 Overview of groundwater monitoring installations

Bore ID	Ground level (m AHD)	Total depth (m BGL)	Screen interval (m BGL)	Target formation	Lithology	Registration number
Project water monitoring bores						
WT1 ¹	410.166	201	126-201	Upper Langra	Sandstone	RN19117
WT2	410.106	120	90-102	Horseshoe Bend Shale	Sandstone	RN19116
WT3a	422.695	222	192-216	Upper Langra	Sandstone	RN19118
WT3b	422.695	328	298-322	Lower Langra	Sandstone	RN19118
WT4a	443.320	234	210-228	Horseshoe Bend Shale	Sandstone	RN19119
WT4b	443.320	287	281-287	Upper Langra	Sandstone	RN19119
WT5a ²	439.458	134	5.7-134	Horseshoe Bend Shale	Sandstone	RN19120
WT5b	439.458	180	168-174	Horseshoe Bend Shale	Sandstone	RN19120
WT6a	426.030	194	170-188	Horseshoe Bend Shale	Sandstone	RN19194
WT6b	426.030	306	237-252	Lower Langra	Sandstone	RN19194

Table 6.1 Overview of groundwater monitoring installations

Bore ID	Ground level (m AHD)	Total depth (m BGL)	Screen interval (m BGL)	Target formation	Lithology	Registration number
Converted production bores						
PB1 ¹	409.761	216	141-216	Upper Langra	Sandstone	RN19192
PB2 ¹	422.531	330	270-330	Stairway Sandstone	Sandstone	RN19193

Notes: 1.Open hole.
2.Open hole annulus.

6.1.4 Geophysical logging

Downhole geophysical logging was undertaken by Endeavour Geophysics Pty Ltd (Endeavour) at various bore locations across the Chandler Facility area in September 2015. These included:

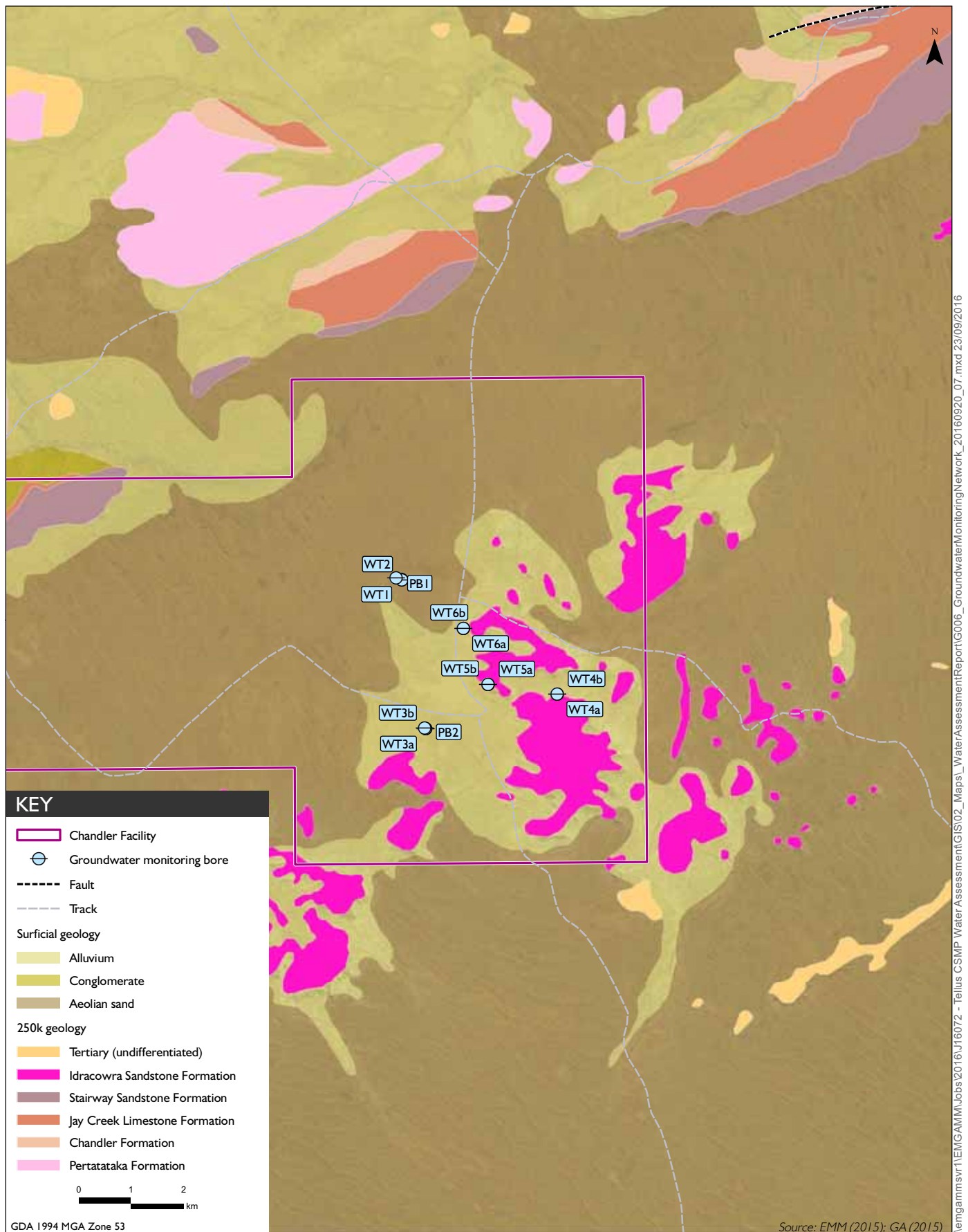
- PBT1 (production bore);
- CH003 (exploration bore);
- WT1 (water monitoring bore);
- WT2 (water monitoring bore);
- WT3 (water monitoring bore);
- WT4 (water monitoring bore); and
- WT5 (water monitoring bore).

The geophysical tools used included calliper, gamma, resistivity and neutron. The gamma logs are included in Appendix B).

Geophysical information provides fine detail on the geological units, and inferred hydrogeology via changes in conductivity.

6.1.5 Surface geophysical logging

Electroseismic and electrotelluric surveying was undertaken by Geo9 Pty Limited in September 2015. The survey covered a 500 x 500 m area across the Chandler Facility area and was designed to determine potential hydraulic conductivity and the groundwater presence and flow potential of geological formations to a maximum depth of 390 metres Below Ground Level (m BGL). Refer to Section 8.2.1 for more detail on the electroseismic and electrotelluric surveying.



Groundwater monitoring network
Chandler Facility
Water Assessment
Figure 6.1

6.1.6 Pumping tests

Pumping tests are conducted by pumping water from a test bore at a sufficient, constant rate and for a sufficient duration that stresses the aquifer and initiates a groundwater level response (drawdown) in monitoring bores. One constant rate pumping test was conducted in the Chandler Facility area: a 5-day test at PB1 (upper Langra) at a rate of 4 L/s.

Pumping tests are designed as a direct and reliable way to obtain estimates of aquifer properties including storativity, transmissivity and horizontal hydraulic conductivity. Pumping tests can also provide information on the extent and sustainability of the aquifer and the degree of connection with nearby surface water bodies if present.

EMM attempted to determine aquifer properties by assessing groundwater level and pumping rate observations. However, limitations in the data lead to inconclusive results. The low pumping rate achieved and the limited extent of drawdown (as observed at WT1) indicates that the local groundwater system is likely to have a low transmissivity and a limited extent.

6.1.7 Groundwater level monitoring

Groundwater level monitoring commenced in May 2015 at the eight project monitoring bores, as detailed in Section 8. Bores have been dipped at monthly intervals over the 14-month monitoring period, and they show muted or negligible responses to rainfall, indicating very subdued rainfall recharge. The dataset provides a useful groundwater level record of baseline data and will provide data on subsequent responses to rainfall and runoff variations and the effects of the Chandler Facility.

6.1.8 Groundwater quality monitoring

During the monitoring bore installation, an initial round of groundwater quality monitoring was undertaken by Ride Consulting in June 2015. Bores were sampled once by EMM in May 2016.

The procedures for sample collection by EMM in May 2016 are outlined below. The groundwater sampling method employed for each bore was determined based on the depth of the bore, the depth to groundwater and the permeability of the screened formation. Higher yielding, shallower monitoring bores are purged and sampled using a submersible pump. Typically, three well volumes are purged prior to sampling to allow a representative groundwater sample to be collected. If purged until dry, the bore is allowed to recharge and the recharge water is sampled.

Water quality parameters (including pH, temperature and electrical conductivity (EC)) are measured during purging and pumping to monitor water quality changes, and to indicate representative groundwater suitable for sampling and analysis.

Field and laboratory QA/QC procedures are undertaken to ensure results were accurate, reliable and precise. Some QA/QC procedures included: analysis of unstable parameters in the field, calibration of equipment, submitting laboratory samples within holding times, collection of blind duplicate samples, keeping samples chilled and wearing gloves during sampling.

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7 Groundwater

7.1 Geological setting

The Proposal area is located within the south-eastern extent of the Amadeus Basin, and about 80 km north-west of the boundary with the Pedirka Basin and the western Eromanga Basin (see Figure 5.7 and Figure 5.8).

The Chandler Facility targets the Chandler Formation, a unit of the Pertaoorrtta Group of Cambrian age (485-541 million years old) within the Chandler Syncline of the southern Amadeus Basin. The Chandler Formation occurs in an extensive evaporite unit comprised of gypsum and halite. The salt deposit was formed when a relatively shallow water basin was repeatedly flooded with subsequent evaporation resulting in the deposition, desiccation and precipitation of evaporites (Coffey 2012). The Chandler Syncline halite mineral deposit is yellow to red brown, transparent and glassy, and is interspersed with brown siltstone and claystone. The deposit is encountered between 755 and 811 m BGL, and is up to 275 m in thickness (Tellus exploration borehole CH001A). In other parts of the Amadeus Basin halite deposits range in thickness from less than 50 m to over 1,000 m and average 470 m thick in the Rodinga area (Potash Australia Ltd, 2008).

Overlying the Chandler Formation are deposits of siltstones and sandstones associated with the Pertaoorrtta Group (Giles Creek Formation, Jay Creek Sandstone Formation), Larapinta Group (Stairway Sandstone Formation), Finke Group (Horseshoe Bend Shale Formation and Langra Formation) and the Idracowra Sandstone Formation.

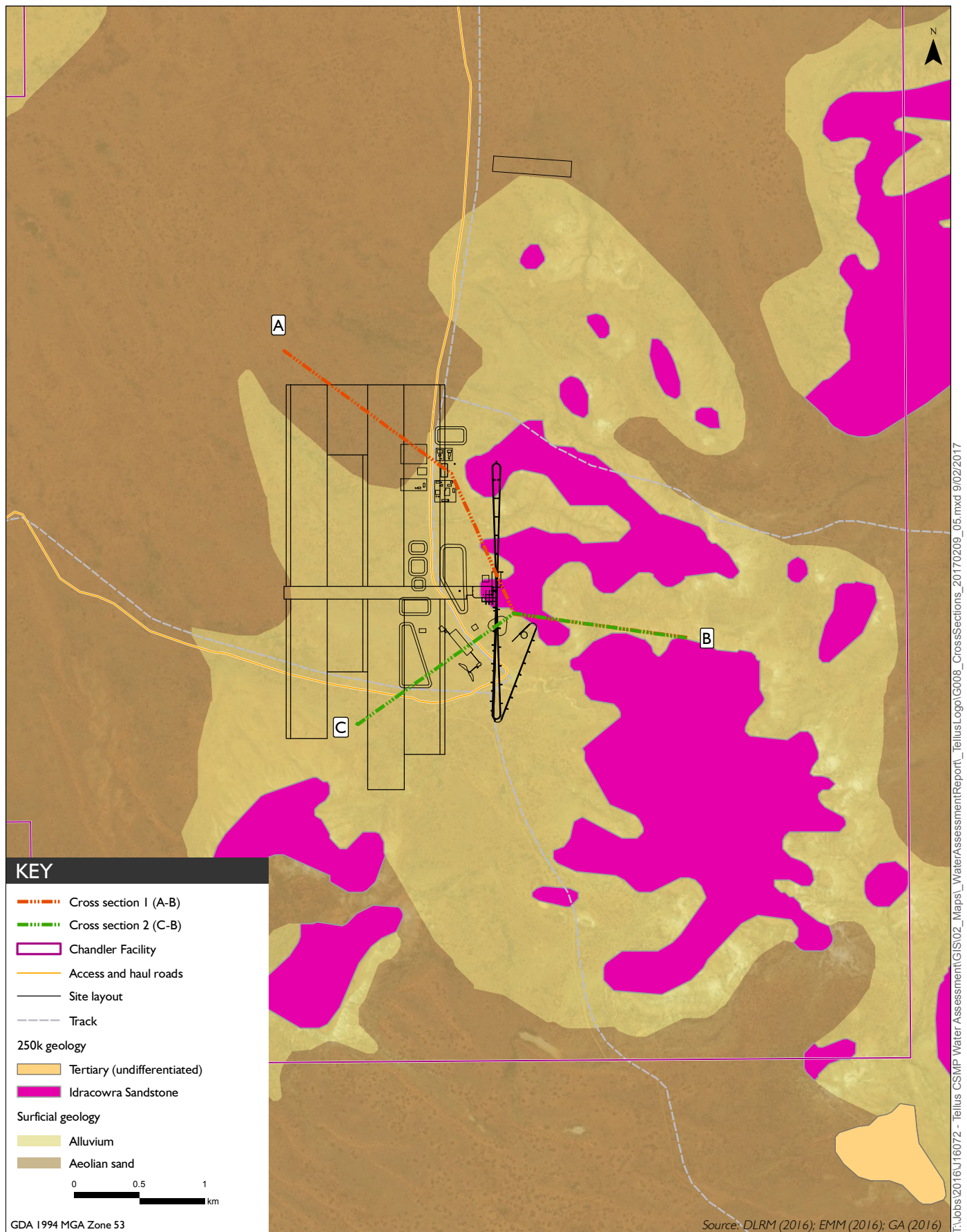
Exploration drilling has characterised the overlying geological formations as follows:

- Idracowra Sandstone Formation) a kaolinitic sandstone present caps the Maryvale Hills across the Chandler Facility area and has a maximum thickness of 40 m;
- Horseshoe Bend Shale Formation: a massive, red brown siltstone/very fine grained, soft to firm quartz sandstone with moderate mica. Occasional beds of light brown, fine grained sandstone up to one metre in thickness;
- Langra Formation: subdivided into three members: the upper, a very fine to coarse light brown sandstone; middle, a mottled red brown siltstone and lower, a pale brown to orange very fine to fine sandstone with interbedded siltstone;
- Stairway Sandstone: a white coarse to medium grained sandstone with interbedded siltstone and minor shale;
- Jay Creek Sandstone Formation: comprises upper layers of siltstone with thin interbeds of dolomite and minor fine grained sandstone, and lower layers of shale, and laminated claystone and siltstone (Ride Consulting 2015); and
- Gilles Creek Dolomite Formation: a fine-grained, massive, yellow-brown dolomitic limestone unit, with minor shale bands.

Underlying the Chandler Formation is the Pertatataka Formation, a siltstone and shale formation with lenses of sandstone, dolomite, limestone and conglomerate (Bureau of Mineral Resources, Geology and Geophysics 1968).

Geological cross sections have been inferred and prepared by Ride Consulting (2015) from the exploration and water bore drilling across the Proposal. The location of these sections is shown on Figure 7.1 and the cross sections are shown in Figure 7.2 and Figure 7.3.

To the south of the Chandler Facility the overall formation deposition is mostly flat lying with localised deformation. West of the Chandler Facility, associated with the Charlotte Ranges, is a major anticline, which causes the formations at the Chandler Facility to dip towards the south-east. To the north-east of the Chandler Facility, near the Hugh River, the geology is again deformed as it tilts upwards in what is assumed to be another major anticline.

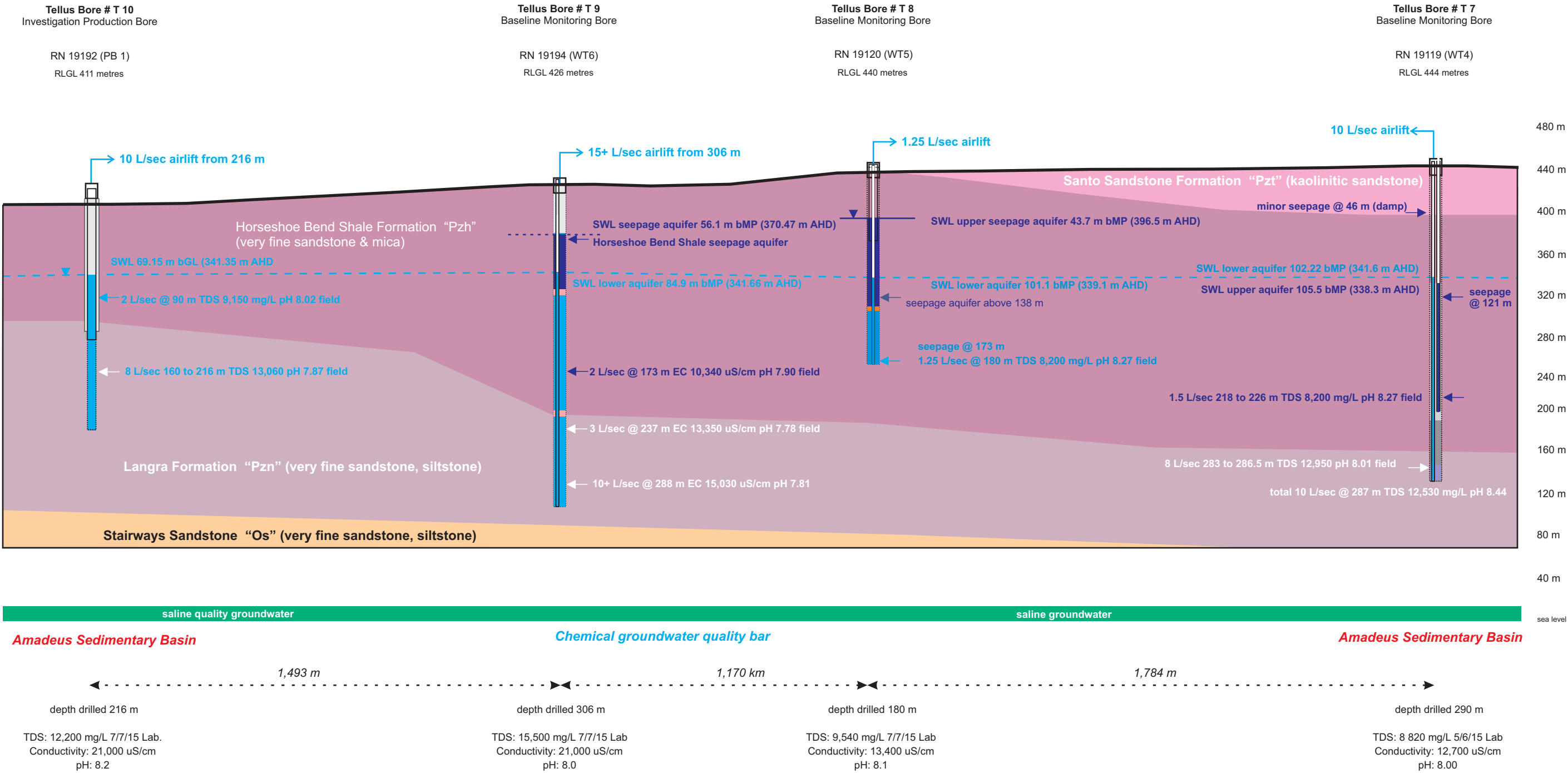


Geology and cross section lines
Chandler Facility
Water Assessment
Figure 7.1

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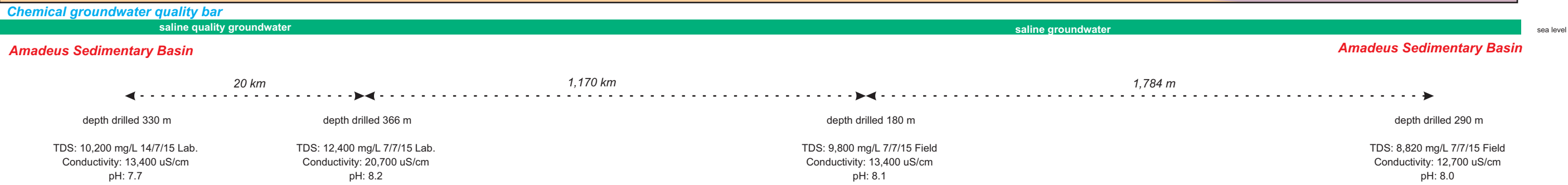
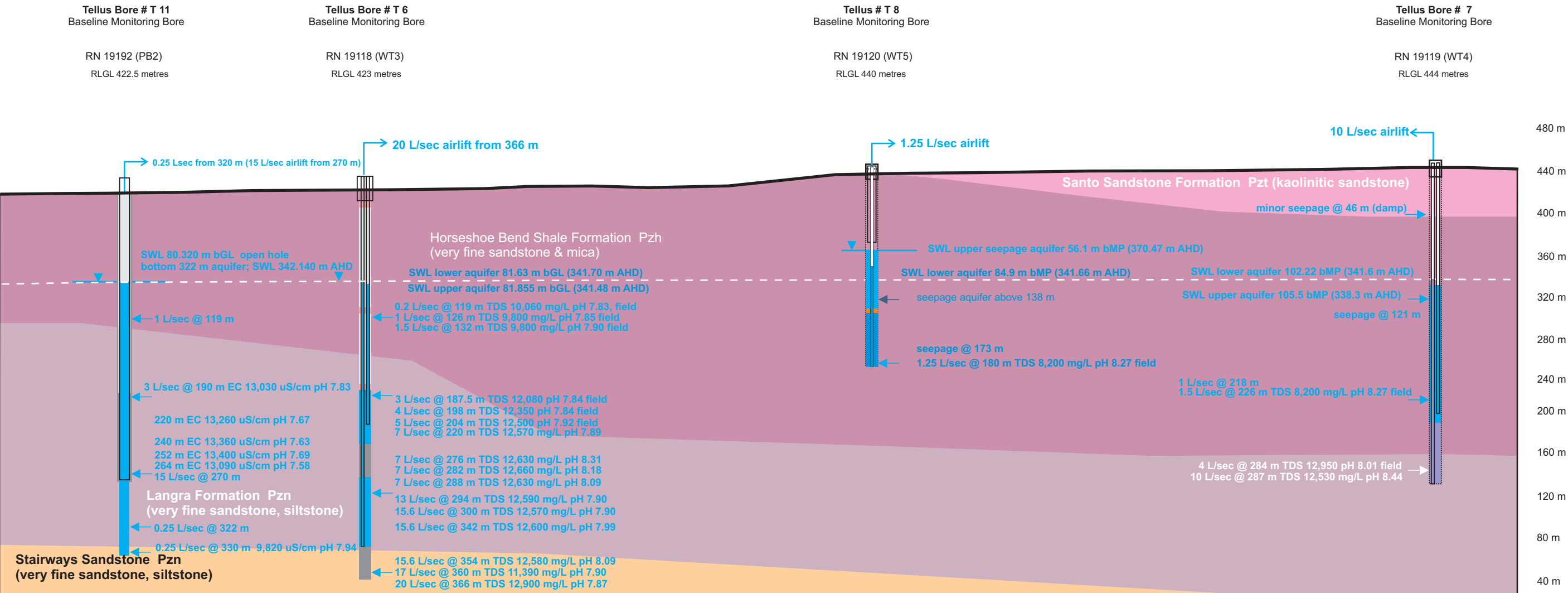
Section WNW-ESE through Tellus Holdings Ltd 2015 Water Investigation Bores T 10 (PBT 1), T 9 (WT 6), T 8 (WT 5), T 7 (WT 4)

Elevation
metres
A.H.D.



Section WNW-ESE through Tellus Holdings Ltd 2015 Water Investigation Bores T11 (PB2), T 6 (WT3), T 8 (WT 5), T 7 (WT 4)

Elevation
metres
A.H.D.



7.2 Groundwater setting

Proposal groundwater monitoring bores target the fractured sandstone aquifer, present across the south-east of the Amadeus Basin. During the Proposal groundwater drilling campaign, inflows were first intersected in the Horseshoe Bend Shale Formation between 80 and 100 m BGL. Subsequent groundwater level monitoring has seen a rise in groundwater levels by up to 25 m from the water cuts observed during drilling, indicating the groundwater system is semi-confined with low primary porosity and permeability, and the groundwater level monitored is therefore the piezometric surface.

Groundwater flow is interpreted to be via fracture flow (secondary porosity), although limited groundwater flow through primary porosity may also occur. During borehole drilling the lowest water cuts were observed where fractures are assumed to be absent and the geology is fine grained (Ride Consulting 2015). Typically, geological units become more consolidated with depth, accompanied by less groundwater ingress. However, as overall groundwater ingress increased with depth during drilling through the sandstone/siltstone units, fracture frequency is also assumed to be maintained with depth.

Borehole water cuts in the relatively shallow Horseshoe Band Shale Formation were mostly comparable and ranged from 0.2 to 2 L/s; the highest yields were observed in the Chandler Facilities north-western extent. The next unit encountered, was the Langra Formation, which exhibited a larger range of borehole water cuts, more typical of fractured rock groundwater flow. The average water cut for the upper Langra Formation was 4.2 L/s, the middle Langra Formation was 7.5 L/s and the lower Langra Formation was 11 L/s. Water cuts for the next unit, Stairway Sandstone, were recorded at two bores and these were reported at between 15 and 20 L/s (in the centre of the Chandler Facility area). Water cuts observed during drilling typically over-estimate sustainable yield. A potential groundwater yield associated with this geological Formation is therefore likely to be significantly less and closer to 5 L/s.

The Jay Creek Formation exhibits the potential for groundwater presence within the upper sequences of this Formation, as defined through the estimated porosity measurements of 30% observed at Mt Charlotte 1. The Jay Creek Formation transitions into a calcareous dolomitic unit toward its basal extent, where it overlies the Giles Creek Formation. Groundwater potential is negligible within this extent, given the massive nature of the unit and the limited fracture potential.

The presence of halite in the Chandler Formation demonstrates that it is hydrogeologically isolated from the overlying groundwater systems. Otherwise, if the water cuts observed in the overlying sedimentary units were indicative of enhanced aquifer permeability, then associated groundwater flows would be expected to result in dissolution of the Chandler Formation evaporite deposits. Basal shale layers in the Jay Creek and Giles Creek Formations are inferred to form an aquitard, preventing downwards groundwater flow. Therefore, the uppermost regional aquifer is confined to the sandstone and siltstone fractured units that overly the Chandler Formation.

7.2.1 Shallow aquifer mapping

An electroseismic and electrotelluric aquifer mapping survey was undertaken by Geo9 Pty Limited (Geo9) at the Chandler Facility in September 2015 (Geo9 2015). The dataset was used to indicatively model relative hydraulic conductivity using electroseismic hydraulic conductivity tomography within the survey area to a maximum depth of approximately 390 m BGL (approximately 410 m above the Chandler deposit). Based on calibration with bore log data, the model indicates that there are three main aquifer zones within the saturated thickness of the sandstone aquifer, predominately between 140 and 350 m BGL (approximately 405-615 m above the Chandler deposit), with minor small perched groundwater systems existing above the regional water table (inferred to be approximately 90 m below ground).

Groundwater appears to be located in discrete horizontal zones of relative high hydraulic conductivity at varying depths throughout the Lower Langra Formation (see Figure 7.4). EMM consider the groundwater flow potential of the Horseshoe Bend Shale Formation, Langra Formation and Jay Creek Sandston Formation groundwater systems are likely to be dominated by secondary porosity given the consolidated and deformed nature of the geology.

Based on the model data, Geo9 inferred that groundwater recharge does not appear to be strongly driven by local infiltration with the majority of recharge most likely occurring remote to the site. The lack of hydraulic conductivity observed in shallower zones (<140 m BGL) and the depth of the piezometric surface (at approximately 90 m BGL) was interpreted to indicate that the near surface is relatively dry with little surface recharge to the groundwater locally.

Geo9 assessed that given the local arid climate and lack of apparent surface recharge, groundwater in the system is likely to be ancient. However, EMM notes that the 8 months preceding the survey were particularly dry, which may have influenced the lack of hydraulic conductivity in the near surface zones and the lack of evidence of local recharge.

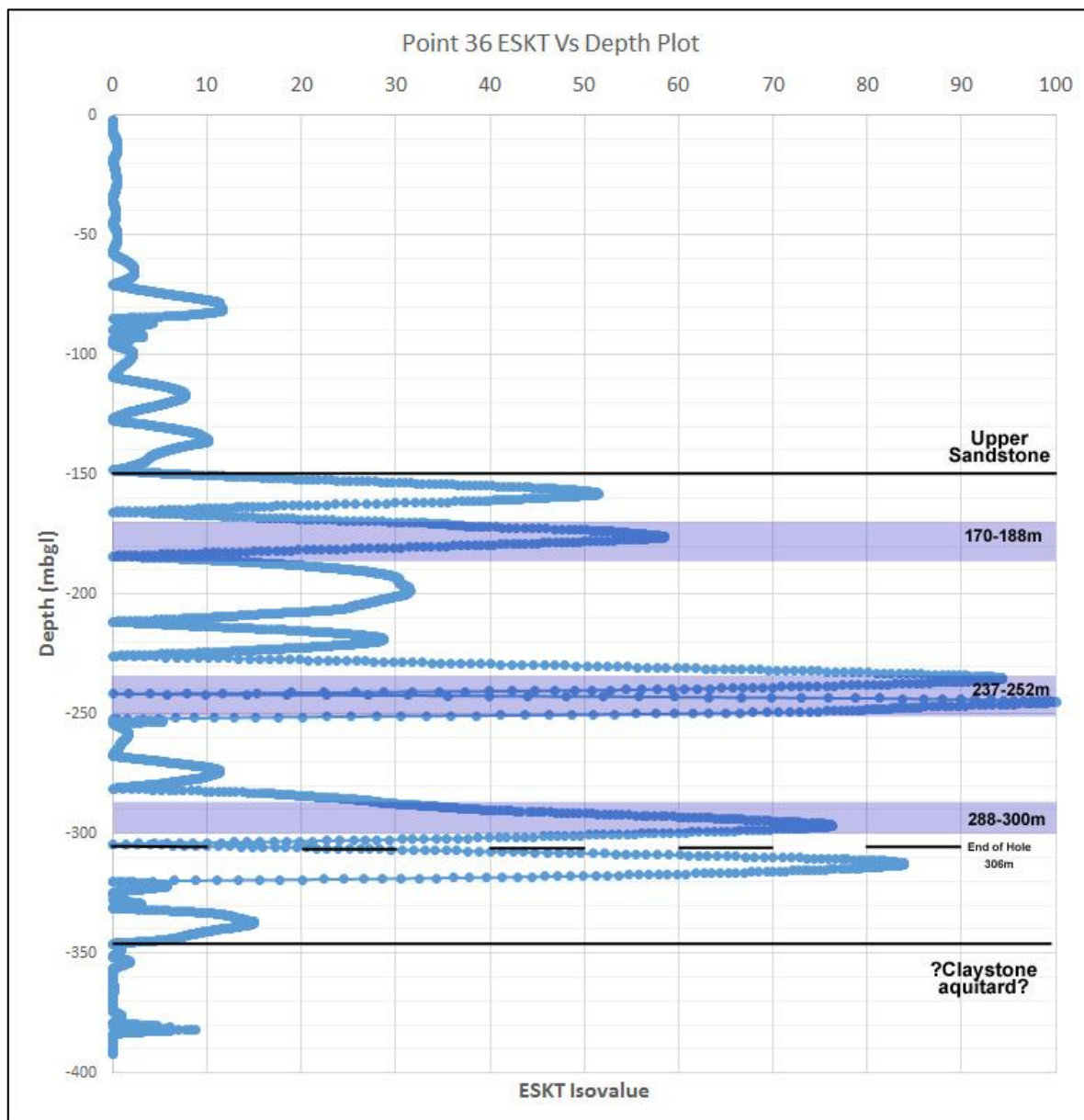


Figure 7.4 Electroseismic hydraulic conductivity tomography across the Chandler Facility (Geo9 2015)

7.2.2 Groundwater levels and flow

Hydrographs from Proposal groundwater monitoring bores are presented below with daily rainfall (Figure 7.5, Figure 7.6 and Figure 7.7). The rainfall record comprised a composite dataset from Alice Springs Airport weather station (BoM station 015590) from 1 June 2015 until 6 November 2015, and the local Chandler Facility automated weather station data, from 7 November 2015 onwards.

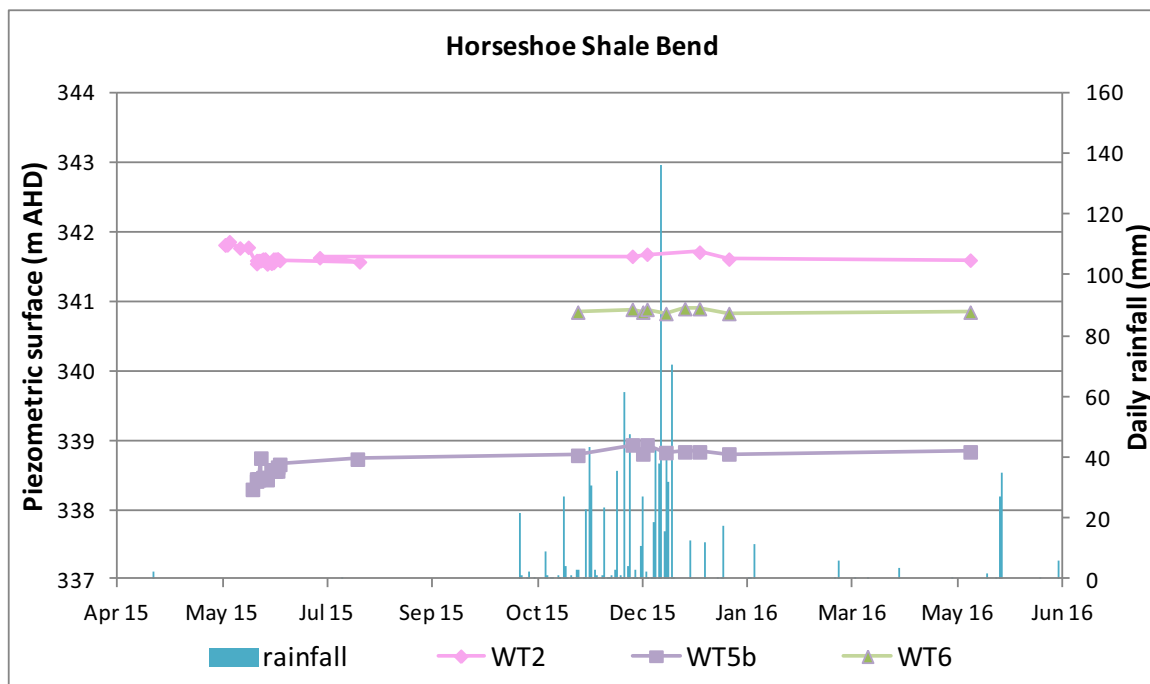


Figure 7.5 Hydrograph for the Horseshoe Bend Shale Formation

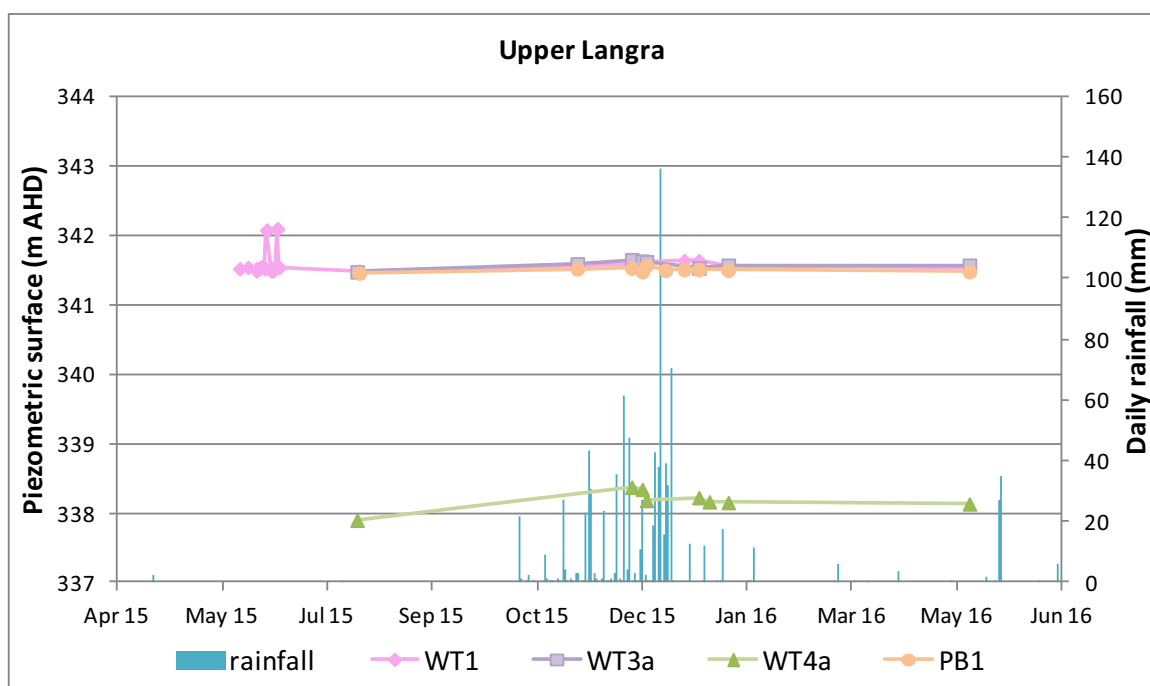


Figure 7.6 Hydrograph for the Upper Langra Formation

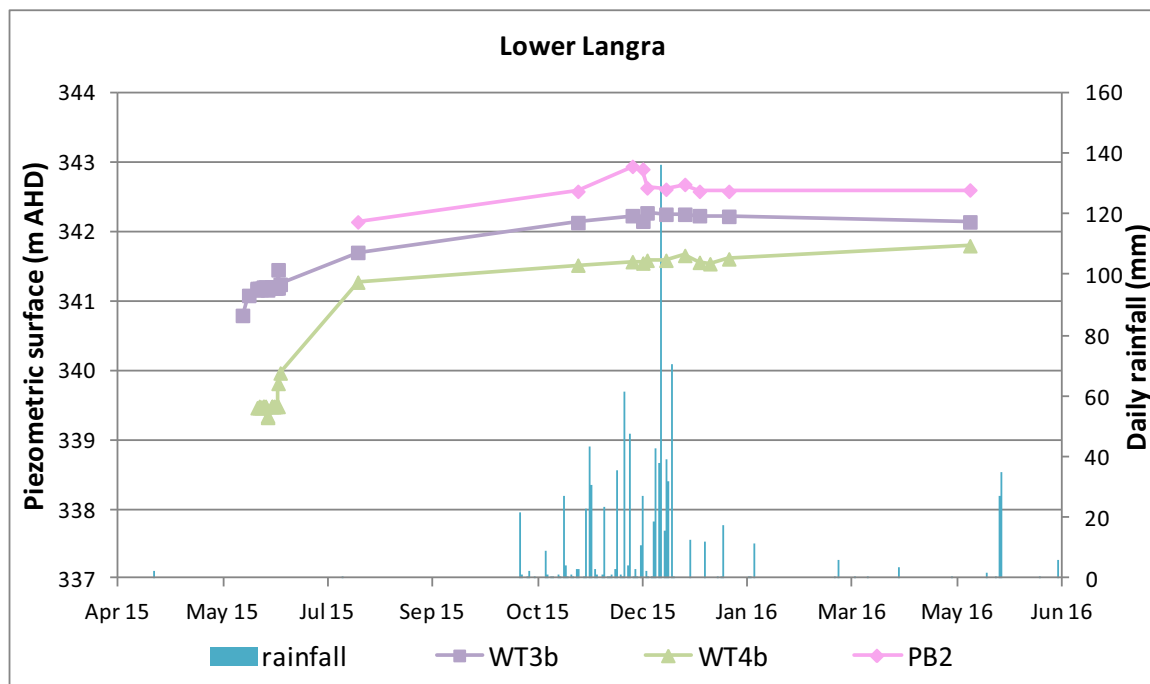


Figure 7.7 Hydrograph for the Lower Langra Formation

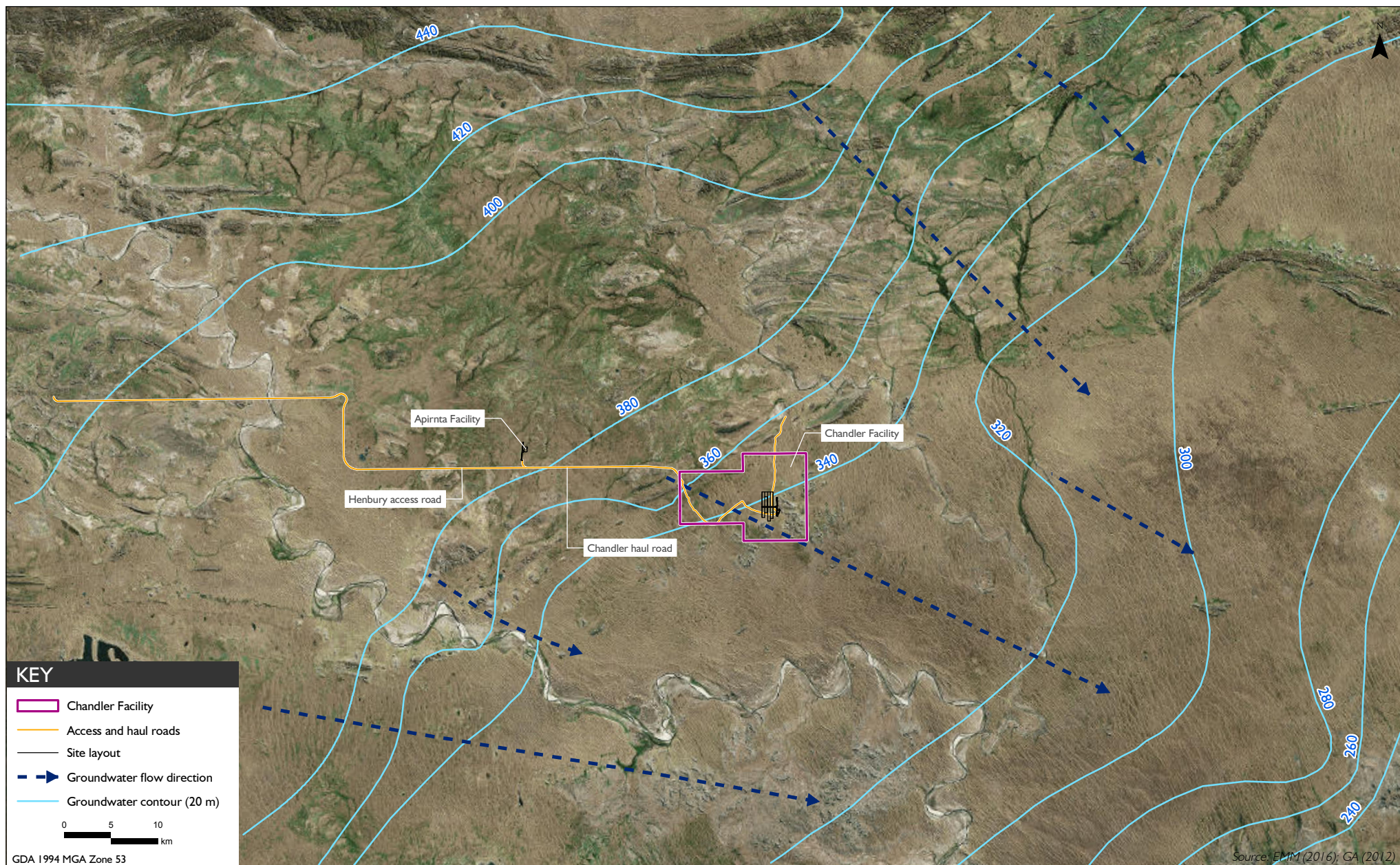
At the Chandler Facility the piezometric levels for the Horseshoe Bend Shale Formation and Langra Formation (Upper and Lower) are within 338 and 343 m AHD, a 5 m range. Recovery from drilling is relatively slower in the Lower Langra, as seen by the time for the piezometric surface to stabilise. This could be indicative of lower permeability and/or storage in this lower formation.

Overall there is minimal response to rainfall recharge in the piezometric surfaces monitored; the aquifer is dominated by lateral flow rather than vertical flow. In the uppermost formation, the Horseshoe Bend Shale Formation, there is a minor and delayed response (ie 0.06 m rise over 15 days) to rainfall recharge at WT2 and WT6a only.

The hydrographs for the Horseshoe Shale Bend Formation show a decline in piezometric surface (by up to 2 m) from west to south-east, consistent with the regional groundwater flow direction. The relatively low piezometric surface in WT4b, in the east, compared to the western monitoring bores screening the Lower Langra Formation again confirms the regional west to south-east groundwater flow direction in the deeper unit. Comparable piezometric surfaces in the Upper Langra Formation indicate this unit is more confined than the overlying and underlying groundwater units.

The piezometric surfaces for the Upper Langra Formation are comparable, with the exception of WT4a. The level at WT4a, in the Chandler Facility areas east, is lower than the piezometric surface at WT4b, targeting the Lower Langra Formation at this nested site. This an upward vertical gradient within the Langra Formation. Upwards vertical piezometric surfaces are likely to be influenced by local fracturing.

Analysis of the regional groundwater piezometric surfaces (see Figure 7.8) indicates that groundwater flows from the west of the Chandler Facility, where it is heavily controlled by topographic gradients, towards the south-east. Beyond the Charlotte Ranges the groundwater flow direction shifts from easterly to south-easterly.



Regional groundwater contours

Chandler Facility
Water Assessment

Figure 7.8

7.2.3 Groundwater recharge and discharge

The main groundwater flow mechanism for the fractured sandstone aquifer is considered to be rainfall recharge to outcropping units to the west and north-west of Chandler and then regional through flow to the east and south-east.

As monthly average evaporation exceeds monthly average rainfall by up to 11 times, recharge is episodic and occurs during intense rainfall events that cause flooding of the overlying local alluvial groundwater systems adjacent to watercourses. Downwards infiltration from alluvial groundwater systems can then potentially recharge the underlying fractured rock sandstone aquifer. Although, as discussed above, groundwater level changes were observed to be muted or negligible in response to rainfall across the Proposal groundwater monitoring bores over the 14-month monitoring period, and recharge to deeper systems is interpreted as being lateral from the west-north-west.

Relic playas to the west of the Proposal area are interpreted to have been historic areas of discharge. However, discharge now occurs to the east to the northern Eromanga Basin (Lloyd and Jacobson 1987; Coffey 2012), which is consistent with the regional groundwater flow direction observed from the Proposal groundwater monitoring bores and the standing water levels within regional landholder bores.

Down hydraulic gradient of the Chandler Facility, five groundwater springs are observed to be discharging at the banks of the Finke River to the south and south-east (see Section 7.3.2). These include Horseshoe Bend Spring, Black Hill Spring, Polly's Spring, Micks Soak and Pascoes Spring. All springs other than Pascoes Spring (c. 20 km south) are located more than 50 km south-east of the Chandler Facility and are likely to be discharging from the shallow alluvial groundwater system, which will not be intercepted by the Proposal.

The groundwater flow direction at the Horseshoe Bend Spring location is oriented west/east, whereas the flow from the Proposal area is oriented north-west/south-east. This indicates that groundwater discharges at the Horseshoe Bend spring area are likely to be sourced from a separate groundwater system to the south of the Finke River.

7.2.4 Groundwater quality

Groundwater quality results collected between May 2015 and May 2016 are presented as an average for each sampling location in Table 8.1.

Table 7.1 Mean groundwater quality results (May 2015–May 2016)

Analyte	Units	WT1	WT2	WT3a	WT3b	WT4a	WT4b	WT5b	WT6b	PBT1	PBT2
Formation		Upper Langra	Horse shoe Bend Shale	Upper Langra	Lower Langra	Upper Langra	Upper Langra	Horse shoe Bend Shale	Langra	Upper Langra	Lower Langra
Field analytes											
pH	-	8.1	8.1	8.9	8.1	8.0	8.0	8.0	8.1	8.2	7.9
EC ¹	uS/cm	19,800	16,800	16,400	18,200	13,400	16,200	13,400	12,725	17,580	13,800
Laboratory analytes											
TDS ²	mg/L	11,482	9,150	12,850	-	8,820	-	9,540	12,725	10,047	10,400
TSS ³	mg/L	15.7	89	80	56	98	89	498	289	67.4	50.5

Table 7.1 Mean groundwater quality results (May 2015–May 2016)

Analyte	Units	WT1	WT2	WT3a	WT3b	WT4a	WT4b	WT5b	WT6b	PBT1	PBT2
Formation		Upper Langra	Horse shoe Bend Shale	Upper Langra	Lower Langra	Upper Langra	Upper Langra	Horse shoe Bend Shale	Langra	Upper Langra	Lower Langra
Major ions											
Calcium	mg/L	741	617	1010	779	234	153	597	279	446	695
Chloride	mg/L	3,081	4,025	4,240	5,270	562	634	3,450	1,850	7,030	4,613
Magnesium	mg/L	341	304	36	274	<1	<1	320	186	102	346
Sodium	mg/L	3,010	2,435	2,320	2,720	637	559	1,740	1,180	2,236	2,266
Potassium	mg/L	74	76	68	87	138	86	61	49	2,365	85
Sulfate	mg/L	1,883	1,682	1,220	1,220	175	237	1,170	806	1,840	1,490
Alkalinity											
Bicarbonate as CaCO ₃	mg/L	145	170	90	236	<1	<1	197	26	141	65
Carbonate as CaCO ₃	mg/L	<1	<1	<1	<1	98	21	<1	<1	<1	<1
Hydroxide as CaCO ₃	mg/L	<1	<1	<1	<1	803	273	<1	<1	<1	<1
Total metals											
Arsenic	mg/L	<0.001	<0.001	<0.001	0.001	0.001	<0.001	0.007	0.003	0.002	<0.001
Chromium	mg/L	0.004	0.02	0.02	0.006	0.07	0.02	0.004	0.012	0.003	0.002
Copper	mg/L	0.002	0.01	0.003	0.002	0.006	0.003	0.005	0.01	0.002	0.001
Iron	mg/L	0.4	3.4	1.6	1.5	2.5	0.8	19.5	6.4	69.8	38.1
Lead	mg/L	0.002	0.024	0.002	0.002	0.004	0.002	0.005	0.01	0.003	<0.001
Manganese	mg/L	0.01	0.1	0.06	0.4	0.05	0.02	0.05	0.2	3.7	3.5
Nickel	mg/L	0.002	0.01	0.01	0.01	0.004	0.002	0.004	0.013	0.003	0.004
Zinc	mg/L	0.01	3.5	0.2	0.6	0.3	4.0	3.9	0.7	30.8	0.02

Notes: Samples collected 16 May, 2016.

1. EC = electrical conductivity.

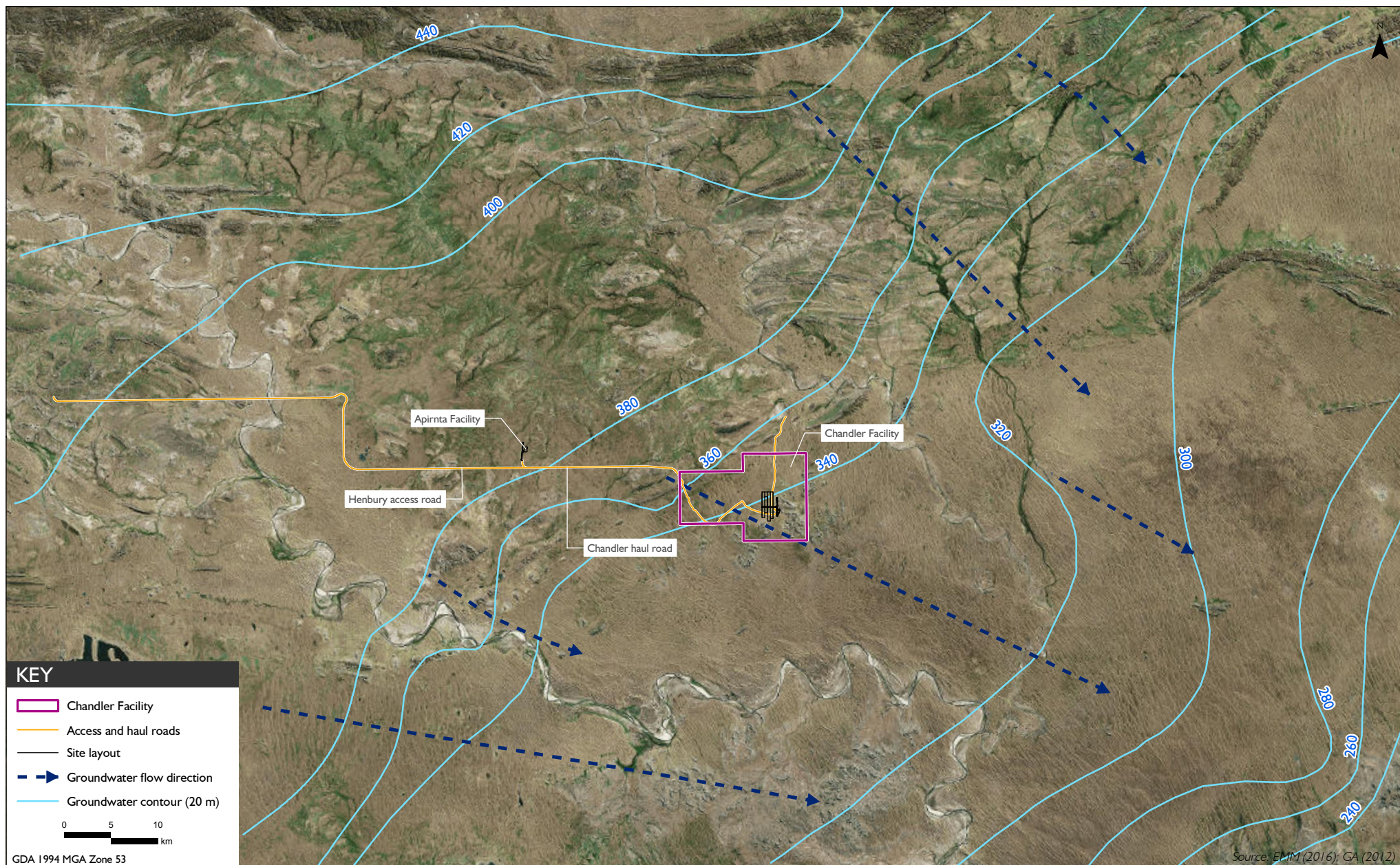
2. TDS = total dissolved solids.

3. TSS = total suspended solids.

The groundwater quality results are reasonably comparable between the different target formations. The pH is slightly alkaline, averaging 8, and salinity is moderately saline. The electrical conductivity ranged between 12,600 and 21,000 microSeimens per centimetre ($\mu\text{S}/\text{cm}$) which indicates groundwater within the Proposal area is saline (EPA 2016). There is a range of total suspended solids values; this is likely associated with bore construction rather than groundwater quality.

The water type at all locations was dominated by sodium and chloride, with minor calcium and sulfate ions (Figure 7.9). Total iron and zinc measurements were typically two to three orders of magnitude higher than the other total metal analytes. The highest iron and zinc results were observed at monitoring bore PBT1.

Regional water quality monitoring conducted by the NT Government indicates that salinity is comparable (ie moderately saline) for other monitoring locations targeting the Langra Formation. Regional mean electrical conductivity (11,307 $\mu\text{S}/\text{cm}$) is slightly lower than observed within the proposed Chandler Facility area but remains within a saline category. Regional monitoring in the Stairway Sandstone, underlying the Langra Formation, has comparable pH and electrical conductivity results (mean electrical conductivity: 16,578 $\mu\text{S}/\text{cm}$) to the Chandler Facility Langra Formation. Regional water type for the Langra Formation and Stairway Sandstone is also dominated by sodium and chloride. The water is generally suitable only for industrial uses.



Regional groundwater contours

Chandler Facility
Water Assessment

Figure 7.8

7.3 Water use

7.3.1 Landholder bores

The Amadeus Basin hosts numerous groundwater supply borefields across central and south-eastern NT. Regionally, the Roe Creek and Rocky Hill Borefields, located approximately 100 km north of the Proposal provide the potable supply to Alice Springs. Both borefields are located within the Orange Creek/Missionary Syncline and target the Mereenie Aquifer System (see Section 5.9) that is distinctly separate to the Chandler Syncline system.

Elsewhere, closer to the Proposal and within the south-east extent of the Amadeus Basin, numerous landholder bores target the shallow near-surface sediment groundwater systems along the Finke and Hugh Rivers. Other bores target deeper groundwater within the Idracowra and Stairway Sandstone.

A search for landholder bores registered for 'production' has been undertaken. A 25 km and 75 km spatial buffer around the Chandler Facility has been calculated (Figure 7.11 and Figure 7.12).

Landholder bores located within the 25 km spatial buffer have been tabulated in Table 7.2, with groundwater levels, flow direction and water quality further interpreted in subsequent sections. A complete list of bores located within the 75 km spatial buffer has been included for reference in Appendix C.

In total, 36 landholder production bores were identified within the 25 km spatial buffer and 193 were identified within the 75 km spatial buffer.

i Groundwater levels

The groundwater levels within a 25 km spatial buffer were mostly relatively shallow with a range between 6.44 and 18.4 m BGL. It is noted that landholder bores are generally located in lower lying creek lines and areas of the landscape that typically intercept localised groundwater in alluvial/colluvial sediment and weathered bedrock (ie Idracowra Sandstone and Stairway Sandstone).

Elsewhere, bores targeting the deeper groundwater associated with the Stairway Sandstone, groundwater levels ranged between 31 and 88.4 m BGL (relatively shallow by comparison with the Chandler Formation). Groundwater levels, once converted to a common elevation datum ranged between 409.9 m AHD and 306.6 m AHD, which demonstrates a wide range of about 100 metres. The shallower level (306.6 m AHD) measures the piezometric surface within the Stairway Sandstone down hydraulic gradient along the eastern boundary of Alice Creek. The higher level (409.9 m AHD) is measured to the west of the Chandler Facility along the Charlotte Range.

The shallowest below ground levels were observed at Top Soak Bore—RN12534 (5.2 m BGL) along the southern boundary of the ephemeral Finke River at an elevation of 345.1 m AHD. The inferred geology at this location comprised shallow Cainozoic alluvials underlain by Idracowra Sandstone.

ii Water quality

Groundwater quality results where available for landholder bore reports have been tabulated and are provided in Appendix D.

Overall water quality results indicate the groundwater conditions within the shallow local groundwater systems were highly variable, ranging from fresh to saline, in accordance with the classification system reported by the Australian Water Resources Council, 1998. The recorded electrical conductivity ranged between 412 $\mu\text{S}/\text{cm}$ at ID 144 (RN14572) and 52,600 at ID 123 (RN12533). Total Dissolved Solids (TDS) reflected the brackish conditions with an average concentration of 1,305 milligrams per litre (mg/L) recorded across the 13 shallow alluvium bores. Water quality within the deeper groundwater system associated with the Stairway Sandstone and the Idracowra Sandstone reflected more saline conditions with an average TDS concentration of 3,829 mg/L. Conversely, the shallow Titjikala aquifer reflected fresh conditions (>500 mg/L), with an average TDS concentration of 334 mg/L recorded across the 7 bores targeting the alluvial system.

The major ion chemistry of the shallow (< 20 m deep) and deep landholder bores (> 20 m deep) within the 25 km spatial buffer displayed highly variable water types. The majority of shallow landholder bores targeting the alluvium and tertiary sediment were dominated by calcium, chloride and bicarbonate, whereas water types within the deeper landholder bores targeting the Stairway Sandstone, Idracowra Sandstone and Titjikala aquifer were more closely associated with sodium, chloride and bicarbonate.

The hydrogeochemical composition of the water quality within the 36 landholder bores has been graphically represented in the piper diagram below (Figure 7.10). A piper diagram is a graphical representation of the relative concentrations of major ions (Ca^{2+} , Mg^{2+} , Na^{2+} , K^{+} , Cl^{-} , HCO_3^{-} , and SO_4^{2-}).

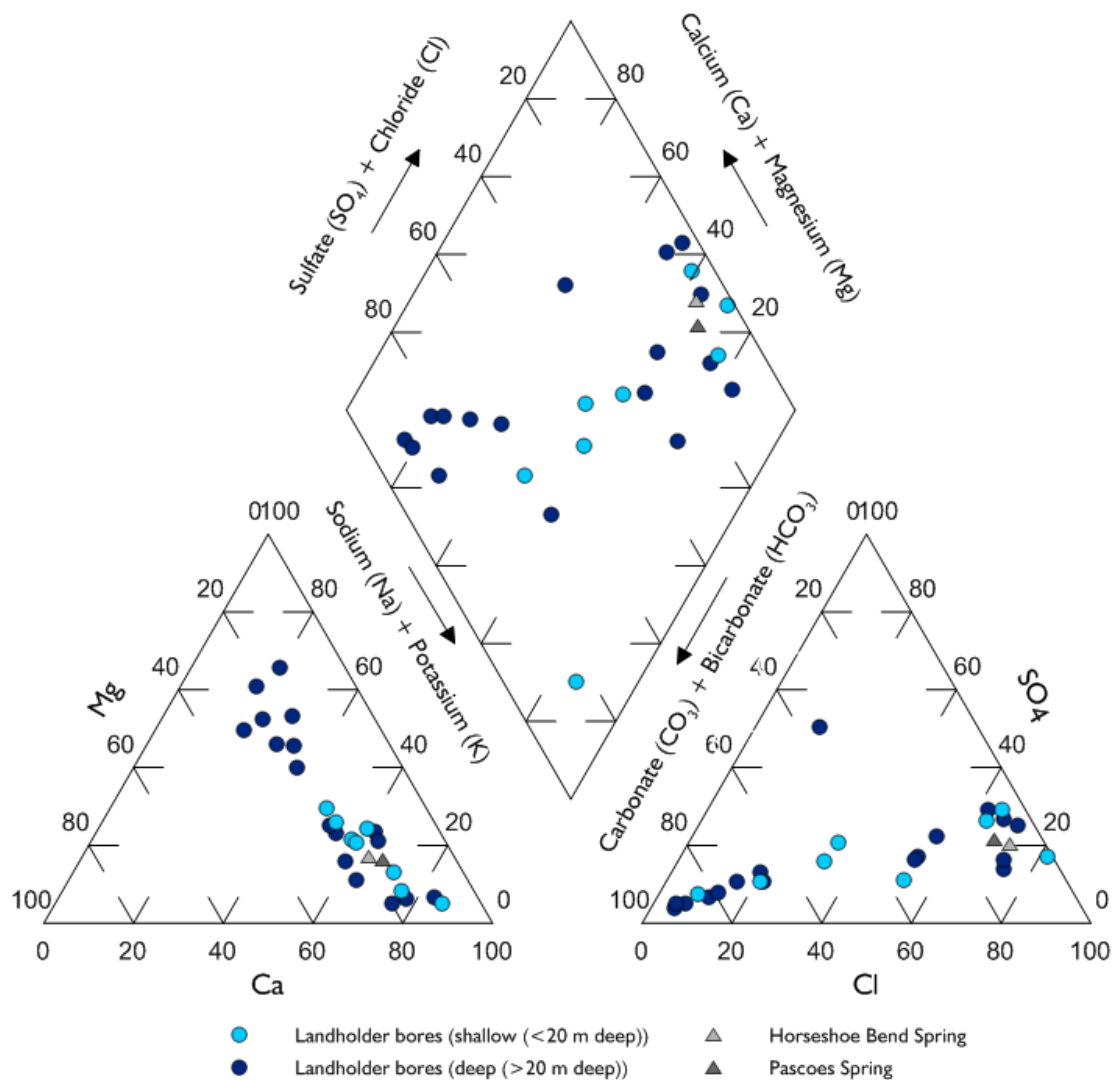


Figure 7.10 Piper plot showing major ion composition of groundwater from landholder bores

7.3.2 Springs

Five groundwater springs are located within a 75 km radius of the Chandler Facility (Figure 8.10), the nearest (Pascoes Spring) being approximately 20 km south-west of the proposed Chandler Facility. The remaining four springs (Horseshoe Bend Spring, Black Hill Spring, Polly's Spring, and Micks Soak) are all located approximately 50 km south-east of the Chandler Facility, situated along the Finkel River.

Riparian vegetation communities consisting predominantly of River Red Gum and Coolabah are likely to be partially sustained through intermittent baseflow provided by these four groundwater springs. However, the majority of water sustaining these ecological communities is thought to be provided through flooding events.

Approximately 230 km south-east of the Chandler Facility the Dalhousie Spring complex emanates in an area underlain by the Lake Eyre Basin, western Eromanga Basin and the Pedirka Basin, but beyond the south-eastern boundary of the Amadeus Basin. The Dalhousie Spring complex is considered in this assessment as it is an important ecological and cultural asset (the highest discharging spring complex in the GAB). The Dalhousie Spring complex has previously been exclusively attributed as a discharge feature of the Eromanga Basin.

The latest information (Wohling et al, 2013), however, indicates that the Dalhousie Springs complex is also of hydrogeological significance to the Pedirka Basin. While it is not known for certain, there is no evidence for any hydraulic connectivity with the Amadeus Basin. Groundwater flow to the Dalhousie Springs complex is now known to be supported in part by discharge from the Crowne Point Formation, a key groundwater system within the Pedirka Basin.

The Crowne Point Formation outcrops near the boundary with the Amadeus Basin, and receives recharge via infiltration from ephemeral Finke River flows. There is a further contribution from the Finke River alluvium to the underlying Algebuckina Sandstone (a key Eromanga Basin groundwater system). The recharge potential is evidenced by mounding in the Finke River alluvium, and the groundwater flows via the Pedirka and Eromanga Basin formations contribute to Dalhousie Spring complex discharge (i.e. no contributions from the Amadeus Basin formations)(Wohling *et al.*, 2013).

7.3.3 Ecosystems that potentially use groundwater

Two ecological communities (*Eucalyptus camaldulensis* var. *Obtuse* and *Eucalyptus coolabah* subsp. *Arida*) have been identified by DENR to persist within the riparian corridors of the Finke and Hugh Rivers. These communities are commonly identified in the Bureau of Meteorology's Atlas of Groundwater Dependent Ecosystems (BoM 2016) as having a *moderate potential for groundwater interaction*. The root structure is considered to be shallow (<15 m) and may potentially receive a source of water from perched shallow groundwater systems (ie alluvial sources) associated with ephemeral creeks. Neither of these ecological communities has been listed as endangered ecological communities (EECs).

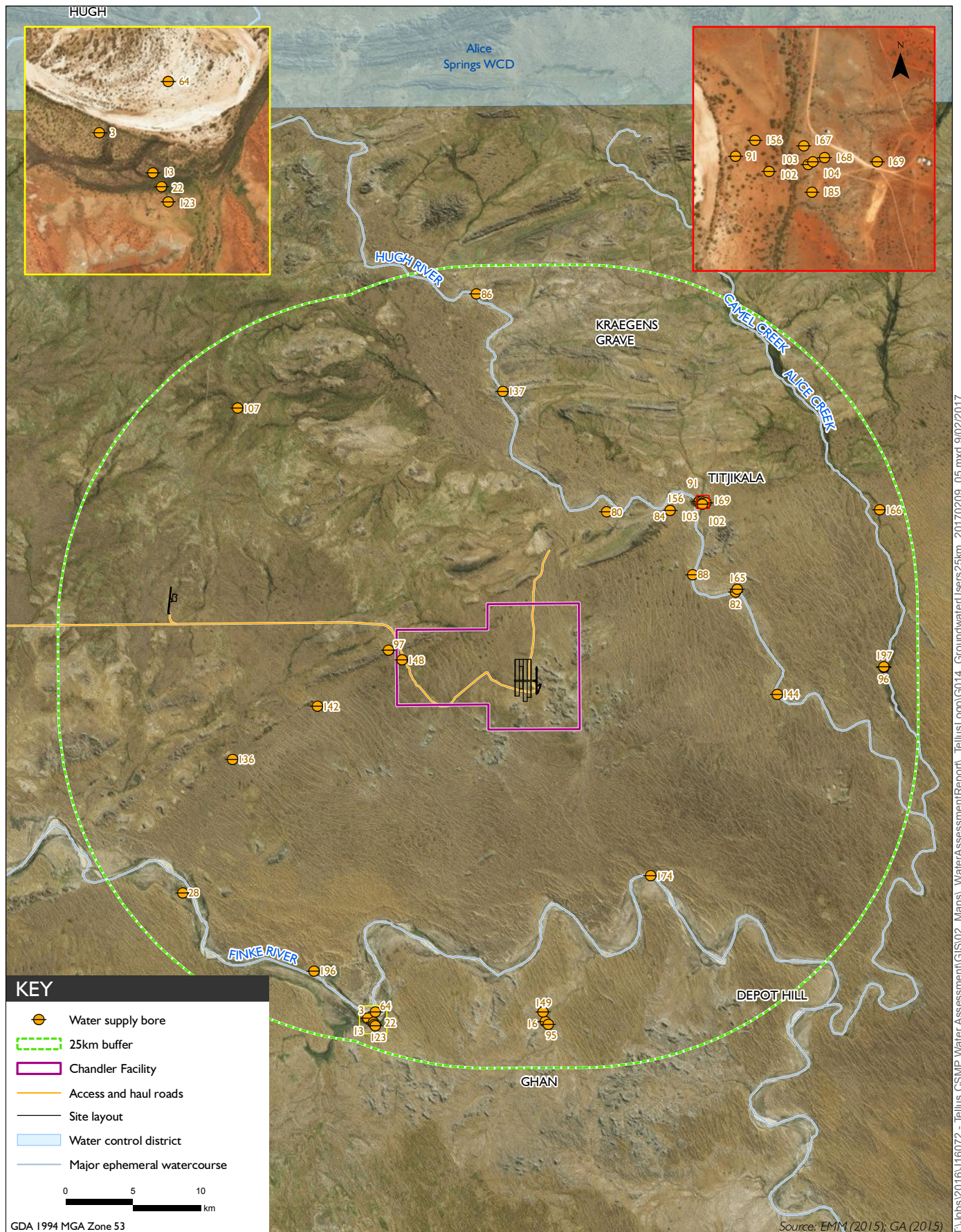
Table 7.2 Key sensitive landholder bores (25 km spatial buffer)

Reference ID	Easting ¹	Northing ¹	Surface elevation (m AHD) ²	Bore depth (m AHD) ²	Water level (m AHD) ²	Screened formation	Yield (L/second) ³	Property
3	381558.0	7231748.0	351.2	334.8	342.6	Alluvium	1.4	Maryvale
13	382000.0	7231417.0	350.3	340.4	344.8	Alluvium	2.0	Maryvale
16	394684.0	7231490.0	342.8	307.0	335.0	Idracowra Sandstone	0.5	Maryvale
22	382073.0	7231298.0	351.0	334.8	343.5	Alluvium	1.0	Maryvale
28	367922.0	7240985.0	358.4	434.3	441.5	Alluvium	1.5	Idracowra
64	382127.9	7232170.9	350.0	-	-	Alluvium?	-	Maryvale
80	399199.8	7269101.8	379.0	327.8	-	Stairway Sandstone	0.4	Maryvale
82	408720.8	7263168.8	354.0	-	-	Alluvium	-	Maryvale
84	403887.8	7269218.8	387.0	-	-	Santo Sandstone	-	Maryvale
86	389576.9	7285189.7	398.4	-	-	Alluvium	-	Maryvale
88	405554.8	7264471.8	362.5	326.7	344.2	Quaternary/Tertiary sediment	6.2	Maryvale
91	405978.8	7269804.8	364.9	337.5	352.2	Alluvium	1.5	Maryvale
95	394899.9	7231292.9	342.6	315.2	333.2	Idracowra Sandstone	0.4	Maryvale
96	419677.8	7257637.8	348.7	303.0	336.5	Idracowra Sandstone	1.1	Maryvale
97	383103.9	7258901.8	483.0	376.3	409.9	Stairway Sandstone	0.8	Maryvale
102	406111.5	7269743.3	365.0	315.8	353.8	Titjikala Sandstone	18.7	Maryvale
103	406265.0	7269773.0	367.0	306.0	352.0	Titjikala Sandstone	18.7	Maryvale
104	406283.0	7269784.0	367.1	306.1	351.6	Titjikala Sandstone	12.5	Maryvale
107	371964.9	7276760.7	447.8	427.8	-	Tertiary sediment	-	Henbury
123	382127.9	7231170.9	348.1	336.1	339.1	Alluvium	0.1	Maryvale
136	371585.9	7250849.8	384.3	319.3	353.3	Stairway Sandstone	2.0	Idracowra
137	391551.9	7278014.7	388.6	352.6	380.1	Stairway Sandstone	3.5	Maryvale
142	377846.9	7254757.8	410.4	308.4	337.4	Stairway Sandstone	2.5	Idracowra
144	411807.8	7255627.8	352.2	321.2	345.7	Alluvium	6.9	Maryvale
148	384127.9	7258170.8	423.5	303.5	335.1	Stairway Sandstone	0.8	Maryvale
149	394527.9	7232170.9	351.7	300.7	-	Idracowra Sandstone	-	Maryvale

Table 7.2 Key sensitive landholder bores (25 km spatial buffer)

Reference ID	Easting ¹	Northing ¹	Surface elevation (m AHD) ²	Bore depth (m AHD) ²	Water level (m AHD) ²	Screened formation	Yield (L/second) ³	Property
156	406054.8	7269866.8	364.4	322.4	351.9	Alluvium	5.5	Maryvale
165	408860.8	7263358.8	357.1	282.1	326.1	Santo Sandstone	3.0	Maryvale
166	419380.8	7269262.8	359.6	253.6	306.6	Santo Sandstone	1.0	Maryvale
167	406247.0	7269845.0	366.7	246.5	352.1	Titjikala	12.0	Maryvale
168	406329.0	7269798.0	368.6	318.6	350.2	Titjikala	1.0	Maryvale
169	406534.0	7269783.0	374.6	307.3	348.3	Titjikala	1.0	Maryvale
174	402473.9	7242244.9	328.8	-	-	Alluvium?	-	Maryvale
185	406279.0	7269664.0	367.4	307.4	352.9	Titjikala	5.0	Maryvale
196	377597.0	7235212.0	354.2	324.2	343.2	Alluvium	2.0	Idracowra
197	419688.0	7257647.0	348.9	228.9	335.9	Idracowra Sandstone	0.6	Maryvale

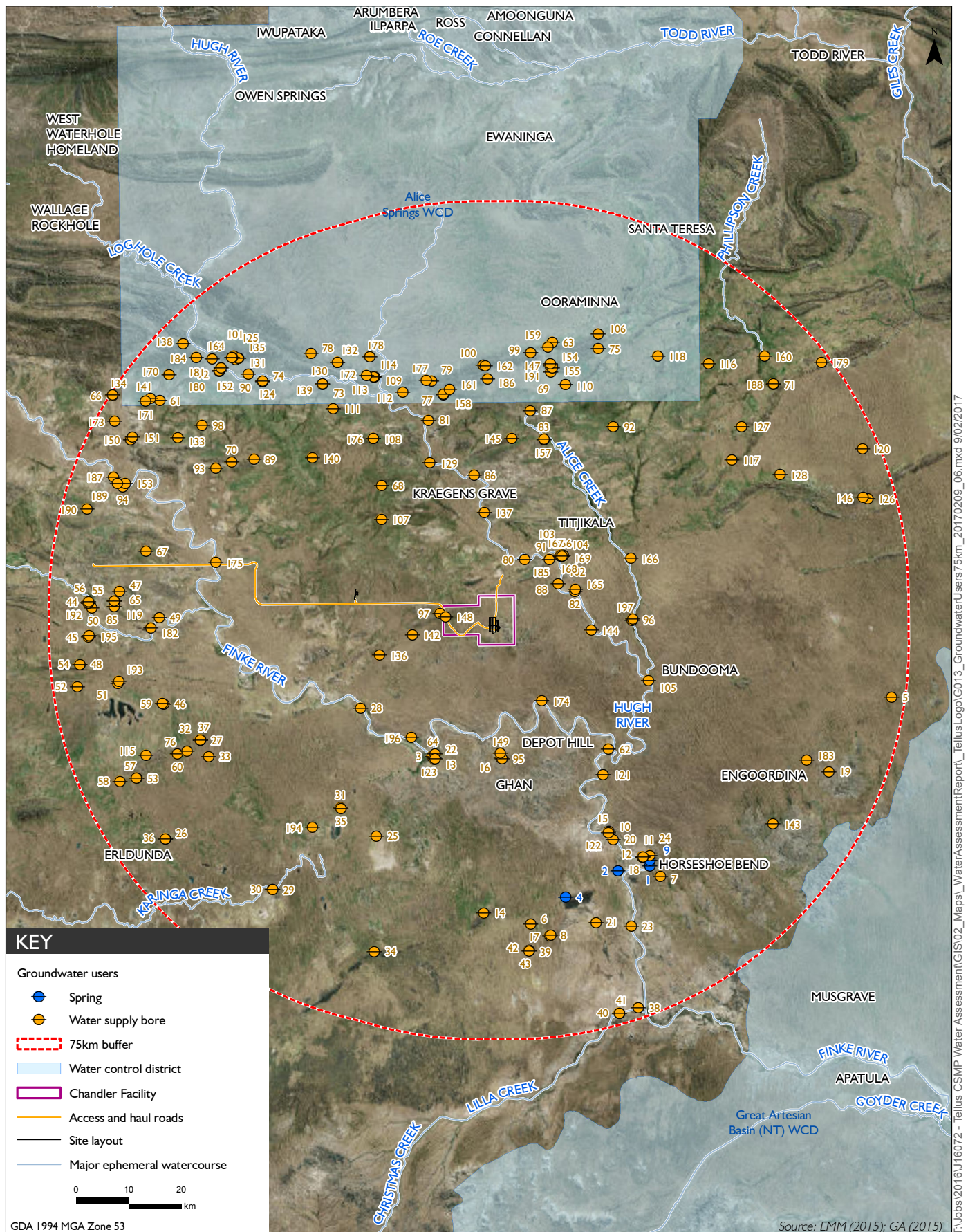
Notes: 1. GDA 1994 MGA Zone 53.
2. m AHD=metres Above Height Datum.
3. L/second=litres per second.
4.-=not available.



Groundwater users within 25 km of the Chandler Facility

Chandler Facility
Water Assessment

Figure 7.11



Groundwater users within 75 km of the project area

Chandler Facility
Water Assessment

Figure 7.12

8 Site conceptual model

8.1 Introduction

A site conceptual model is a simplified representation of the physical hydrological and hydrogeological setting and understanding of the system. This includes the identification and description of the geologic and hydrologic frameworks, recharge to the system, groundwater flow dynamics and surface-groundwater interaction processes.

8.2 Groundwater systems

The Proposal area is within the Chandler Syncline, itself within the south-eastern extent of the Amadeus Basin. The Chandler Syncline hosts various local groundwater systems, all of which have minor confining layers and permeability barriers to groundwater flow. The basal unit overlying the Chandler Formation and target salt resource is the Giles Creek Dolostone Formation, comprising predominantly dolomitic calcareous shales and sand and silt sediment. Overlying the Giles Creek Dolostone Formation is the Jay Creek Limestone Formation, comprising predominantly of marine shale, silt and sand sediments and thin beds of dolomite.

Overlying the Jay Creek Limestone Formation is the Stairway Sandstone Formation, a thick geological sequence comprising predominantly continental coarse to medium grained sandstone within interbedded minor silt and shale beds. Overlying the Stairway Sandstone Formation is the Langra Formation, a geological unit subdivided into three member units, represented at depth by interbedded silt and shale beds, gradually transitioning into extensive fine to medium grained sand.

Overlying the Langra Formation is the Horseshoe Bend Shale Formation, a massive siltstone and quartzitic sandstone deposit. Directly above the Horseshoe Bend Shale Formation and partially eroded at surface across the Proposal area is the Idracowra Sandstone, a kaolinitic sandstone represented across the Maryvale Hills and discontinuous across the Proposal area.

Locally in the vicinity of the Proposal area, there is limited recharge from direct rainfall and minor recharge is expected to occur via infiltration from overlying alluvial systems during major flooding events. Minor direct rainfall recharge may occur locally, but the low rainfall and high evaporation means this volume would be minimal and the presence of stratified low permeability clays and silts in the middle and lower members of the Langra Formation is likely to result in the formation of perched localised groundwater systems in the upper Langra Formation and Horseshoe Bend Shale Formation.

Consistent with topographic gradients, hydraulic gradients are very gentle in the south-eastern extent of the Amadeus Basin, and the broad flow direction in all groundwater systems is generally from north-west to south-east. However, the basement structure (typically associated with folding) influences the groundwater flow direction in certain areas across the Proposal area (see Figure 8.2, Figure 8.3, Figure 8.4 and Figure 8.5).

The horizontal hydraulic conductivity in geological units is likely to be highly variable, due to the depositional environments and volume of clay; substantial lateral flow through Formations is therefore not expected.

There is an upwards hydraulic gradient from the Langra Formation to the Horseshoe Bend Shale Formation based on pressure head differences observed through groundwater monitoring, but there is no evidence of substantial flow volumes between these units. Elsewhere, within the 25 km spatial buffer around the Chandler Facility, landholder bores located within the shallow alluvium report shallow groundwater levels which are likely to be perched systems, with very little vertical leakage to the underlying Idracowra Sandstone Formation and Horseshoe Bend Shale Formation.

The saline groundwater quality within the Chandler Syncline is differs markedly from the potable water quality reported for the Mereenie Aquifer System about 100 km north within the Northern Amadeus Basin. The Chandler Syncline system is considered to be a separate groundwater system entirely and therefore not connected to the groundwater sources utilised for the Alice Springs Water Supply. The evidence confirms that the Chandler Syncline system is distinct and separate from the Mereenie Aquifer System in terms of geological structure, lithological units, groundwater flow properties, hydraulic gradients and hydrogeochemistry.

Water quality within shallow alluvial groundwater accessed by landholder bores to the north and west of the Chandler Facility, particularly at Titjikala, is generally potable. Whereas groundwater quality observed within the Horseshoe Bend Shale and Langra local groundwater systems at the Chandler Facility is poor and equivalent to seawater. Salts originating from the marine depositional environment, and the enhanced climatic nature of the environment (ie low precipitation/high evaporation), coupled with long groundwater residence times is likely to contribute to the poor groundwater quality observed within the Chandler Syncline.

8.3 Surface water and groundwater connectivity

The widespread absence of permanent surface water features across the Proposal area means that the groundwater and surface water systems are not connected in the vicinity of the Chandler Facility. Shallow groundwater levels and gradients within the alluvium groundwater system indicate some potential for connectivity to the south-east along the Finke River about 20 km from the Chandler Facility.

There are no groundwater monitoring bores located directly adjacent to the Finke River and screened within the deeper groundwater systems (ie Idracowra Sandstone, Horseshoe Bend Shale or Langra Formation). Therefore, it is difficult to gain a comprehensive understanding of connectivity in areas along the Finke River directly down hydraulic gradient of the Chandler Facility. Characterisation of the water type of the springs located along the Finke River to the south and south-east of the Chandler Facility suggest the source of water from these springs is likely to be derived from the perched shallow alluvial sediment and not the deeper groundwater system connected to the Chandler Facility.

This implies a lack of connectivity, which would mean that any potential drawdown impacts in the deeper groundwater systems arising from Proposal dewatering through abstraction or mining activities would not impact surface water resources. It should also be noted that the drawdown impacts arising from the Proposal would be of such low magnitude and extent that they would not reach the spring areas. This is due to the low rate of groundwater pumping throughout the Proposal life (3.42 L/s, which is broadly consistent with stock and domestic rates), and also the limited extent of drawdown due to the relatively low permeability aquifer units, and the intervening aquitard units.

8.4 Groundwater modelling of drawdown impacts

The De Glee (1930) analytical model of steady state drawdown in leaky aquifer systems has been applied to investigate the pumping and drawdown relationship, based on site specific hydrogeological data and the site hydrogeological conceptual model. The De Glee model uses steady state drawdown data and allows the characteristics of the aquifer and aquitard to be determined. The model has been used in northern South Australia to investigate the drawdown effects due to extractions in the Eromanga Basin as part of the Far North Water Allocation Plan.

Based on aquifer properties obtained through the Proposal drilling and monitoring program, a groundwater drawdown of 0.4 m has been calculated at a distance of 1 km from a bore assumed to be continuously pumping at a rate of 3.42 L/s (maximum project water demand during the operation phase) (see Figure 8.1). This distance drawdown relationship was calculated using the De Glee solution:

$$s_m = Q/(2\pi KD) K_0(r/L)$$

Table 8.1 defines the variables used in the above solution.

Table 8.1 Aquifer parameters

Variable ID	Parameter	Unit	Adopted value
s_m	Steady-state drawdown at a distance r from the well	m	0.4 ¹
r	Distance from well	m	1000
Q	Well discharge	m ³ /day ²	295.62
L	$\sqrt{KDc}$: Leakage factor	m	447
K	Aquifer permeability (hydraulic conductivity)	m/day	0.1
D	Aquifer thickness	m	100
c	D'/K' : Hydraulic resistance of the aquitard	days	20,000
D'	Saturated thickness of the aquitard	m	20
K'	Hydraulic conductivity of the aquitard for vertical flow	m/day	0.001
$K_0(x)$	Bessel function	~	0.085

Notes: 1. calculated solution.

2. m³/day = cubic metres per day.

The De Glee analytical modelling method is consistent with the Proposal conceptual model (semi-confined or leaky aquifer conditions). The results indicate that water take through mine dewatering and groundwater abstraction is likely to have a limited and very localised drawdown impact, primarily confined to the defined Project area.

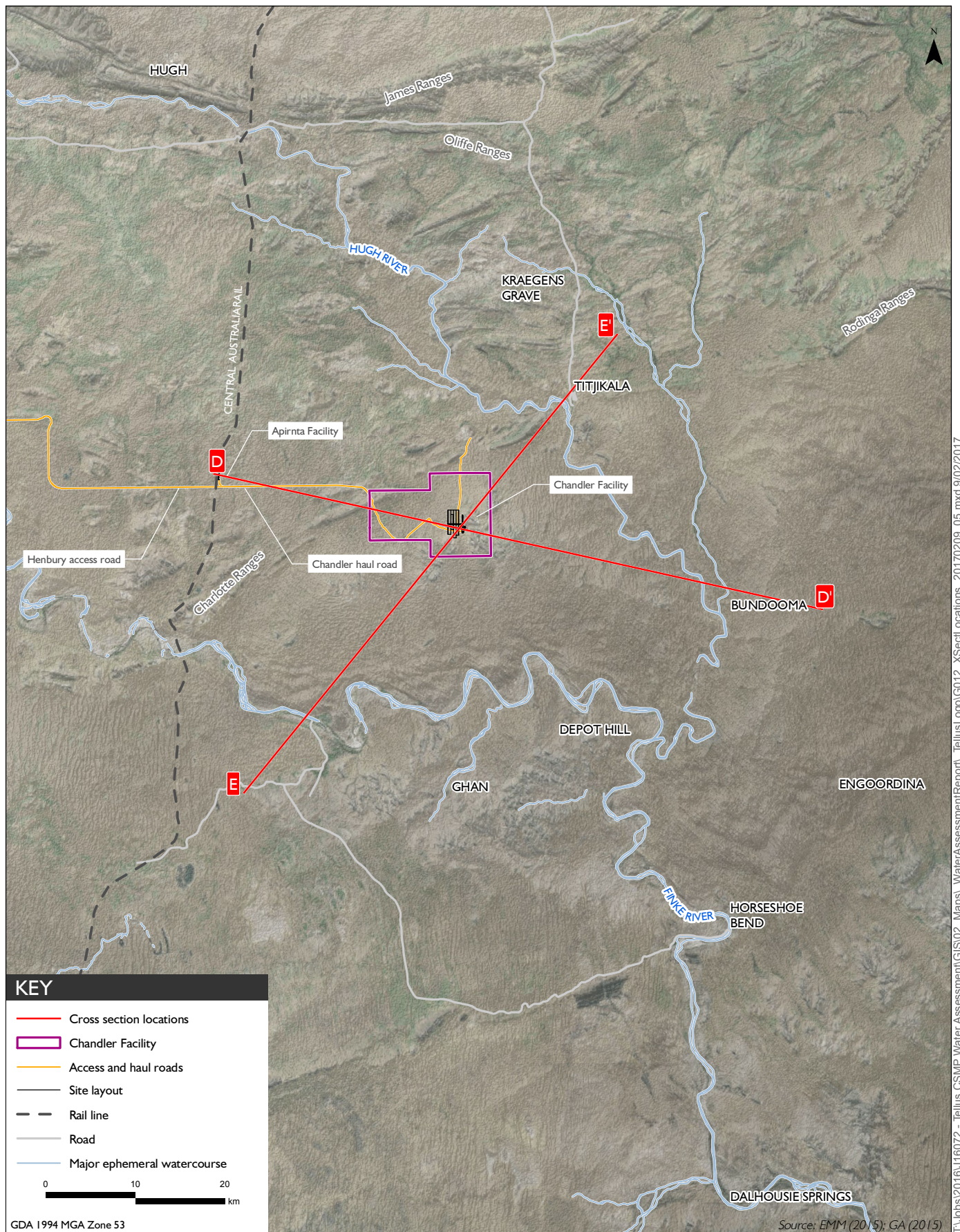
Further detailed analytical interpretation will be completed following the implementation of additional monitoring and pumping tests within the Langra and Stairway Sandstone groundwater systems across the Proposal area.

The potential impacts of groundwater dewatering at depths between 160 m below ground level to 220 m below ground would be included in the conceptual model following the completion of detailed design and further drilling campaigns expected to commence in March 2017. In addition, any potential impacts of drawdown will be further discussed and illustrated through supplementary material to this EIS.



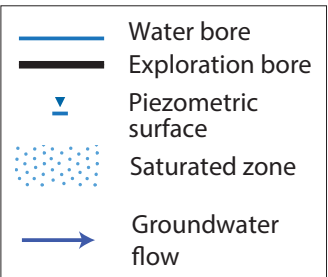
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Project-related drawdown
Chandler facility
Water assessment
Figure 8.1

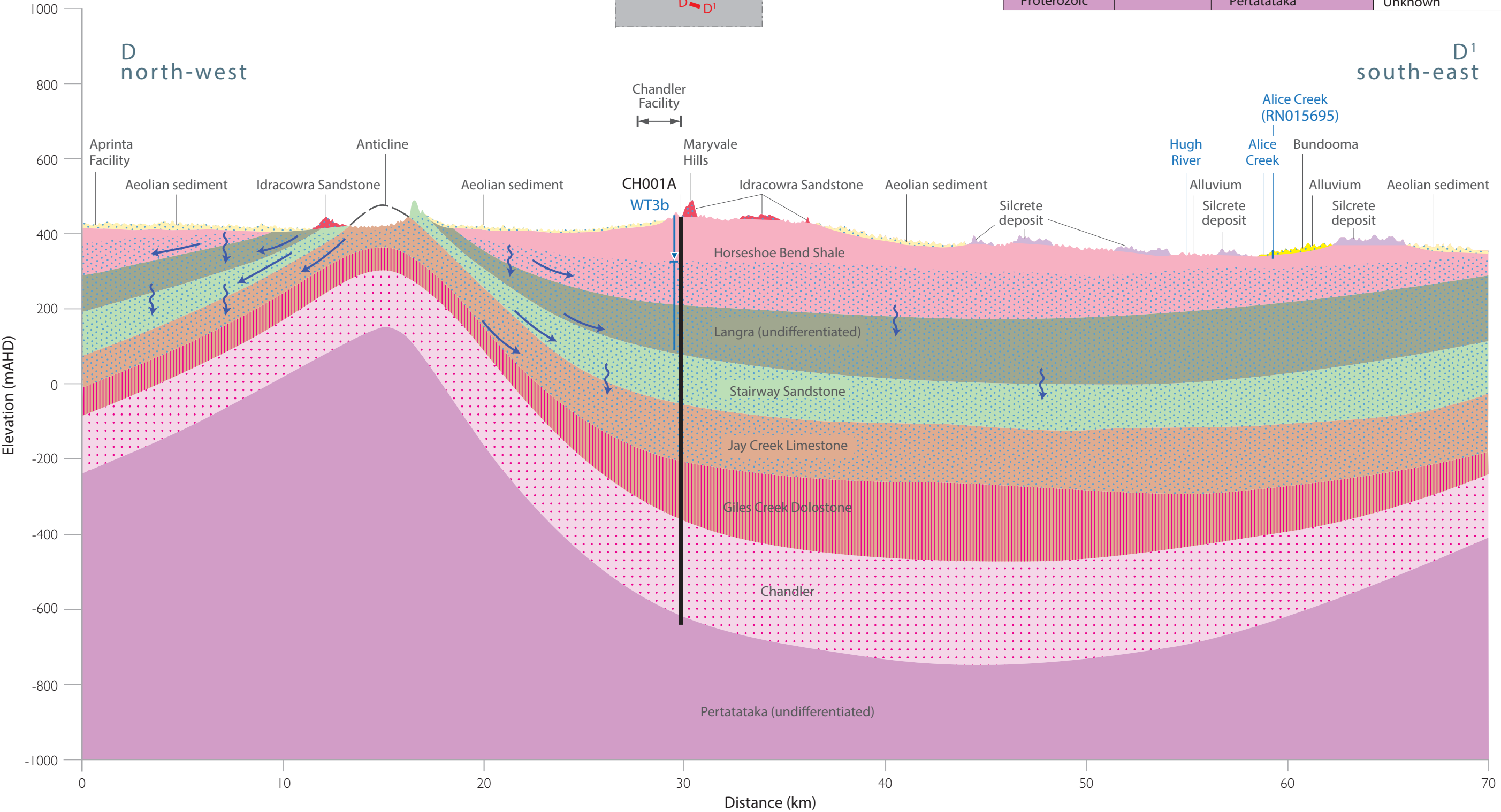


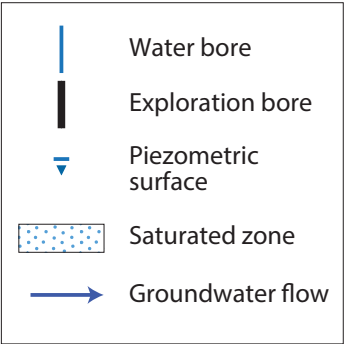
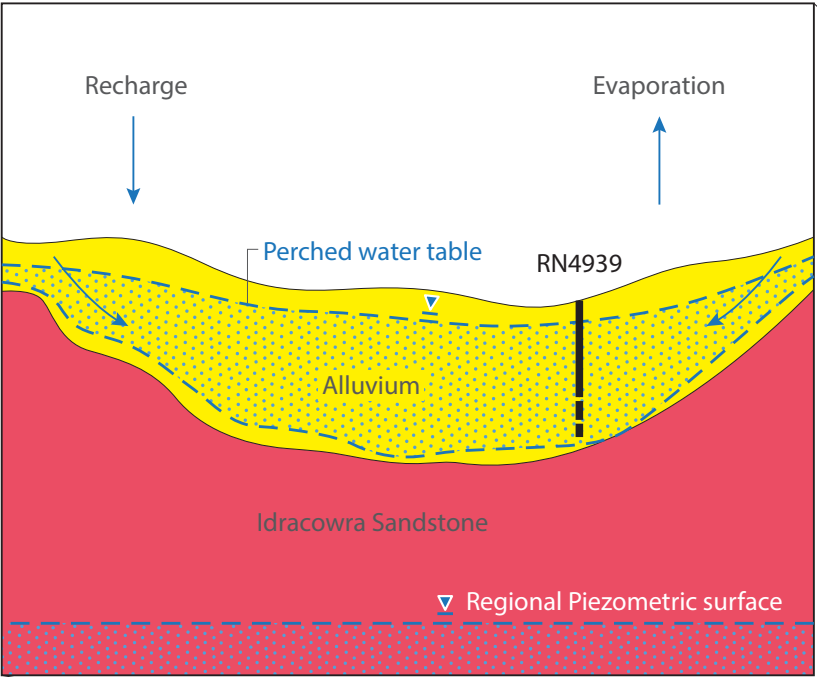
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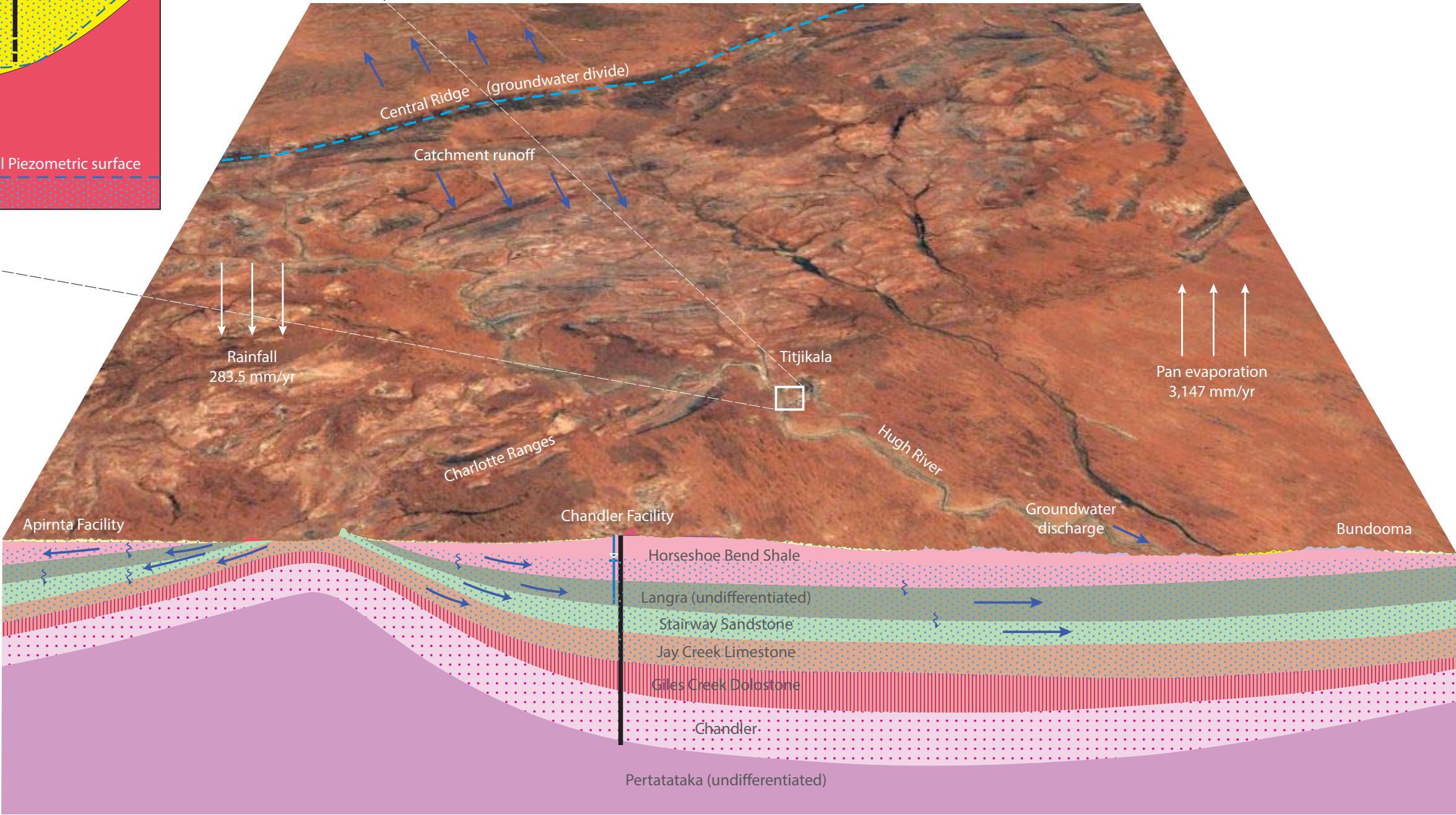


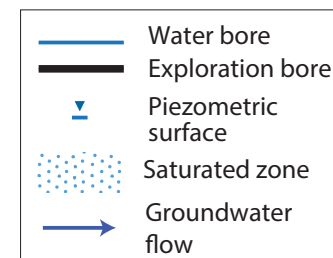
Age	Group	Formation	Hydrogeology
Quaternary		Alluvium	Aquifer (perched)
		Aeolian sediment	Aquifer (perched)
Tertiary		Silcrete deposit	Aquitard (local)
Carboniferous	Finke	Idracowra Sandstone	Aquifer
		Horseshoe Bend Shale	Aquifer
		Langra	Aquifer
Devonian	Larapinta	Stairway Sandstone	Aquifer
		Jay Creek Limestone	Aquifer
Cambrian	Pertaoorrt	Giles Creek Dolostone	Aquitard
		Chandler	Aquitard
		Pertatataka	Unknown
Proterozoic			



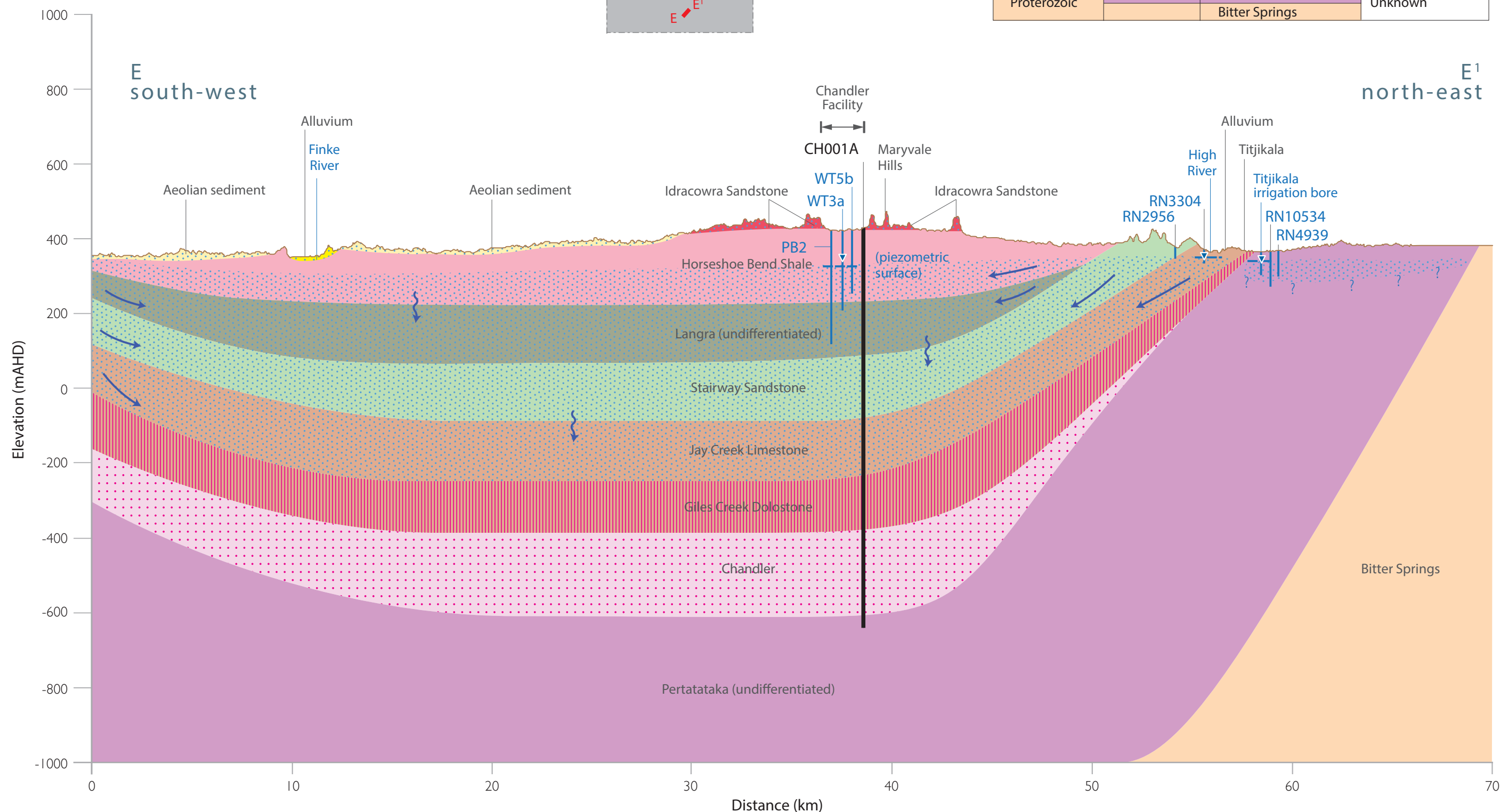


Age	Group	Formation	Hydrogeology
Quaternary		Alluvium	Aquifer (perched)
		Aeolian sediment	Aquifer (perched)
Tertiary		Silcrete deposit	Aquitard (local)
Carboniferous		Idracowra Sandstone	Aquifer
Devonian	Finke	Horseshoe Bend Shale	Aquifer
		Langra	Aquifer
Ordovician	Larapinta	Stairway Sandstone	Aquifer
Cambrian	Pertaoorrt	Jay Creek Limestone	Aquifer
		Giles Creek Dolostone	Aquitard
		Chandler	Aquitard
Proterozoic		Pertatataka	Unknown





Age	Group	Formation	Hydrogeology
Quaternary		Alluvium	Aquifer (perched)
		Aeolian sediment	Aquifer (perched)
Tertiary		Silcrete deposit	Aquitard (local)
Carboniferous		Idracowra Sandstone	Aquifer
		Horseshoe Bend Shale	Aquifer
Devonian	Finke	Langra	Aquifer
		Stairway Sandstone	Aquifer
Ordovician	Larapinta	Jay Creek Limestone	Aquifer
Cambrian	Pertaoorrt	Giles Creek Dolostone	Aquitard
		Chandler	Aquitard
Proterozoic		Pertatataka	Unknown
		Bitter Springs	Unknown



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9 Water balance

9.1 Introduction

A water balance involves the estimation of the storage and flow of water in a defined area, during a given timeframe. A mass balance equation is used in which the change of water stored within an open (natural) hydrological system is equal to the inputs to the system minus the outputs from the system (Todd and Mays 2005):

$$\text{Inflows} = - \text{Outflows} + \text{Change in storage } (\Delta S)$$

9.2 Water balance

A water balance combining the mine water management system, abstracted saline and potable groundwater, and saline water intercepted during construction has been prepared for the construction and operations phases. The water balance is based on the conceptual mine plan and would be updated following the completion of detailed design. The results of the updated water balance would be carried through into the Proposal's Water Management Plan.

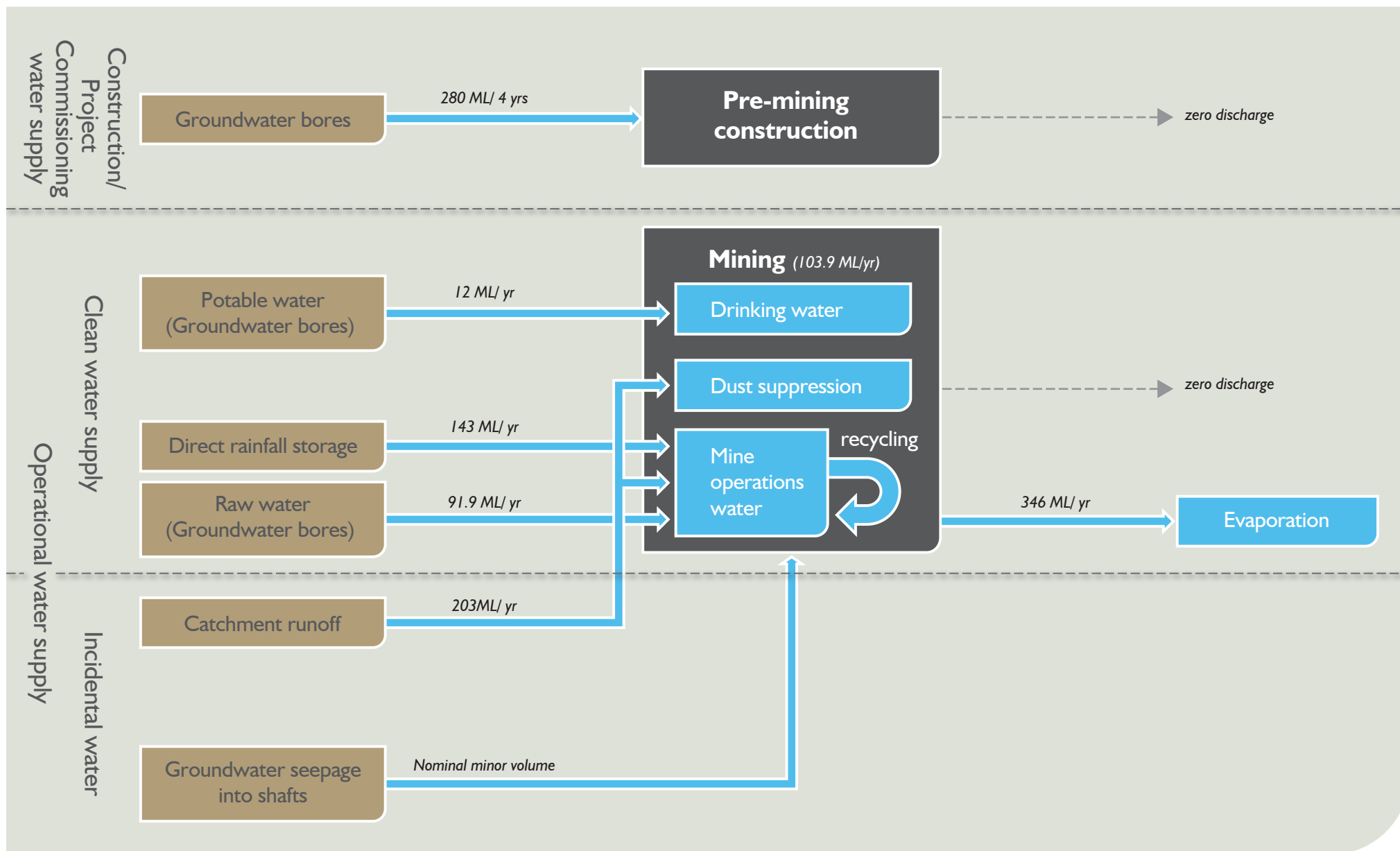
The conceptual water balance is presented in Table 9.1 below and indicates marginal net change in total site water inventory during the operation phase. A representative water schematic is also shown in Figure 9.1.

Table 9.1 Water balance (average rainfall year)

Parameter	Construction (ML/year) ¹	Operation -Year 1 (ML/yr)
Inflows to water management system		
Groundwater inflow to shafts	0	0
Catchment runoff	203	203
Direct rainfall on water storages	143	143
Raw water supply for processing/dust suppression activities	54	91.9
Potable water supply	16	12
Total inflows	416	450
Outflows from water management system		
Net site water management system	70	103.9
Uncontrolled releases	0	0
Evaporation	346	346
Total outflows	416	412
Net change in total site water inventory	0	0

Notes: 1. ML/year = megalitres per year.

The water management system maximises the capture and reuse of mine affected water. The majority of water will be sourced from groundwater abstraction with make-up water supplied via on-site sources (ie rainfall runoff). Mine affected water will be reused to the supply the processing plant and water dust suppression demands in addition to groundwater abstraction. abstraction. All water abstracted for the Proposal will be for non-consumptive use. No abstracted groundwater will leave the Proposal area with all waters being returned to the groundwater system through mining/processing activities.



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10 Groundwater impact assessment

10.1 Introduction

Potential groundwater impacts of the Proposal are discussed and assessed in this section. Changes to groundwater levels, groundwater chemistry and the hydrogeology itself are considered in respect of the sensitive receptors that were identified earlier in Section 4. Specifically, the significance of change and subsequent impact is considered.

10.2 Groundwater levels

The conceptual model, described in Section 8, has predicted changes in groundwater levels as a result of the Proposal generally across the Proposal area and locally at identified sensitive receptors.

10.2.1 Abstraction

Groundwater abstraction will service the primary potable and raw water supply demands across the Proposal. A maximum water demand of approximately 54 ML/year of groundwater will be required over the 4-year construction/commissioning period, thereafter reducing during the Proposal operations. Abstraction will service five primary activities:

i Chandler Facility borefield

Two production bores will be located adjacent to the decline portal within the MIA and will target the Langra groundwater system. Water supply will be used for construction ahead of mining. Impacts are minor, with only minor localised drawdown predicted as a result of extraction from these bores.

ii Chandler camp site borefield

Two production bores will be located within the MIA to provide potable water supply during construction and operation of the Proposal. Impacts are minor, with only minor localised drawdown predicted as a result of extraction from these bores.

Based on results obtained through the groundwater monitoring bore drilling program, monitoring and the conceptual understanding of the site a groundwater drawdown rate of 0.4 m has been calculated at an approximate distance of 1 km from a bore continuously pumping at the peak take Proposal water demand of approximately 103.9 ML/year (3.42 L/s).

iii Chandler Haul Road and Apirnta Facility

Two production bores sited along the Chandler Haul Road will target the Langra and Stairway Sandstone groundwater systems at depths of between 50 and 150 m BGL and will meet dust suppression and construction water demands along the Chandler Haul Road and at the Apirnta Facility. Impacts are minor, with only minor localised drawdown predicted as a result of extraction from these bores. Landholder bores (RN10082 and RN14584) abstracting water from the Stairway Sandstone groundwater system are both located greater than 1000 m from the nearest proposed production bore and are therefore not considered to be potentially impacted by project abstraction demands.

Elsewhere, the relatively minor drawdown associated with Proposal-related abstraction is of such a low magnitude and localised extent that is unlikely to cause any impacts of concern to those sensitive receivers identified earlier in Section 4.1.1 and Section 7.3.1 and is not explored further as a potential impact.

10.2.2 Mining

The Proposal will intercept groundwater during the construction of the mine decline and the two ventilation shafts within the MIA. Four localised groundwater systems are expected to be intercepted during the construction phase of the Proposal; these are understood to be:

1. The Horseshoe Bend Shale Formation.
2. The Langra (Upper and Lower) Formation.
3. The Stairway Sandstone Formation.
4. The Jay Creek Limestone Formation.

The limited extent of these localised groundwater systems as demonstrated by the extensive surface and downhole geophysics work and the conceptual model, is likely to result in limited groundwater storage. This is further evidenced by the PB2 pumping test, where transmissivity and sustainable yield both indicated the Langra groundwater system was only capable of supporting small groundwater yields. Therefore, any groundwater inflows to the decline and ventilation shafts are expected to be easily managed using standard underground mine sealing techniques during construction and operation of the Proposal.

Any groundwater intercepted during construction is likely to result in the dewatering of the localised groundwater systems. Due to the limited extent of these systems and the stratified nature of the geology, dewatering impacts arising from mining operations are not expected to impact those sensitive receivers identified in Section 4.1.1 and Section 7.3.1.

The proponent would construct multiple engineering barriers to prevent groundwater inflow during the construction of subsurface works to limit the extent of dewatering. Details of mitigating/control measures, notably including shotcreting of any significant inflow areas along the decline and/or mine path, are provided in Section 11 (refer to Table 11.5).

10.2.3 Impacts to private landholder bores

Registered private landholder bore details were obtained from DENR in July 2016. Within a 25 km radius of the Proposal area there are 36 private landholder bores, predominantly utilising groundwater for stock and domestic purposes. The majority of the bores are screened in the alluvium and Titjikala groundwater systems, however deeper bores to the west and east of the Chandler Facility are known to intercept the Stairway Sandstone and Idracowra Sandstone (see Figure 7.11).

As detailed in Section 10.2.2, dewatering impacts arising from the construction of subsurface works are expected to be localised and are not likely to impact the landholder bores identified in Section 4.1.1 and Section 7.3.1.

Groundwater abstraction within the Stairway Sandstone associated with the operation of the Chandler Haul Road borefield may also result in localised drawdown. The nearby landholder bores targeting the Stairway Sandstone (RN10082 and RN14584) may experience some reduction in groundwater levels and supply (see Section 11 for further discussion).

Water resource impacts to the Alice Springs water supply borefields (Roe Creek borefield and Rocky Hill borefield) arising from Proposal-related dewatering and/or groundwater abstraction is not expected as demonstrated through the conceptual model (see Section 8).

10.3 Groundwater dependent ecosystems

There are no known GDEs within the vicinity of the Proposal. There is the potential for low to moderate impacts to River Red Gum and Coolabah vegetation proximal to the Proposal area, as these ecosystems are considered to be partially dependent on groundwater (see Section 10.5 for further discussion).

10.4 Groundwater quality

10.4.1 Waste emplacement

As detailed in Section 3, the Chandler Facility will receive and store waste below ground in isolation over the 25-year mining life. The final inventory of waste product to be received is yet to be agreed. An indicative waste inventory to be accepted at the proposed Chandler Facility is provided in Appendix E.

Waste will be transported by rail and temporarily stored above ground within shipping containers at the Apirnta Facility, where it will then be transported by road train and eventually transported down the Chandler Facility's decline shaft for storage in the Chandler Facility's waste storage repository.

The potential for groundwater contamination via waste leakage is greatest during rail and road transportation of the product. Impacts arising from train derailment or a truck rolling over could result in contaminants spilling across ephemeral drainage lines and infiltrating the porous alluvium. Bores targeting shallow groundwater systems across the Proposal area have been identified in Section 7.3.1.

Contamination of groundwater arising from the storage of waste in the underground repository is unlikely to pose a groundwater contamination risk given the natural impermeability of the halite resource. The mine's ongoing management of groundwater inflows and surface water flooding at the decline portal is critical to avoid potential contamination.

The proponent will implement a multi-barrier safe storage and transportation criteria to ensure risks to the environment are sufficiently managed. These are discussed in detail in 11.

10.5 Ecosystems that potentially rely on groundwater

Two ecological communities (*Eucalyptus camaldulensis* var. *Obtuse* and *Eucalyptus coolabah* subsp. *Arida*) have been identified by DENR to persist within the riparian corridors of the Finke and Hugh Rivers. These communities are commonly identified in the Bureau of Meteorology's Atlas of Groundwater Dependent Ecosystems (BoM 2016) as having a *moderate potential for groundwater interaction*. The root structure is considered to be shallow (<15 m) and may potentially receive a source of water from perched shallow groundwater systems (ie alluvial sources) residing within ephemeral creeks.

The Proposal is unlikely to impact storage within the alluvium, with mining and groundwater abstraction targeting the deeper (220 plus metre area) hard rock groundwater systems.

Contamination of shallow alluvial groundwater sources is possible during the transit of waste product (as discussed above in Section 10.4.1).

10.6 Hydrostratigraphy

The mining process will result in localised alteration to the physical structure and distribution (ie stratigraphy) of the Horseshoe Bend Shale, Langra, Stairway Sandstone, Jay Creek Limestone, Giles Creek Dolostone and Chandler Formations. On a regional scale the current hydrostratigraphy and associated aquifer properties are not expected to change.

Generally, it is expected that, due to the proposed mining method (room and pillar) and the subsequent commitment to backfilling the mining void with waste material, the potential for subsidence and therefore alterations to the overlying stratified geology is not considered a risk.

10.7 Cumulative impacts

The Chandler Proposal is seeking to take groundwater for the Proposal over 29 years, but with a peak take spanning over 25 years during the operational phase of the Proposal. Over this 25-year peak take the proponent is seeking to take approximately 104 ML/year, and thereafter considerably reducing their expected take.

There are no known mines or large infrastructure Proposals within a 50 km radius of the proposed Proposal, and therefore cumulative impacts relating to groundwater resources have not been considered further.

11 Risk management, mitigation and monitoring measures

11.1 Risk assessment and management framework

An evaluation of Proposal activities and potential impacts to groundwater, surface water, GDEs and landholder bores associated with these activities has been completed. The Proposal activities are discussed in Section 3.3, with potential environmental impacts arising for the Proposal activities discussed later in Sections 10. A risk assessment matrix has been used (Table 11.1), in accordance with the Proposal's terms of reference, to quantify the level of risk based on the following:

- the likelihood of a potential impact occurring; and
- the consequence of a potential impact.

The definition of likelihood and the consequences are detailed in Table 11.2 and Table 11.3 respectively.

Table 11.1 Risk assessment matrix

Likelihood	Consequences				
	1 insignificant	2 minor	3 moderate	4 major	5 severe
A almost certain	medium	significant	high	high	extreme
B likely	medium	medium	significant	high	extreme
C moderate	low	medium	Significant	high	high
D unlikely	low	low	medium	significant	high
E rare	low	low	low	medium	significant

Table 11.2 Classification of likelihood for construction activities

Level	Categorisation of likelihood	Description
A	almost certain	is expected to occur during the Proposal, >90% probability
B	likely	will probably occur during the Proposal, ~50% probability
C	moderate	might occur at some time during the Proposal, ~25% probability
D	unlikely	could occur at some time during the Proposal, ~10% probability
E	rare	only occur in exceptional circumstances, <1% probability

Table 11.3 **Classification of consequence**

Level	Categorisation of consequence	Description
1	insignificant	no significant change in flow volumes, water levels or water quality
2	minor	minor short term and reversible change in flow volumes, water levels or water quality
3	moderate	moderate, minor breaches of environmental statutes or changes to flow volumes, water levels or water quality
4	major	major, ongoing breaches of environmental statutes with major changes to flow volumes, water levels or water quality
5	severe	shutdown of the Proposal due to environmental breach causing severe changes to flow volumes, water levels or water quality that may be irreversible

Risks will be managed as follows based on the risk rating in Table 11.1:

- Low: no additional management measures required.
- Medium: routine monitoring and management measures to be implemented.
- Significant: specific monitoring and management measures to be implemented.
- High: further specific additional management measures required to reduce risk as far as possible.
- Extreme: unacceptable risk—further specific additional management measures (including redesign) required to reduce risk.

11.2 Risk evaluation

The risks of potential impacts caused by Proposal activities, assuming no controls are in place are summarised in Table 11.4. Potential impacts identified as having a medium or above risk classification may be downgraded if appropriate controls and management measures are implemented and maintained. The proposed commitments to the implementation of management measures and residual risk levels are provided in Table 11.5.

Table 11.4 **Assessment of potential impacts**

Component	Potential impact	Receptor	Risk analysis (likelihood and consequence)			
			Low	Medium	Significant	High
Earthworks	spills of hydrocarbons leaching/running into groundwater/ephemeral creeks	surface water/ groundwater			C 3	
Blasting	increased nutrient load (ammonium nitrate)	groundwater		C 2		
	increased hydraulic connection between surface and groundwater resources	surface water/ groundwater		D 3		

Table 11.4 Assessment of potential impacts

Component	Potential impact	Receptor	Risk analysis (likelihood and consequence)			
			Low	Medium	Significant	High
Material stockpiling	leaching or mobilised contaminants	surface water/shallow groundwater			B 3	
Excavations	local depressurisation of groundwater resources	Groundwater			B 3	
	altering the local groundwater flow system	Groundwater			C 3	
	reducing baseflow to possibly connected waterways	Groundwater	D 1			
	decreased baseflow to possible GDEs reliant on surface expression of groundwater	GDEs	D 1			
	decreased groundwater availability to possible GDEs reliant on the subsurface presence of groundwater	GDEs		D 3		
Surface infrastructure	decreased groundwater recharge	groundwater		C 2		
Fuels and chemical storage and refuelling	spills of hydrocarbons that leach downwards or are mobilised	surface water/ groundwater			D 4	
Transportation/ storage of Schedule 2 waste	waste spills that mobilise in ephemeral creek lines or underground in storage	surface water/ groundwater			D 4	

11.3 Environmental management measures

Water management for the Proposal combines site surface water management, management of abstracted groundwater and the correct transportation and storage of Schedule 2 waste. The key to successful water management for this Proposal will be the separation and control of water from different sources and of different water qualities. In addition, a water monitoring program to assess impacts and ensure the functioning of the site water management system will be implemented. The proposed mine site water management strategy and infrastructure will be designed to ensure that the Proposal has a negligible impact on the quality of surface runoff and potential receiving environments.

11.3.1 Water management

A water management system will be designed to:

- segregate different water sources and different water qualities, (ie mine affected water, and raw water from the groundwater inflows/abstracted groundwater, sediment-laden water);
- capture and contain mine affected water and prevent discharge to receiving water environments;
- ensure unused abstracted, saline groundwater is contained and evaporated rather than discharged to the surface;

- capture and segregate runoff from the following locations:
 - processing area,
 - salt overburden stockpiles;
 - topsoil and subsoil stockpiles; and
 - other disturbed areas.
- divert clean runoff away from areas disturbed by mining activities to minimise the volume of mine affected water;
- manage sediment laden water in accordance with an erosion and sediment control plan that would be part of the water management plan, which will include the capture and treatment of sediment laden water in sediment dams;
- reuse and recycle water in mining operations;
- include contingency measures to accommodate either a surplus or deficit of site water; and
- communicate with key stakeholders (ie DENR, NT EPA, landholders, other users).

11.3.2 Residual risk levels and environmental management measures

A range of environmental requirements for the Proposal are identified by the NT EPA in the Chandler Salt Mine Proposal terms of reference. Specific management measures to address the requirements relating to water and the potential impacts identified in Table 11.4 have been outlined in Table 11.5. In addition, the residual risk associated with each potential impact has been recalculated.

As seen in Table 11.5 the control measure(s) focus on lowering the likelihood of an impact occurring, typically the consequence will remain unchanged, except where the risk control measure applied directly reduces the impact/consequence (e.g. silt fences on the surface, shotcreting of underground works).

Table 11.5 Groundwater management measures

Component	Potential impact	Control measure	Risk analysis		
			Low	Medium	Significant
Vegetation clearing	erosion and sedimentation of disturbed areas including surrounding waterways	installation of silt fences, bund walls and geo mats/geo fabrics vegetation clearing will occur immediately before construction works progressive revegetation	E 3		
Earthworks	spills of hydrocarbons leaching/running into groundwater/ephemeral creeks	implementation of spill kits on site and training of personnel in their use handling of chemicals will be as per manufacturer's instructions	E 3		

Table 11.5 **Groundwater management measures**

Component	Potential impact	Control measure	Risk analysis		
			Low	Medium	Significant
Culvert and drainage works	disruption to flow and increased turbulence	installation of silt fences and geo mats/geo fabrics windrows on contours to reduce slope length and surface flow velocities		D 3	
	creek bed and bank scouring	installation of silt fences and geo mats/geo fabrics	E 3		
	direct impact on streambeds through excavation works	installation of silt fences and geo mats/geo fabrics		D 3	
Blasting	increased nutrient load (ammonium nitrate)	groundwater quality monitoring as early warning mechanism		C 2	
	increased hydraulic connection between surface and groundwater resources	groundwater level monitoring to detect fluxes additional surface geophysics mapping to characterise potential shallow and deep groundwater connectivity		D 3	
Material stockpiling	leaching or mobilised contaminants	installation of silt fences and bund walls possible treatment with liquid lime to neutralise lower pH spoil as per the acid sulfate soils procedure	E 3		
Excavations	local depressurisation of groundwater resources	shotcreting areas of groundwater inflow to prevent further ingress groundwater level monitoring as early warning mechanism	E 3		
	altering the local groundwater flow system	shotcreting areas of groundwater inflow to prevent further ingress groundwater level monitoring as early warning mechanism	E 3		
	reducing baseflow to possibly connected waterways	regular monitoring of springs along the Finke River groundwater level monitoring as early warning mechanism	E 2		
	decreased baseflow to possible GDEs reliant on surface expression of groundwater	regular monitoring of springs along the Finke River regular Rapid Appraisal of Riparian Condition groundwater level monitoring as early warning mechanism	E 2		
	decreased groundwater availability to possible GDEs reliant on the subsurface presence of groundwater	regular assessment of River Red Gum and Coolabah ecosystem health using the RARC guidelines and RCE method groundwater level monitoring as early warning mechanism	E 3		

Table 11.5 **Groundwater management measures**

Component	Potential impact	Control measure	Risk analysis		
			Low	Medium	Significant
Surface infrastructure	localised flooding	construct drainage channels, bunds and sediment dams to rainfall events equal to 30 mm 24-hour rainfall event	E 2		
	increased surface runoff	construct drainage channels, bunds and sediment dams to rainfall events equal to 30 mm 24-hour rainfall event	E 2		
	decreased/increased groundwater recharge	groundwater quality monitoring as early warning mechanism clean and dirty runoff will be separated, with dirty runoff stored on site	E 3		
Fuels and chemical storage and refuelling	spills of hydrocarbons that leach downwards or are mobilised	designated spill kits will be located across site and at refuelling areas storage and handling of chemicals will be as per manufacturer's instructions at surface, refuelling will be undertaken away from waterways in designated, impermeable areas below ground, refuelling will be undertaken in dry, enclosed, banded areas		E 4	
Transportation/ storage of Schedule 2 waste	waste spills that mobilise in ephemeral creek lines or underground in storage	waste will be stored within double-barrier containers such as double-lined bulk bags or PVC bags stored within barrels and transported in ISO 20' shipping containers designated spill kits will be located across site once underground, waste will be separated in zoned areas based on the chemical characteristics of each waste product once waste is emplaced, salt backfilling will fill the remaining backfill and secure the waste. An engineered wall will then isolate the waste from the remaining mining void		E 4	

Following the implementation of control and mitigation management measures the residual risk of the potential impacts to the various receptors have reduced in all cases. All risks initially characterised as either significant or high have been downgraded to either medium or low and are therefore considered to pose moderate to negligible risks to local water resources.

11.4 Water Management Plan

A draft Water Management Plan (WMP) is included as an Appendix to the Chandler EIS. It details management measures to mitigate impacts to water resources during the construction and operation of the Proposal. The WMP details how Tellus will undertake the following:

- avoid contamination of surface or groundwater resources;
- protect water quality and levels for existing and future land users of bores and/or surface water ways;
- avoid the exposure of sensitive biological receptors to contaminants or water of a poor quality that may be harmful;
- a program for monitoring flow events in Proposal drainage lines, Finke River and the Hugh River to collect baseline water quality and ephemeral flow data;
- establish a procedure for maintenance and inspection of on-site water management structures such as drains, culverts, bunds, silt traps, sediment dams, evaporation pond, abstraction bores, water tanks and the water treatment plant;
- monitoring and management of abstracted groundwater volumes in real time;
- ensure treatment / neutralisation occurs of hazardous materials to identified safe levels, before any controlled environmental release is considered;
- treat and manage domestic wastewater and sewage;
- respond to any spill or contaminant events; and
- monitor water levels in water storages in parallel with monitoring forecast weather conditions to ensure that adequate storage capacity is available.

11.5 Monitoring

11.5.1 Surface water

Surface water monitoring includes sampling from key storages within the mine water management system and surface water flows (when present). The monitoring parameters are based on the expected water quality of the sampled water, while the frequency of monitoring is related to the climatic conditions. Specifically, water quality monitoring in surface water flows will comprise physiochemical parameters when there is sufficient volume. Water quality monitoring comprising physiochemical parameters and chemical analytes is proposed at the sediment dams in the unlikely event there is run-off.

Regular inspection of surface drainage infrastructure will be a crucial component of the surface water monitoring program. All drains will be regularly inspected to identify actual or potential problems, including erosion or sediment depositions. Dam lining and stock pile bund walls will also be inspected to verify their integrity.

11.5.2 Groundwater

Groundwater quality and groundwater level monitoring has been carried out on the existing monitoring network or monitoring bores on an intermittent basis since their installation in 2015 for the purpose of baseline data collection. The established monitoring network will be used for ongoing monitoring during construction and operation to assess groundwater level and quality trends. Monitoring data will be used to verify predictions during construction and operations based on the preliminary baseline dataset. Specifically, ongoing groundwater level monitoring will be used to assess changes to groundwater levels and pressures. Ongoing groundwater quality monitoring will ensure early detection of any change in groundwater quality or possible groundwater contamination.

It is recommended that ongoing groundwater level and quality monitoring continues; this will include:

- continuous monitoring of targeted groundwater elevations; and
- targeted groundwater quality sampling on a quarterly basis (sampling suite provided in Table 11.6).

Table 11.6 Groundwater quality sampling suite

Analysis / classification	Parameter
In-field analysis	
Depth to groundwater	metres below top of casing
Chemical properties	pH, dissolved oxygen
Physical properties	temperature, electrical conductivity, total dissolved solids
Laboratory analysis	
Hydrocarbons ¹	TPH, BTEX
Dissolved metals and total metals	aluminium, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, zinc
Major ions	alkalinity, bicarbonate, calcium, carbonate, chloride, hydroxide, magnesium, potassium, sodium, sulfate, fluoride
Nutrients	total nitrogen, total phosphorus, nitrite, nitrate, ammonia
Project waste ²	To be determined on the basis of the waste that is to be transferred and stored but at a minimum will include PAH, antimony, beryllium, boron, molybdenum, selenium, strontium, radium and uranium

Notes: 1. TPH=total petroleum hydrocarbons; BTEX=benzene, toluene, ethylbenzene and xylenes;

The groundwater level and quality monitoring frequency will be revised in consultation with the DENR and NT EPA, via the Water Management Plan during the pre-construction, construction, operational and closure phases of the Proposal.

Additional monitoring locations will be constructed during the pre-construction phase of the Proposal (known as Stage 2 sites). The additional sites will involve the construction and installation of bores, targeting the shallow alluvium supporting groundwater supplies adjacent to the distant Finke River and Hugh River. Locally, the expanded program will also include further nested installations into the aeolian sediment, Horseshoe Bend Shale and Langra groundwater systems, and a deep nested monitoring bore targeting the Stairway Sandstone and the Jay Creek Limestone groundwater systems. The locations, proposed construction depths and purpose of each of the Stage 2 sites is detailed in the Proposal Water Management Plan

Field based physicochemical water quality monitoring of any groundwater dewatered from the mine will occur on a regular basis. Any water dewatered from the mine will be metered to ensure the water management system accurately represents total inflows and outflows across the site.

The Proposal Water Management Plan contains details for the groundwater monitoring program and will also include the establishment of groundwater level and quality triggers, actions and contingencies that will be implemented in the event that monitoring indicates an impact. This process would also comprise the ongoing evaluation of monitoring data and the redefinition of triggers, actions and contingencies if required, in consultation with DENR and EPA.

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12 Conclusions

The Proposal comprises the construction and operation of a salt mine and waste storage transfer facility within the Amadeus Basin. This water assessment has been prepared to address specific requirements relating to groundwater and surface water in the NT EPA *Final Terms of Reference*. Specifically, the water assessment has taken into account Proposal activities associated with the Proposal that could impact on groundwater and surface water receptors in the region.

12.1 Surface water systems

The Hugh and Finke Rivers are the key surface water features in the vicinity of the Proposal area. These ephemeral watercourses are considered to be drainage channels that convey surface water flow in normal flow events (rather than permanent surface water features as such). Flow in these rivers is characteristically infrequent, however when flowing, supports permanent wetlands and waterholes that provide internationally significant habitats for waterbirds and aquatic flora and fauna (Miles *et al* 2015). Dryland rivers, such as the Fink River and Hugh River, also support consumptive and recreational water users and are widely used for agricultural and town supplies in inland Australia.

Several ephemeral drainage lines discharge to the Finke River and Hugh River along the reaches adjacent to the Proposal area, none of these systems are directly intercepted by the Proposals surface infrastructure area at both the Chandler Facility and the Apirnta Facility. These are predominantly topographically controlled by various sand dunes, ranges and outcropping basement rock visible across the Proposal area. The Charlotte Ranges to the west of the Proposal are a source of ephemeral drainage for the Finke River, while the ranges to the north of the Proposal (Olfie Range and James Ranges) drain to the Hugh River.

12.2 Groundwater systems

The Proposal area is within the Chandler Syncline, itself within the south-eastern extent of the Amadeus Basin. The Chandler Syncline hosts various local groundwater systems, all of which have minor confining layers and permeability barriers to groundwater flow.

The depth to groundwater at Chandler is about 90 metres, and the groundwater is saline. The basal unit overlying the Chandler Formation and target salt resource is the Giles Creek Dolostone Formation, comprising predominantly of marine shale, silt and sand sediments and thin beds of dolomite at a depth of about 830 metres. The Giles Creek Dolostone does not host groundwater.

Overlying the Giles Creek Dolostone is the Jay Creek Limestone Formation, a 170 m thick geological unit comprising predominantly shale, silt and sand. Overlying the Jay Creek Limestone Formation is the Stairway Sandstone Formation, a thick sequence comprising predominantly continental coarse to medium grained sandstone within interbedded minor silt and shale beds. The Stairway Sandstone supports numerous landholder bores within the region at shallower depth (<100 m BGL).

Overlying the Stairway Sandstone Formation is the Langra Formation, subdivided into three member units, represented at depth by interbedded silt and shale beds, gradually transitioning into extensive fine to medium grained sand. Overlying the Langra Formation is the Horseshoe Bend Shale Formation, a massive siltstone and quartzitic sandstone deposit. Both the Langra and Horseshoe Bend Shale Formations host brackish to saline groundwater.

The inferred piezometric surface ranges between 60 and 90 m BGL across the Chandler Facility. Directly above the Horseshoe Bend Shale Formation and partially eroded at surface across the Proposal area is the Idracowra Sandstone, a kaolinitic sandstone represented across the Maryvale Hills and discontinuous across the Proposal area. The Idracowra Sandstone supports numerous groundwater users within a 25 km radius of the mine. Groundwater is typically saline and as such is used locally as a stock supply. The Idracowra Sandstone Formation will not be intercepted by mining.

Locally in the vicinity of the Proposal area, there is very low recharge from direct rainfall, but minor recharge is expected to occur via infiltration from overlying alluvial systems during major flooding events. Minor direct rainfall recharge may occur locally, but the low rainfall and high evaporation means this volume would be minimal and the presence of stratified low permeability clays and silts in the middle and lower members of the Langra Formation is likely to result in the formation of perched localised groundwater systems in the upper Langra Formation and Horseshoe Bend Shale Formation. The underlying Stairway Sandstone Formation and Jay Creek Limestone Formation are likely to receive negligible recharge where the two geological units outcrop at surface along the Charlotte Ranges to the west of the Chandler Facility due to their limited outcrop extent and distant location from ephemeral creek lines.

Consistent with topographic gradients, hydraulic gradients are very gentle in the south-eastern extent of the Amadeus Basin, and the broad flow direction in all groundwater systems is generally from north-west to south-east, however, the basement structure influences the groundwater flow direction in certain areas. The structural influences are typically associated with folding.

The horizontal hydraulic conductivity in geological units is highly variable, due to the depositional environments and volume of clay; groundwater flow through Formations is therefore not expected.

There is an upwards hydraulic gradient from the Langra Formation to the Horseshoe Bend Shale Formation based on pressure head differences observed through groundwater monitoring. Elsewhere, within the 25 km spatial buffer around the Chandler Facility, landholder bores located within the shallow alluvium associated with ephemeral creeks report shallow groundwater levels which are likely to be perched systems, with low rates of vertical leakage to the underlying Idracowra Sandstone Formation and Horseshoe Bend Shale Formation.

The saline groundwater quality within the Chandler Syncline differs markedly from the potable water quality reported for the Mereenie Aquifer System about 100 km north within the Northern Amadeus Basin (the MAS is utilised for the Alice Springs Water Supply). The Chandler Syncline is a separate groundwater system entirely, given that the MAS units occur within the Northern Amadeus sub-basin and Orange Creek Syncline, but do not occur within the Chandler Syncline. The evidence confirms that the Chandler Syncline is distinct and separate from the Mereenie Aquifer System in terms of geological structure, lithological units, groundwater flow properties, hydraulic gradients and water chemistry.

Water quality within shallow alluvial groundwater accessed by landholder bores to the north and west of the Chandler Facility, particularly at Titjikala can be characterised as potable. Whereas groundwater quality observed within the Horseshoe Bend Shale and Langra local groundwater systems are poor and equivalent to seawater. Salts originating from the marine depositional environment, and the enhanced climatic nature of the environment (ie low precipitation/high evaporation), coupled with long groundwater residence times is likely to contribute to the poor groundwater quality observed within the Chandler Syncline.

12.3 Water utilisation and management

Water will be utilised and managed at the Chandler Facility in the following ways:

- groundwater from the Langra Formation and/or Stairway Sandstone Formation will be abstracted within the surface infrastructure area of the Chandler Facility, and will be used to meet drilling, processing and dust suppression demands;
- groundwater from Langra and Stairway Sandstone groundwater systems will be abstracted from within the surface infrastructure area of the Chandler Facility, and will be treated for use as a potable supply to meet mine drinking water demands;
- groundwater from Langra and Stairway Sandstone groundwater systems will be abstracted along the Chandler and Henbury haul roads to supplement dust suppression demands;
- where possible, rainwater will be harvested across both the Apirnta Facility and Chandler Facility and used to meet dust suppression and operational demands; and
- incidental groundwater inflows intercepted during the three-year construction monitoring period will be captured and reused where required (ie during drilling or dust suppression).

The total volume of groundwater abstracted during the construction/commissioning phase of the Proposal is estimated at 280 ML. During the operational phase, the total volume of abstracted groundwater estimated to be used over the 25-year mining life is 2,597.5 ML.

12.4 Sensitive receptors

The receptors that have been identified as potentially being sensitive to water impacts in the region include:

- ecosystems that rely on groundwater, including GDEs;
- Finke River, Hugh River and ephemeral water courses; and
- private landholder bores, properties and infrastructure.

Within a 75 km radius of the Chandler Facility there are 193 private landholder bores registered on the DENR groundwater database (as extracted in July 2016), predominantly utilising groundwater for stock and domestic purposes. Thirty-six private landholder bore users were located within a 25 km radius of the Chandler Facility. The majority of the bores are screened in the shallow alluvial deposits along the Finke and Hugh Rivers.

Ecosystems that rely on groundwater are important environmental assets and typically occur where groundwater is at or near the land surface. The vegetation in the Proposal area are typically hardy, resilient species that periodically rely on groundwater and are not considered to be GDEs, noting that the depth to groundwater at the Facility is about 90 metres.

12.5 Groundwater assessment

The Proposal will cause localised changes to the groundwater conditions due to groundwater abstraction demands and potential mine dewatering arising from induced groundwater inflow. Local groundwater systems intercepted by mining and other Proposal-related activities are not considered to support GDEs, baseflow to surrounding/local surface water systems or potable groundwater supplies.

The local groundwater systems are considered to be compartmentalised, with flow and storage restricted by claystone and siltstone aquitards, and as such potential impacts to surrounding receivers are significantly negated by the disconnection of these systems.

Springs observed to be discharging along the Finke River (e.g. Horseshoe Bend Spring) about 20-50 km south-south-east of the Chandler Facility are inferred to be deriving their source of water from perched shallow alluvium, and are therefore understood to be isolated from potential dewatering impacts arising from mining within the deeper local groundwater systems.

12.5.1 Mining

Any groundwater intercepted by the construction of subsurface works is likely to result in the dewatering of the localised groundwater systems. Due to the isolated extent of any shallow perched systems, the stratified nature of the underlying deeper aquifers, and the 90 metre depth to groundwater, dewatering impacts arising from mining operations will be localised in extent and will not impact nearby sensitive receivers.

12.5.2 Groundwater abstraction

The conceptual and analytical model concluded that abstraction from the Langra Formations at the rate specified during the peak operational water demand for the Proposal would result in drawdown up to 0.4 m at a distance of 1 km from production bores. A similar dynamic response in groundwater levels is expected within the Stairway Sandstone along the Chandler Haul Road, with abstraction demands for dust suppression likely to result in localised drawdown. Drawdown impacts are unlikely to extend to nearby landholder bores.

Elsewhere, the relatively minor drawdown associated with Proposal-related abstraction is unlikely to cause any impacts of concern to other sensitive landholder bore and environmental groundwater users.

12.5.3 Waste emplacement

The potential for groundwater contamination via waste leakage is greatest during rail and road transportation of the product. Impacts arising from train derailment or a truck rolling over could result in contaminants spilling across ephemeral drainage lines and infiltrating the porous alluvium.

Contamination of groundwater arising from the storage of waste in the underground repository is unlikely to pose a groundwater contamination risk given the natural impermeability of the halite resource. A quantified operational and post closure risk assessment has been undertaken (Quintessa, 2016) which quantitatively modelled the potential risks associated with an underground contamination event and potential impacts on overlying groundwater. The report concluded that there were no plausible risks to the overlying groundwater resource due to the impermeability of the halite resource.

12.5.4 Hydrostratigraphy

On a regional scale the current hydrostratigraphy and associated aquifer properties are not expected to change. However, along the Chandler mine paths, the aforementioned Formations will be excavated and backfilled following mining.

Generally, it is expected that, due to the proposed mining method (room and pillar) and the subsequent commitment to backfilling the mining void with waste material, the potential for subsidence and therefore alterations to the overlying stratified geology is not considered a risk.

12.6 Cumulative impacts

The Chandler Proposal is seeking to take groundwater for the Proposal over 29 years, but with a peak take spanning over the 25 year operational phase. Over this 25-year peak take Tellus are seeking to take approximately 104 ML/year, and thereafter considerably reducing their expected take.

There are no known mines or large infrastructure projects within a 50 km radius of the Proposal, and therefore cumulative impacts relating to groundwater resources have not been considered further.

12.7 Summary

A water assessment was undertaken in accordance with the NT EPA *Final Terms of Reference*. Water investigations, focusing on the hydrologic and hydrogeologic regime, have spanned two years and comprise the collection of extensive site data. The receptors identified as potentially being potentially sensitive to water impacts in the region included:

- ecosystems that rely on groundwater, including GDEs;
- Finke River, Hugh River and ephemeral drainages; and
- private landholder bores, properties and infrastructure.

Overall there are few water related impacts as a result of the Proposal due to:

- depth to groundwater of 90 metres, and localised magnitude and extent of groundwater-related impacts;
- only 5 landholder bores within a 10 km radius of the proposed mine, and the sparse distribution of bores beyond that (36 bores total within 25 km);
- the absence of GDEs (mainly due to depth to groundwater of 90 metres and general aridity); and
- compliance with the *Water Act*, *Mining Management Act*, and the *Waste Management Pollution Control Act*.

To date, assessment of the Proposal site water quality suggests there will be no negative change in the water quality of receiving environments. In addition, the proposed mine site water management strategy and infrastructure will be designed to ensure that the Proposal has negligible impacts on the quality of surface runoff.

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Glossary of terms

Acidity	Base neutralising capacity.
Alkalinity	Acid neutralising capacity.
Alluvium	Unconsolidated sediments (clays, sands, gravels and other materials) deposited by flowing water. Deposits can be made by streams on river beds, floodplains, and alluvial fans.
Alluvial aquifer	Permeable zones that store and produce groundwater from unconsolidated alluvial sediments. Shallow alluvial aquifers are generally unconfined aquifers.
Anion	An ion with a negative charge.
Anthropogenic	Occurring because of, or influenced by, human activity.
Annual exceedance probability	The probability that a given rainfall total accumulated over a given duration will be exceeded in any one year.
Aquatic ecosystem	The stream channel, lake or estuary bed, water, and (or) biotic communities and the habitat features that occur therein.
Aquitard	A very low-permeability unit that forms either the upper or lower boundary of a groundwater flow system and does not transmit water or allow water to migrate from upper and lower horizons.
Aquifer	Rock or sediment in a formation, group of formations, or part of a formation that is saturated and sufficiently permeable to transmit economic quantities of water.
Baseflow	The part of stream discharge that originates from groundwater seeping into the stream.
Bore	A structure drilled below the surface to obtain water from an aquifer or series of aquifers.
Boundary	A lateral discontinuity or change in the formation resulting in a significant change in hydraulic conductivity, storativity or recharge.
Cation	An ion with a positive charge – usually metal ions when disassociated and dissolved in water.
Confined formation	An aquifer that is overlain by low permeability strata. The hydraulic conductivity of the confining bed is significantly lower than that of the aquifer.
Concentration	The amount or mass of a substance present in a given volume or mass of sample, usually expressed as microgram per litre (water sample) or micrograms per kilogram (sediment sample).
Conceptual model	A simplified and idealised representation (usually graphical) of the physical hydrogeologic setting and the hydrogeological understanding of the essential flow processes of the system. This includes the identification and description of the geologic and hydrologic framework, media type, hydraulic properties, sources and sinks, and important aquifer flow and surface-groundwater interaction processes.
Cone of depression	A depression of the water table or potentiometric surface that has the shape of an inverted cone, which develops around a production bore/gas well from which water is being drawn. It defines the radius of influence of a pumping test.
Confining layer	Low permeability strata that may be saturated but will not allow water to move through it under natural hydraulic gradients.
Contamination	Contamination is the presence of a non-natural compound in soil or water, or unwanted compound in chemicals or other mixtures.
Discharge	The volume of water flowing in a stream or through an aquifer past a specific point in a given period of time.
Discharge area	An area in which there are upward or lateral components of flow in an aquifer.

Drawdown	A lowering of the water table in an unconfined aquifer or the pressure surface of a confined aquifer caused by pumping of groundwater from bores and wells.
Electrical conductivity (EC)	A measure of a fluid's ability to conduct an electrical current and is an estimation of the total ions dissolved. It is often used as a measure of water salinity.
Fault	A fracture in rock along which there has been an observable amount of displacement. Faults are rarely single planar units; normally they occur as parallel to sub-parallel sets of planes along which movement has taken place to a greater or lesser extent. Such sets are called fault or fracture zones.
Fluvial	Pertaining to a river or stream.
Fluvial deposit	A sedimentary deposit consisting of material transported by suspension or laid down by a river or stream.
Fracture	Breakage in a rock or mineral along a direction or directions that are not cleavage or fissility directions.
Fractured rock aquifer	These occur in sedimentary, igneous and metamorphosed rocks which have been subjected to disturbance, deformation, or weathering, and which allow water to move through joints, bedding planes, fractures and faults. Although fractured rock aquifers are found over a wide area, they generally contain much less groundwater than alluvial and porous sedimentary rock aquifers.
Groundwater	The water contained in interconnected pores or fractures located below the water table in the saturated zone.
Groundwater dependent ecosystems (GDEs)	Groundwater dependent ecosystems are communities of plants, animals and other organisms whose extent and life processes are dependent (or partially dependent) on groundwater.
Groundwater flow	The movement of water through openings in sediment and rock within the zone of saturation.
Groundwater system	A system that is hydrogeologically more similar than different in regard to geological province, hydraulic characteristics and water quality, and may consist of one or more geological formations.
Hydraulic conductivity	The rate at which water of a specified density and kinematic viscosity can move through a permeable medium (notionally equivalent to the permeability of an aquifer to fresh water).
Hydraulic gradient	The change in total hydraulic head with a change in distance in a given direction.
Hydraulic head	Is a specific measurement of water pressure above a datum. It is usually measured as a water surface elevation, expressed in units of length. In an aquifer, it can be calculated from the depth to water in a monitoring bore. The hydraulic head can be used to determine a hydraulic gradient between two or more points.
Hydrochemistry	Chemical characterisation of water (both surface water and groundwater).
Hydrogeology	The study of the interrelationships of geologic materials and processes with water, especially groundwater.
Hydrology	The study of the occurrence, distribution, and chemistry of all surface waters.
Infiltration	The flow of water downward from the land surface into and through the upper soil layers.
Major ions	Constituents commonly present in concentrations exceeding 10 milligram per litre. Dissolved cations generally are calcium, magnesium, sodium, and potassium; the major anions are sulphate, chloride, fluoride, nitrate, and those contributing to alkalinity, most generally assumed to be bicarbonate and carbonate.
MilliSiemens per centimetre (mS/cm)	A measure of water salinity commonly referred to as EC (see also electrical conductivity). Most commonly measured in the field with calibrated water quality meter.
Monitoring bore	A non-pumping bore, is generally of small diameter that is used to measure the elevation of the water table and/or water quality. Bores generally have a short well screen against a single aquifer through which water can enter.
Nested monitoring site	Multiple monitoring bores screening different formations in close proximity.

Numerical model	A model of groundwater flow in which the aquifer is described by numerical equations (with specified values for boundary conditions) that are usually solved in a computer program. In this approach, the continuous differential terms in the governing hydraulic flow equation are replaced by finite quantities. Computational power is used to solve the resulting algebraic equations by matrix arithmetic. In this way, problems with complex geometry, dynamic response effects and spatial and temporal variability may be solved accurately. This approach must be used in cases where the essential aquifer features form a complex system (ie high complexity models).
Permeability	The property or capacity of a porous rock, sediment, clay or soil to transmit a fluid. It is a measure of the relative ease of fluid flow under unequal pressure. The hydraulic conductivity is the permeability of a material for water at the prevailing temperature.
Permeable material	Material that permits water to move through it at perceptible rates under the hydraulic gradients normally present.
pH	Potential of hydrogen; the logarithm of the reciprocal of hydrogen-ion concentration in gram atoms per litre; provides a measure on a scale from 0 to 14 of the acidity or alkalinity of a solution (where 7 is neutral, greater than 7 is alkaline and less than 7 is acidic).
Piezometer	See monitoring bore.
Piezometric surface	In a confined aquifer this is the surface representation of the level to which water will rise in a bore.
Porosity	The proportion of open space within an aquifer, comprised of intergranular space, pores, vesicles and fractures.
Porous rock	Consolidated sedimentary rock containing voids, pores or other openings (joints, cleats, fractures) which are interconnected in the rock mass and may be capable of storing and transmitting water.
Precipitation	(1) in meteorology and hydrology, rain, snow and other forms of water falling from the sky (2) the formation of a suspension of an insoluble compound by mixing two solutions. Positive values of saturation index (SI) indicate supersaturation and the tendency of the water to precipitate that mineral.
Pumping test	A test made by pumping a bore for a period of time and observing the change in hydraulic head in the aquifer. A pumping test may be used to determine the capacity of the bore and the hydraulic characteristics of the aquifer.
Quaternary	The most recent geological period extending from approximately 2.5 million years ago to the present day.
Recharge	The process which replenishes groundwater, usually by rainfall infiltrating from the ground surface to the water table and by river water reaching the water table or exposed aquifers. The addition of water to an aquifer.
Recharge area	A geographic area that directly receives infiltrated water from surface and in which there are downward components of hydraulic head in the aquifer. Recharge generally moves downward from the water table into the deeper parts of an aquifer then moves laterally and vertically to recharge other parts of the aquifer or deeper aquifer zones.
Recovery	The difference between the observed water level during the recovery period after cessation of pumping and the water level measured immediately before pumping stopped.
Residence time	The time that groundwater spends in storage before moving to a different part of the hydrological cycle (ie it could be argued it is a rate of replenishment).
Riparian	Relating to the banks of a natural waterway.
Salina	An artificial pond whereby evaporation of saline water eventually results in the accumulation of salts.
Salinity	The concentration of dissolved salts in water, usually expressed in EC units or milligrams of total dissolved solids per litre (mg/L TDS).

Salinity classification (Australia Water Resources Council 1988)	Fresh water quality – water with a salinity <800 µS/cm. Marginal water quality – water that is more saline than freshwater and generally waters between 800 and 1,600 µS/cm. Brackish quality – water that is more saline than freshwater and generally waters between 1,600 and 4,800 µS/cm. Slightly saline quality – water that is more saline than brackish water and generally waters with a salinity between 4,800 and 10,000 µS/cm. Moderately saline quality – water that is more saline than brackish water and generally waters between 10,000 and 20,000 µS/cm. Saline quality – water that is almost as saline as seawater and generally waters with a salinity greater than 20,000 µS/cm. Seawater quality – water that is generally around 55,000 µS/cm.
Saturated zone	The zone in which the voids in the rock or soil are filled with water at a pressure greater than atmospheric pressure. The water table is the top of the saturated zone in an unconfined aquifer.
Screen	A type of bore lining or casing of special construction, with apertures designed to permit the flow of water into a bore while preventing the entry of aquifer or filter pack material.
Standing water level (SWL)	The height to which groundwater rises in a bore after it is drilled and completed, and after a period of pumping when levels return to natural atmospheric or confined pressure levels.
Storativity	The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. It is equal to the product of specific storage and aquifer thickness. In an unconfined aquifer, the storativity is equivalent to specific yield.
Stratigraphy	The depositional order of sedimentary rocks in layers.
Surface water-groundwater interaction	This occurs in two ways: (1) streams gain water from groundwater through the streambed when the elevation of the water table adjacent to the streambed is greater than the water level in the stream; and (2) streams lose water to groundwater through streambeds when the elevation of the water table is lower than the water level in the stream.
Tertiary	Geologic time at the beginning of the Cainozoic era, 65 to 2.5 million years ago, after the Cretaceous and before the Quaternary.
Total Dissolved Solids (TDS)	A measure of the salinity of water, usually expressed in milligrams per litre (mg/L). See also EC.
Transmissivity	The rate at which water of a prevailing density and viscosity is transmitted through a unit width of an aquifer or confining bed under a unit hydraulic gradient. It is a function of properties of the liquid, the porous media, and the thickness of the porous media.
Unconfined formation	Also known as a water table aquifer. An aquifer in which there are no confining beds between the zone of saturation and the surface. The water table is the upper boundary of an unconfined aquifer.
Unsaturated zone	That part of an aquifer between the land surface and water table. It includes the root zone, intermediate zone and capillary fringe.
Water quality	Term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.
Water quality data	Chemical, biological, and physical measurements or observations of the characteristics of surface and ground waters, atmospheric deposition, potable water, treated effluents, and waste water and of the immediate environment in which the water exists.

List of units

°C	degrees Celsius
ha	hectares
L/s	litres per second
m	metres
m AHD	metres Australian Height Datum
m BGL	metres below ground level
m btoc	metres below top of casing
m/d	metres per day
m ³ /d	cubic metres per day
mm/yr	millimetres per year
m/y	metres per year
ML	megalitres
ML/y	megalitres per year
mS/cm	milliSiemens per centimetre
mg/L	milligrams per litre
t	tonnes

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Abbreviations

ANZECC/ARMCANZ	Australian and New Zealand guidelines for fresh and marine water quality
BoM	Bureau of Meteorology
CRT	Constant Rate Test
EC	Electrical conductivity
EIS	Environmental Impact statement
EP&A Act	Environmental Protection & Assessment Act
EPBC Act	Environment Protection and Biodiversity Conservation Act
K	Hydraulic conductivity
NHMRC	National Health and Medical Research Council
SSD	State Significant Development
TDS	Total Dissolved Solids
WA	Water Act
WMA	Water Management Act

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Appendix A

Groundwater monitoring bore logs

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Bore Cross-section Amadeus Basin Maryvale Region

Maryvale Station

Investigation Production Bore
Tellus Groundwater Investigation Bore PBT1

T10
RN 19192
RLGL 409.762 m AHD (Ausurv)

General Location: adjacent Tellus Holdings deep cored bore CH003, approx 3 km north west of Halfway Dam

Australian Grid Location: (zone 53 datum GDA 94) easting 392 499 m northing 7 258 504 m

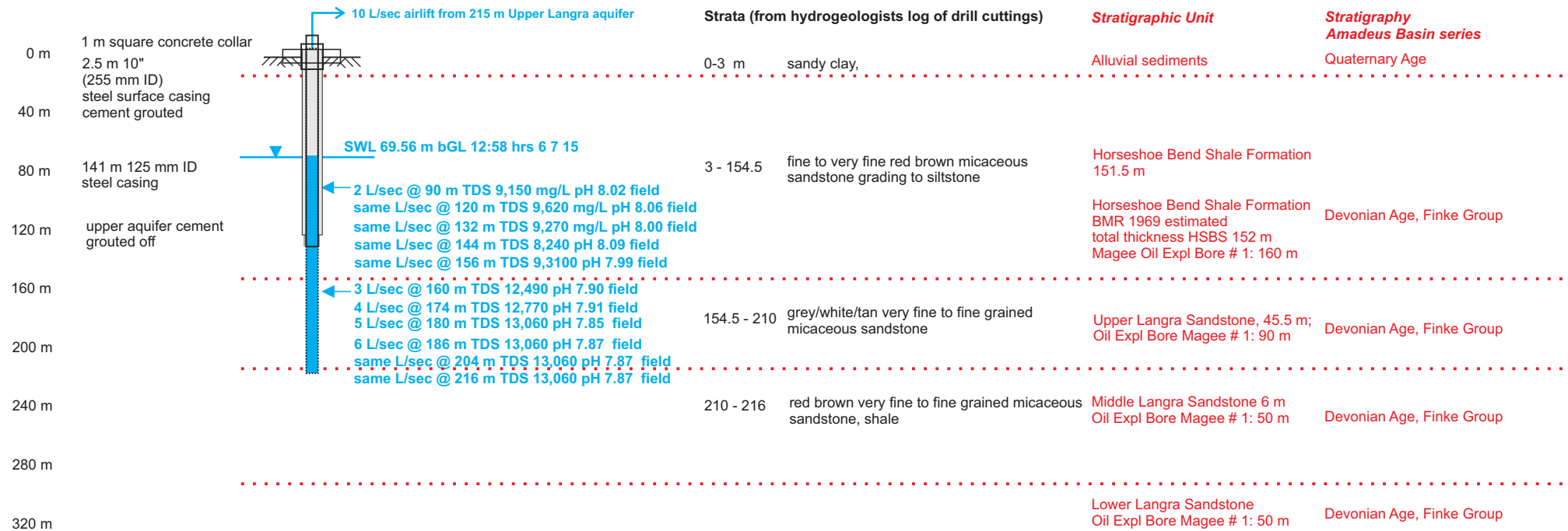
longitude 133 ° 56 ' 11.68488 " latitude -24 ° 47 ' 3.9295 "

Down hole geophysical logging: selected suite Endeavour Geophysics

Monitoring measuring point: top of steel production, 410.608 m AHD

Baseline water level monitoring: upper Langra Formation 341.498 m AHD 22 01 2016

Current status: completed as an investigation production bore into the upper Langra Formation (Horseshoe Bend Shale aquifer cement grouted off)



Total depth drilled: 216 m

Total Dissolved solids (field): 13,000 mg/L
Conductivity (EC field): 19,500 uS/cm

Water Bore Driller: P Juett
Contractor: Diverse Group Pty Ltd
Atlas Copco T3W rotary rig
Drilling completed: 6th July 2015

Drilled rotary air drilling, 8" OD steel surface casing; 139 m 125 mm OD steel oil field casing upper aquifer grouted off; open hole at bottom

Completion status: completed as an investigation production bore. Headworks completed

Prepared by Graham Ride 5th July 2015

File: Tellus\Tellus Database\
Bore A4 X sections\T10 A4 X section SR 15 01 16
Update 15 1 16; PC 22 10 2015; GR 10 11 15; GR 9 12 15

Hydrogeological assessment consultancy: Chandler Salt Mine Project
Tellus Holdings Limited: hydrogeological assessment, stage 1 groundwater investigation

Ride Consulting

Bore Cross-section Amadeus Basin Maryvale Region

Maryvale Station

Investigation Production Bore
Tellus Groundwater Investigation Bore PBT2

T11
RN 19193
RLGL 422.525 m AHD

General Location: adjacent WT3 (RN 19118) near original Tellus groundwater investigation site 5, approx 1.2 km west of north west Halfway Dam

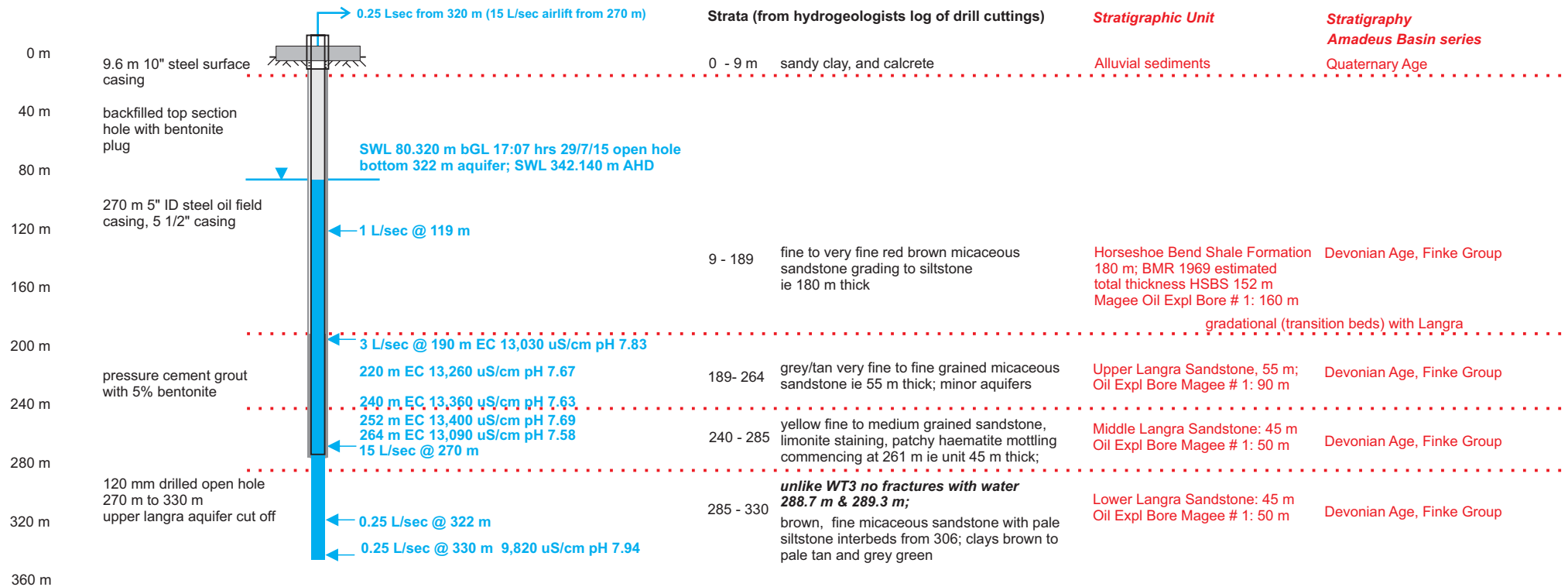
Australian Grid Location: (zone 53 datum GDA 94) easting 392 958 m northing 7 255 638 m
longitude 133 ° 56 ' 27.20181 " latitude -24 ° 48 ' 37.21085 "

Down hole geophysical logging: NIL

Monitoring measuring point: 22 January 2016 top of steel production casing, 423.180 m AHD levelled from Sam Demur survey of bench mark

Baseline water level monitoring: current standing water level 22/01/2016 342.580 m AHD

Current status: small diameter production bore constructed to determine hydraulic characteristics of lower Langra Formation aquifers but fracture aquifer intersected in adjacent WT3 not intersected in this bore at the same depth. Only a 0.25 L/sec aquifer intersected at 322 m. A decision whether to deepen bore has yet to be made.



Total depth drilled: 330 m

Total Dissolved solids (field): 12,600 mg/L
Conductivity (EC field): 19,100 uS/cm

Water Bore Driller: P Juett
Contractor: Diverse Group Pty Ltd
Atlas Copco T3W rotary rig
Drilling completed: 14th July 2015

Drilled rotary air drilling, 8" OD steel surface casing; 6 1/2" hammer; reamed to 270 m, cement grout pumped down tremie pipe into hole annulus to surface, water for grout carted from Alice Springs

Completion status: completed as an investigation production bore with screwed oil field casing and cement grout sealing off Horseshoe Bend and Upper Langra Formation aquifers. Open hole below bottom of casing to total depth.

Prepared by Graham Ride 12th July 2015

File: Tellus\Tellus Database\
Bore A4 X sections\T11 A4 X section SR 15 01 16
Update 15 1 2016; PC 22 10 2015; GR 10 11 15

Hydrogeological assessment consultancy: Chandler Salt Mine Project
Tellus Holdings Limited: hydrogeological assessment, stage 1 groundwater investigation

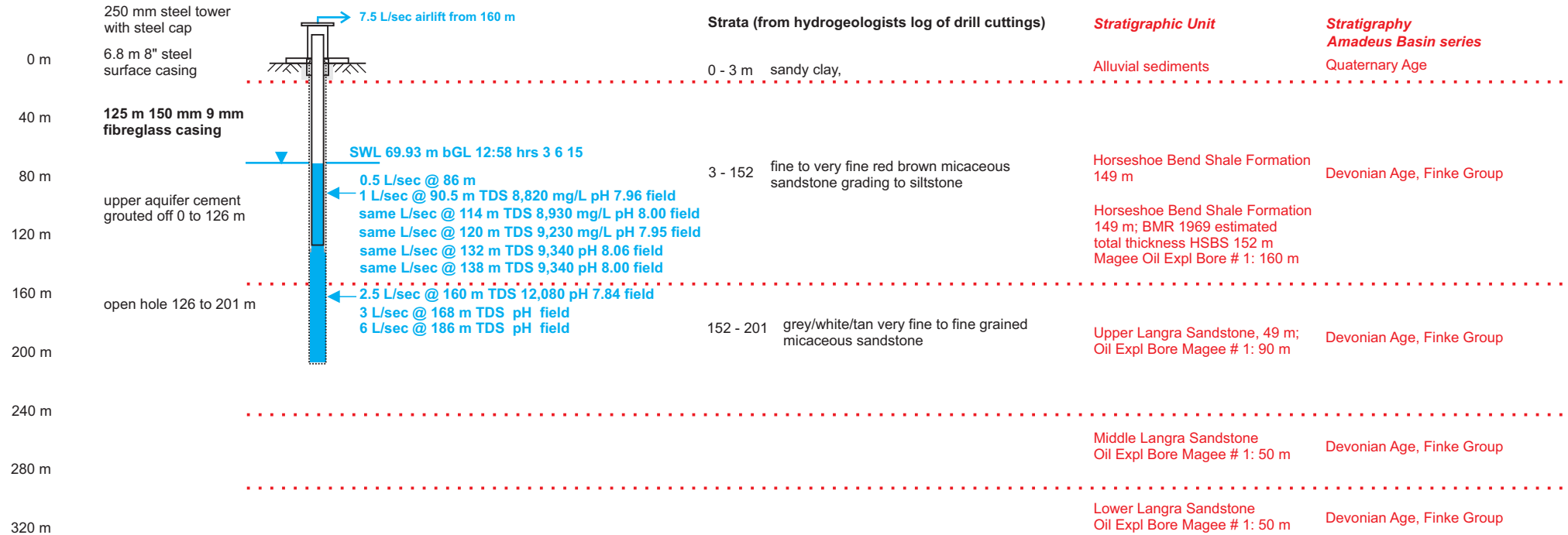
Ride Consulting

Bore Cross-section Amadeus Basin Maryvale Region

Maryvale Station

Investigation / Monitoring Bore
Tellus Groundwater Investigation Bore WT1

T4
RN 19117
RLGL 410.180 m AHD Ausurv



Total depth drilled: 201 m

Total Dissolved solids (field): 12,500 mg/L
Conductivity (EC field): 19,000 uS/cm

Water Bore Driller: P Juett
Contractor: Diverse Group Pty Ltd
Atlas Copco T3W rotary rig
Drilling completed: 2nd June 2015

Drilled rotary air drilling, 8" OD steel surface casing; 125 m 150 mm fibreglass casing upper aquifer grouted off from below fibreglass casing; open hole at bottom

Completion status: completed as a water level monitoring bore. Headworks completed

Prepared by Graham Ride 7th June 2015

File: Tellus\Tellus Database\Bore A4 X sections\
T4 A4 X section SR 15 01 16
Update PC 15 01 2016; SR 15 01 16

Hydrogeological assessment consultancy: Chandler Salt Mine Project
Tellus Holdings Limited: hydrogeological assessment, stage 1 groundwater investigation

Ride Consulting

Bore Cross-section Amadeus Basin Maryvale Region

Maryvale Station

*Investigation / Monitoring Bore
Tellus Groundwater Investigation Bore WT2*

General Location: adjacent Tellus Holdings deep cored bore CH003, approx 3 km north west of Halfway Dam

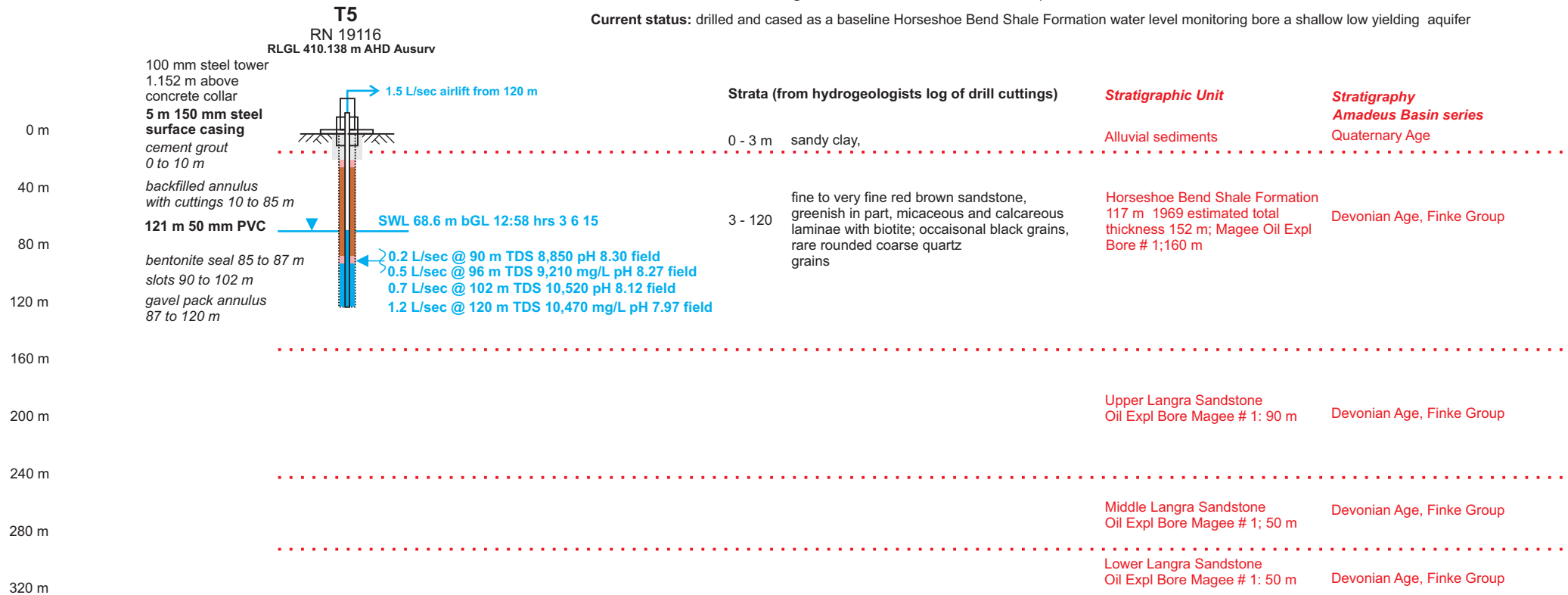
Australian Grid Location: (zone 53 datum GDA 94) easting 392 518.551 m northing 7 258 476.121 m; Ausurv Trimble TRX position June 2015
longitude 133 ° 56 ' 12.33770 " latitude -24 ° 47 ' 4.84048 "

Down hole geophysical logging: selected suite Endeavour Geophysics

Monitoring measuring point: 3rd June 2015 top of steel surface casing; 4th June 2015 top of fibreglass casing, 700 mm above ground level

Baseline water level monitoring: Horseshoe Bend Shale Formation aquifer estimated 341.608 m AHD 22 01 16

Current status: drilled and cased as a baseline Horseshoe Bend Shale Formation water level monitoring bore a shallow low yielding aquifer



Total depth drilled: 120 m

Total Dissolved solids (field): 10,320 mg/L
Conductivity (EC field): 15,640 uS/cm

Water Bore Driller: P Juett
Contractor: Diverse Group Pty Ltd
Atlas Copco T3W rotary rig
Drilling completed: 27th July 2015

Drilled rotary air drilling, 6" OD steel surface casing; 120 m 50 mm PVC casing, slotted 90 to 102 m

Completion status: completed as a water level monitoring bore. Bore headworks completed

Prepared by Graham Ride 7th June 2015

File: Tellus\ Tellus Database \
Bore A4 X sections\T5 A4 X section SR 15 01 16
Update SR 15 01 16

Hydrogeological assessment consultancy: Chandler Salt Mine Project
Tellus Holdings Limited: hydrogeological assessment, stage 1 groundwater investigation

Ride Consulting

Bore Cross-section Amadeus Basin Maryvale Region

Maryvale Station

Investigation / Monitoring Bore
Tellus Groundwater Investigation Bore WT3

General Location: near original Tellus Holdings groundwater investigation site 5, approx 1.2 km west north west of Halfway Dam

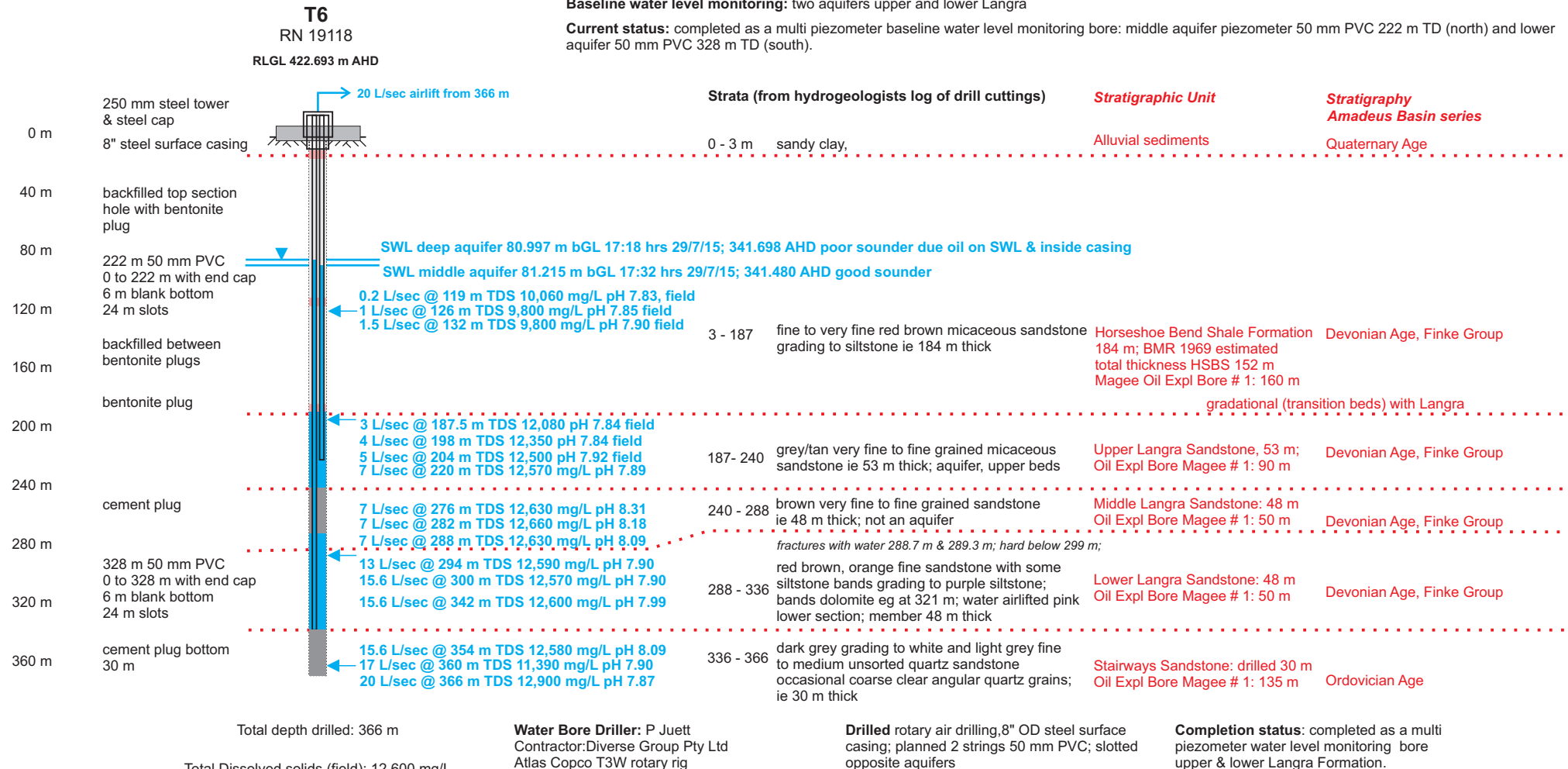
Australian Grid Location: (zone 53 datum GDA 94) easting 392 975.594 m northing 7 255 631.011 m Ausurv Trimble TRX position June 2015
longitude 133 ° 56 ' 27.82649 " latitude -24 ° 48 ' 37.44248 "

Down hole geophysical logging: selected suite, Endeavour Geophysics 4/7/2015

Monitoring measuring point: 29/7/15 middle 50 mm PVC (north) 423.330 m AHD; lower 50 mm PVC (south) 423.330 m AHD; 3th June 2015

Baseline water level monitoring: two aquifers upper and lower Langra

Current status: completed as a multi piezometer baseline water level monitoring bore: middle aquifer piezometer 50 mm PVC 222 m TD (north) and lower aquifer 50 mm PVC 328 m TD (south).



Prepared by Graham Ride
7th June 2015

File: Tellus\Tellus Database\
Bore A4 X sections\ T6 A4 X section SR 15 01 16
Update SR 15 01 16; SR 15 01 16

Hydrogeological assessment consultancy: Chandler Salt Mine Project
Tellus Holdings Limited: hydrogeological assessment, stage 1 groundwater investigation

Ride Consulting

Bore cross section Amadeus Basin Maryvale Region

Maryvale Station

Investigation / Monitoring Bore
Tellus Groundwater Investigation Bore WT4

General Location: Tellus Holdings Site 21, approx 1.8 km east of Halfway Dam

Australian Grid Location: (zone 53 datum GDA 94) easting 395 942.543 m northing 7 256 290.972 Ausurv Trimble TRX position June 2015

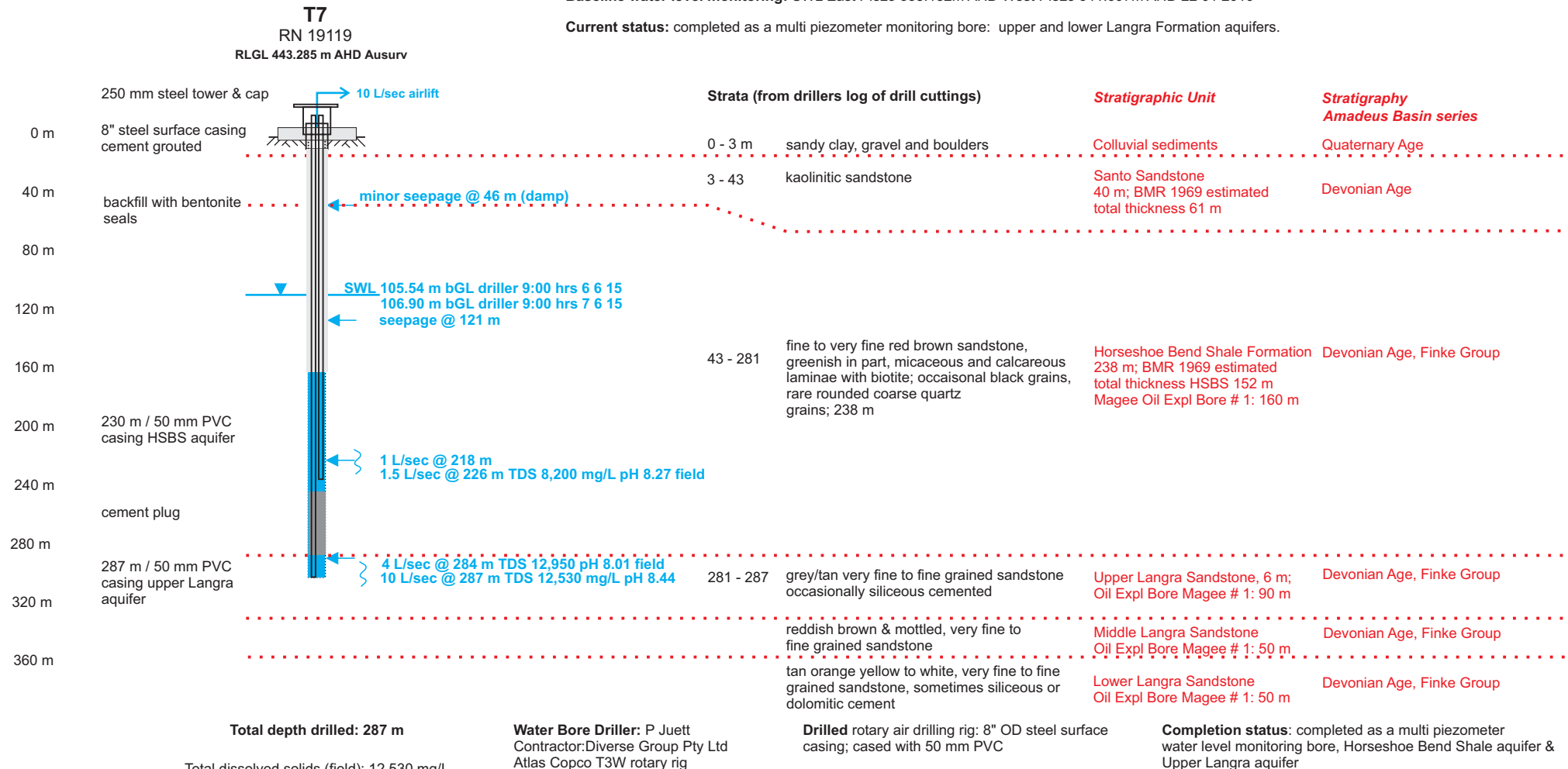
longitude 133 ° 58 ' 13.67182 " latitude -24 ° 48 ' 16.72650 "

Down hole geophysical logging: selected suite, Endeavour Geophysics

Monitoring measuring point: 22nd of January 2016 MP; East Piezo MP 443.722 m AHD, West Piezo MP 443.757 m AHD

Baseline water level monitoring: SWL East Piezo 338.152m AHD West Piezo 341.607m AHD 22 01 2016

Current status: completed as a multi piezometer monitoring bore: upper and lower Langra Formation aquifers.



Prepared by Graham Ride
6th June 2015

File: Tellus\Tellus Database\Bore A4 X sections\
T7 X section A4 SR 15 01 16
Update SR 15 01 16

Total dissolved solids (field): 12,530 mg/L
Conductivity (EC field): 19,000 uS/cm

Water Bore Driller: P Juett
Contractor: Diverse Group Pty Ltd
Atlas Copco T3W rotary rig

Drilled rotary air drilling rig: 8" OD steel surface casing; cased with 50 mm PVC

Hydrogeological assessment consultancy: Chandler Salt Mine Project
Tellus Holdings Limited: hydrogeological assessment, stage 1 groundwater investigation

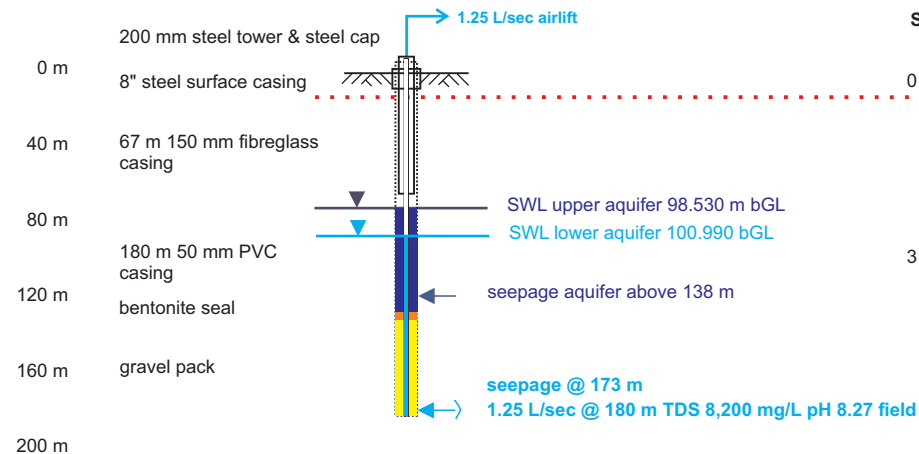
Ride Consulting

Bore cross section Amadeus Basin Maryvale Region

Maryvale Station

Investigation / Monitoring Bore
Tellus Groundwater Investigation Bore WT5

T8
RN 19120
RLGL 439.458 m AHD Ausurv



Strata (from hydrogeologist log of drill cuttings)

Stratigraphic Unit

Stratigraphy Amadeus Basin series

0 - 3 m sandy clay, gravel and boulders

Colluvial sediments

Quaternary Age

Devonian Age

3 - 180 fine to very fine red brown sandstone, greenish in part, micaceous and calcareous laminae with biotite; occasional black grains, rare rounded coarse quartz grains

Horseshoe Bend Shale Formation
177 m; BMR 1969 estimated
total thickness HSBS 152 m
Magee Oil Expl Bore # 1: 160 m

Devonian Age, Finke Group

Upper Langra Sandstone, 4 m;
Oil Expl Bore Magee # 1: 90 m

Devonian Age, Finke Group

Total depth drilled: 180 m

Total dissolved solids (field): 8,650 mg/L
Conductivity (EC field): 13,100 uS/cm

Water Bore Driller: P Juett
Contractor: Diverse Group Pty Ltd
Atlas Copco T3W rotary rig
Bore drilled: 7th & 8th June 2015

Drilled rotary air drilling rig: 8" OD steel surface casing; cased with 67 m 150 mm OD fibreglass and 180 m 50 mm PVC with gravel pack and bentonite seal

Completion status: completed as a multi piezometer water level monitoring bore

Prepared by Graham Ride 7th June 2015

File: Tellus\Tellus Database\
Bore A4 X sections\T8 A4 X section SR 15 01 16
Update SR 15 01 16

Hydrogeological assessment consultancy: Chandler Salt Mine Project
Tellus Holdings Limited: hydrogeological assessment, stage 1 groundwater investigation

Ride Consulting

Bore Cross-section Amadeus Basin Maryvale Region

Maryvale Station

Investigation / Monitoring Bore
Tellus Groundwater Investigation Bore WT6

General Location: east of CH001A and main access track on a low rise

Australian Grid Location: (zone 53 datum GDA 94) easting 393 690 m northing 7 257 551 m Ausurv Trimble TRX position June 2015

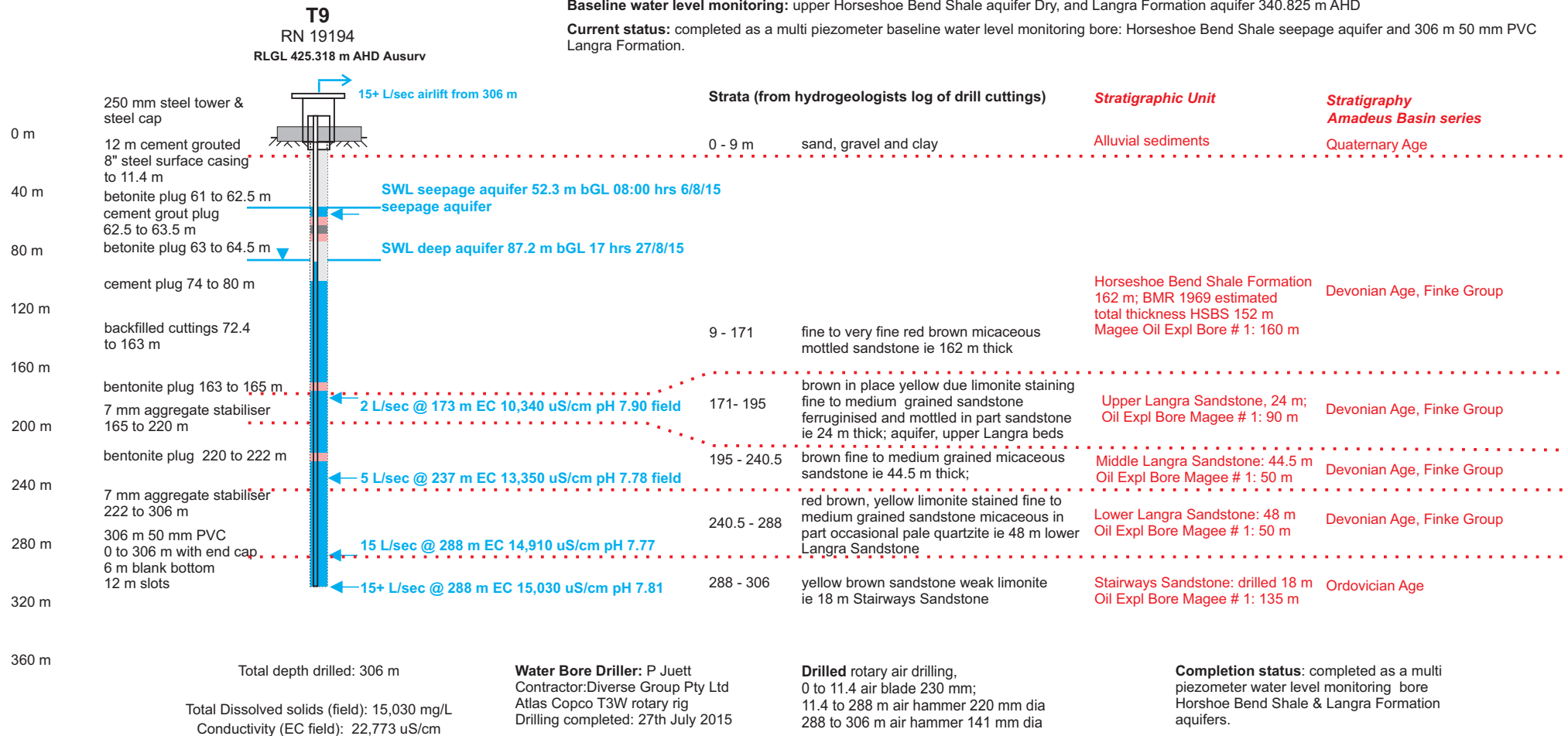
longitude 133 ° 56 ' 53.79659 " latitude -24 ° 47 ' 35.20836

Down hole geophysical logging: Nil; Down Hole Camera Diverse Group

Monitoring measuring point: 22nd of January 2016; HSBS MP 425.815m AHD; Langra Formation MP 425.795m AHD

Baseline water level monitoring: upper Horseshoe Bend Shale aquifer Dry, and Langra Formation aquifer 340.825 m AHD

Current status: completed as a multi piezometer baseline water level monitoring bore: Horseshoe Bend Shale seepage aquifer and 306 m 50 mm PVC Langra Formation.



Prepared by Graham Ride 11th August 2015

File: Tellus\Tellus Database\
Bore A4 X sections\T9 A4 X section SR 15 01 16
Update SR 15 01 16

Hydrogeological assessment consultancy: Chandler Salt Mine Project
Tellus Holdings Limited: hydrogeological assessment, stage 1 groundwater investigation

Ride Consulting

Appendix B

Geophysical bore logs

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ENDEAVOUR GEOPHYSICS

TELLUS HOLDINGS

PBT1



GAMMA/MAGNETIC SUSCEPTIBILITY/CONDUCTIVITY

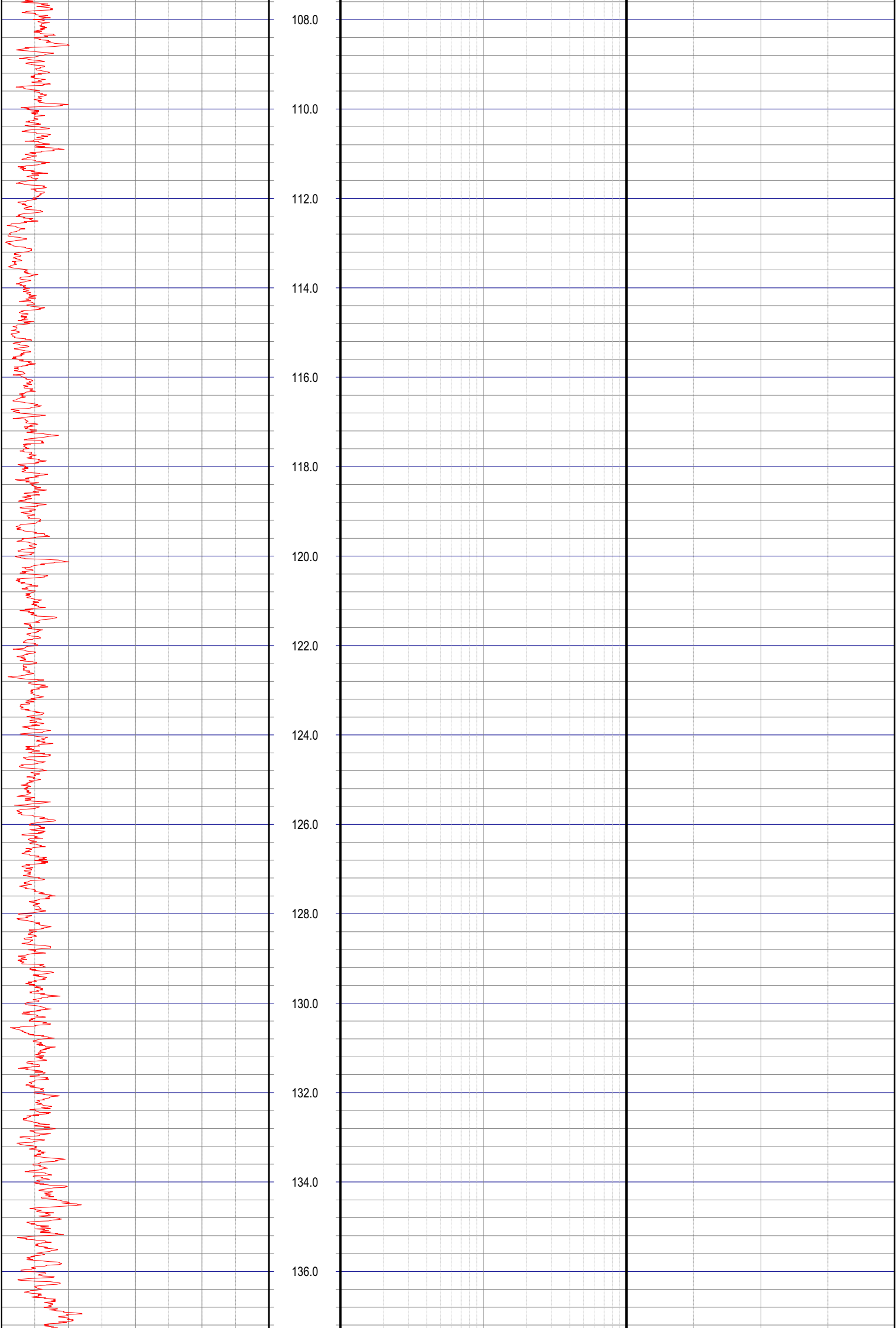
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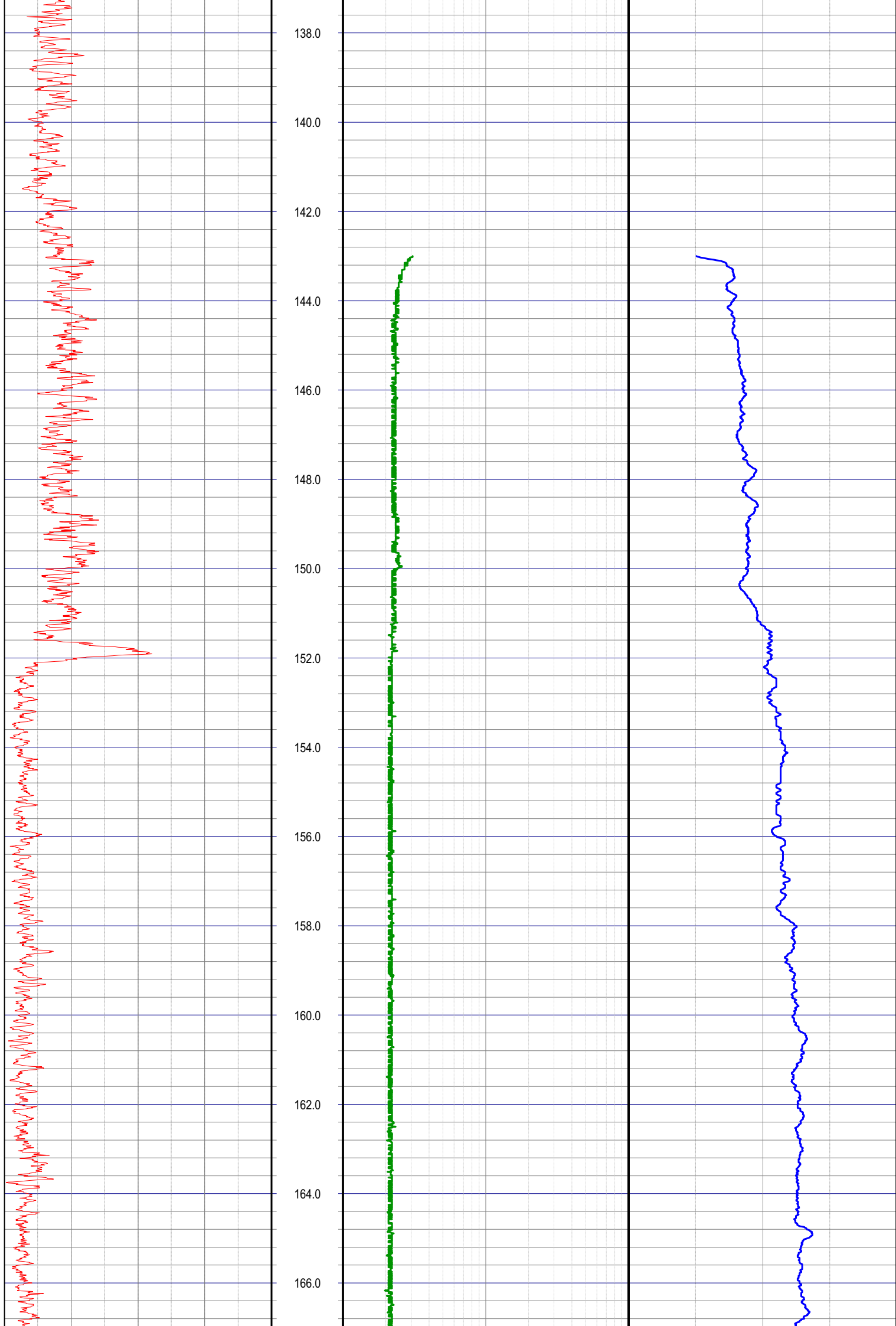
LOCATION		HOLE ATTRIBUTES		LOGGING DETAILS	
LOCATION	CHANDLER	DATE	07/07/2015	RECORDED BY	JONATHAN IRELAND
EL		FLUID LEVEL	69.96 m	WITNESSED BY	GRAHAM RIDE
PROVINCE		FLUID TYPE	Water	UNIT	Navara
STATE	NT	DRILLED DEPTH	216 m	LOGGED DEPTH	214.84 m
COUNTRY	AUSTRALIA	DATUM	GROUND LEVEL	INT LOGGED	GL-214.84 m
LATI		DRILLING COMPANY	DIVERSE RESOURCES	LOGGING RUNS	
LONG		DRILLING RIG	T3W		
GEODETIC DATUM	GDA94	BOREHOLE RECORD		TOOL	ID
COORD	MGA	TYPE	SIZE	START	FINISH
EASTING	392499		FROM m		
NORTHING	7258504		GL		TD
ELEVATION	405m	CASING RECORD			
SRVC	ENDEAVOUR GEOPHYSICS	TYPE	SIZE		
WEB	www.endeavourgeo.com		FROM m		
COMMENTS		Steel	125mm		
			GL		

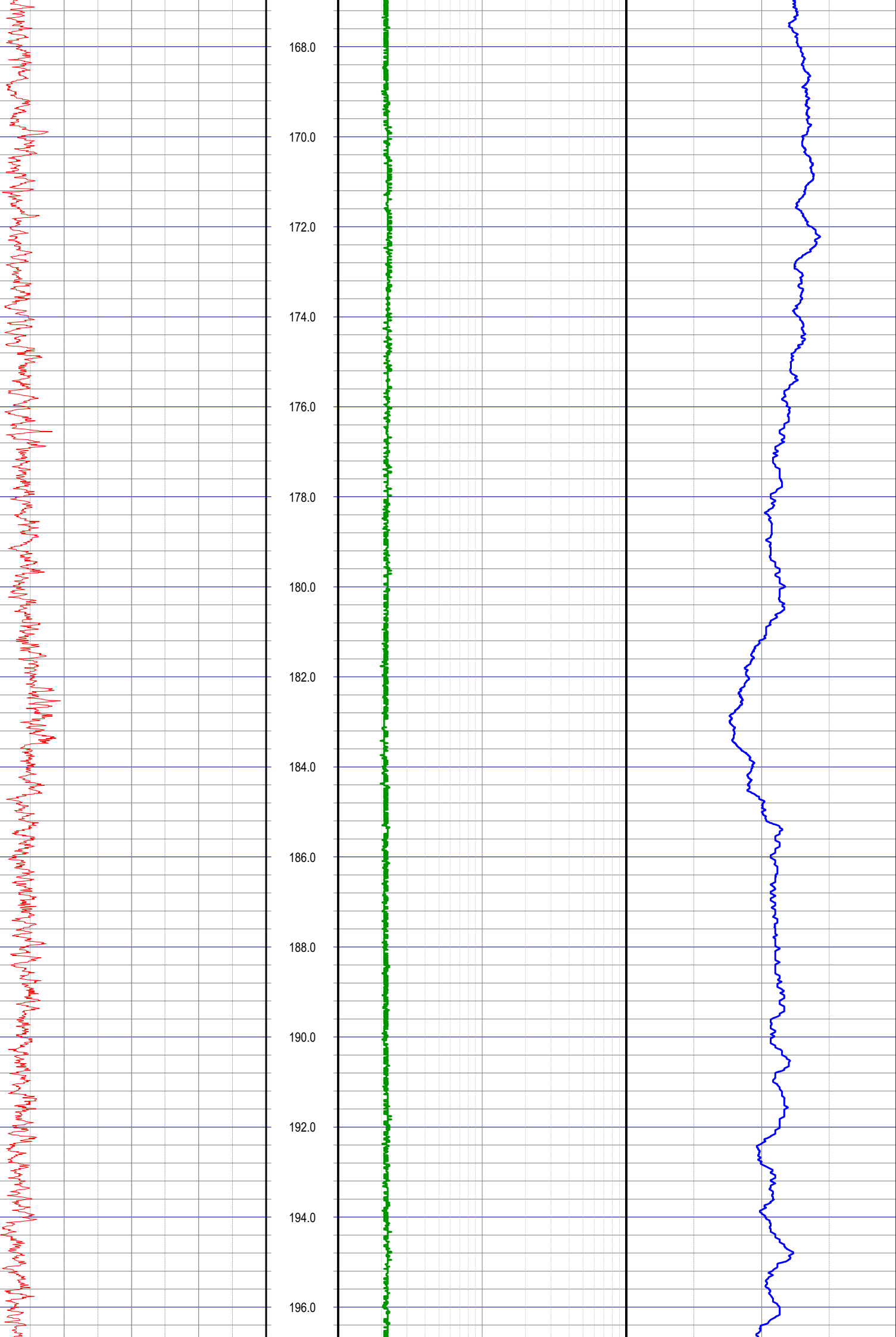
MAGNETIC SUSCEPTIBILITY/INDUCTION CONDUCTIVITY/GAMMA - MIG

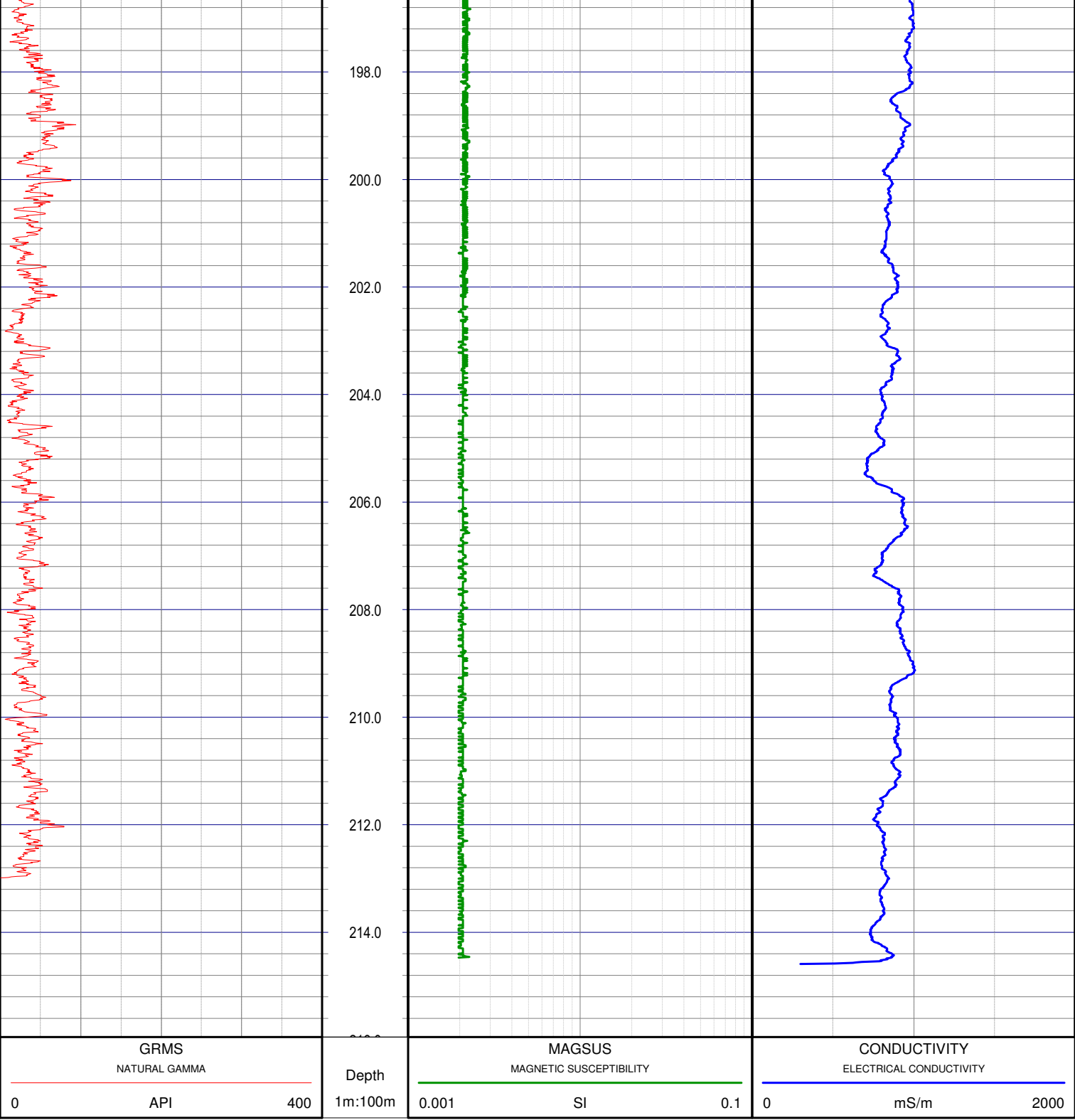


CALIBRATION		MIG_MNEUMONICS		ATTRIBUTES	
MIG_CALIBRATION_DATE	01/01/2015	GRMS_RAW = Natural gamma raw counts/sec		MIG_LENGTH	2700mm
MIG_MODEL	HMI-453E	MS_RAW = Magnetic Sus raw counts/sec		MIG_DIAMETER	45mm
MIG_SERIAL_NO	MIG08	COND_RAW = Conductivity raw counts/sec		MIG_MAGSUS_RANGE	0.0001-2 SI
MIG_GAMMA_CAL	2.0621*{RAW}	GRMS = Calibrated Gamma - API Units		MIG_CONDUCTIVITY_RANGE	1 S/m - 1000 S/m
MIG_MS_CAL	0.00061604423*{MS_RAW} - 0.0041931	MAGSUS = Calibrated Magnetic Susceptibility - SI Units		MIG_LOGGING_SPEED	6m/min
MIG_COND_CAL	0.0003538*{COND_RAW} - 10.192424	CONDUCTIVITY = Calibrated Conductivity - S/m		MIG_INTERCOIL_SPACING	30cm
GRMS NATURAL GAMMA		Depth	MAGSUS MAGNETIC SUSCEPTIBILITY	CONDUCTIVITY ELECTRICAL CONDUCTIVITY	
0 API 400		1m:100m	0.001 SI 0.1	0 mS/m 2000	
		100.0			
		102.0			
		104.0			
		106.0			











ENDEAVOUR GEOPHYSICS

TELLUS HOLDINGS

WT1



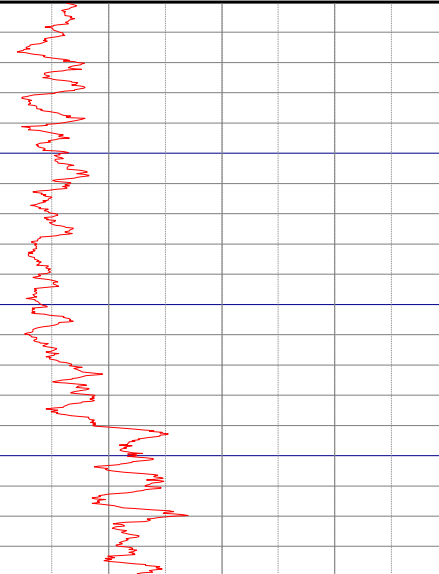
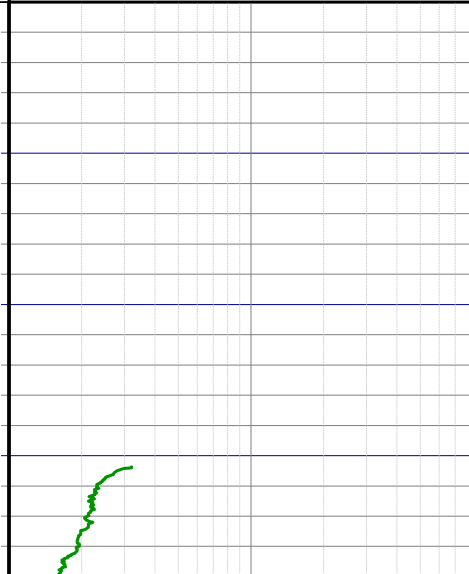
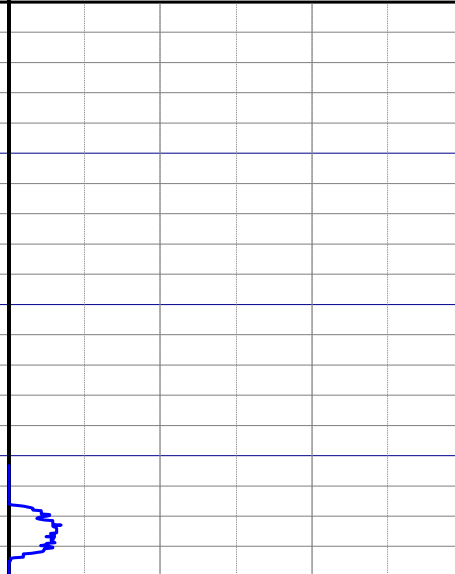
GAMMA/MAGNETIC SUSCEPTIBILITY/CONDUCTIVITY

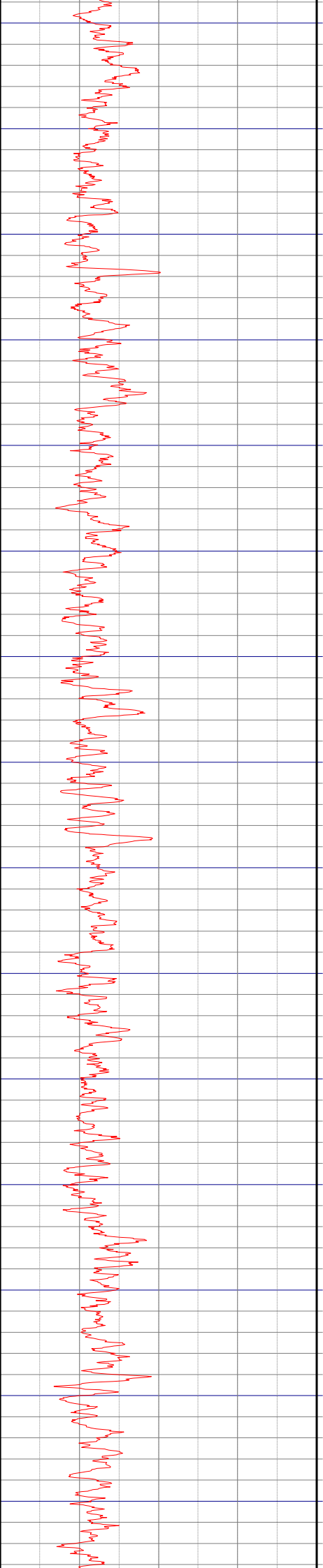
1:100

LOCATION		HOLE ATTRIBUTES		LOGGING DETAILS	
LOCATION	CHANDLER	DATE	03/07/2015	RECORDED BY	JONATHAN IRELAND
EL		FLUID LEVEL	69 m	WITNESSED BY	GRAHAM RIDE
PROVINCE		FLUID TYPE	WATER	UNIT	Navara
STATE	NT	DRILLED DEPTH	201 m	LOGGED DEPTH	201 m
COUNTRY	AUSTRALIA	DATUM	GROUND LEVEL	INT LOGGED	0-201 m
LATI		DRILLING COMPANY	DIVERSE RESOURCES	LOGGING RUNS	
LONG		DRILLING RIG	T3W		
GEODETIC DATUM	GDA94	BOREHOLE RECORD		TOOL	ID
COORD	MGA51			START	FINISH
EASTING	392506.888	TYPE	SIZE		
NORTHING	7258490.812		FROM m		
ELEVATION	411.629m		TO m		
SRVC	ENDEAVOUR GEOPHYSICS	CASING RECORD			
WEB	www.endeavourgeo.com				
COMMENTS		TYPE	SIZE		
			FROM m		
			TO m		
		STEEL	GL	5.5	
		FIBREGLASS150mm	GL	125	

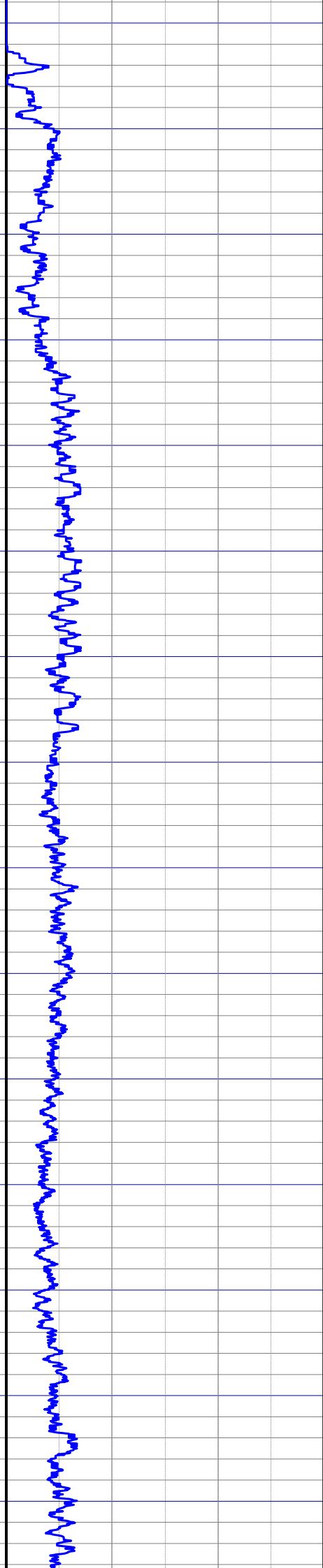
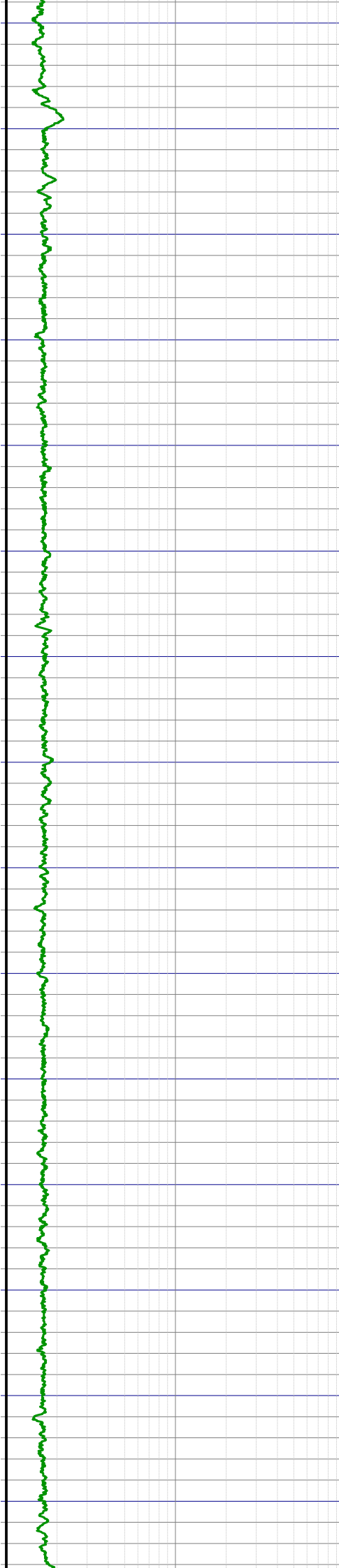
MAGNETIC SUSCEPTIBILITY/INDUCTION CONDUCTIVITY/GAMMA - MIG

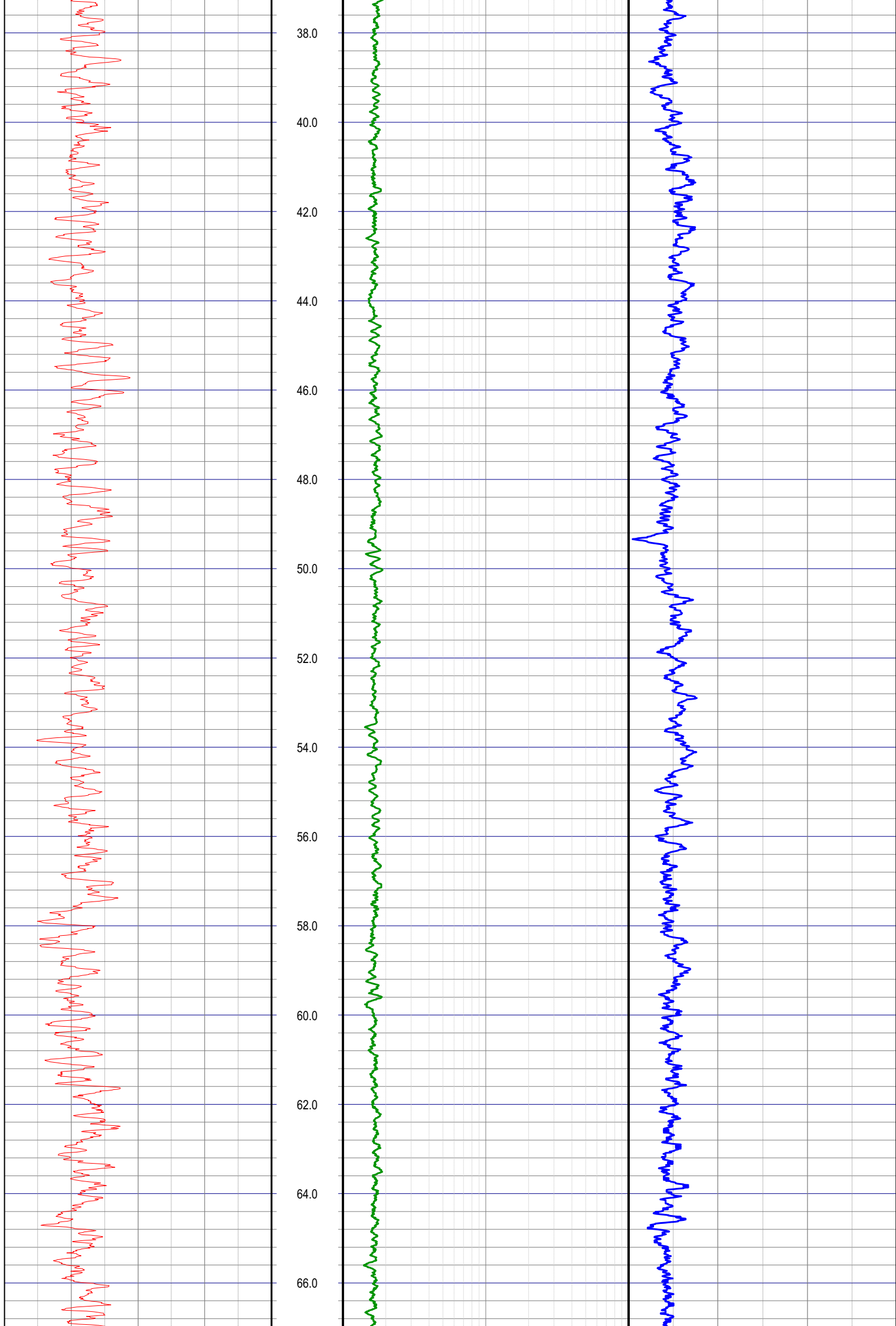


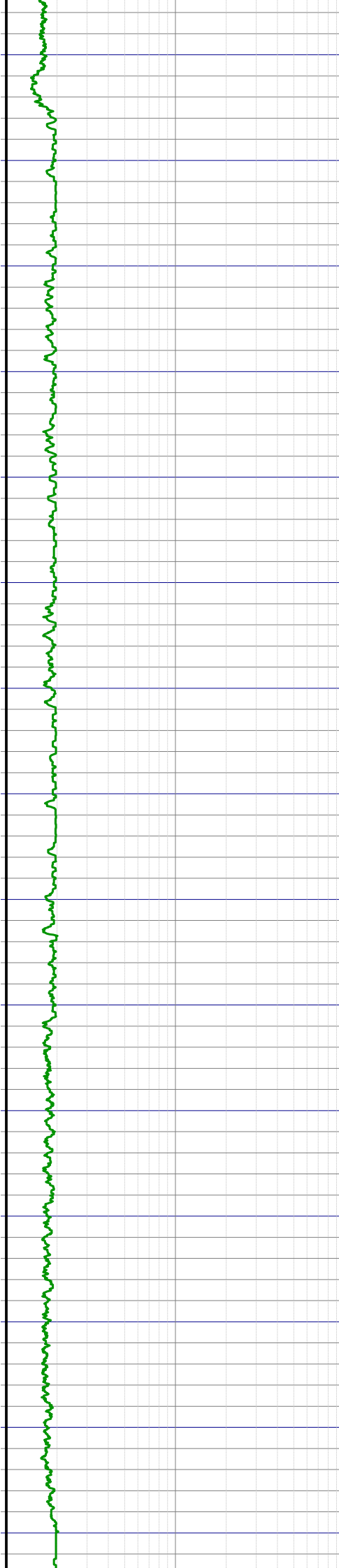
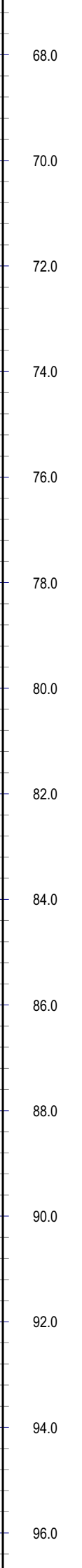
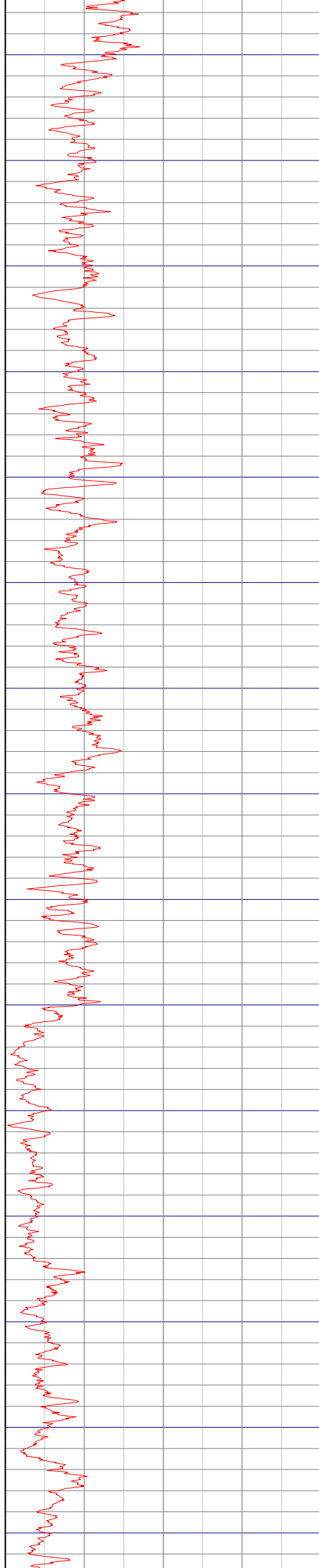
CALIBRATION		MIG_MNEUMONICS		ATTRIBUTES	
MIG_CALIBRATION_DATE	01/01/2015	GRMS_RAW = Natural gamma raw counts/sec		MIG_LENGTH	2700mm
MIG_MODEL	HMI-453E	MS_RAW = Magnetic Sus raw counts/sec		MIG_DIAMETER	45mm
MIG_SERIAL_NO	MIG08	COND_RAW = Conductivity raw counts/sec		MIG_MAGSUS_RANGE	0.0001-2 SI
MIG_GAMMA_CAL	2.0621*{RAW}	GRMS = Calibrated Gamma - API Units		MIG_CONDUCTIVITY_RANGE	3 S/m - 1000 S/m
MIG_MS_CAL	0.00061604423*{MS_RAW} - 0.0041931	MAGSUS = Calibrated Magnetic Susceptibility - SI Units		MIG_LOGGING_SPEED	6m/min
MIG_COND_CAL	0.0003538*{COND_RAW} - 10.192424	CONDUCTIVITY = Calibrated Conductivity - S/m		MIG_INTERCOIL_SPACING	30cm
GRMS NATURAL GAMMA		Depth	MAGSUS MAGNETIC SUSCEPTIBILITY		CONDUCTIVITY ELECTRICAL CONDUCTIVITY
0 API 400		1m:100m	0.001 SI 0.1		0 mS/m 3000
		0.0 2.0 4.0 6.0			

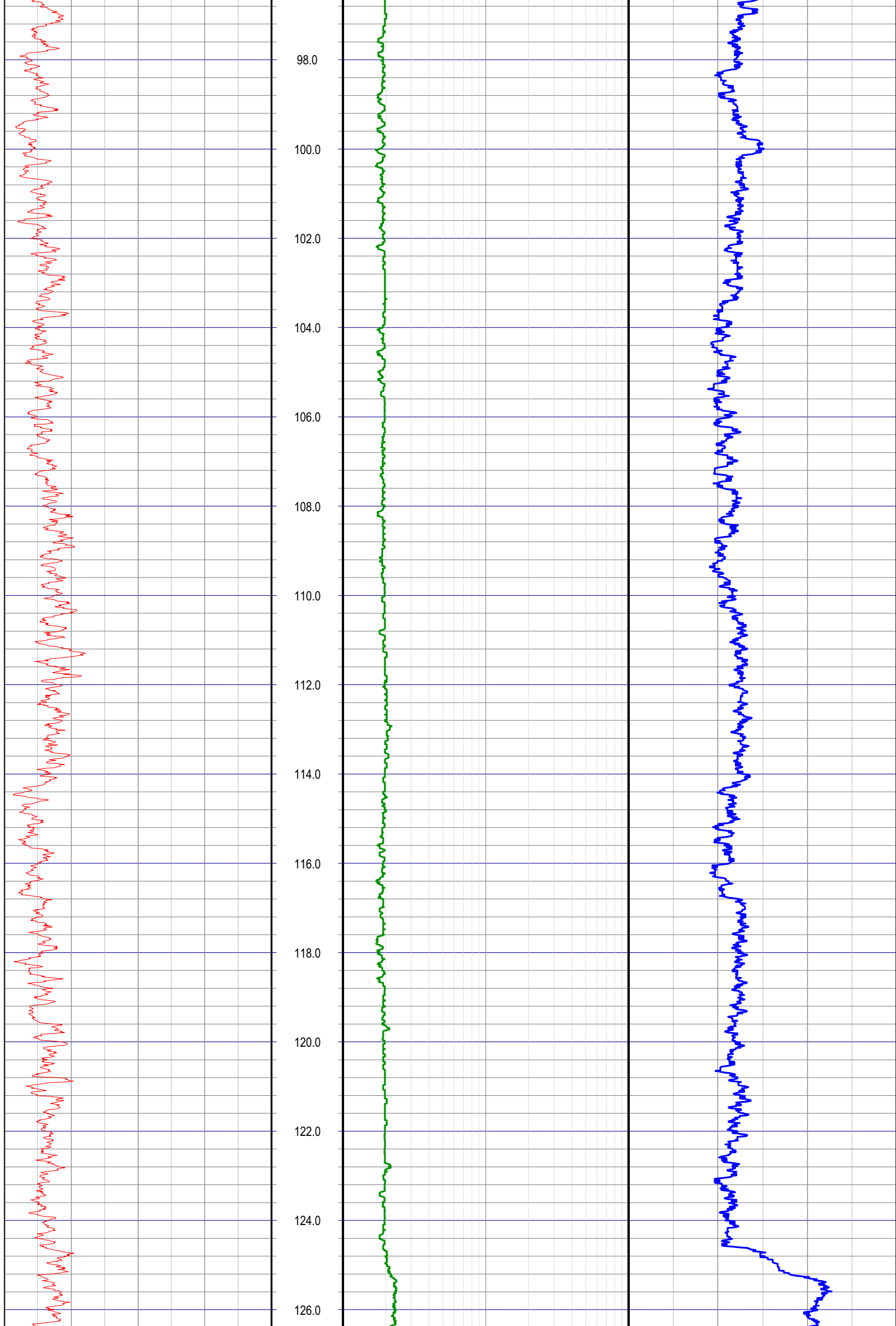


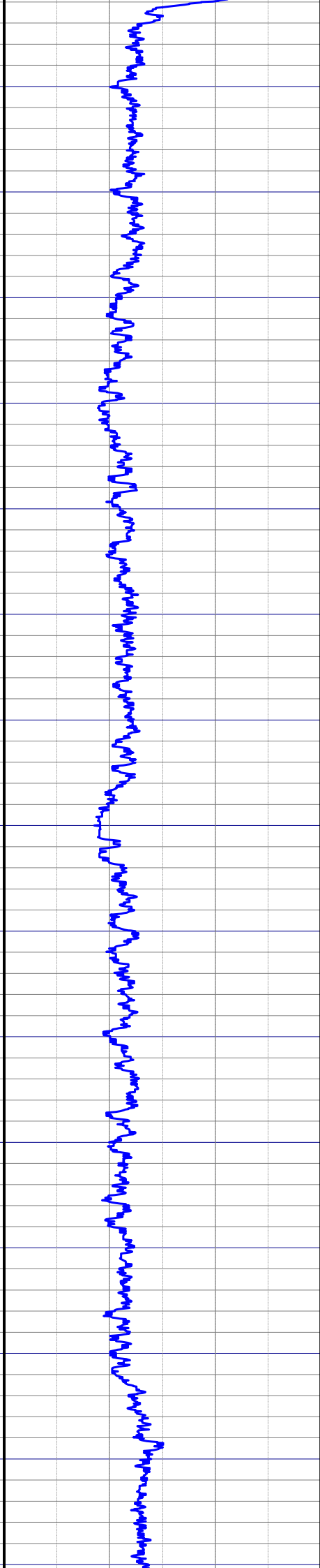
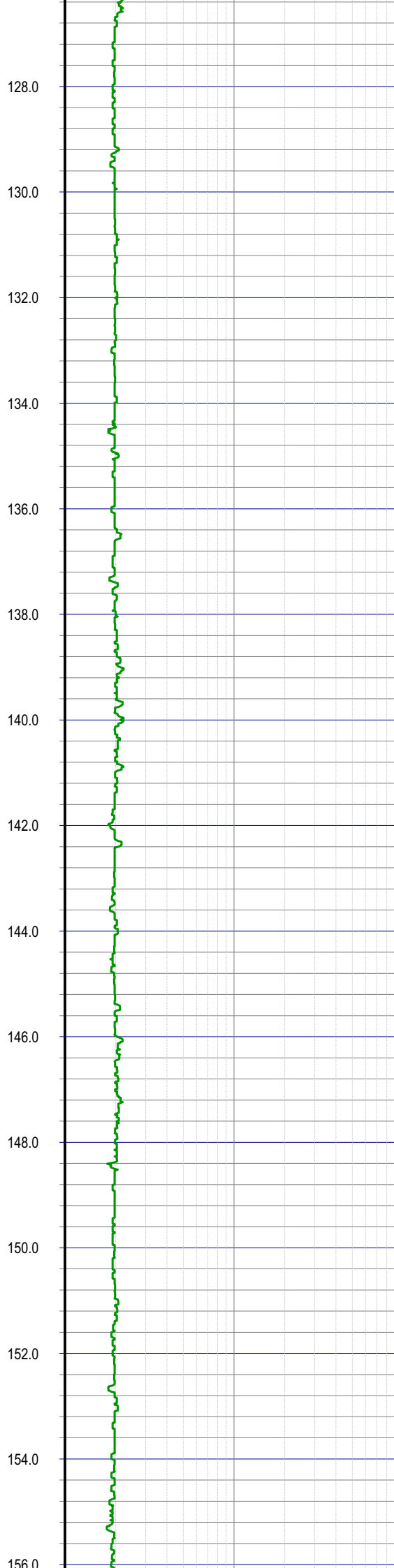
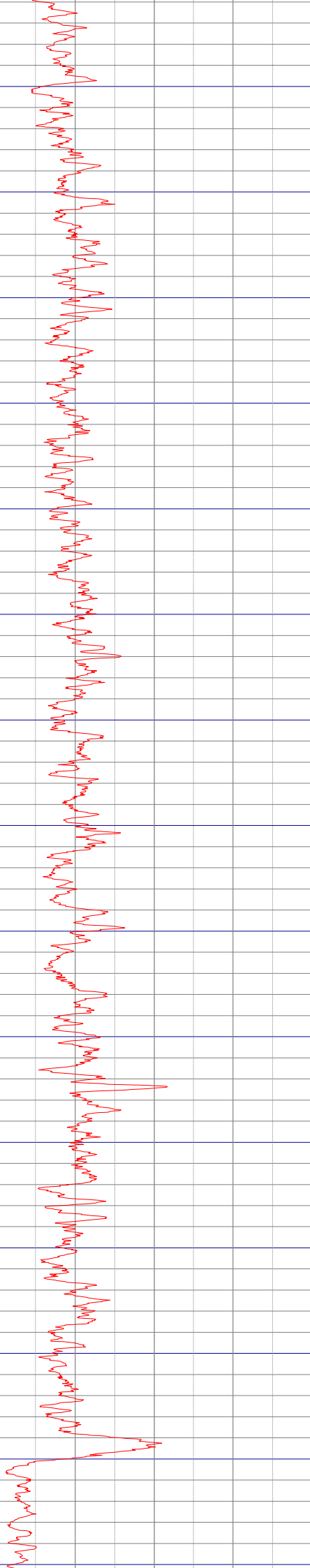
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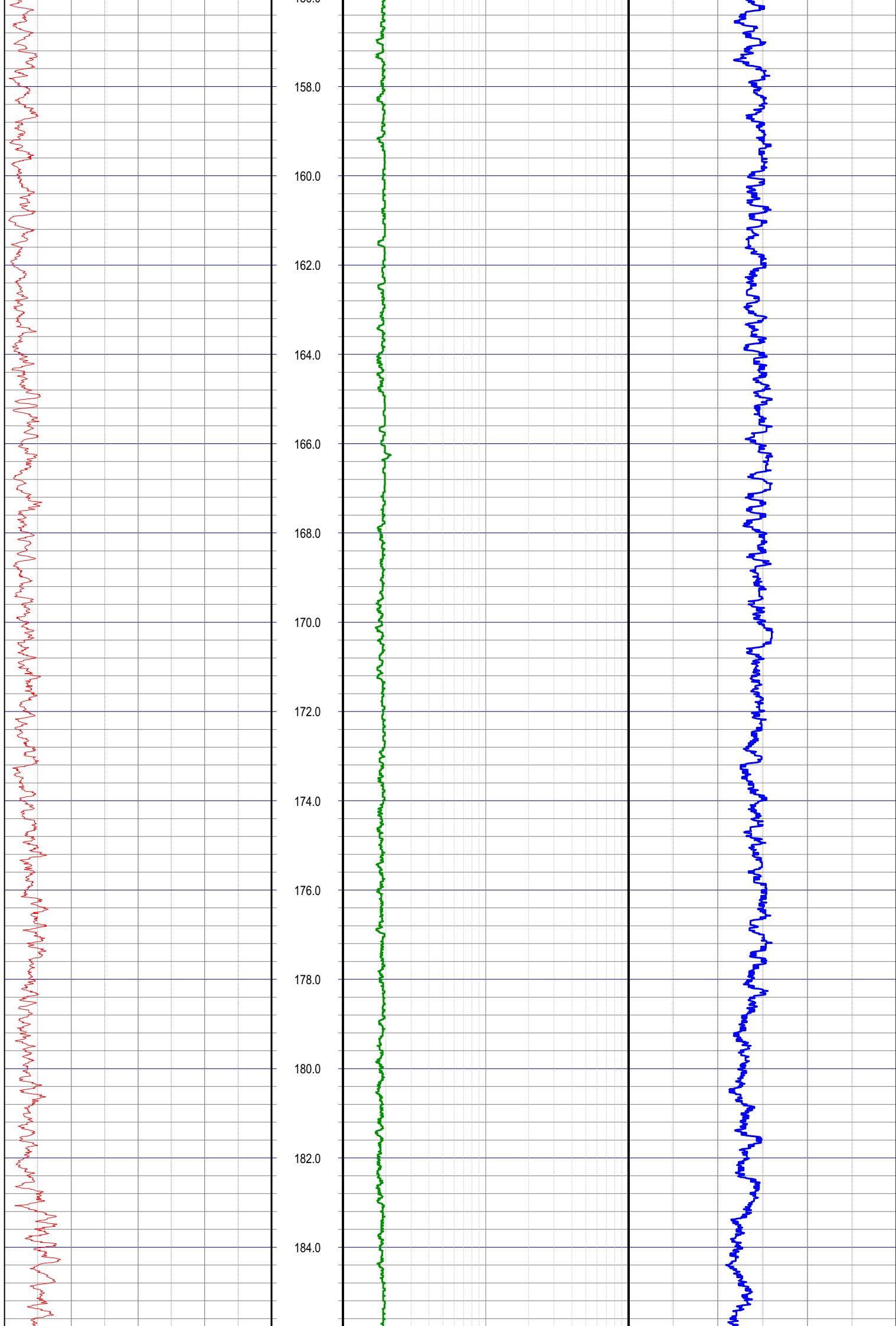


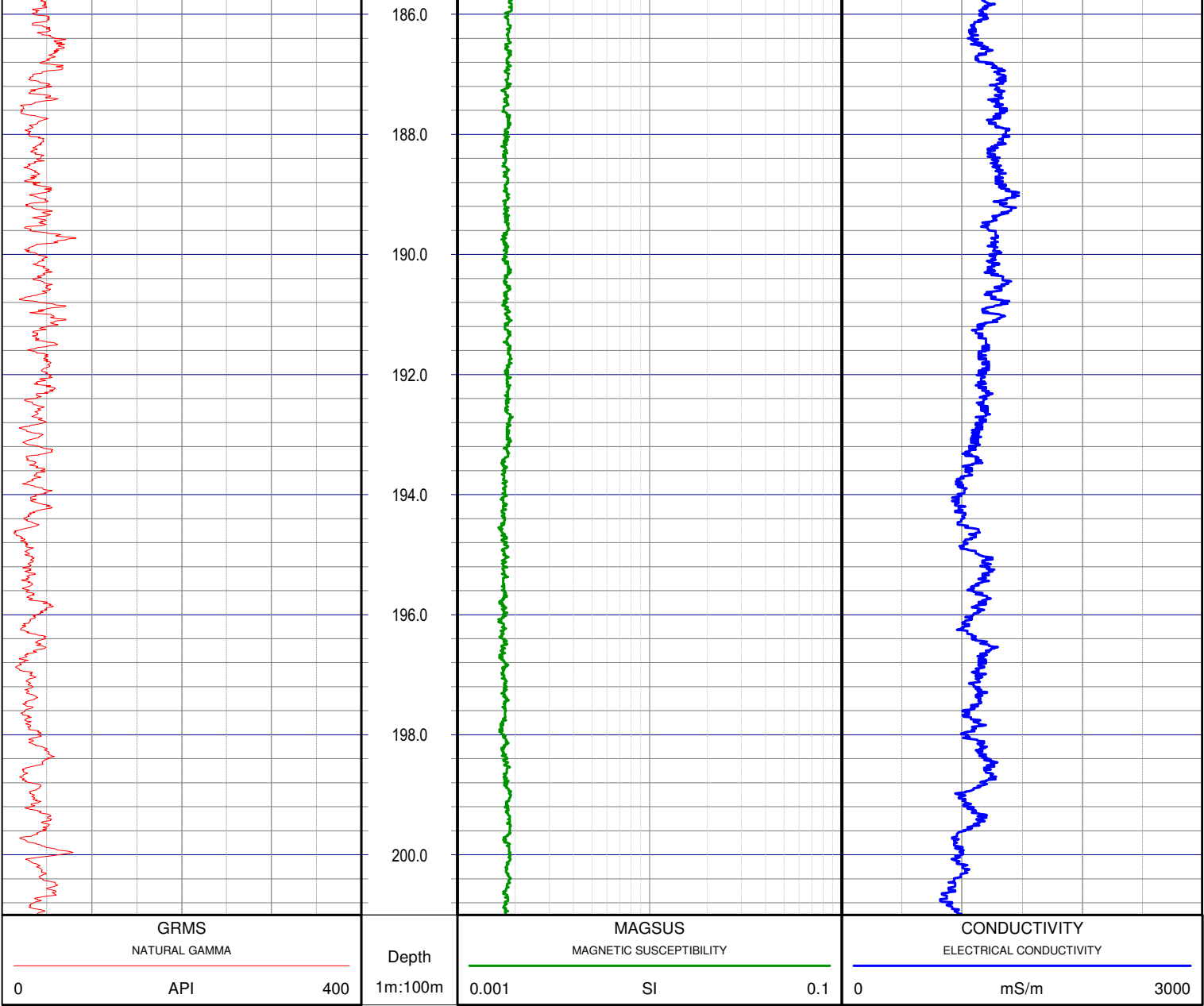














ENDEAVOUR GEOPHYSICS

TELLUS HOLDINGS

WT2

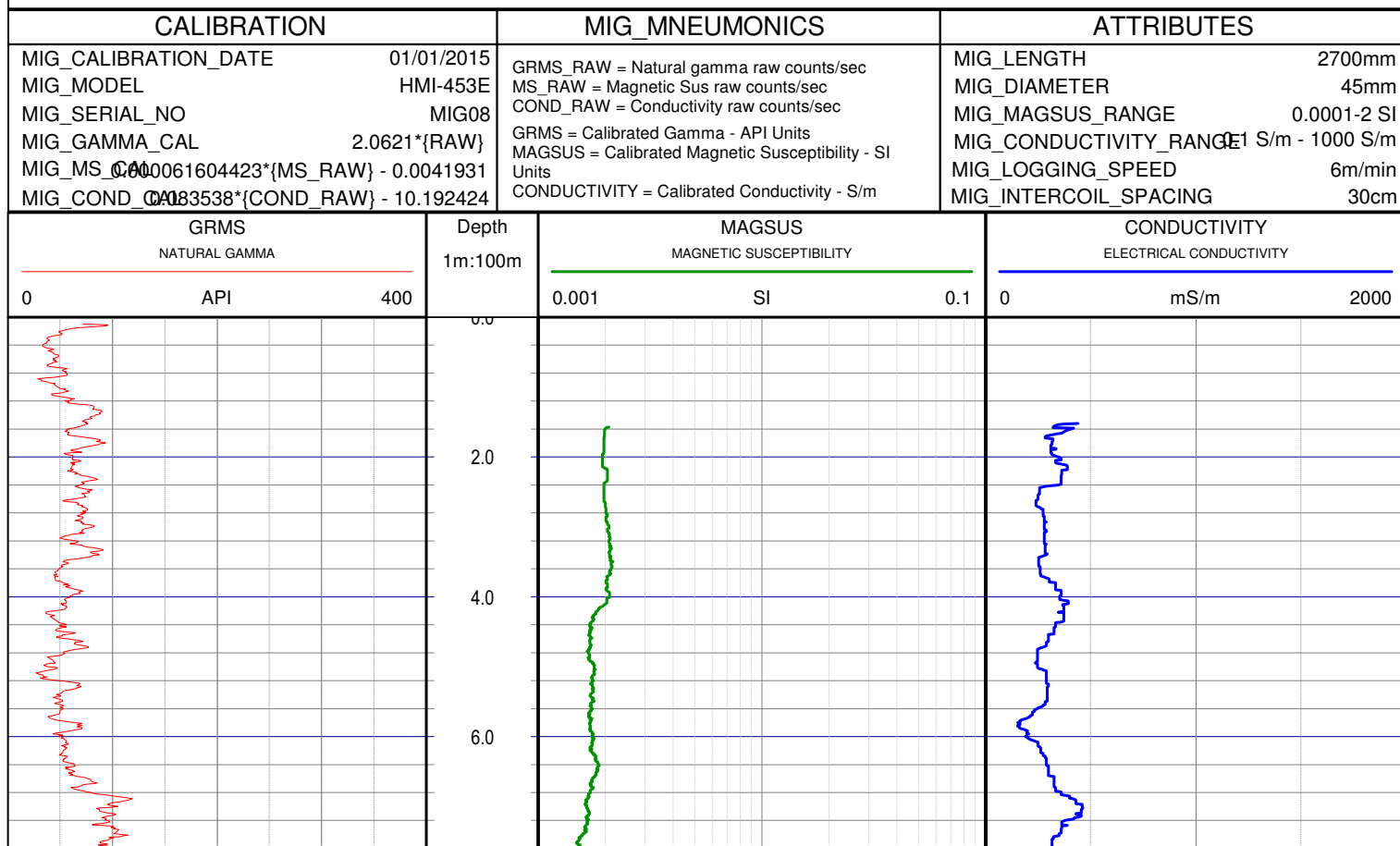


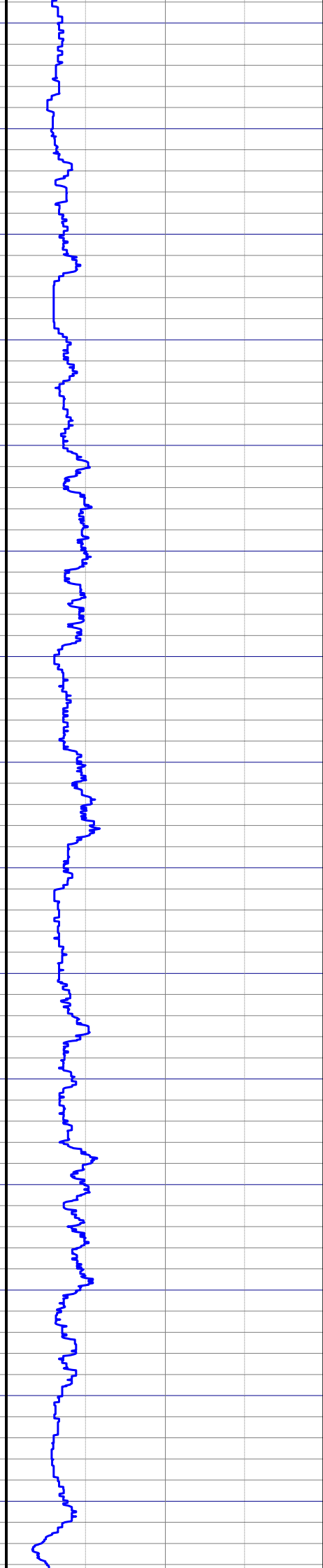
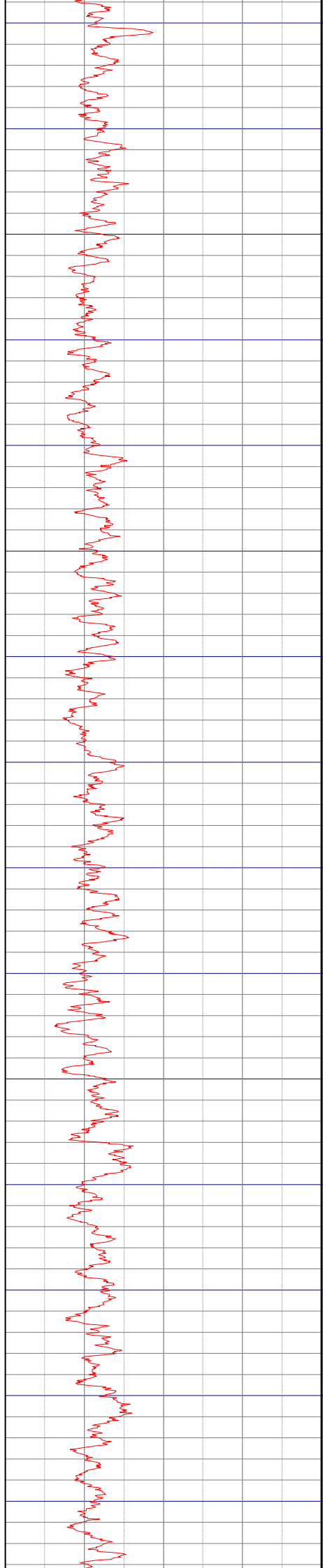
GAMMA/MAGNETIC SUSCEPTIBILITY/CONDUCTIVITY

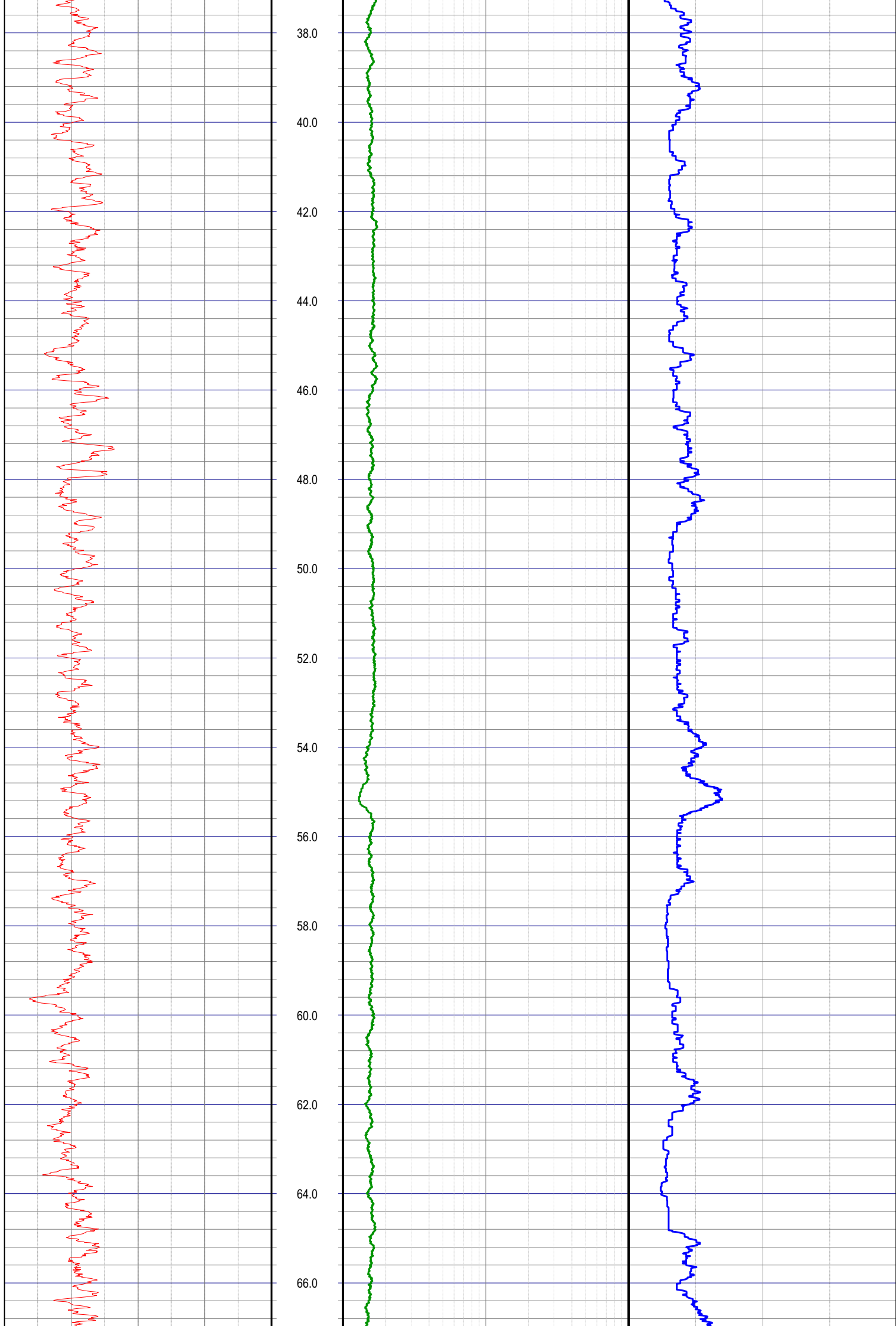
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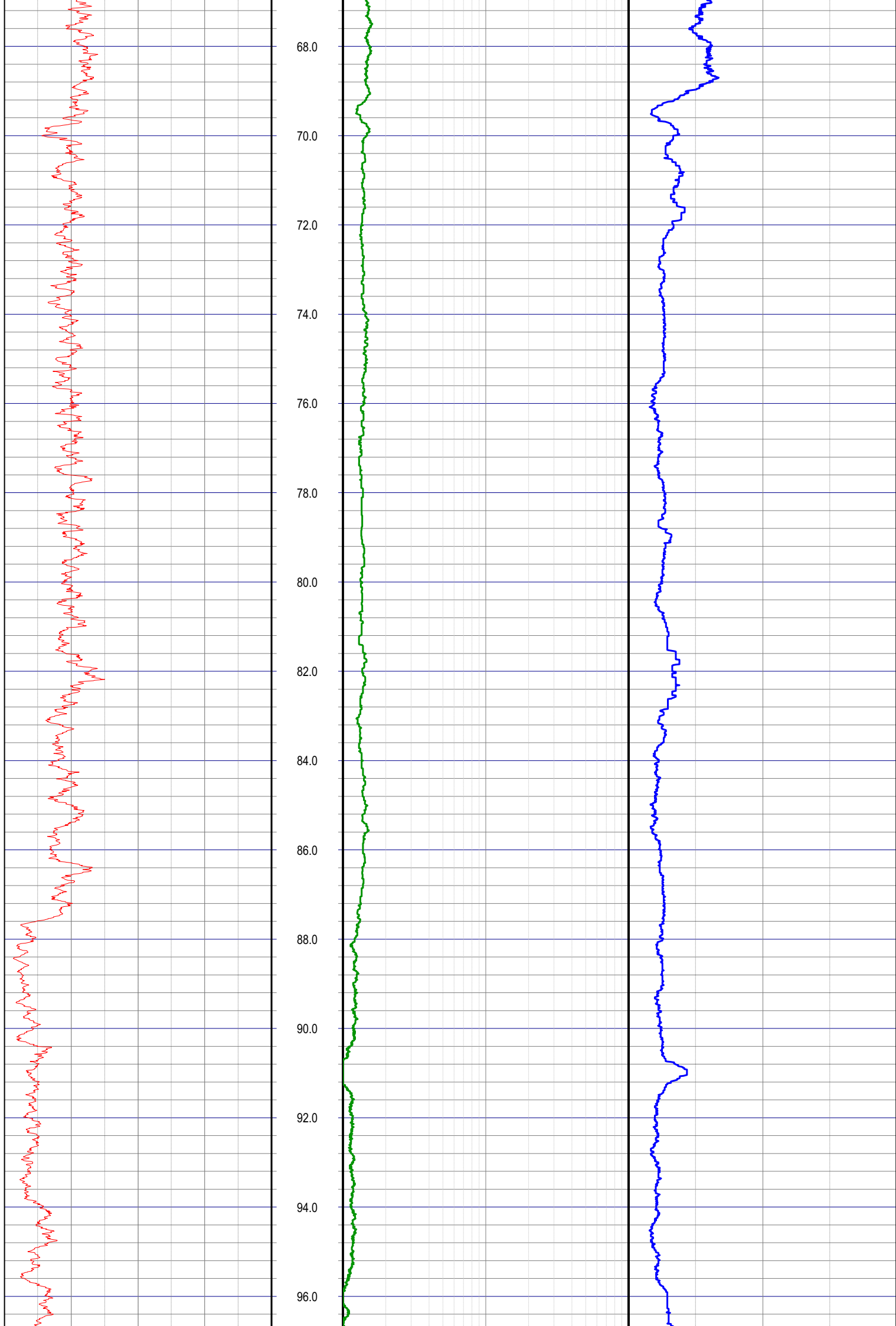
LOCATION		HOLE ATTRIBUTES		LOGGING DETAILS	
LOCATION	CHANDLER	DATE	03/07/2015	RECORDED BY	JONATHAN IRELAND
EL		FLUID LEVEL	69 m	WITNESSED BY	Graham Ride
PROVINCE		FLUID TYPE	Water	UNIT	Navara
STATE	NT	DRILLED DEPTH	120 m	LOGGED DEPTH	120 m
COUNTRY	AUSTRALIA	DATUM	GROUND LEVEL	INT LOGGED	0-120 m
LATI		DRILLING COMPANY	DIVERSE DRILLING	LOGGING RUNS	
LONG		DRILLING RIG	T3W		
GEODETIC DATUM	GDA94	BOREHOLE RECORD		TOOL	ID
COORD	MGA51	TYPE	SIZE	START	FINISH
EASTING	392518.551	FROM m	TO m	MST	522
NORTHING	7258476.121			MIG	08
ELEVATION	411.118m	CASING RECORD			
SRVC	ENDEAVOUR GEOPHYSICS	TYPE	SIZE		
WEB	www.endeavourgeo.com	PVC	50mm		
COMMENTS					
50mm PVC Hole, no FDS Run					

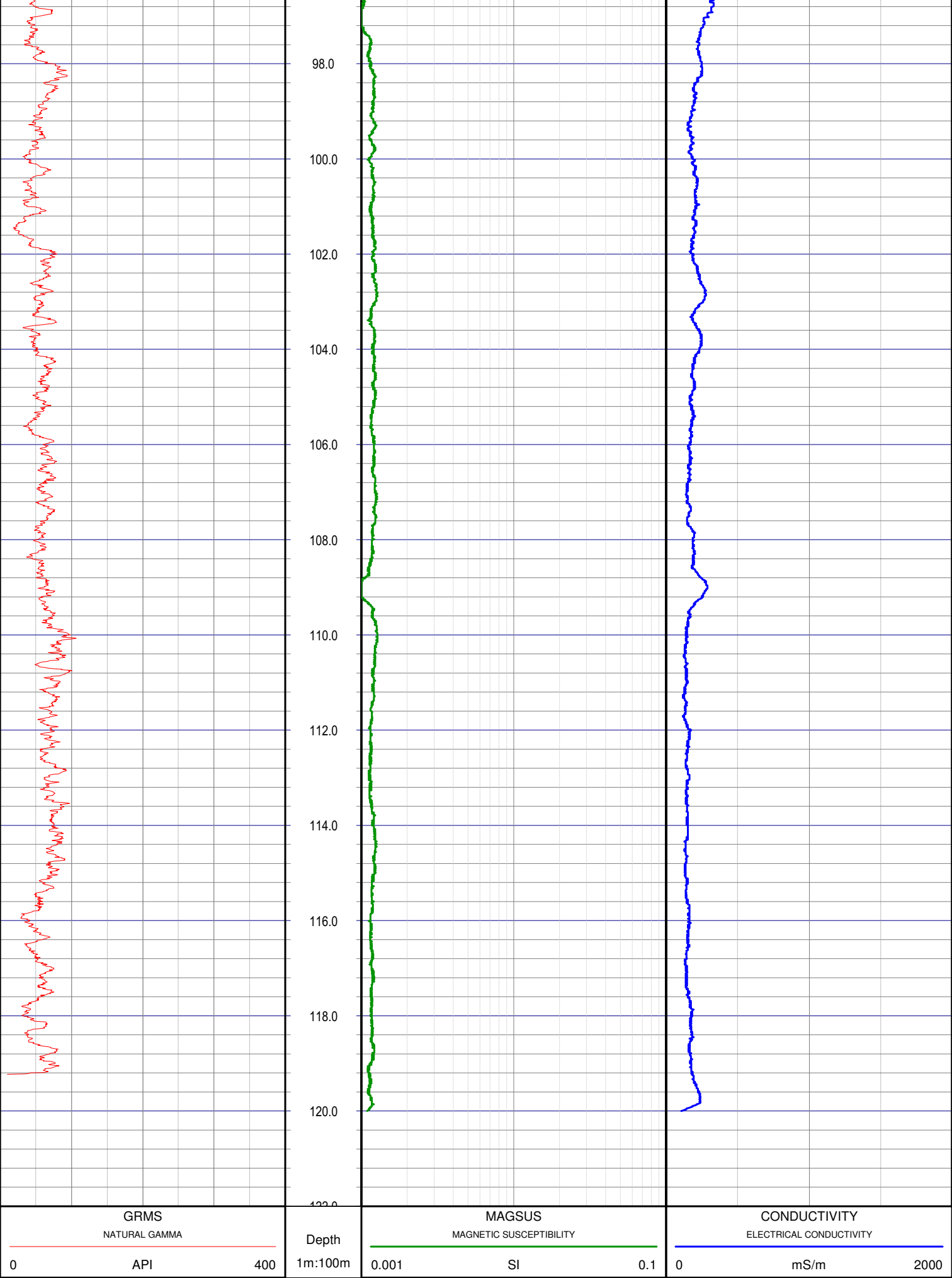
MAGNETIC SUSCEPTIBILITY/INDUCTION CONDUCTIVITY/GAMMA - MIG













ENDEAVOUR GEOPHYSICS

TELLUS HOLDINGS

WT3



GAMMA/MAGNETIC SUSCEPTIBILITY/CONDUCTIVITY

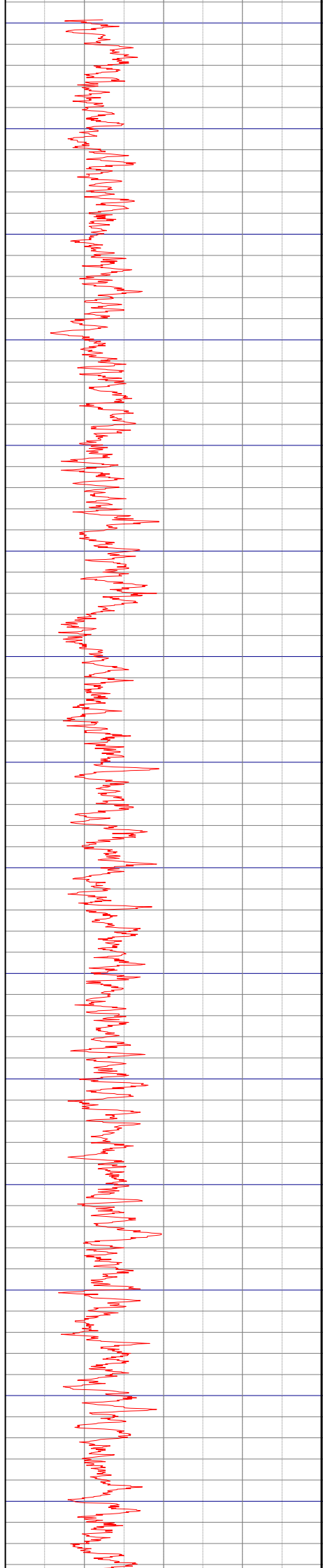
1:100

LOCATION		HOLE ATTRIBUTES		LOGGING DETAILS	
LOCATION	CHANDLER	DATE	04/07/2015	RECORDED BY	JONATHAN IRELAND
EL		FLUID LEVEL	81.5 m	WITNESSED BY	GRAHAM RIDE
PROVINCE		FLUID TYPE	Water	UNIT	NAV
STATE	NT	DRILLED DEPTH	366 m	LOGGED DEPTH	366 m
COUNTRY	AUSTRALIA	DATUM	GROUND LEVEL	INT LOGGED	GL - 366 m
LATI		DRILLING COMPANY	DIVERSE RESOURCES	LOGGING RUNS	
LONG		DRILLING RIG	T3W		
GEODETIC DATUM		BOREHOLE RECORD		TOOL	ID
COORD		TYPE	SIZE	FROM m	TO m
EASTING	392975.59		7"	GL	270.8
NORTHING	7255631.01		5.5"	270.8	366
ELEVATION	423.33m	CASING RECORD			
SRVC	ENDEAVOUR GEOPHYSICS	TYPE	SIZE	FROM m	TO m
WEB	www.endeavourgeo.com	STEEL	150mm	0	7
COMMENTS					

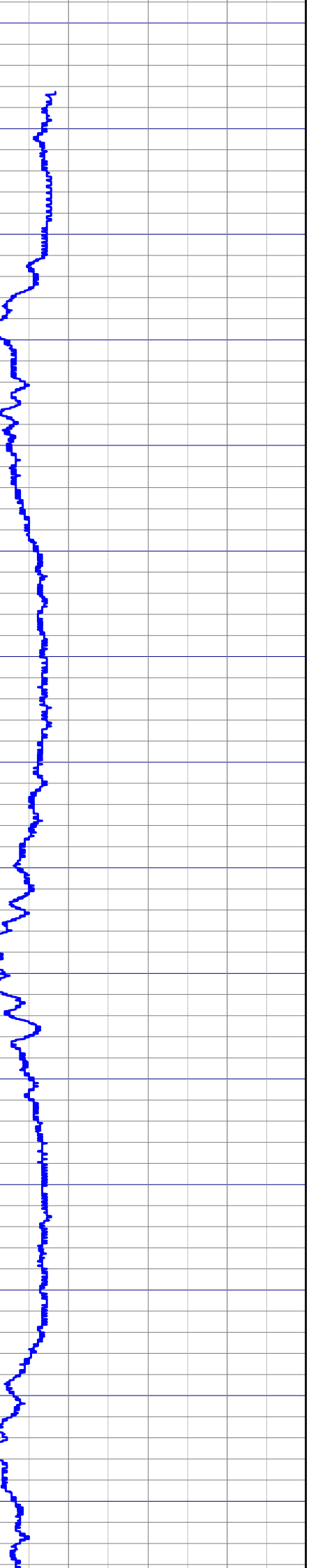
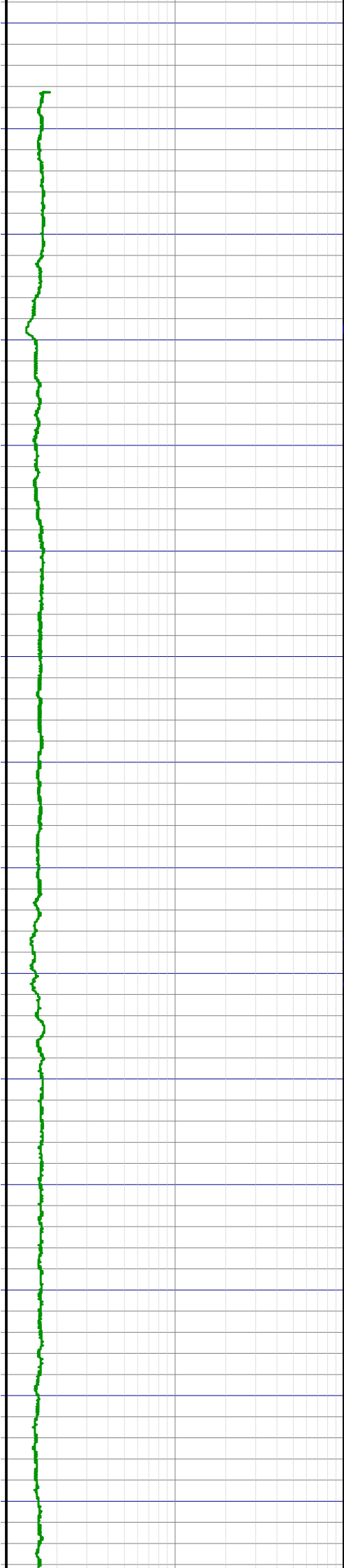
MAGNETIC SUSCEPTIBILITY/INDUCTION CONDUCTIVITY/GAMMA - MIG

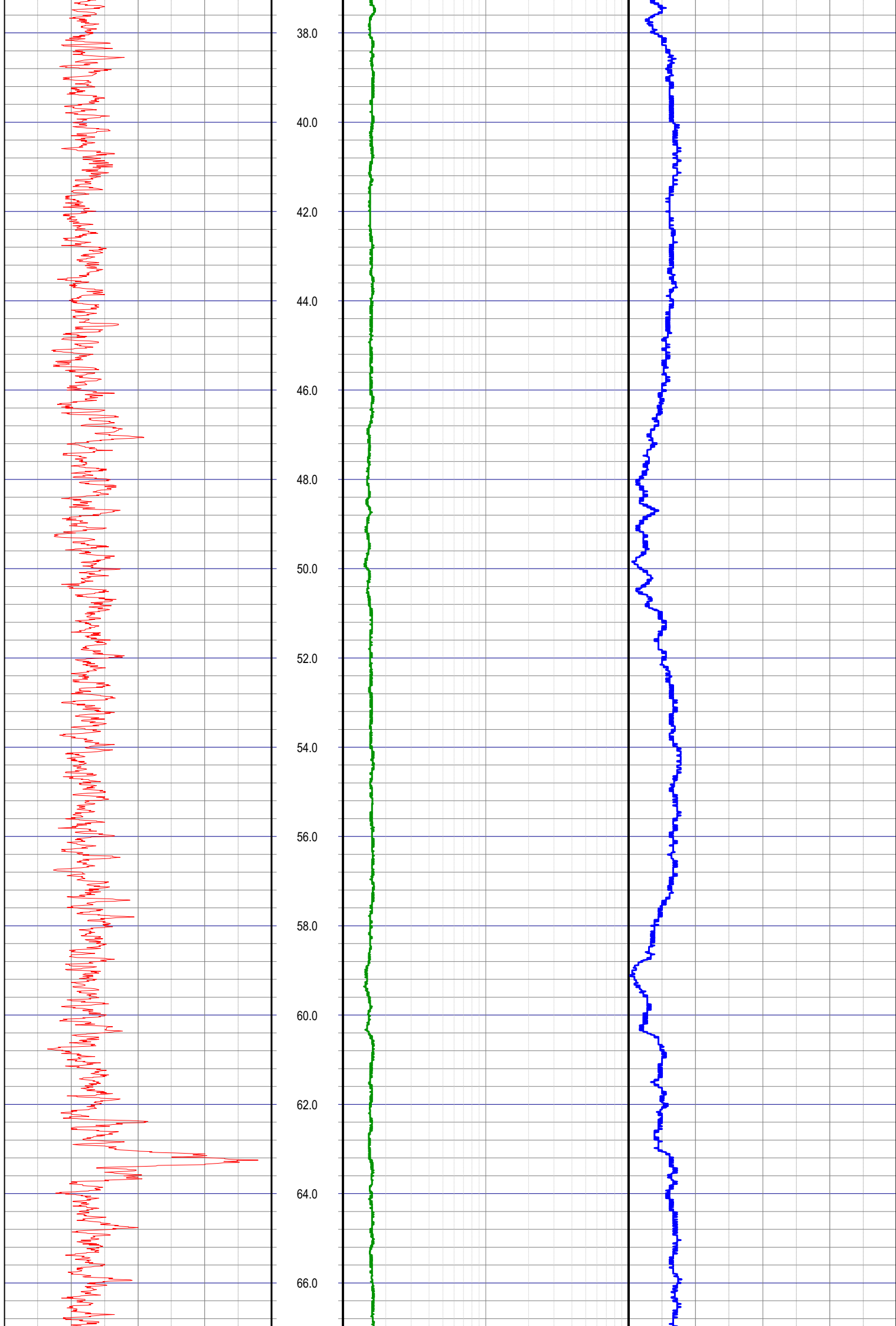


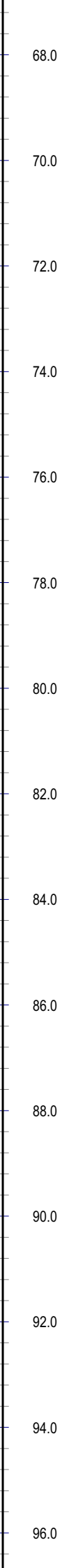
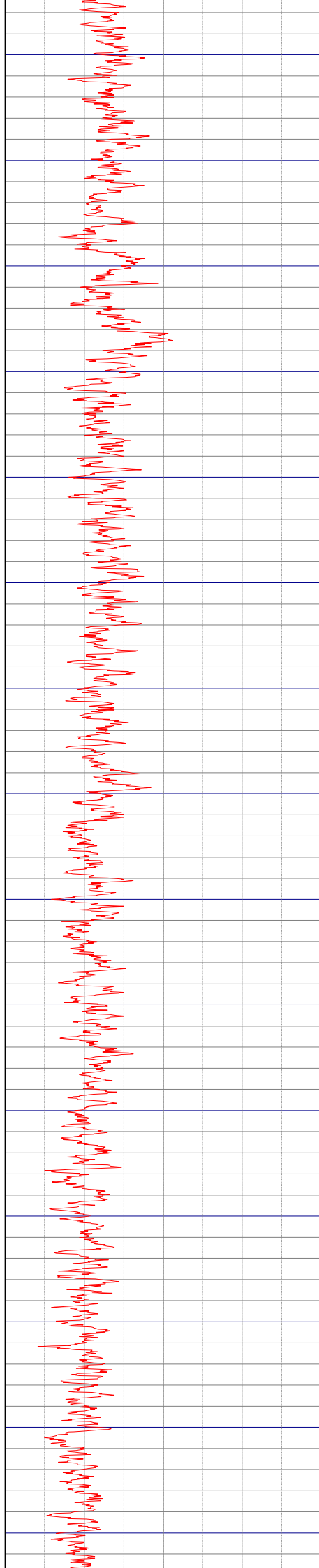
CALIBRATION		MIG_MNEUMONICS		ATTRIBUTES	
MIG_CALIBRATION_DATE	01/01/2015	GRMS_RAW = Natural gamma raw counts/sec		MIG_LENGTH	2700mm
MIG_MODEL	HMI-453E	MS_RAW = Magnetic Sus raw counts/sec		MIG_DIAMETER	45mm
MIG_SERIAL_NO	MIG08	COND_RAW = Conductivity raw counts/sec		MIG_MAGSUS_RANGE	0.0001-2 SI
MIG_GAMMA_CAL	2.0621*{RAW}	GRMS = Calibrated Gamma - API Units		MIG_CONDUCTIVITY_RANGE	3 S/m - 1000 S/m
MIG_MS_CAL	0.00061604423*{MS_RAW} - 0.0041931	MAGSUS = Calibrated Magnetic Susceptibility - SI Units		MIG_LOGGING_SPEED	6m/min
MIG_COND_CAL	0.0003538*{COND_RAW} - 10.192424	CONDUCTIVITY = Calibrated Conductivity - S/m		MIG_INTERCOIL_SPACING	30cm
GRMS NATURAL GAMMA		Depth	MAGSUS MAGNETIC SUSCEPTIBILITY	CONDUCTIVITY ELECTRICAL CONDUCTIVITY	
0 API 400		1m:100m	0.001 SI 0.1	0 mS/m 4000	
		0.0			
		2.0			
		4.0			
		6.0			

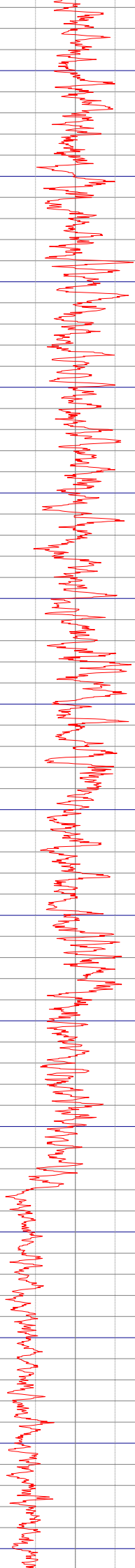


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104.0

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112.0

114.0

116.0

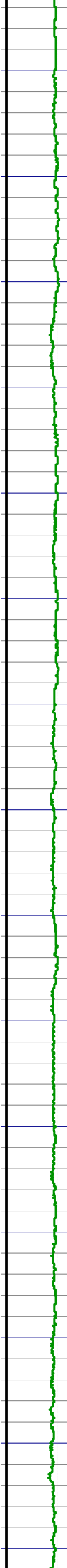
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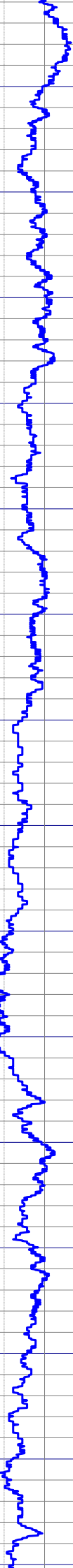
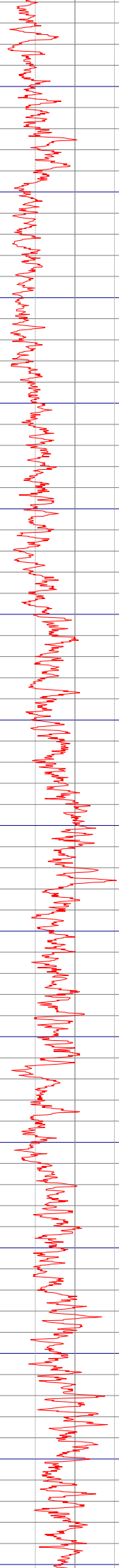
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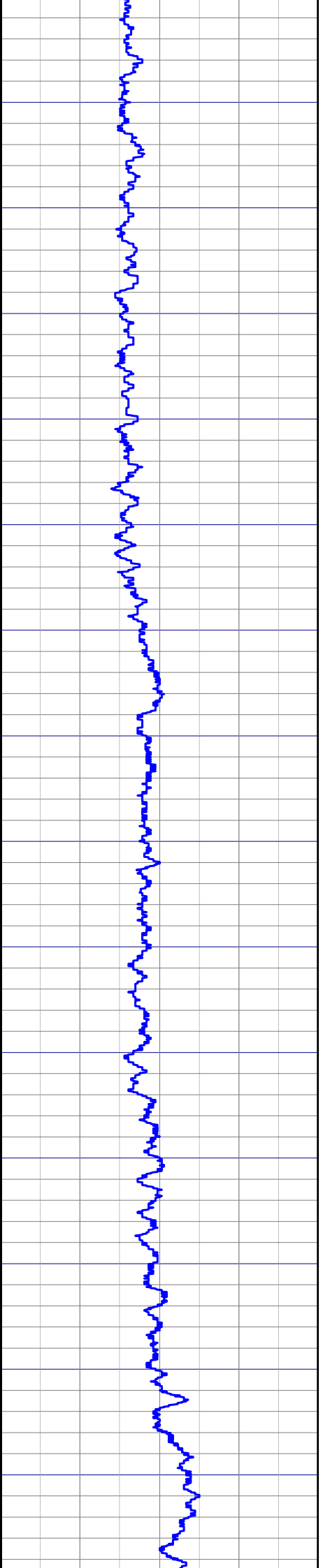
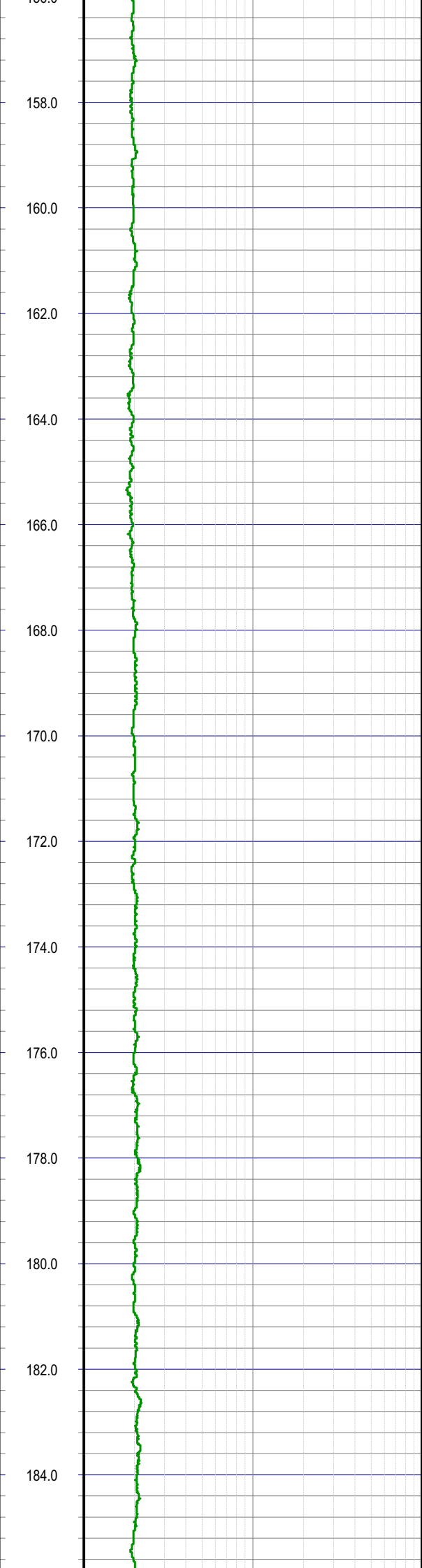
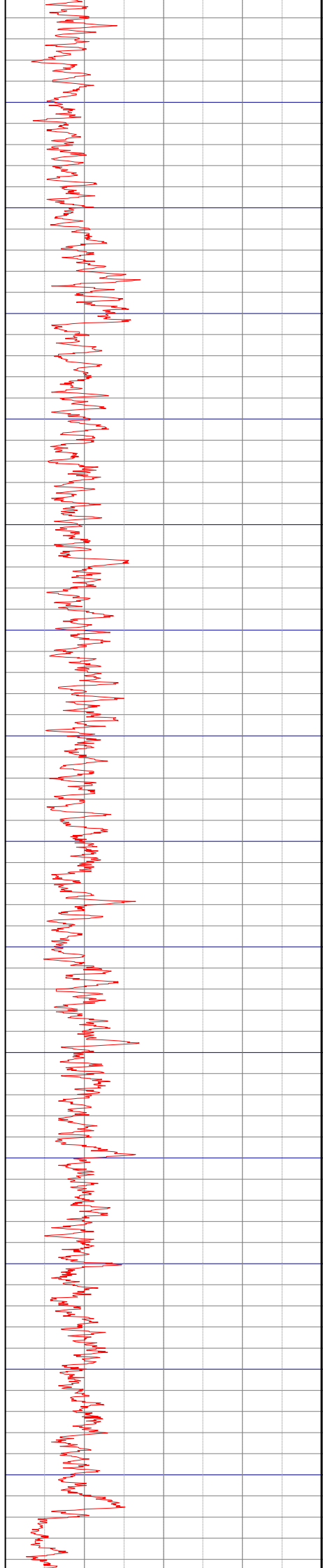
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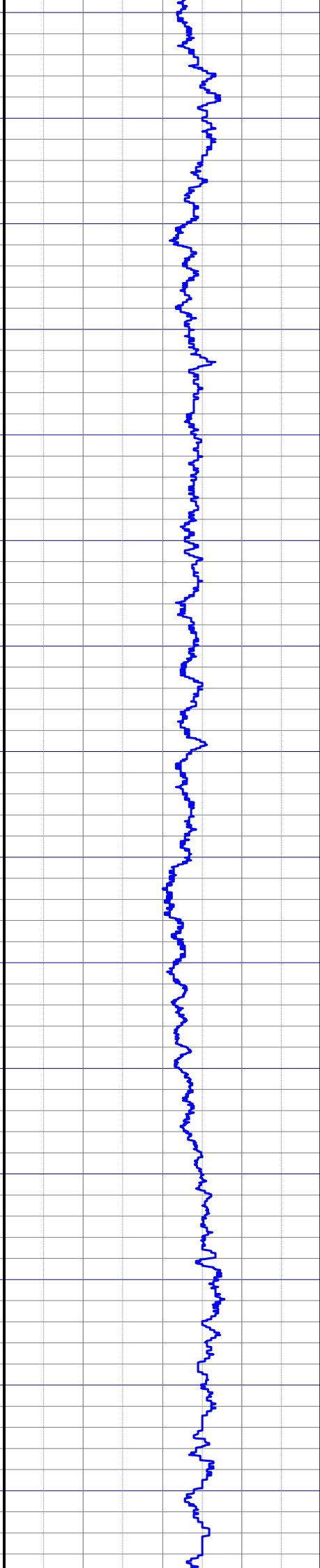
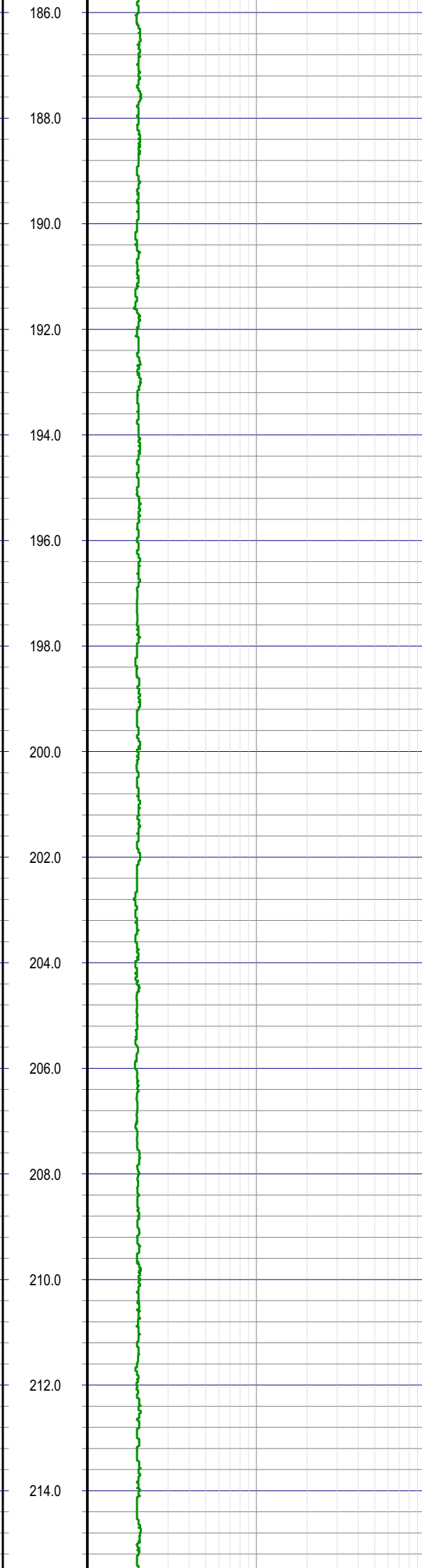
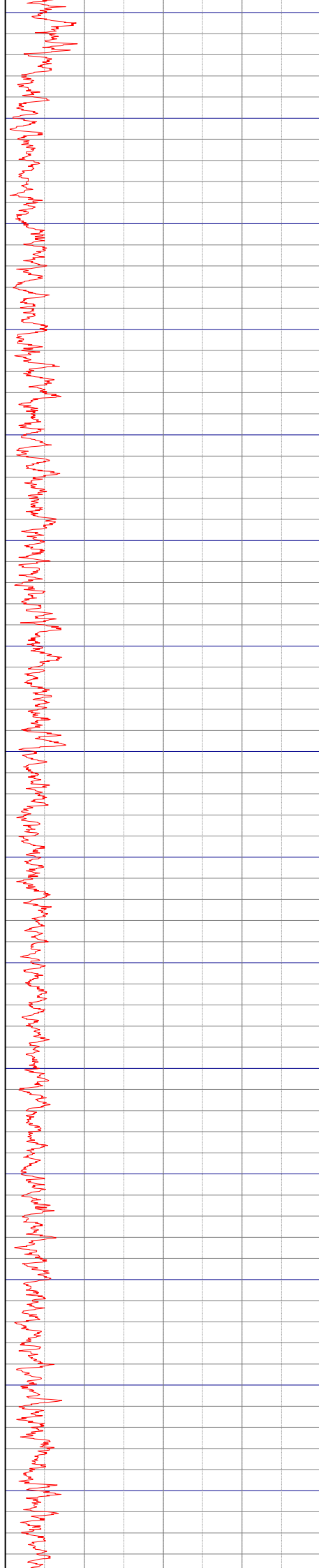
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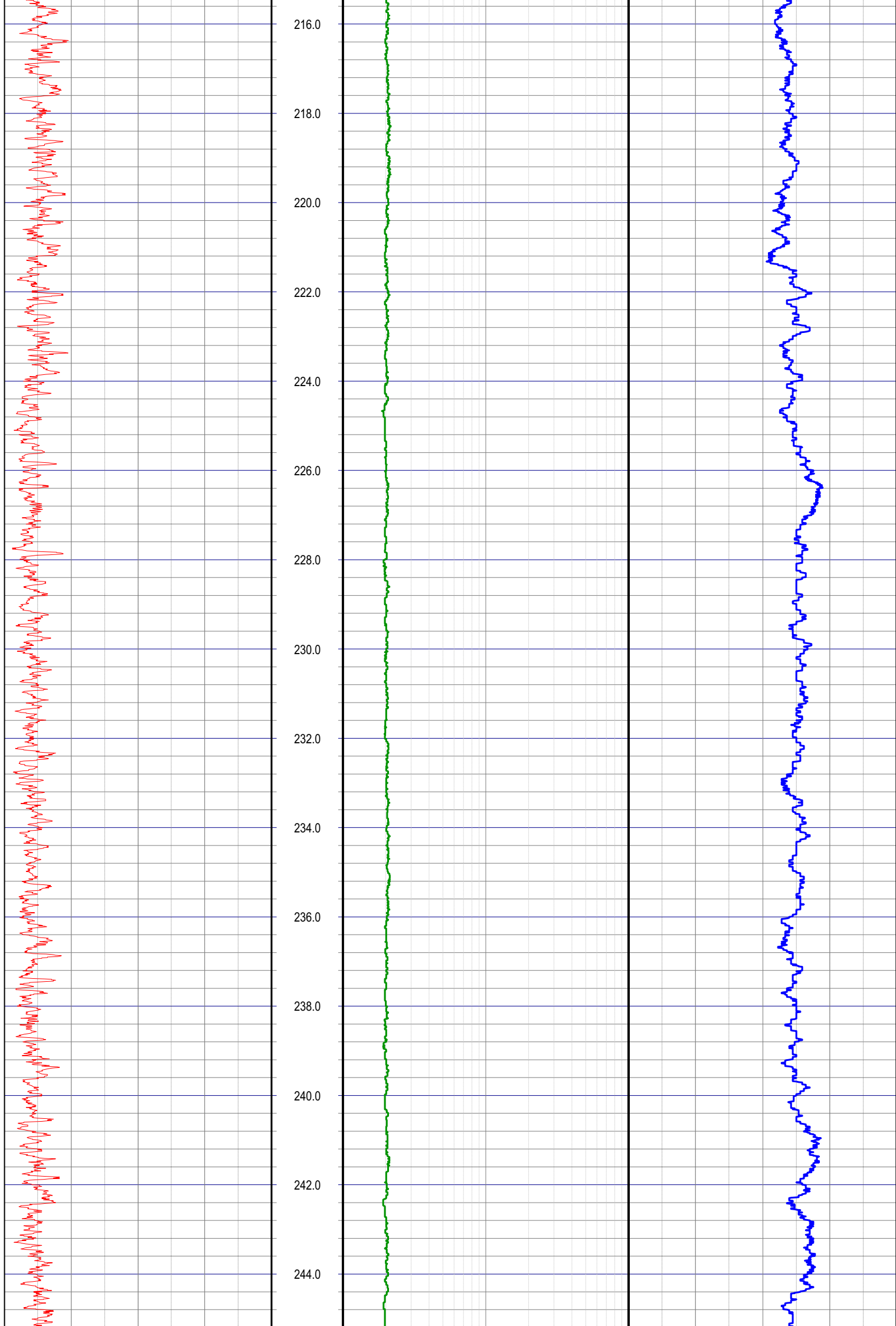
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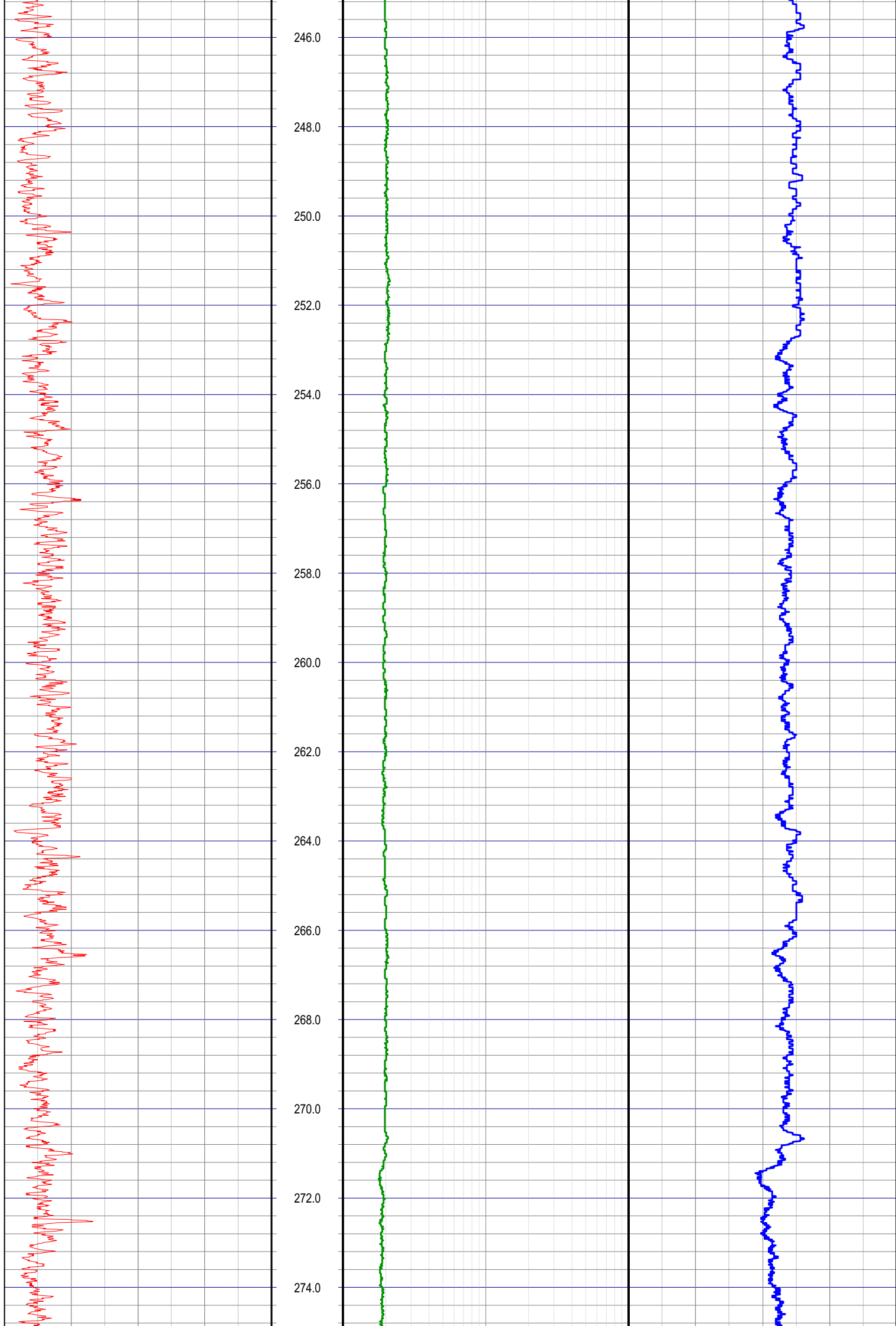


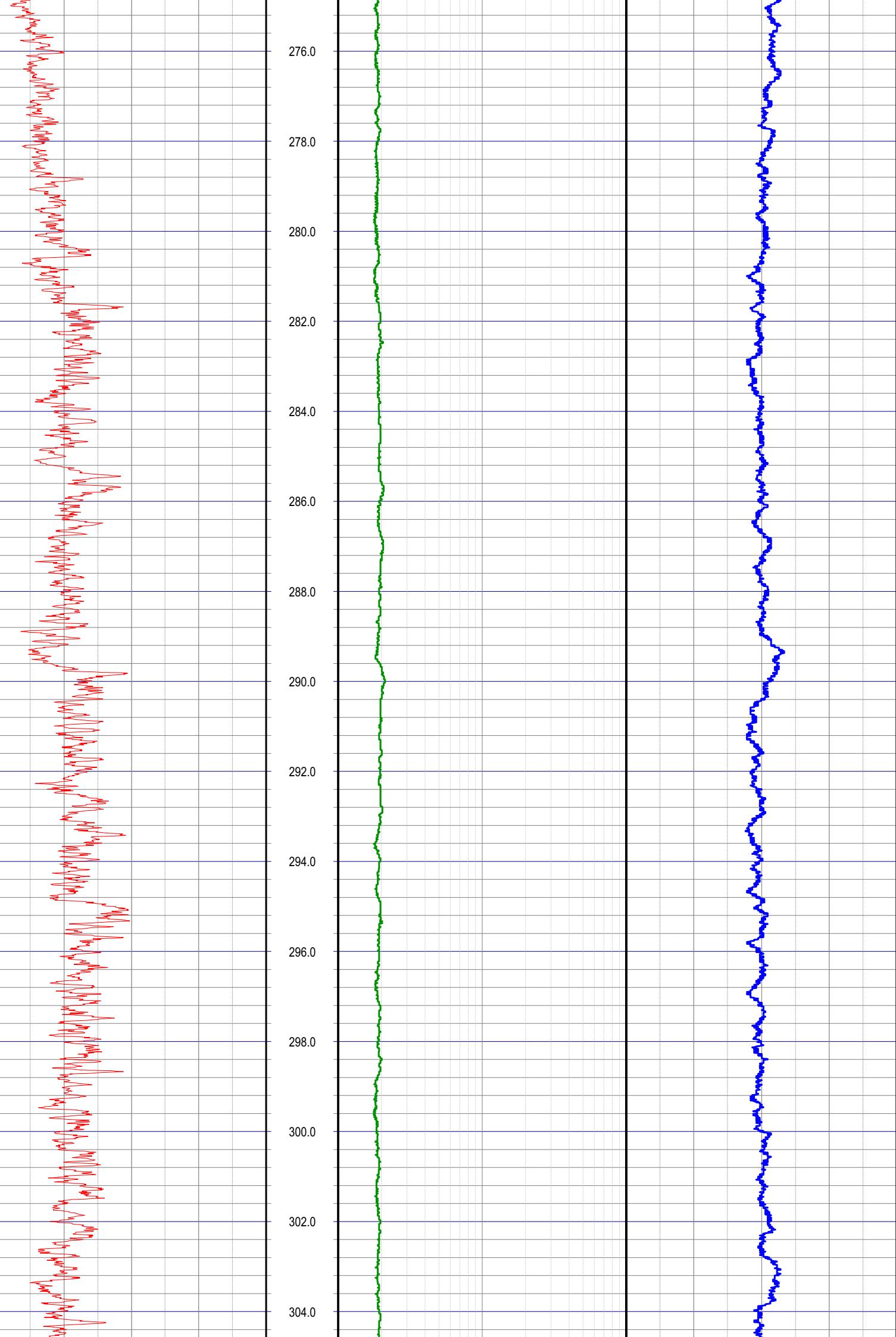


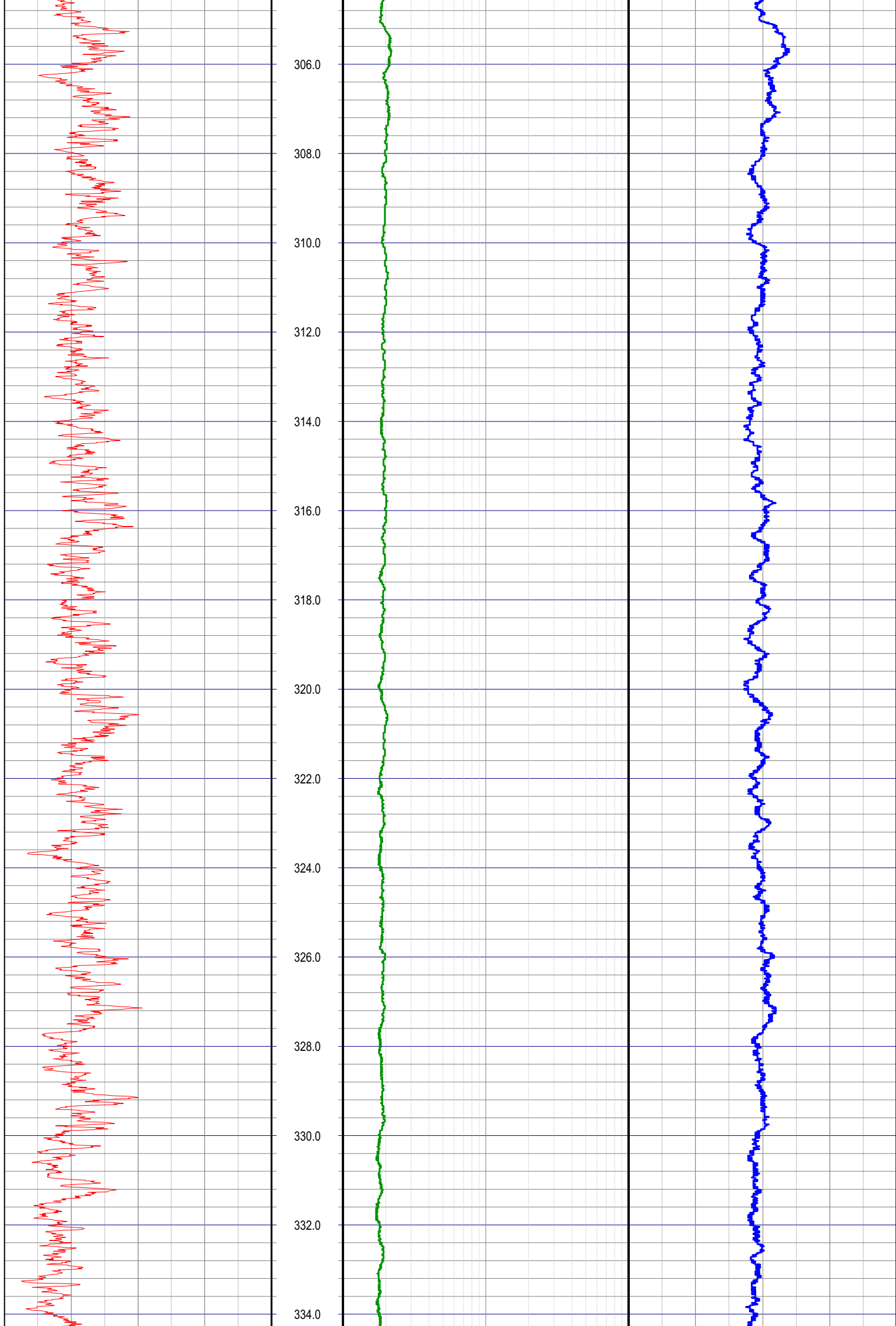


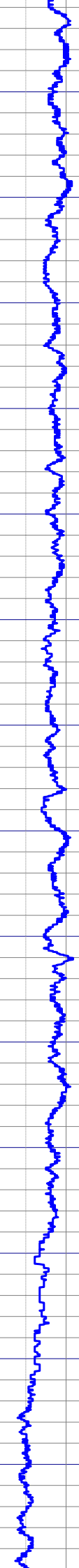
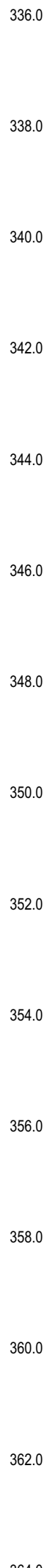
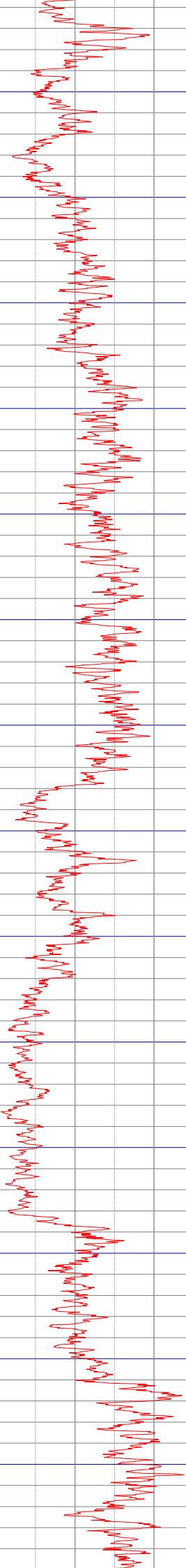


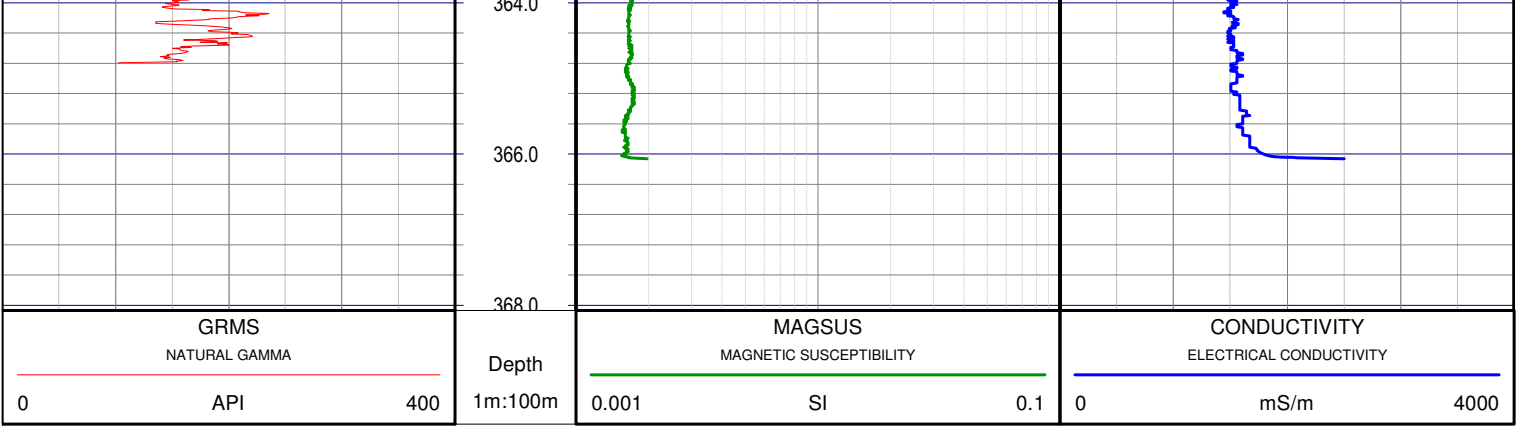














ENDEAVOUR GEOPHYSICS

TELLUS HOLDINGS

WTC4



GAMMA/MAGNETIC SUSCEPTIBILITY/CONDUCTIVITY

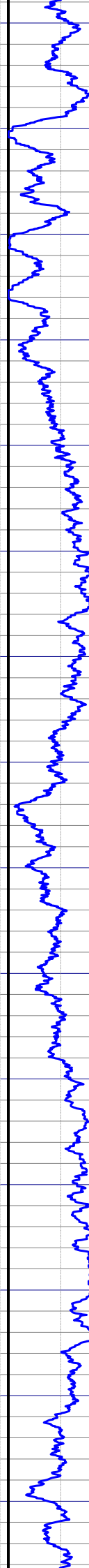
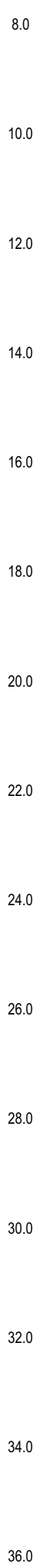
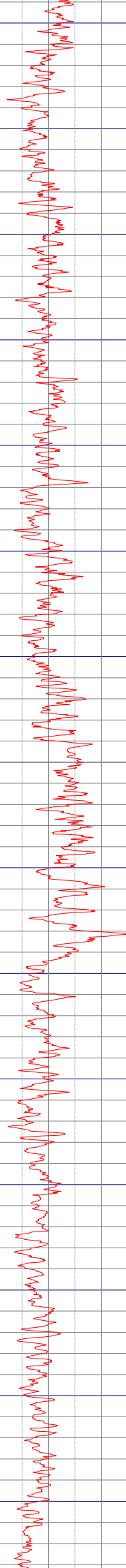
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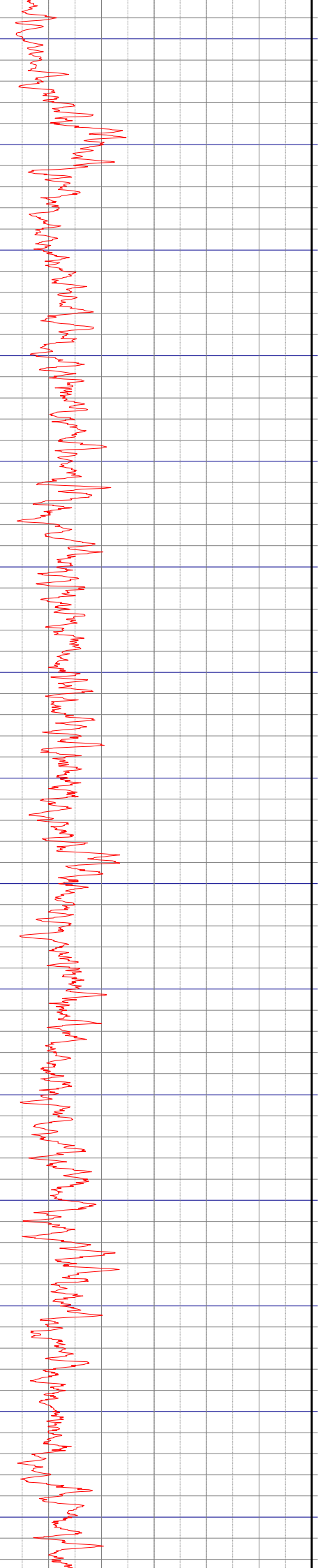
LOCATION		HOLE ATTRIBUTES		LOGGING DETAILS	
LOCATION	CHANDLER	DATE	06/07/2015	RECORDED BY	JONATHAN IRELAND
EL		FLUID LEVEL	103 m	WITNESSED BY	GRAHAM RIDE
PROVINCE		FLUID TYPE	Water	UNIT	Navara
STATE	NT	DRILLED DEPTH	287 m	LOGGED DEPTH	287 m
COUNTRY	AUSTRALIA	DATUM	GROUND LEVEL	INT LOGGED	0-287 m
LATI		DRILLING COMPANY	DIVERSE RESOURCES	LOGGING RUNS	
LONG		DRILLING RIG	T3W		
GEODETIC DATUM	GDA94	BOREHOLE RECORD		TOOL	ID
COORD	MGA51	TYPE	SIZE	START	FINISH
EASTING	395942.543	GL		MST	522
NORTHING	7256290.972			FWS	022
ELEVATION	443.785m			FDS	706
SRVC	ENDEAVOUR GEOPHYSICS	CASING RECORD		MIG	08
WEB	www.endeavourgeo.com	TYPE	SIZE		
COMMENTS		STEEL	200mm		
			GL		

MAGNETIC SUSCEPTIBILITY/INDUCTION CONDUCTIVITY/GAMMA - MIG

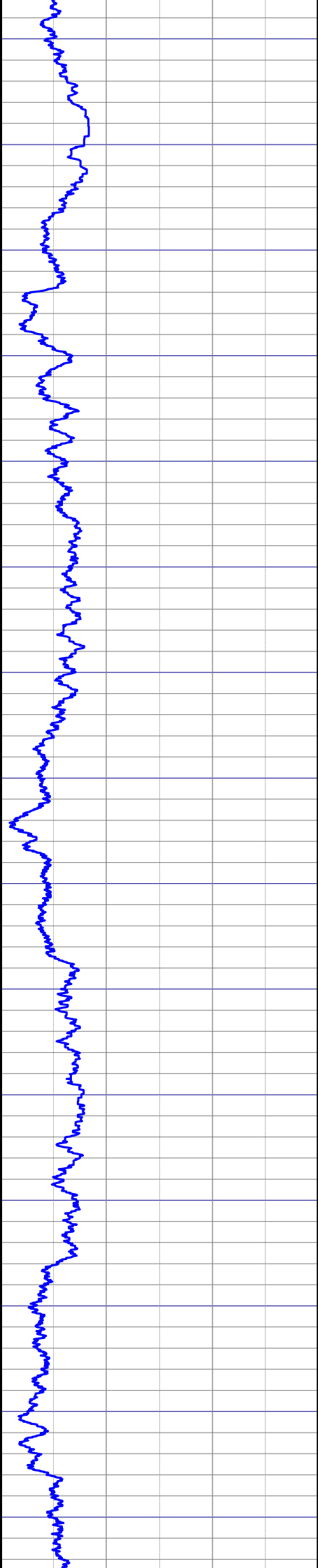
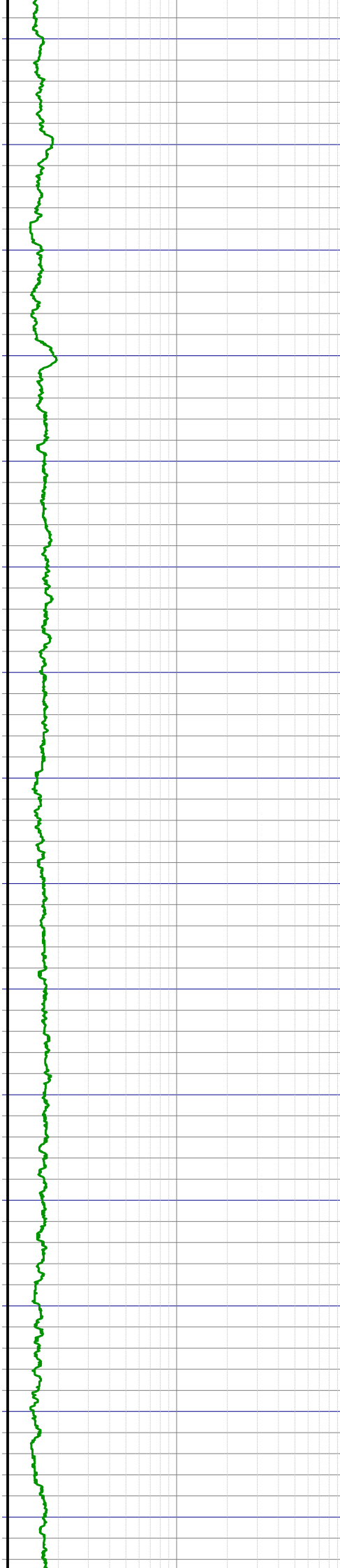


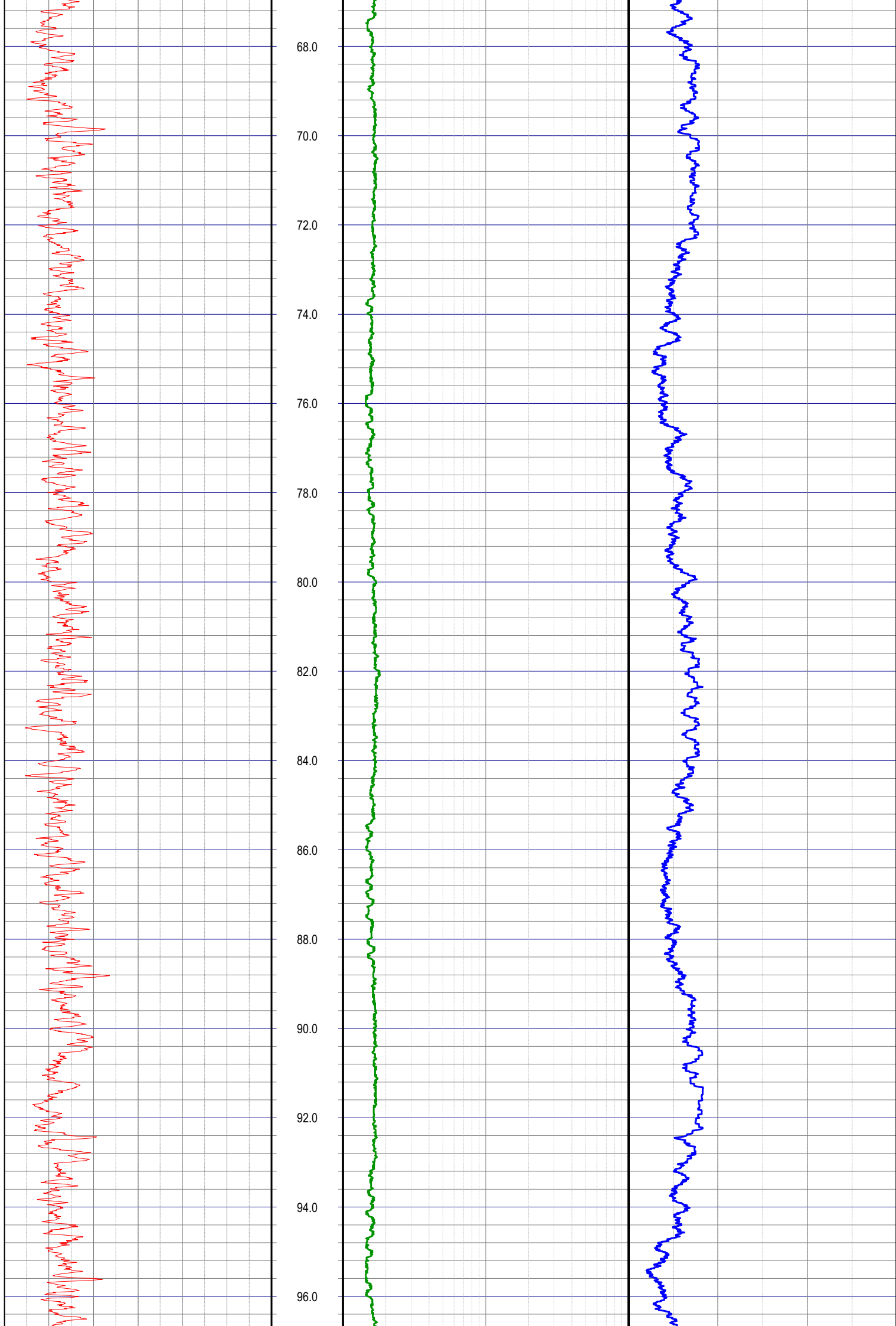
CALIBRATION		MIG_MNEUMONICS		ATTRIBUTES	
MIG_CALIBRATION_DATE	01/01/2015	GRMS_RAW = Natural gamma raw counts/sec		MIG_LENGTH	2700mm
MIG_MODEL	HMI-453E	MS_RAW = Magnetic Sus raw counts/sec		MIG_DIAMETER	45mm
MIG_SERIAL_NO	MIG08	COND_RAW = Conductivity raw counts/sec		MIG_MAGSUS_RANGE	0.0001-2 SI
MIG_GAMMA_CAL	2.0621*{RAW}	GRMS = Calibrated Gamma - API Units		MIG_CONDUCTIVITY_RANGE	1 S/m - 1000 S/m
MIG_MS_CAL	0.00061604423*{MS_RAW} - 0.0041931	MAGSUS = Calibrated Magnetic Susceptibility - SI Units		MIG_LOGGING_SPEED	6m/min
MIG_COND_CAL	0.0003538*{COND_RAW} - 10.192424	CONDUCTIVITY = Calibrated Conductivity - S/m		MIG_INTERCOIL_SPACING	30cm
GRMS NATURAL GAMMA		Depth	MAGSUS MAGNETIC SUSCEPTIBILITY		CONDUCTIVITY ELECTRICAL CONDUCTIVITY
0API600		1m:100m	0.001SI0.1		0mS/m3000

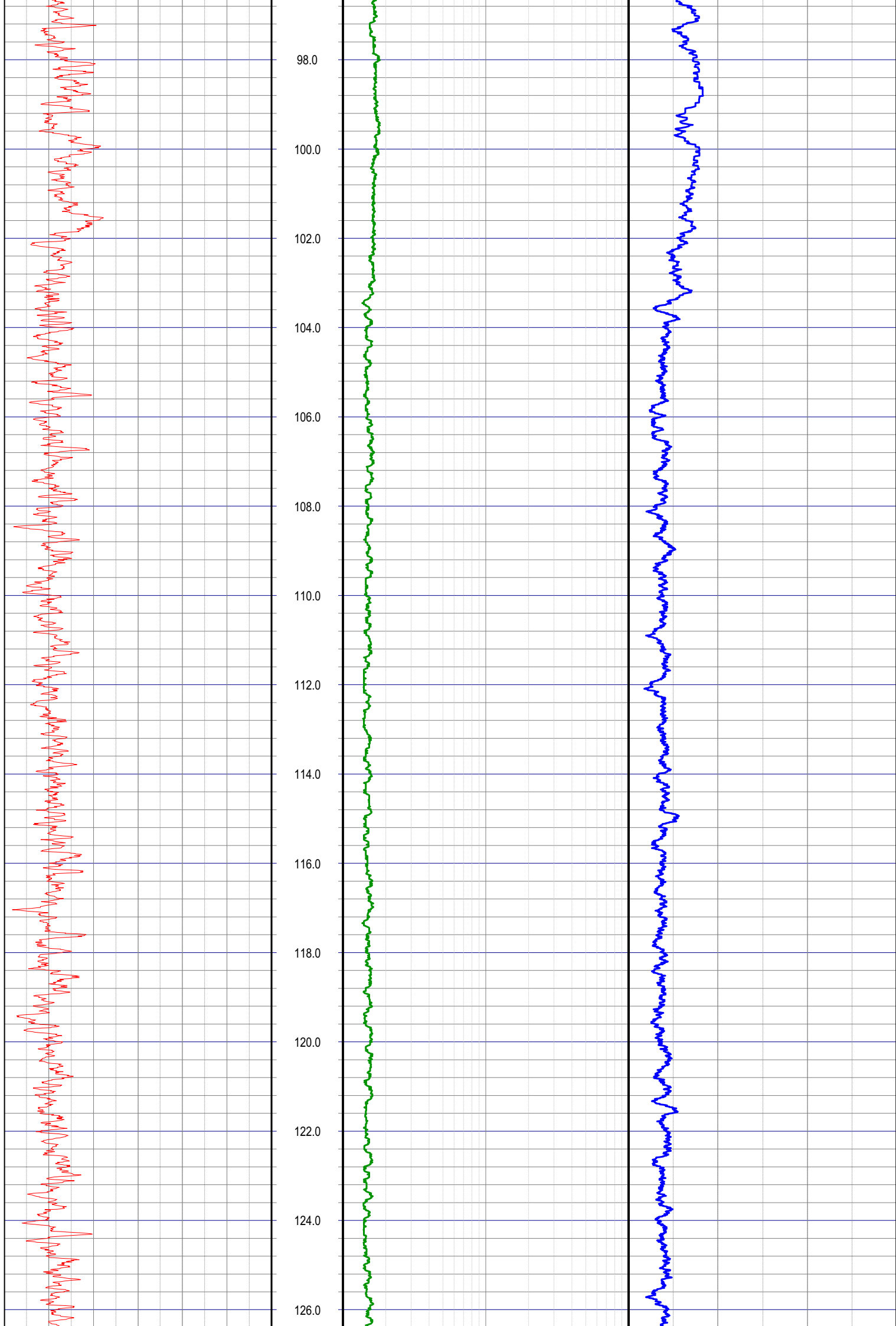


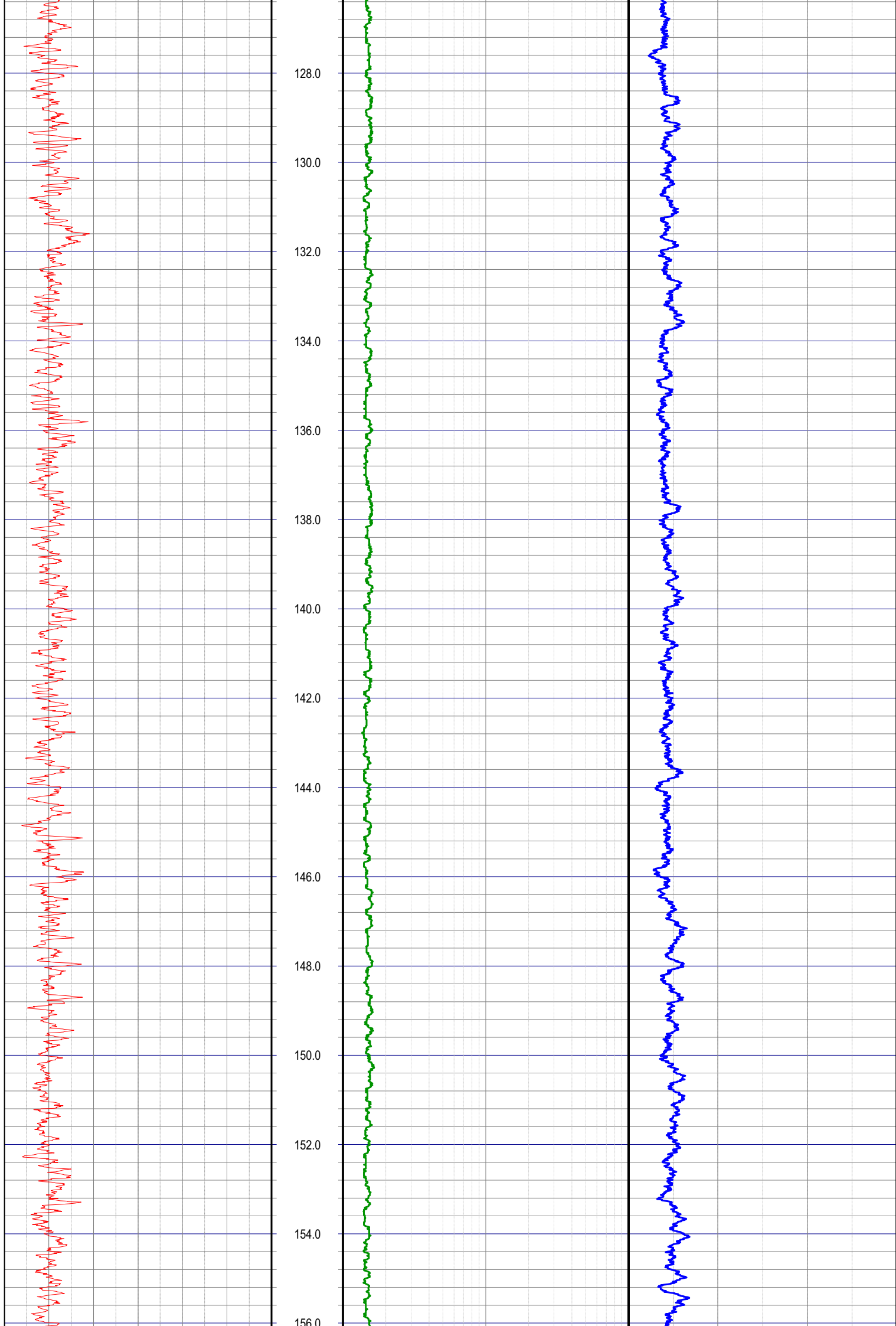


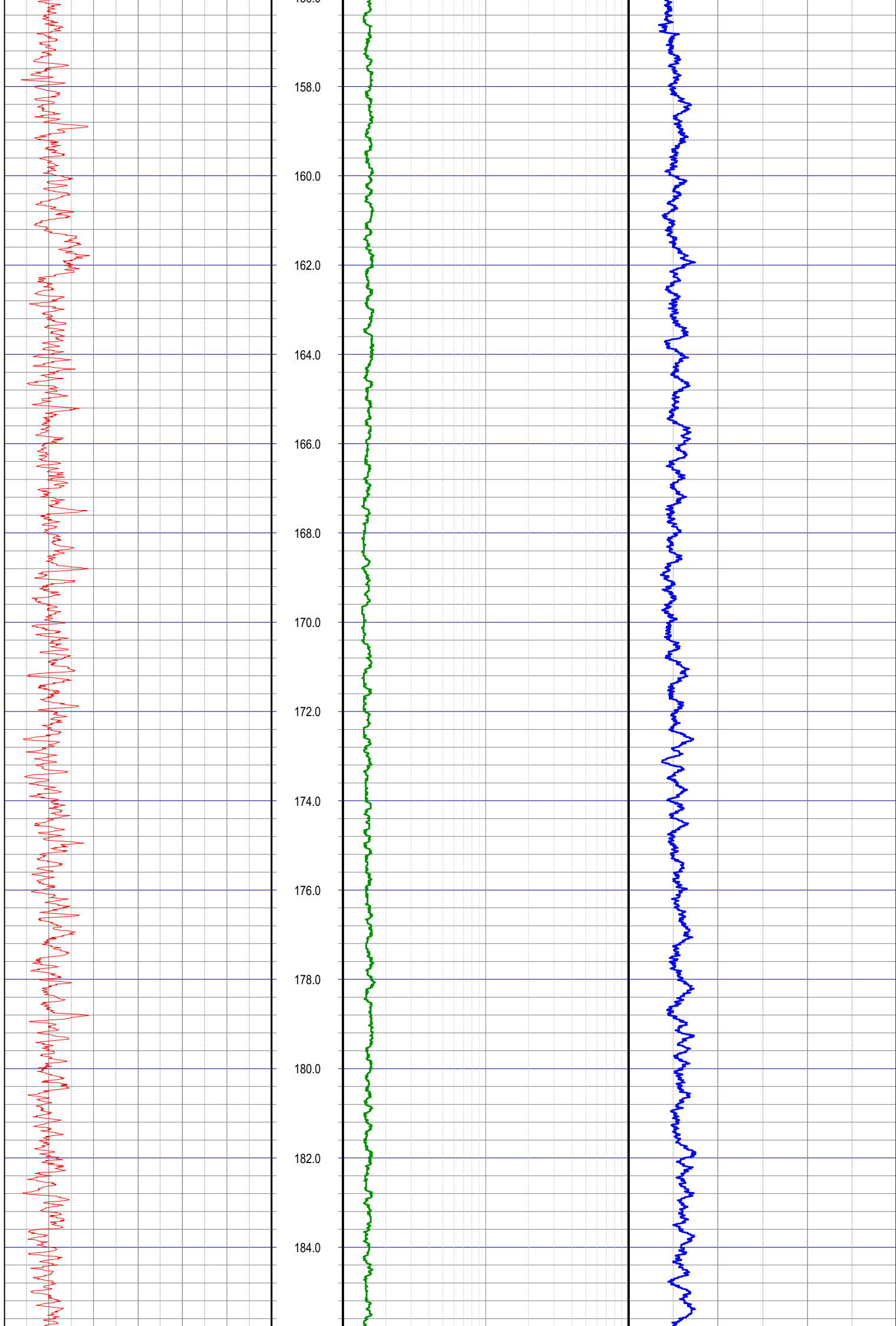
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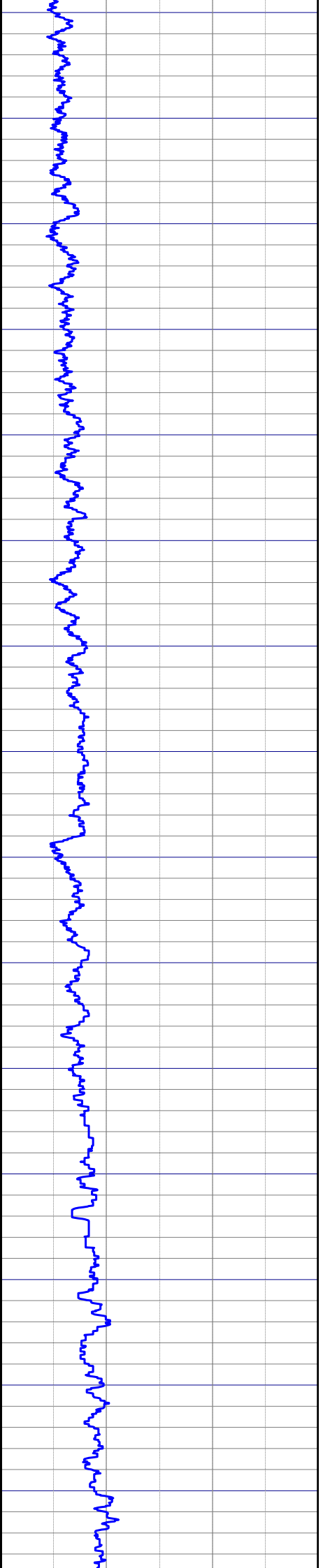
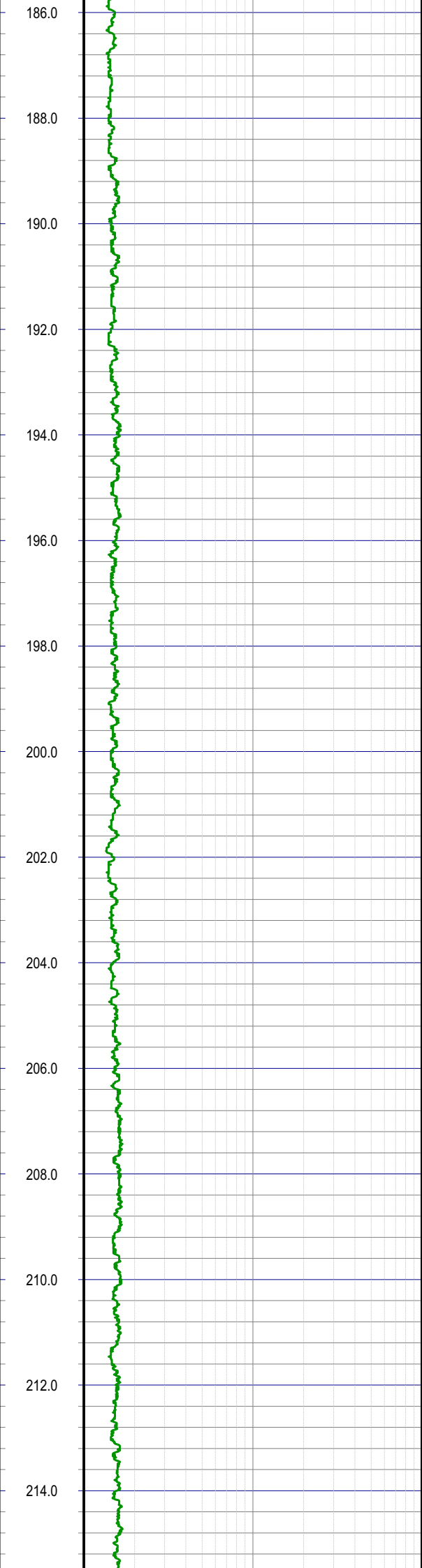
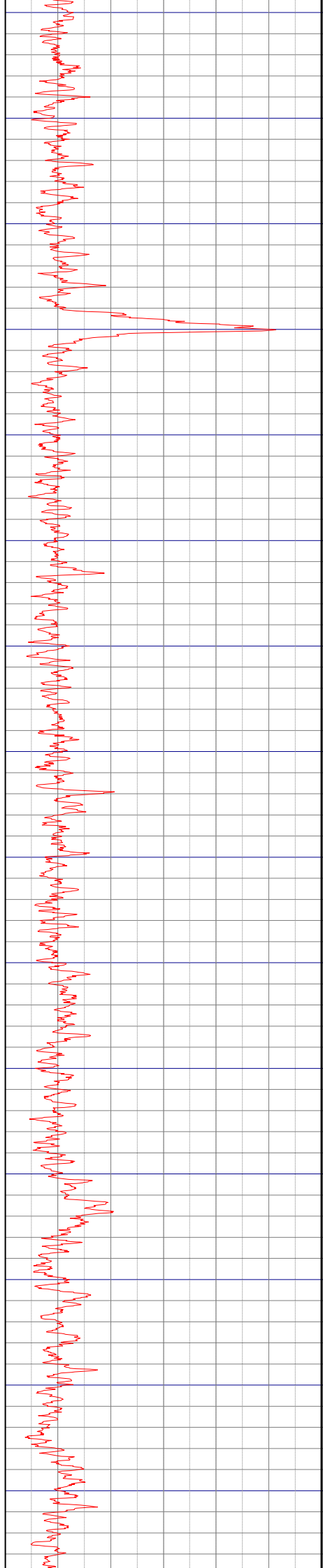


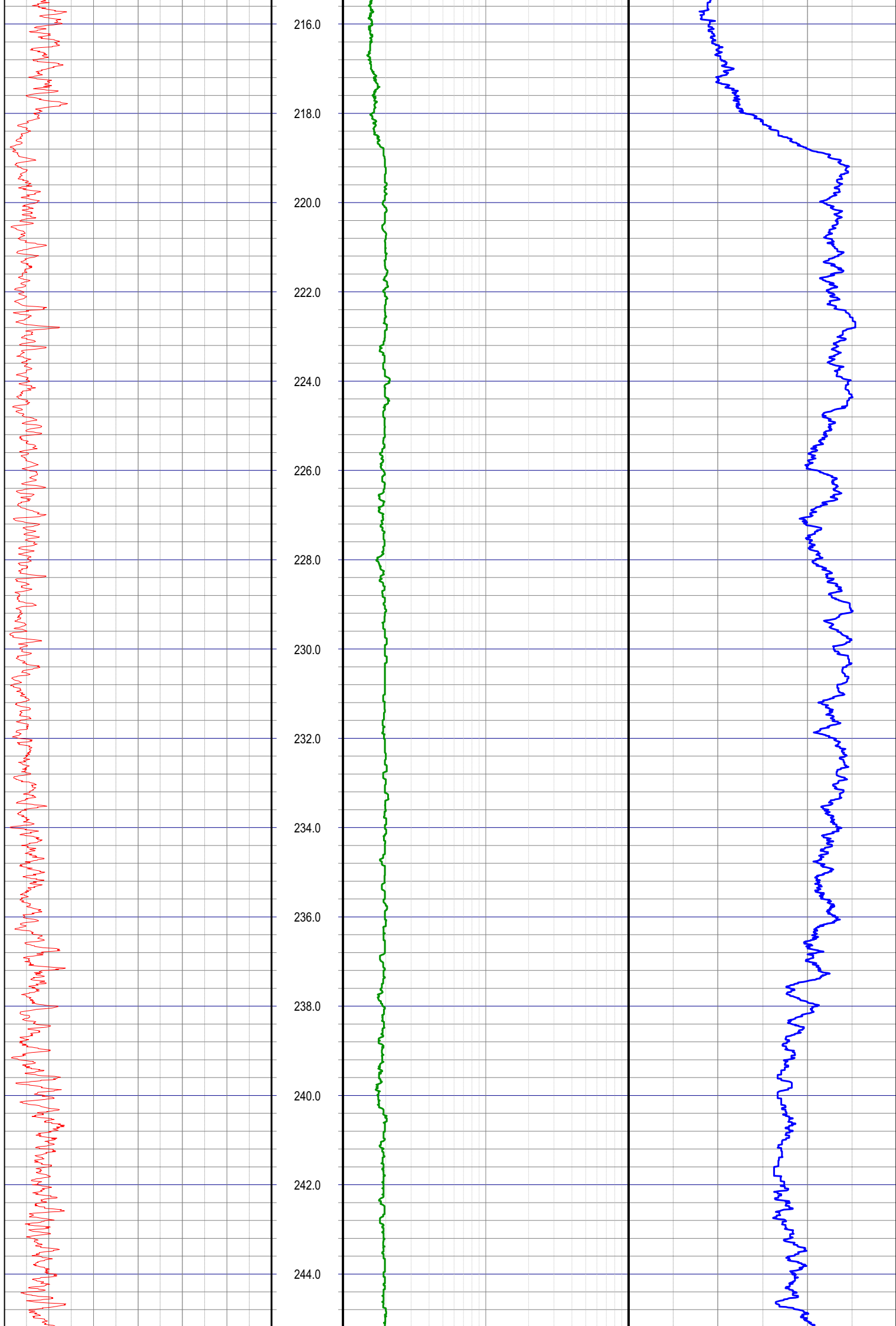


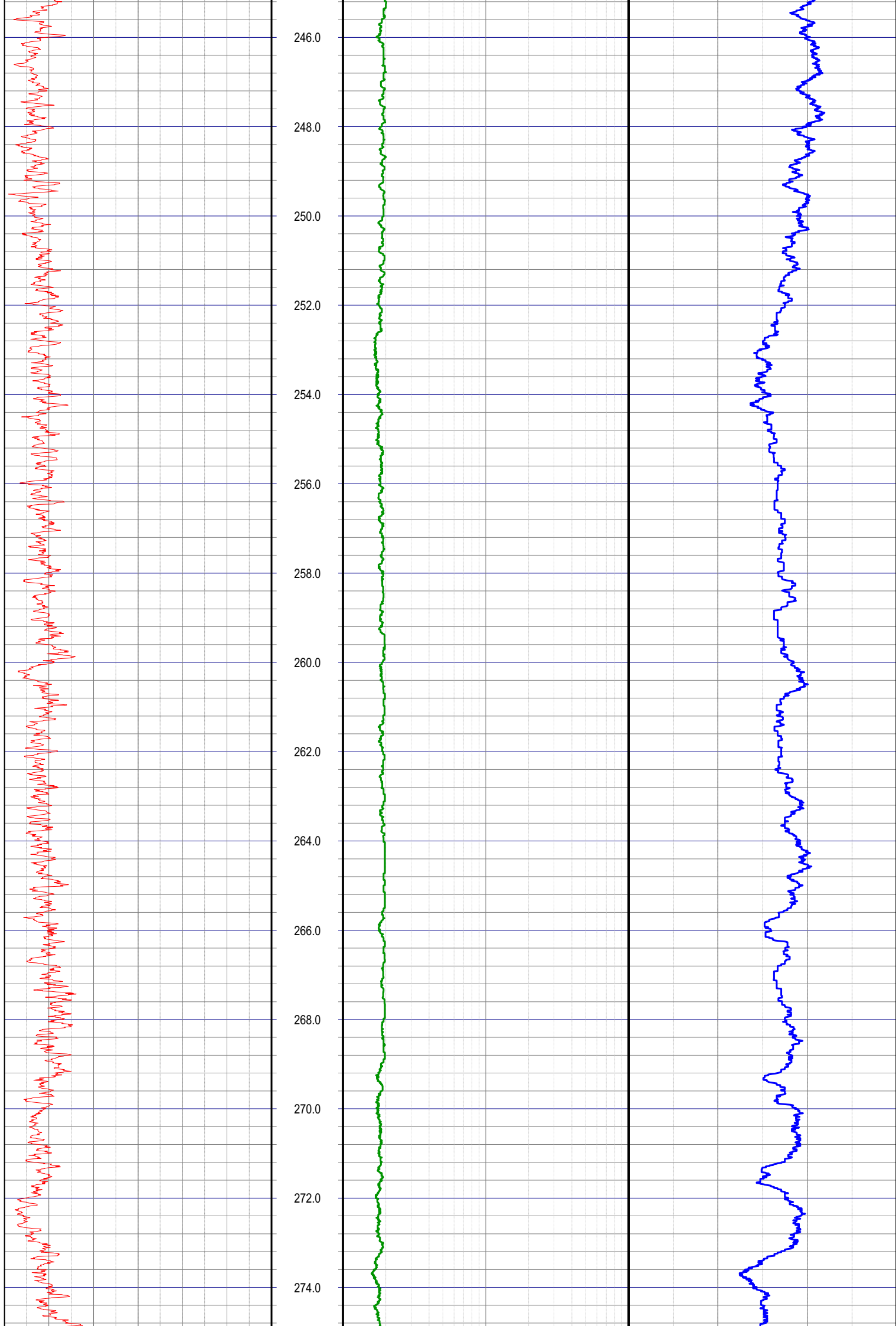


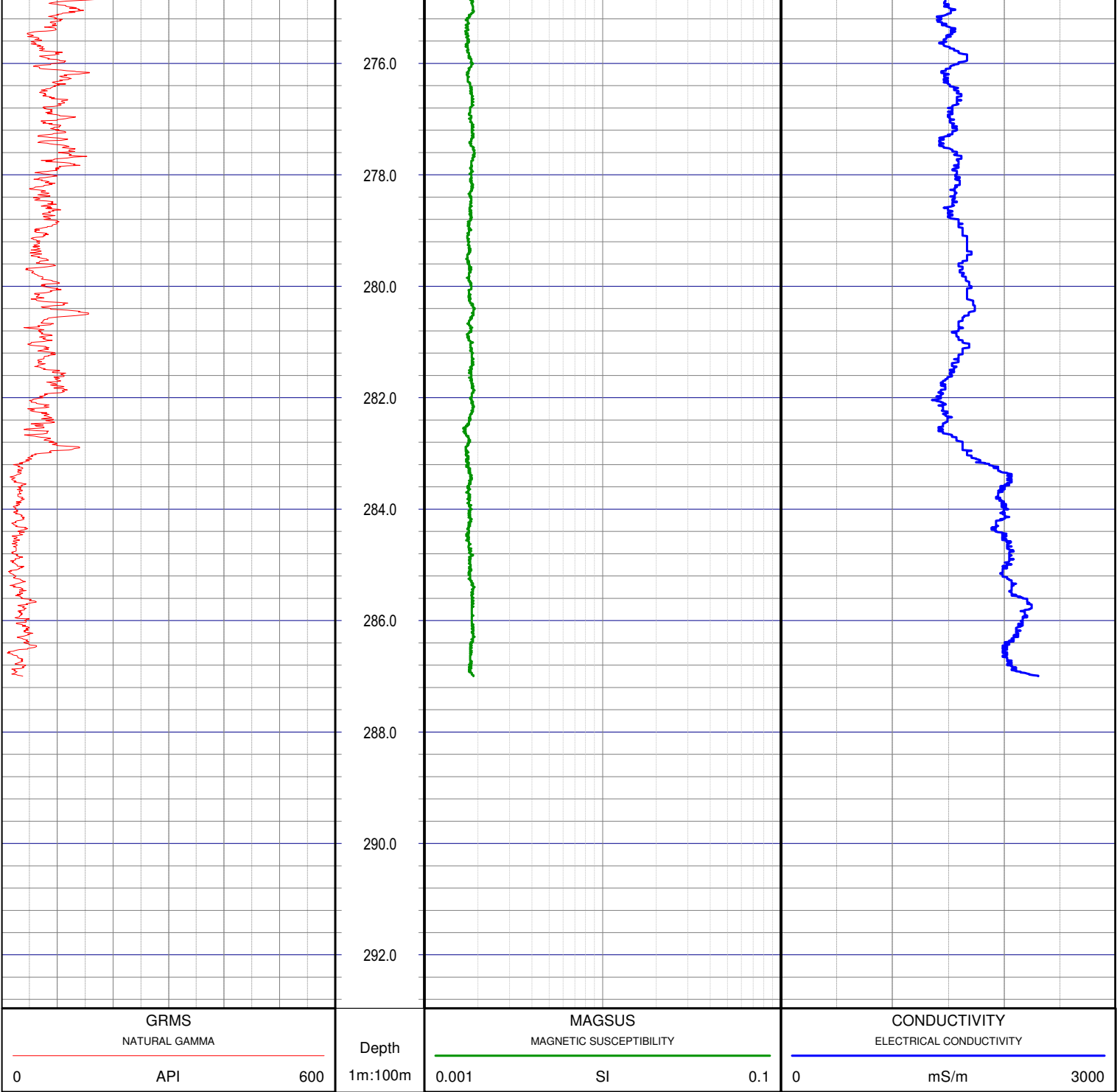














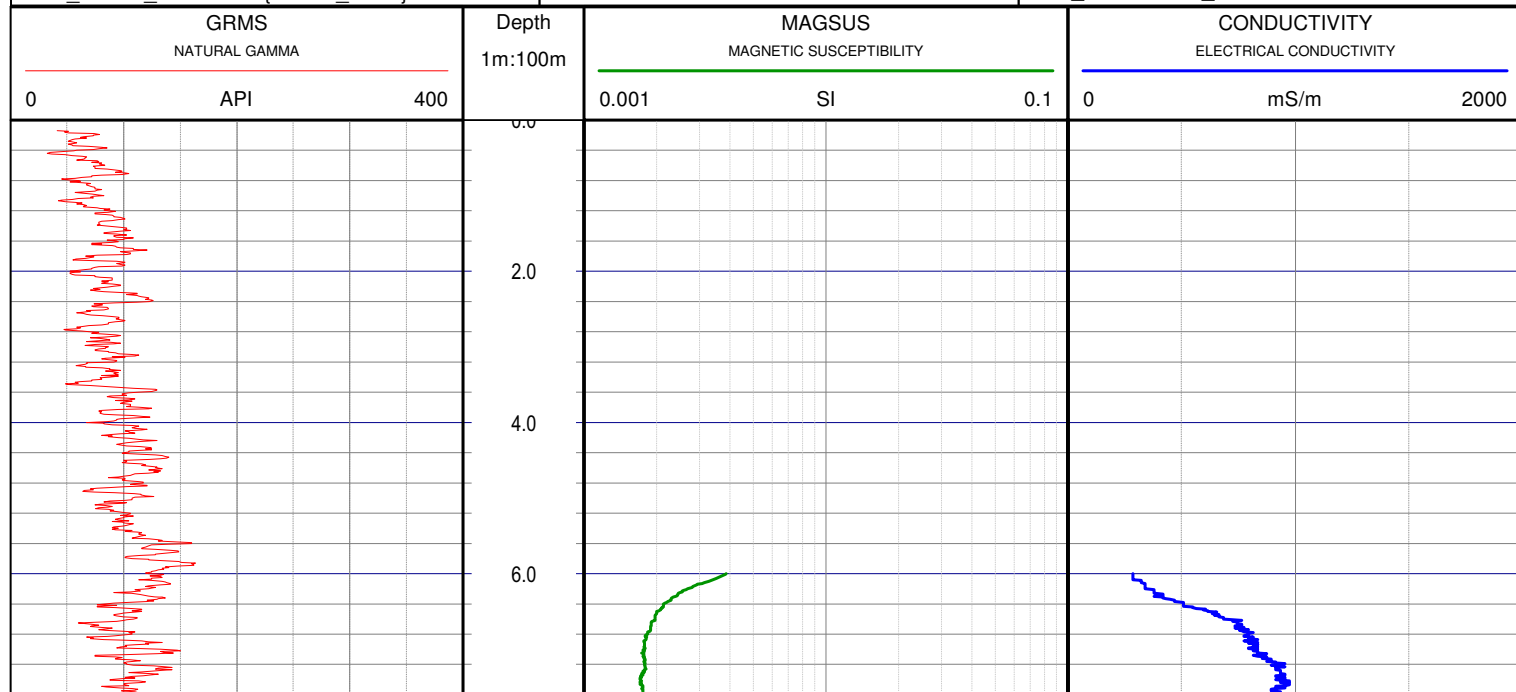
WT5

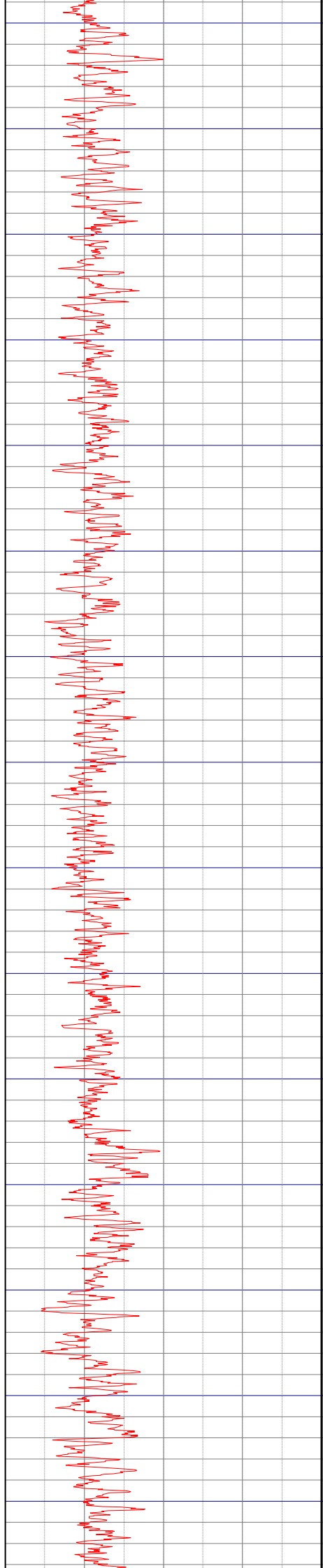


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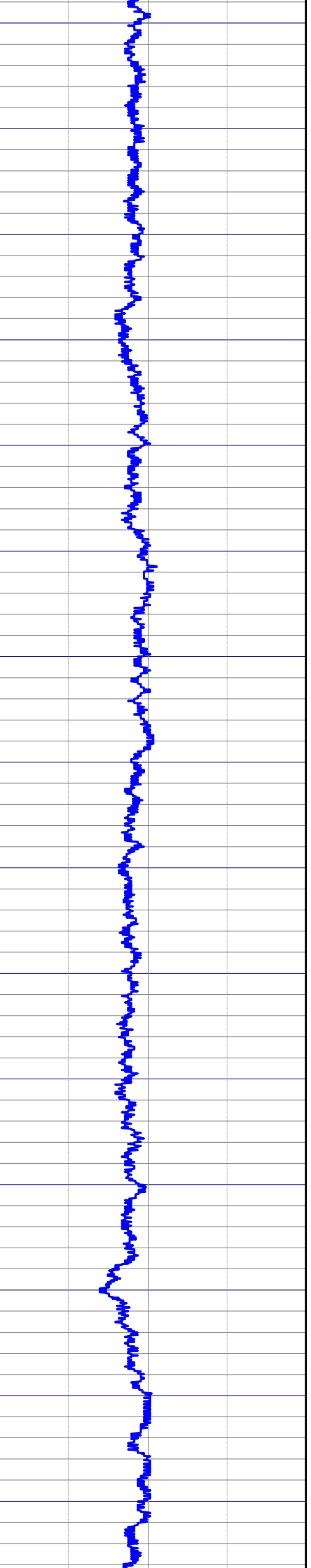
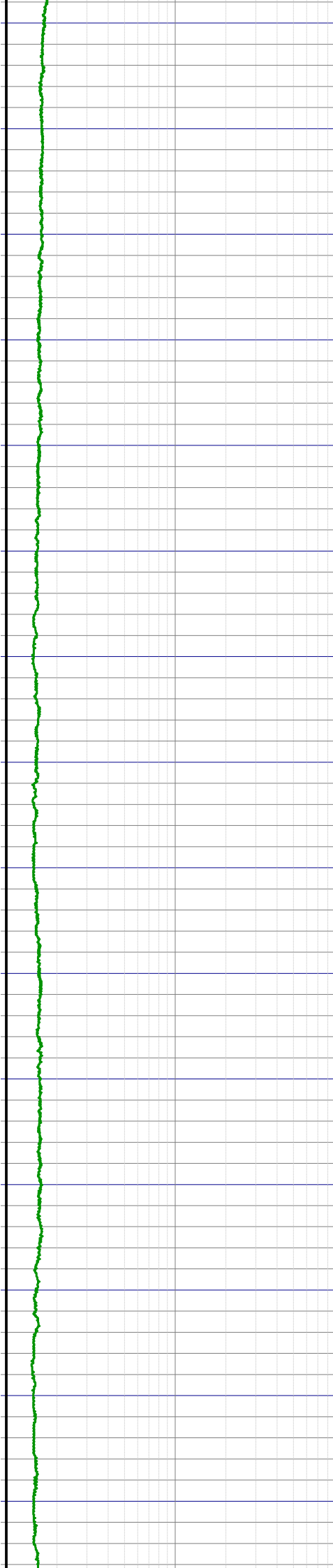
LOCATION		HOLE ATTRIBUTES				LOGGING DETAILS			
LOCATION	Chandler	DATE	07/07/2015			RECORDED BY	JONATHAN IRELAND		
EL		FLUID LEVEL	102 m			WITNESSED BY	GRAHAM RIDE		
PROVINCE		FLUID TYPE	WATER			UNIT	Navara		
STATE	NT	DRILLED DEPTH	180 m			LOGGED DEPTH	177 m		
COUNTRY	Australia	DATUM	GROUND LEVEL			INT LOGGED	0-177 m		
LATI		DRILLING COMPANY DIVERSE RESOURCES				LOGGING RUNS			
LONG		DRILLING RIG	T3W			TOOL	ID	START	FINISH
GEODETIC DATUM	GDA94	BOREHOLE RECORD				MST	522	177.4	GL
COORD	MGA51	TYPE	SIZE	FROM m	TO m	MIG	08	177.37	GL
EASTING	394168.286								
NORTHING	7256478.378								
ELEVATION	440.121m								
SRVC	ENDEAVOUR GEOPHYSICS	CASING RECORD							
WEB	www.endeavourgeo.com	TYPE	SIZE	FROM m	TO m				
COMMENTS		STEEL	200mm	GL	5.5				
50mm PVC Casing, no run of FWS or FDS		FIBREGLASS	150mm	GL	67				
		PVC	50mm	GL	180				

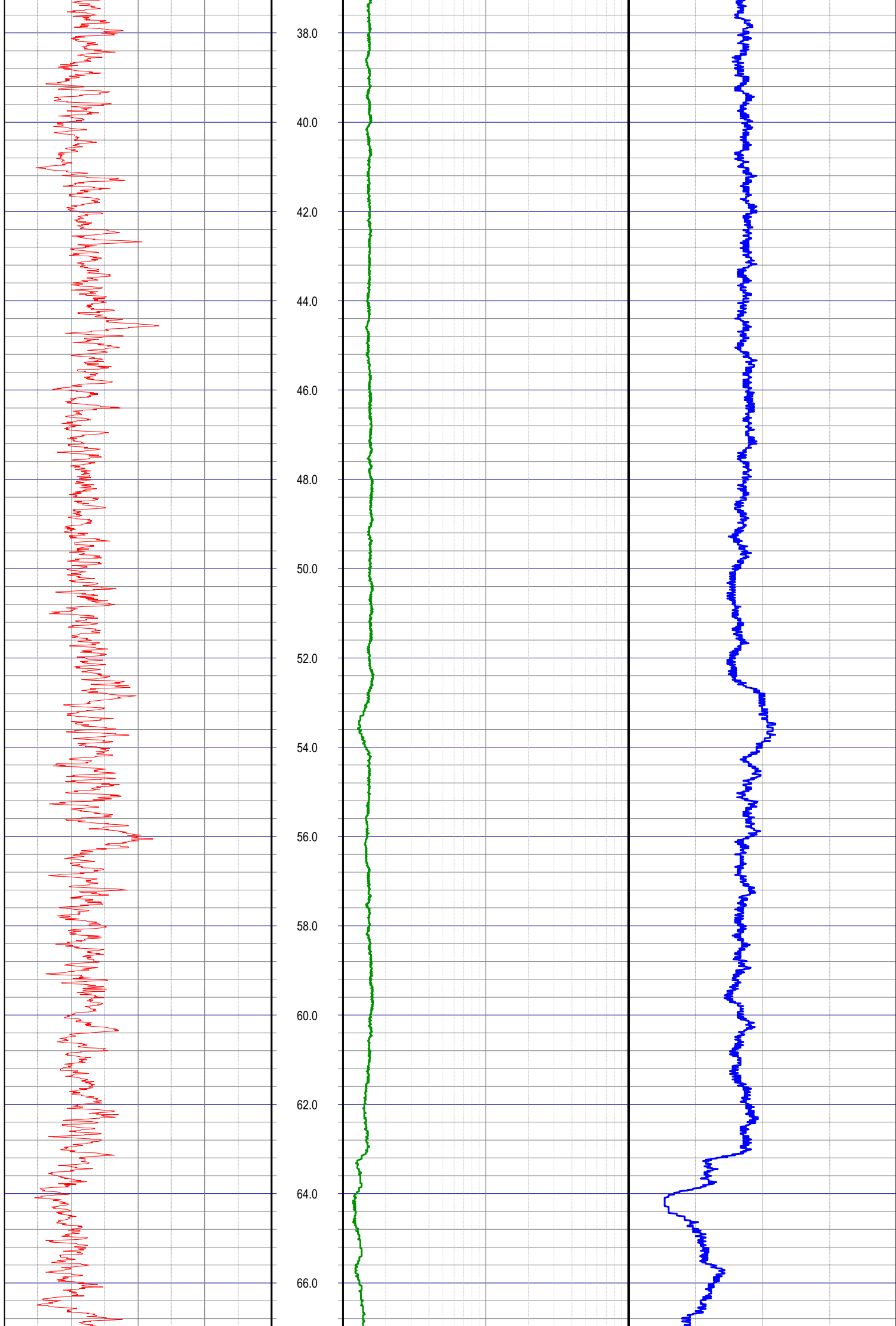
CALIBRATION		MIG_MNEUMONICS	ATTRIBUTES	
MIG_CALIBRATION_DATE	01/01/2015	GRMS_RAW = Natural gamma raw counts/sec	MIG_LENGTH	2700mm
MIG_MODEL	HMI-453E	MS_RAW = Magnetic Sus raw counts/sec	MIG_DIAMETER	45mm
MIG_SERIAL_NO	MIG08	COND_RAW = Conductivity raw counts/sec	MIG_MAGSUS_RANGE	0.0001-2 SI
MIG_GAMMA_CAL	2.0621*[RAW]	GRMS = Calibrated Gamma - API Units	MIG_CONDUCTIVITY_RANGE	0.1 S/m - 1000 S/m
MIG_MS_CAL	0.00061604423*[MS_RAW] - 0.0041931	MAGSUS = Calibrated Magnetic Susceptibility - SI Units	MIG_LOGGING_SPEED	6m/min
MIG_COND_CAL	0.0083538*[COND_RAW] - 10.192424	CONDUCTIVITY = Calibrated Conductivity - S/m	MIG_INTERCOIL_SPACING	30cm

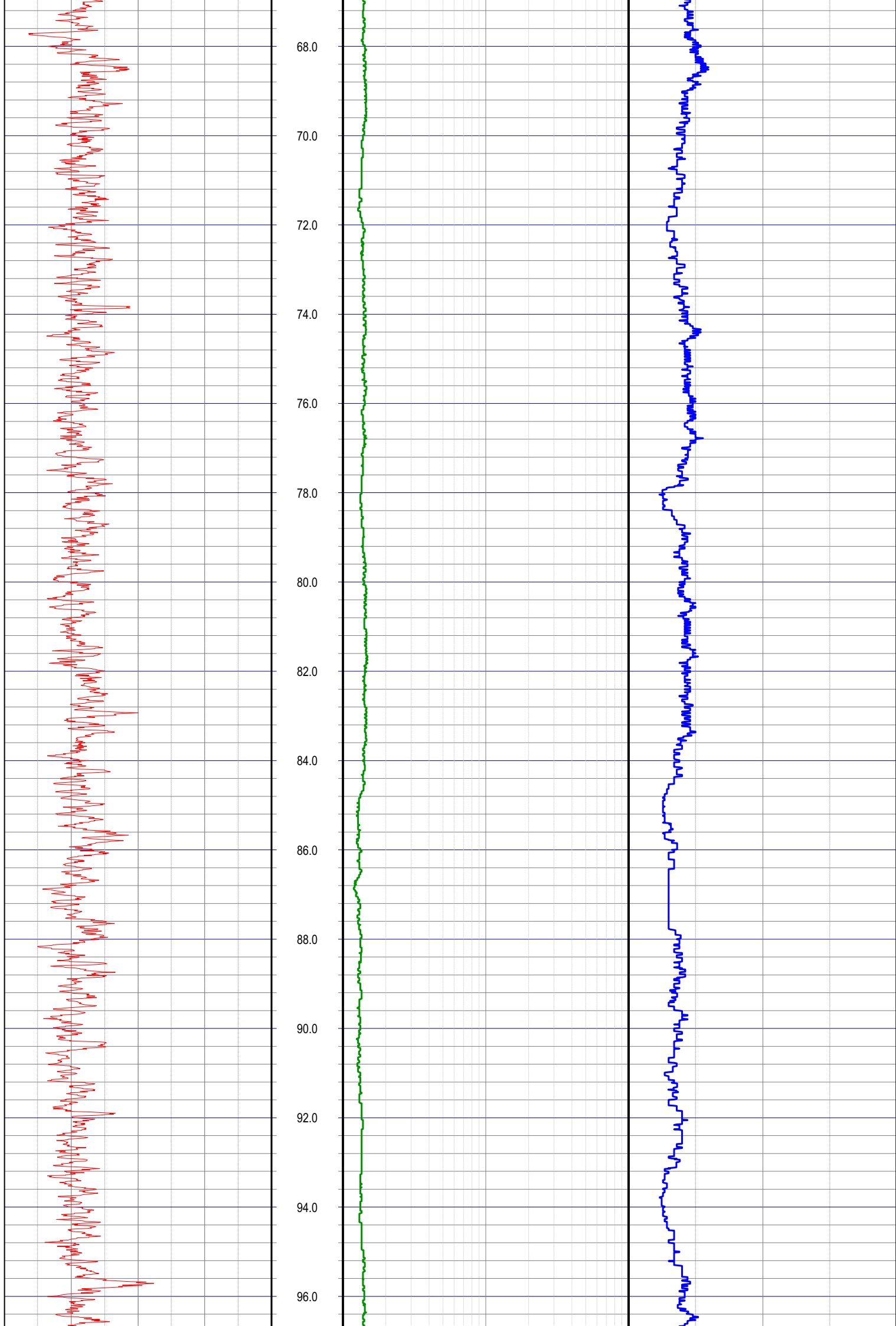


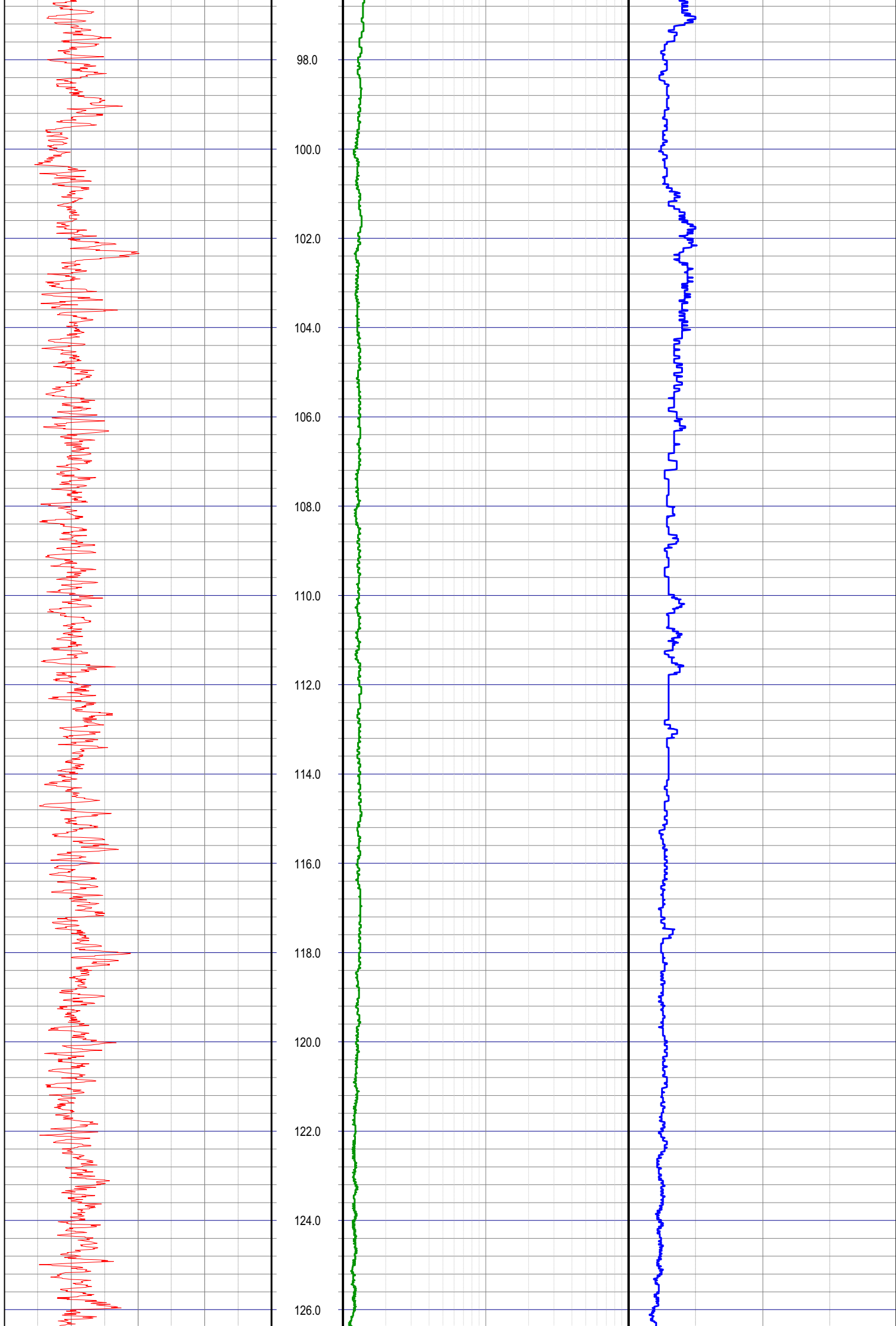


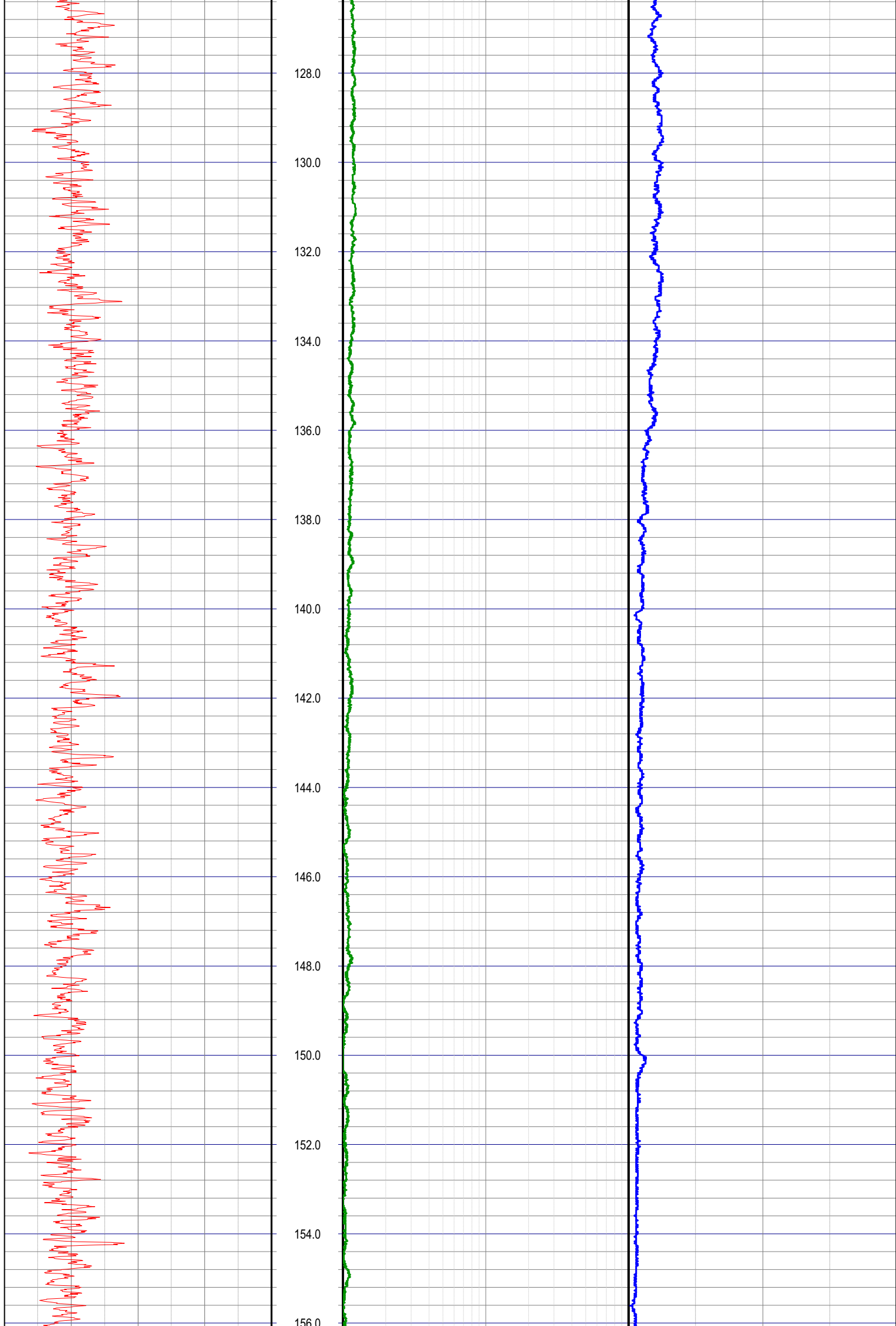
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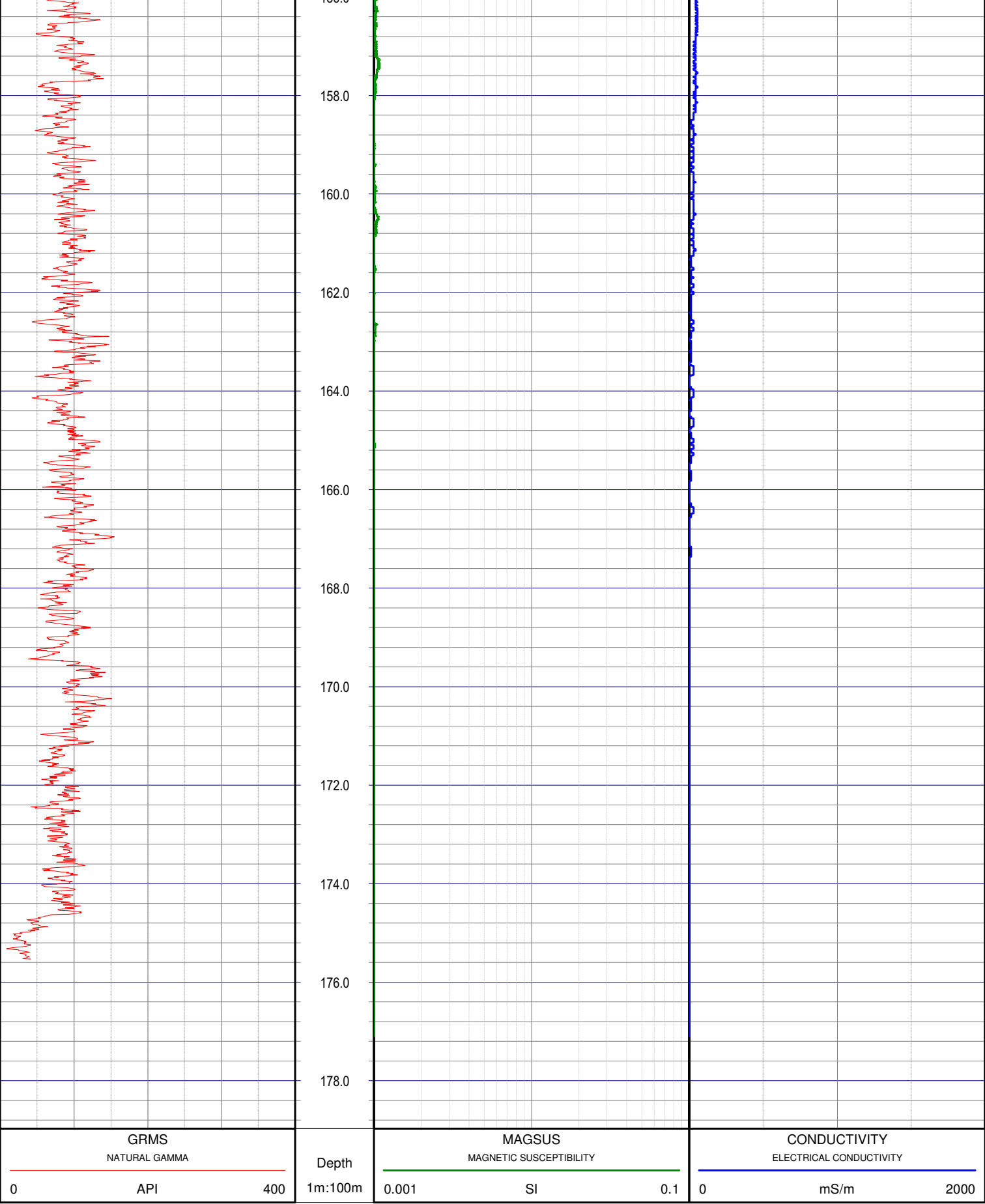












Appendix C

Landholder bore summary - 75 km spatial search

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Table C.1 Landholder bore summary – 75 km spatial search

Reference ID	Registration number	Type	Depth (m BGL)	Inferred groundwater system
1	RN3997	Spring	-	Quaternary sediments
2	RN4003	Spring	-	Quaternary/Langra Formation
3	RN4375	Water supply bore	15	Quaternary sediments
4	RN6565	Spring	-	Quaternary/Winnall Beds
5	RN7055	Water supply bore	274	Langra Formation
6	RN7178	Water supply bore	128	Langra Formation
7	RN11512	Water supply bore	24	Quaternary sediments
8	RN11920	Water supply bore	158	Langra Formation
9	RN12525	Spring	37	Quaternary sediments
10	RN12530	Water supply bore	10	Quaternary sediments
11	RN12531	Water supply bore	6	Quaternary sediments
12	RN12532	Water supply bore	8	Quaternary sediments
13	RN12534	Water supply bore	10	Quaternary sediments
14	RN14493	Water supply bore	120	Winnall Beds
15	RN14644	Water supply bore	10	Quaternary sediments
16	RN14714	Water supply bore	42	Idracowra Sandstone
17	RN14717	Water supply bore	141	Langra Formation
18	RN14774	Water supply bore	9	Quaternary sediments
19	RN15825	Water supply bore	114	Langra Formation
20	RN16905	Water supply bore	-	Quaternary Sediments
21	RN17435	Water supply bore	24	Langra Formation
22	RN17443	Water supply bore	15	Quaternary Sediments
23	RN17444	Water supply bore	6	Quaternary Sediments
24	RN17445	Water supply bore	10	Quaternary Sediments
25	RN1339	Water supply bore	12	Idracowra sandstone
26	RN2374	Water supply bore	16	Recent/Tertiary sediments
27	RN4253	Water supply bore	25	Recent sediments
28	RN4478	Water supply bore	14	Recent sediments
29	RN10814	Water supply bore	66	Idracowra sandstone
30	RN10815	Water supply bore	51	Idracowra sandstone
31	RN13418	Water supply bore	43	Idracowra sandstone
32	RN13422	Water supply bore	15	Recent sediments
33	RN14118	Water supply bore	95	Meerenie sandstone
34	RN14120	Water supply bore	103	Langra siltstone unit L4
35	RN15832	Water supply bore	45	Idracowra sandstone
36	RN17466	Water supply bore	18	Recent sediments
37	RN17496	Water supply bore	25	Recent sediments
38	RN1840	Water supply bore	14	Quaternary alluvium
39	RN11911	Water supply bore	194	-
40	RN14135	Water supply bore	20	Quaternary alluvium
41	RN14136	Water supply bore	20	Quaternary alluvium
42	RN14138	Water supply bore	111	-

Table C.1 Landholder bore summary – 75 km spatial search

Reference ID	Registration number	Type	Depth (m BGL)	Inferred groundwater system
43	RN16903	Water supply bore	96	-
44	RN1312	Water supply bore	40	Recent sediments
45	RN1314	Water supply bore	8	Recent sediments
46	RN2375	Water supply bore	84	Tertiary sediments
47	RN3208	Water supply bore	43	Recent & Tertiary sediments
48	RN3210	Water supply bore	95	Stairways/Pertoorra
49	RN7005	Water supply bore	76	Tertiary or Inindia Beds
50	RN13889	Water supply bore	90	Bitter Springs Formation
51	RN14499	Water supply bore	90	Mereenie Sandstone
52	RN14500	Water supply bore	158	Pertnjarra siltstone
53	RN14665	Water supply bore	109	Mereenie Sandstone
54	RN15238	Water supply bore	103	Stairways Sandstone
55	RN16207	Water supply bore	29	Recent sediments
56	RN16892	Water supply bore	30	Recent sediments
57	RN16956	Water supply bore	145	Mereenie Sandstone
58	RN16957	Water supply bore	121	Mereenie Sandstone
59	RN17009	Water supply bore	103	Tertiary/ Pertnjarra
60	RN544	Water supply bore	69	-
61	RN573	Water supply bore	-	-
62	RN966	Water supply bore	-	-
63	RN975	Water supply bore	98	-
64	RN1276	Water supply bore	-	-
65	RN1311	Water supply bore	-	-
66	RN1319	Water supply bore	-	-
67	RN1321	Water supply bore	-	-
68	RN1685	Water supply bore	-	-
69	RN1796	Water supply bore	-	-
70	RN1950	Water supply bore	83	-
71	RN2386	Water supply bore	75	-
72	RN2406	Water supply bore	46	-
73	RN2407	Water supply bore	-	-
74	RN2408	Water supply bore	32	-
75	RN2436	Water supply bore	-	-
76	RN2531	Water supply bore	102	-
77	RN2892	Water supply bore	47	-
78	RN2893	Water supply bore	94	-
79	RN2894	Water supply bore	52	-
80	RN2957	Water supply bore	51	-
81	RN3286	Water supply bore	-	-
82	RN3287	Water supply bore	-	-
83	RN3288	Water supply bore	-	-
84	RN3304	Water supply bore	-	-

Table C.1 Landholder bore summary – 75 km spatial search

Reference ID	Registration number	Type	Depth (m BGL)	Inferred groundwater system
85	RN3305	Water supply bore	-	-
86	RN3308	Water supply bore	-	-
87	RN3963	Water supply bore	-	-
88	RN4469	Water supply bore	36	-
89	RN4472	Water supply bore	53	-
90	RN4661	Water supply bore	53	-
91	RN4939	Water supply bore	27	-
92	RN6103	Water supply bore	137	-
93	RN7012	Water supply bore	132	-
94	RN7014	Water supply bore	52	-
95	RN7050	Water supply bore	27	-
96	RN7345	Water supply bore	46	-
97	RN10082	Water supply bore	107	-
98	RN10129	Water supply bore	107	-
99	RN10329	Water supply bore	154	-
100	RN10374	Water supply bore	95	-
101	RN10481	Water supply bore	122	-
102	RN10530	Water supply bore	49	-
103	RN10534	Water supply bore	61	-
104	RN10535	Water supply bore	61	-
105	RN10747	Water supply bore	24	-
106	RN10773	Water supply bore	92	-
107	RN11505	Water supply bore	20	-
108	RN11506	Water supply bore	81	-
109	RN11507	Water supply bore	68	-
110	RN11664	Water supply bore	52	-
111	RN11799	Water supply bore	78	-
112	RN11838	Water supply bore	109	-
113	RN11853	Water supply bore	138	-
114	RN11854	Water supply bore	95	-
115	RN11928	Water supply bore	141	-
116	RN11940	Water supply bore	79	-
117	RN11982	Water supply bore	148	-
118	RN11984	Water supply bore	139	-
119	RN12112	Water supply bore	49	-
120	RN12348	Water supply bore	200	-
121	RN12526	Water supply bore	13	-
122	RN12528	Water supply bore	8	-
123	RN12533	Water supply bore	12	-
124	RN12941	Water supply bore	48	-
125	RN13044	Water supply bore	119	-
126	RN13360	Water supply bore	2090	-

Table C.1 Landholder bore summary – 75 km spatial search

Reference ID	Registration number	Type	Depth (m BGL)	Inferred groundwater system
127	RN13398	Water supply bore	200	-
128	RN13404	Water supply bore	201	-
129	RN13416	Water supply bore	38	-
130	RN13666	Water supply bore	100	-
131	RN13668	Water supply bore	128	-
132	RN13669	Water supply bore	102	-
133	RN13885	Water supply bore	64	-
134	RN13890	Water supply bore	64	-
135	RN13891	Water supply bore	94	-
136	RN14150	Water supply bore	65	-
137	RN14367	Water supply bore	36	-
138	RN14480	Water supply bore	87	-
139	RN14482	Water supply bore	24	-
140	RN14488	Water supply bore	145	-
141	RN14489	Water supply bore	51	-
142	RN14492	Water supply bore	102	-
143	RN14495	Water supply bore	305	-
144	RN14572	Water supply bore	31	-
145	RN14573	Water supply bore	90	-
146	RN14574	Water supply bore	132	-
147	RN14576	Water supply bore	90	-
148	RN14584	Water supply bore	120	-
149	RN14638	Water supply bore	51	-
150	RN14722	Water supply bore	42	-
151	RN14723	Water supply bore	9	-
152	RN14738	Water supply bore	38	-
153	RN14940	Water supply bore	12	-
154	RN15178	Water supply bore	120	-
155	RN15179	Water supply bore	118	-
156	RN15432	Water supply bore	42	-
157	RN15433	Water supply bore	50	-
158	RN15434	Water supply bore	57	-
159	RN15435	Water supply bore	148	-
160	RN15600	Water supply bore	66	-
161	RN15625	Water supply bore	59	-
162	RN15644	Water supply bore	98	-
163	RN15674	Water supply bore	68	-
164	RN15675	Water supply bore	68	-
165	RN15833	Water supply bore	75	-
166	RN15834	Water supply bore	106	-
167	RN15901	Water supply bore	120	-
168	RN15902	Water supply bore	50	-

Table C.1 Landholder bore summary – 75 km spatial search

Reference ID	Registration number	Type	Depth (m BGL)	Inferred groundwater system
169	RN15903	Water supply bore	67	-
170	RN16153	Water supply bore	83	-
171	RN16161	Water supply bore	64	-
172	RN16167	Water supply bore	53	-
173	RN16279	Water supply bore	60	-
174	RN16632	Water supply bore	-	-
175	RN16793	Water supply bore	20	-
176	RN16794	Water supply bore	83	-
177	RN16814	Water supply bore	70	-
178	RN17056	Water supply bore	114	-
179	RN17231	Water supply bore	262	-
180	RN17415	Water supply bore	201	-
181	RN17417	Water supply bore	200	-
182	RN17427	Water supply bore	-	-
183	RN17527	Water supply bore	15	-
184	RN17576	Water supply bore	182	-
185	RN17707	Water supply bore	60	-
186	RN17956	Water supply bore	164	-
187	RN18068	Water supply bore	17	-
188	RN18200	Water supply bore	84	-
189	RN18380	Water supply bore	12	-
190	RN18473	Water supply bore	75	-
191	RN18480	Water supply bore	90	-
192	RN19022	Water supply bore	36	-
193	RN19024	Water supply bore	54	-
194	RN19079	Water supply bore	89	-
195	RN19229	Water supply bore	30	-
196	RN19243	Water supply bore	30	-
197	RN19275	Water supply bore	120	-

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Appendix D

Landholder bores (25 km) - water quality

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Table D.1 Landholder bores (25 km) - water quality

Reference ID	Registration number	Water level (m AHD)	Total dissolved solids (mg/L)	Electrical conductivity (µS/cm)	Screened formation
3	RN4375	342.6	460	735	Alluvium
13	RN12534	344.8	-	-	Alluvium
16	RN14714	335	3225	6000	Idracowra Sandstone
22	RN17443	343.5	-	-	Alluvium
28	RN4478	441.5	1700	2590	Alluvium
64	RN1276	-	-	-	Alluvium
80	RN2957	-	-	-	Stairway Sandstone
82	RN3287	-	-	-	Alluvium
84	RN3304	-	-	-	Santo Sandstone
86	RN3308	-	-	-	Alluvium
88	RN4469	344.2	-	-	Quaternary/Tertiary sediment
91	RN4939	352.2	-	-	Alluvium
95	RN7050	333.2	-	-	Idracowra Sandstone
96	RN7345	336.5	-	-	Idracowra Sandstone
97	RN10082	409.9	-	-	Stairway Sandstone
102	RN10530	353.8	-	-	Titjikala Sandstone
103	RN10534	352	-	-	Titjikala Sandstone
104	RN10535	351.6	-	-	Titjikala Sandstone
107	RN11505	-	-	-	Tertiary sediment
123	RN12533	339.1	-	-	Alluvium
136	RN14150	353.3	-	-	Stairway Sandstone
137	RN14367	380.1	-	-	Stairway Sandstone
142	RN14492	337.4	-	-	Stairway Sandstone
144	RN14572	345.7	-	-	Alluvium
148	RN14584	335.1	-	-	Stairway Sandstone
149	RN14638	-	-	-	Idracowra Sandstone
156	RN15432	351.9	-	-	Alluvium
165	RN15833	326.1	-	-	Santo Sandstone
166	RN15834	306.6	-	-	Santo Sandstone
167	RN15901	352.1	-	-	Titjikala
168	RN15902	350.2	-	-	Titjikala
169	RN15903	348.3	-	-	Titjikala
174	RN16632	-	-	-	Alluvium?
185	RN17707	352.9	-	-	Titjikala
196	RN19243	343.2	-	-	Alluvium
197	RN19275	335.9	-	-	Idracowra Sandstone

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Appendix E

Indicative waste inventory to be accepted at Chandler Facility

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Table E.1 **Listed waste inventory**

Waste product	Transport	Temporary storage	Disposal
Acidic solutions or acids in solid form	✓	✓	✓
Animal effluent and residues	X	X	X
Antimony, antimony compounds	✓	✓	✓
Arsenic, arsenic compounds	✓	✓	✓
Asbestos	✓	✓	✓
Barium compounds other than barium sulphate	✓	✓	✓
Basic solutions or bases in solid form	✓	✓	✓
Beryllium, beryllium compounds	✓	✓	✓
Boron compounds	✓	✓	✓
Cadmium, cadmium compounds	✓	✓	✓
Ceramic-based fibres with physio-chemical characteristics similar to those of asbestos	✓	✓	✓
Chlorates	✓	✓	✓
Chromium compounds that are hexavalent or trivalent	✓	✓	✓
Clinical and related wastes	✓	✓	✓
Cobalt compounds	✓	✓	✓
Containers that are contaminated with residues of a listed waste	✓	✓	✓
Copper compounds	✓	✓	✓
Cyanides (inorganic)	✓	✓	✓
Cyanides (organic)	✓	✓	✓
Encapsulated, chemically fixed, solidified or polymerised wastes	✓	✓	✓
Ethers	✓	✓	✓
Filter cake	✓	✓	✓
Fire debris and fire washwaters	✓	✓	✓
Fly ash	✓	✓	✓
Grease trap waste	✓	✓	✓
Halogenated organic solvents	✓	✓	✓
Highly odorous organic chemicals (including mercaptans and acrylates)	✓	✓	✓
Inorganic fluorine compounds excluding calcium fluoride	✓	✓	✓

Table E.1 **Listed waste inventory**

Waste product	Transport	Temporary storage	Disposal
Inorganic sulfides	✓	✓	✓
Isocyanate compounds	✓	✓	✓
Lead, lead compounds	✓	✓	✓
Mercury, mercury compounds	✓	✓	✓
Metal carbonyls	✓	✓	✓
Nickel compounds	✓	✓	✓
Naturally Occurring Radioactive Materials (NORM's) arising from the oil and gas, mining and agricultural fertiliser industry	✓	✓	✓
Non-toxic salts	✓	✓	✓
Organic phosphorus compounds	✓	✓	✓
Organic solvents excluding halogenated solvents	✓	✓	✓
Organohalogen compounds that are not otherwise specified in this Schedule	✓	✓	✓
Percholates	✓	✓	✓
Phenols, phenol compounds including chlorophenols	✓	✓	✓
Phosphorus compounds other than mineral phosphates	✓	✓	✓
Polychlorinated dibenzo-furan (any cogener)	✓	✓	✓
Polychlorinated dibenzoo-p-dioxin (any cogener)	✓	✓	✓
Residue from industrial waste treatment or disposal operations	✓	✓	✓
Selenium, selenium compounds	✓	✓	✓
Sewerage sludge and residues including nightsoil and septic tank sludge	X	X	X
Soils contaminated with a listed waste	✓	✓	✓
Surface active agents (surfactants) that contain principally organic constituents and that may contain metals and inorganic materials	✓	✓	✓
Tannery wastes (including leather dust, ash sludges and flours)	✓	✓	✓
Tellurium, tellurium compounds	✓	✓	✓
Thalium, thallium compounds	✓	✓	✓
Triethylamine catalysts for setting foundry sands	✓	✓	✓
Tyres	✓	✓	✓
Vanadium compounds	✓	✓	✓

Table E.1 **Listed waste inventory**

Waste product	Transport	Temporary storage	Disposal
Waste chemical substances arising from research and development or teaching activities, including those substances which are not identified and/or are new and the effects of which on human health and/or the environment are not known	✓	✓	✓
Wastes containing peroxides other than hydrogen peroxide	✓	✓	✓
Waste containing cyanides from heat treatment and tempering operations	✓	✓	✓
Waste from the manufacture, formulation and use of wood preserving chemicals	✓	✓	✓
Waste from the production, formulation and use of biocides and phytopharmaceuticals	✓	✓	✓
Waste from the production, formulation and use of inks, dyes, pigments, paints, lacquers and varnish	✓	✓	✓
Waste from the production, formulation and use of organic solvents	✓	✓	✓
Waste from the production, formulation and use of photographic chemicals and processing materials	✓	✓	✓
Waste from the production, formulation and use of resins, latex, plasticisers, glues and adhesives	✓	✓	✓
Waste from the production and preparation of pharmaceutical products	✓	✓	✓
Waste mineral oils unfit for their original intended use	✓	✓	✓
Waste mixtures, or waste emulsions, of oil and water or hydrocarbon and water	✓	✓	✓
Waste pharmaceuticals, waste drugs and waste medicines	✓	✓	✓
Waste resulting from surface treatment of metals and plastics	✓	✓	✓
Waste tarry residues arising from refining, distillation and any pyrolytic treatment	✓	✓	✓
Waste substances and articles containing or contaminated with polychlorinated biphenyls (PCBs), polychlorinated nthalenes (PCNs), polychlorinated terphenyls (PCTs) and/or polybrominated biphenyls (PBBS)	✓	✓	✓
Waste of an explosive nature not subject to the <i>Dangerous Goods Act</i>	✓	✓	✓
Wool scouring waste	✓	✓	✓
Zinc compounds	✓	✓	✓

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SYDNEY

Ground Floor, Suite 1, 20 Chandos Street
St Leonards NSW 2065
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NEWCASTLE

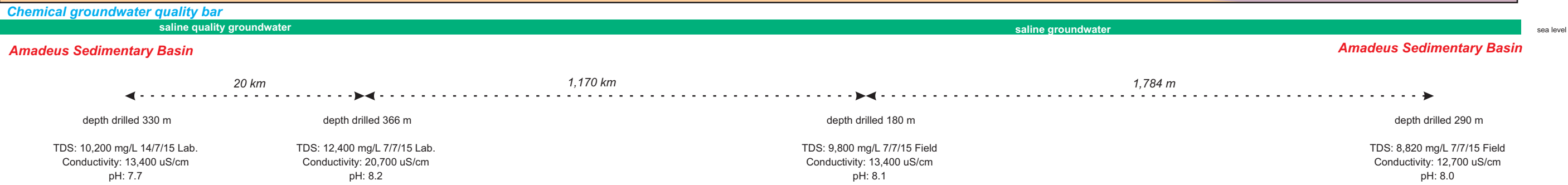
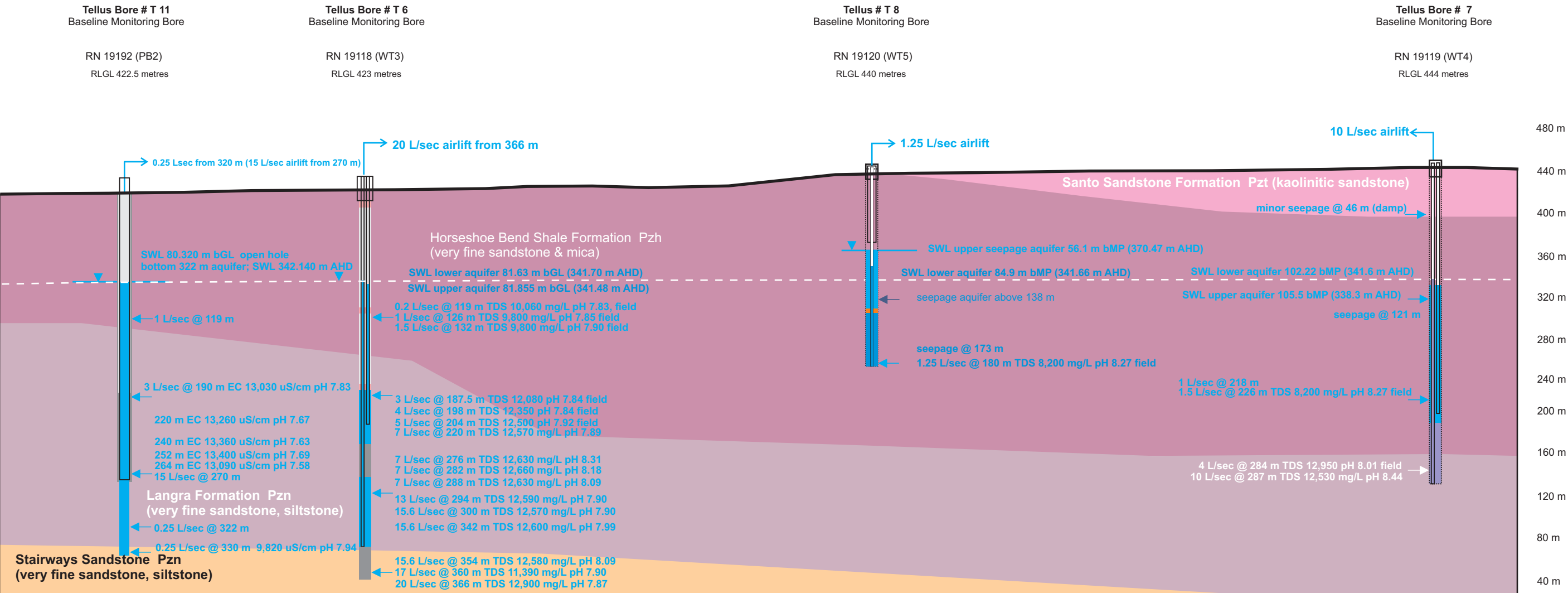
Level 1, Suite 6, 146 Hunter Street
Newcastle NSW 2300
T 02 4907 4800 F 02 4907 4899

BRISBANE

Level 4, Suite 1, 87 Wickham Terrace
Spring Hill QLD 4000
T 07 3839 1800 F 07 3839 1866

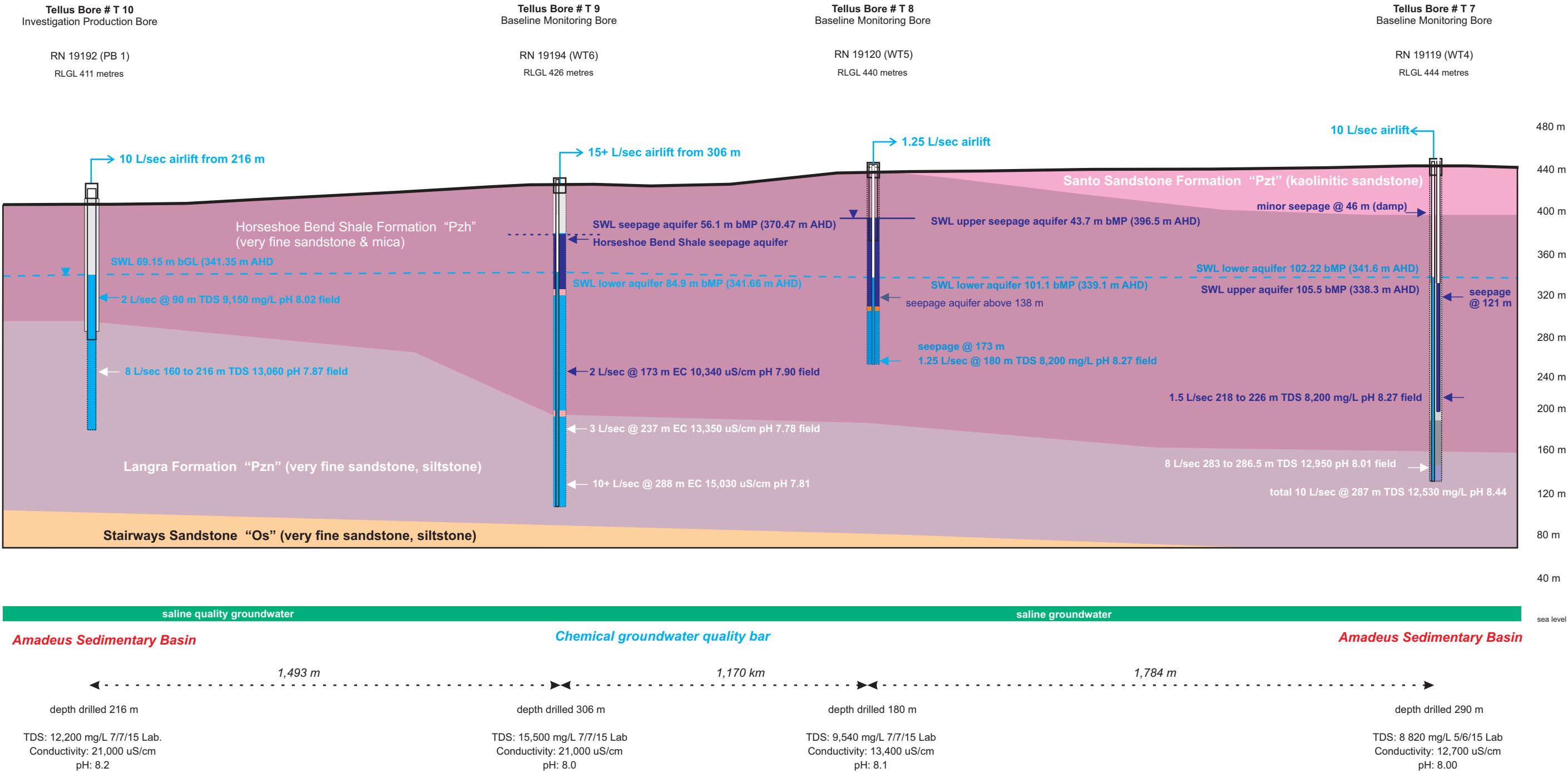
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Elevation
metres
A.H.D.



Section WNW-ESE through Tellus Holdings Ltd 2015 Water Investigation Bores T 10 (PBT 1), T 9 (WT 6), T 8 (WT 5), T 7 (WT 4)

Elevation
metres
A.H.D.





Chandler Salt Mine

Electroseismic and Electrotelluric Survey Report

For Tellus Holdings Ltd
Suite 2, Level 10
151 Castlereagh Street
Sydney NSW 2000

November 2015

Geo9 Project97 Draft Report for client review

Report prepared by:
Michael Cook
Chief Groundwater Exploration
Geologist

Reviewed by:
Paul Ferguson
Chief Scientist
Craig Schultz
Head, Hydrogeology

Overview of findings

- Electroseismic (ES) and electrotelluric surveying was conducted on the Chandler Salt Mine Project on the 22nd of September 2015 with a 35 point survey grid completed covering 500 x 500m to a depth of 390m and 1 additional reference survey point taken at the WT6 bore site.
- A seismic velocity model of 3900 m/s was applied to the electroseismic data in order to estimate the depth of the ES responses. The velocity selected was based on the seismic data provided, the measured electrotelluric response and correlation of the electroseismic data with logged drill holes on site.
- The groundwater flow potential identified by the survey, strongly correlates to highly permeable, horizontal aquifer systems identified in the drill logs. From a depth of approximately 140 m to 260 m there appears a zone of well-connected, relatively high hydraulic conductivity. More isolated and less extensive areas of hydraulic conductivity continue to a depth of approximately 350 m. Below this depth, only a relatively very low hydraulic conductivity response is observed, except in areas where fracturing is observed.
- The zone of higher groundwater potential corresponds closely to the second sandstone unit (*pale grey sandstone - interbedded with red brown medium to coarse sandstone*) observed in the diamond drill hole core log provided.
- Where hydraulic conductivity is observed within the second sandstone unit, it is independent of any observed fracturing response and indicates that aquifer systems are contained within higher permeability sediments within the sandstone.
- Some hydraulic conductivity is also observed within the deeper claystone layer and correlates strongly with the bedding plane fracturing response at this depth.

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1. Introduction

This report presents the findings of the electroseismic (ES) and electrotelluric (ET) aquifer mapping survey undertaken on the 'Chandler Salt Mine Project during September 2015 (Figure 1).

Based on discussions with Jaime Livesey and Richie Phillips from Tellus, a 60 point (10 x 6) survey grid was designed running east-west to investigate an area of interest adjacent to an existing core hole (CH001A) and groundwater bore (WT6 – RN19194). Due to time constraints in the field, the survey was trimmed to 37 points consisting of 6 east-west lines of 6 points each, with one additional point surveyed at the WT6 bore site. The surveys were taken at 100m spacing between survey points, with 100m between survey lines. Survey lines were offset 50m from each other to provide more complete data coverage. One point on the survey in the north-east corner was unable to be collected due to its location on a steep slope.

Electrotelluric data was also collected to complement the ES data and provide additional insight into the local groundwater systems. A combined ES and ET model has been processed for the grid surveyed with detailed analysis and results presented in this report.

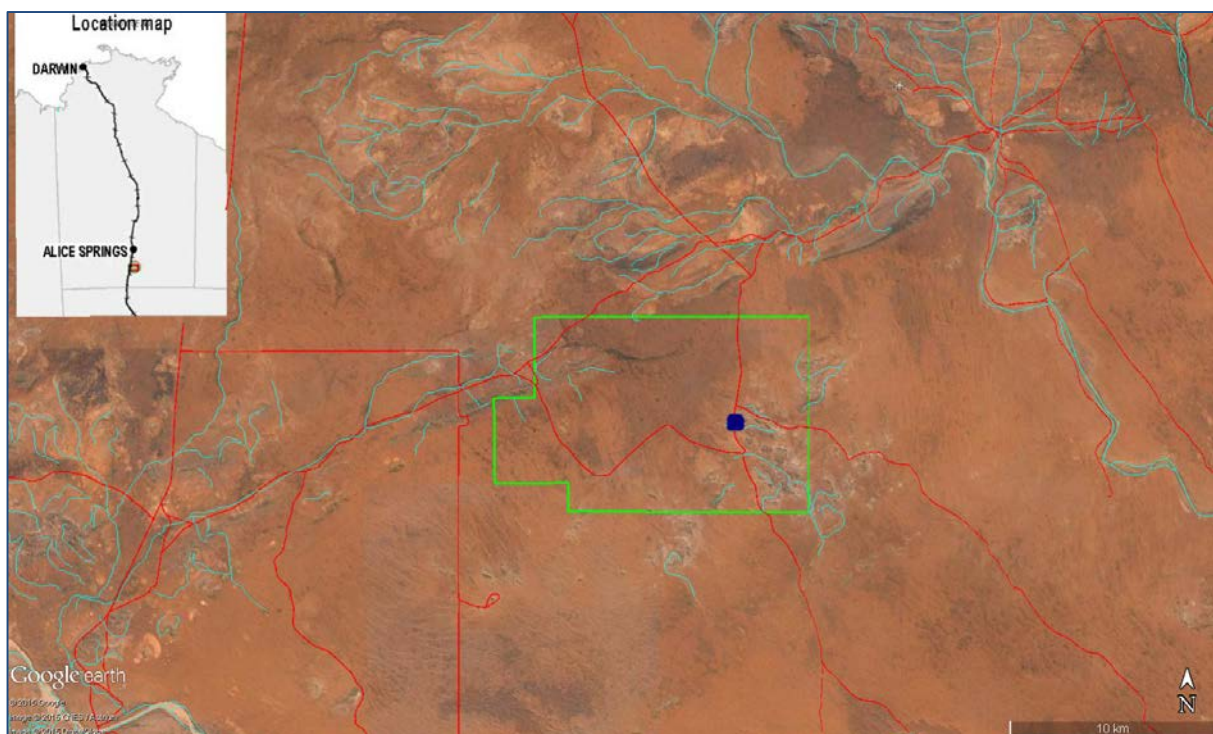


Figure 1: Project location with survey location highlighted in blue.

2. Electro seismic / Electrotelluric Survey

2.1 Survey Design and Data Processing

Electro seismic surveying was conducted on the Chandler Salt Mine Project on the 22nd of September 2015. The survey was aimed at mapping areas of high groundwater potential and to identify the geological controls on regional aquifer development.

Survey details are summarised in Table 1. A 35 point survey grid was completed, covering 500 x 500m. ES data was collected using a sledgehammer and steel plate. One additional point was collected at the bore site (WT6) and survey points are shown in Figure 2. Survey point coordinate details are provided in Appendix 1.

Due to the drop in seismic energy with depth, the ES response becomes attenuated and a correction has to be applied using a depth compensation curve. Survey data has been processed and modelled to a depth of 390 m based on a seismic travel time of 100 ms.

In general, the quality of the data collected is considered excellent. The Total ES Sounding Risk for the model was calculated at 27.25, with any number below 35 regarded as excellent and 50 considered acceptable. The Total Sounding Risk is a combination of the signal to noise risk, and the data quality with regard to phase and amplitude of the measured ES responses. Both of these measures of data quality in the model returned excellent results.

One data point in the northeast of the model (Point 18 or Waypoint 42 on the survey grid) had to be excluded from the results due to data quality issues. At this location, signal strength was very low which appears to be related to physical problems with the seismic wave coupling with the ground attenuating the ES response data. In simple terms, it was impossible to distinguish clear hammer strikes in the signal at this location.

Based on the seismic data provided, the measured ET response and ES correlation with the holes logged at the site, a seismic velocity model of 3900 m/s was applied to the electro seismic data in order to estimate the depth of the ES responses. At this velocity, excellent correlation was observed with the known geology and also with the ET depth calculations. At the model limit of 100 ms travel time, this allowed a maximum model depth of approximately 390m. The model was run at the previously determined seismic velocity of 3608 m/sec, but this velocity was found to be slightly slower than experienced at the survey site. As the ES survey is a collection of individual point data, taken at one particular site and to only a partial depth of the previously determined velocity, such a variation is not unexpected.

Survey details	
No. of Survey Points	36
Survey Lines	6
Points per Line	6
Survey Depth	390m
Survey Point/Line spacing	100m
Line Offset	50m
Survey Orientation	East-West (090°)
Electroseismic recorded	Yes
Electrotelluric recorded	Yes
Estimated Seismic Velocity	3900 metres/sec

Table 1: Geo9 geophysical survey details



Figure 2: Survey layout showing location of data collection points and corresponding model numbers.

3. Electroseismic Modelling

3.1.1 Electroseismic Hydraulic Conductivity Tomography (ESKT)

The *electroseismic hydraulic conductivity tomography* (ESKT) is an indicative measure of hydraulic conductivity (K in Darcy's Law), or the ease at which a fluid, water in this case, can flow through a porous medium. Hydraulic conductivity is expressed as a velocity, based on distance in a given time (usually in units of metres/day or otherwise stated), that a fluid will move through a medium under gravity in the direction of a hydraulic gradient.

ESKT is the measurement of relative hydraulic conductivity across the survey area. The ESKT data shows hydraulic conductivity as a normalised percentage relative to the highest uncalibrated value found across the site, the maximum being 100%. No data exists in the study area at this stage that can be used to calibrate the hydraulic conductivity. Detailed descriptions of all ES modelled data is presented in Appendix 3.

Figure 4 shows a 3D view the ESKT data with an isosurface set to 75% to include all areas of relatively high hydraulic conductivity. Figure 5 shows the same ESKT dataset in oblique view with the ESKT isovalue reduced to 50%. The diagram shows a distinct zone of hydraulic conductivity that corresponds to the *pale-grey medium to coarse grained interbedded sandstone* described in the diamond drill core CH001A which begins at approximately 154m depth.

The ESKT response is very low in the upper 140 m of the model. Below this from a depth of 140 m to approximately 260 m appears to be a zone of well-connected relatively high hydraulic conductivity. Less extensive areas of hydraulic conductivity continue to a depth of approximately 350 m with only a very low response below this depth. Again this corresponds well with the drill-hole data, which indicates a claystone layer beginning at 343 m depth.

Figure 6 shows an ESKT data plot for the bore WT6, which corresponds to Point 36 on the model. The ESKT isovalue is plotted for the entire modelled depth down to 390m with the recorded aquifers highlighted in blue. The plot shows good correlation with the bore log, with each water intersect and screen position corresponding to a zone of high ESKT response and ending with a very low ESKT response, probably representing an underlying aquitard below each aquifer.

The plot also matches well with the known geology with a relatively low hydraulic conductivity interval in the top 150 m corresponding to the logged *very fine to fine grained red-brown well sorted sandstone* (well cemented with clay matrix).

Then there is a distinct change in the next interval of approximately 195 m. This is the higher hydraulic conductivity *pale grey interbedded medium to coarse sandstone with occasional inferred aquifers* before the claystone is hit at approximately 345 m deep. Below this, an extremely low ESKT response is observed to the base of the model at 390m.

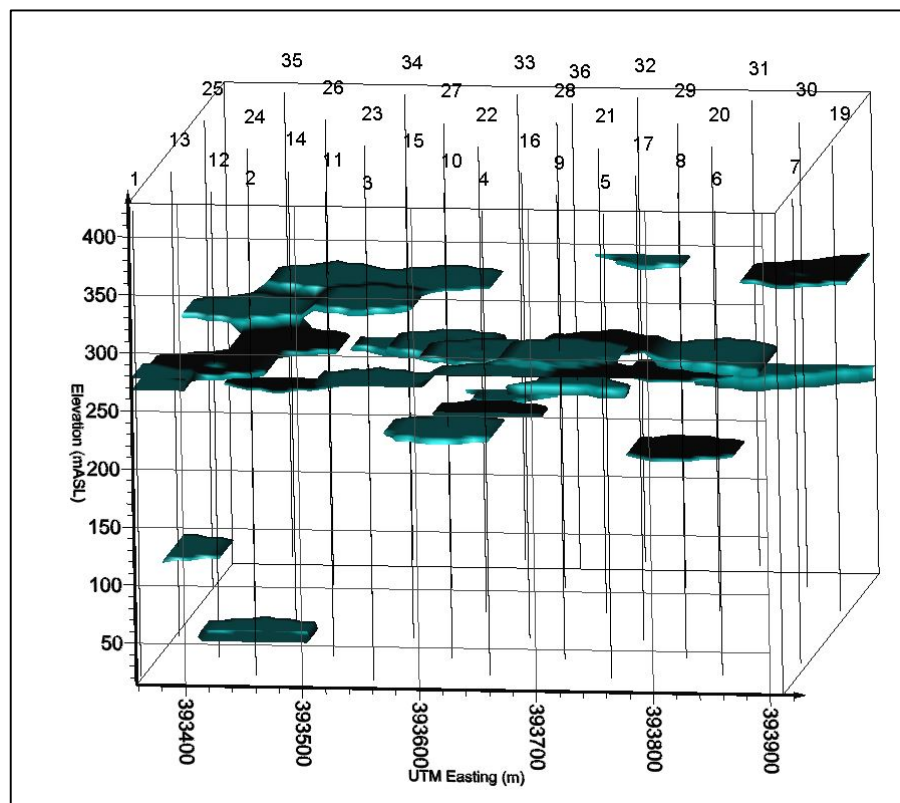


Figure 4. 3D Block showing ESKT isosurface @ 75% across survey area to indicate areas of highest relative hydraulic conductivity.

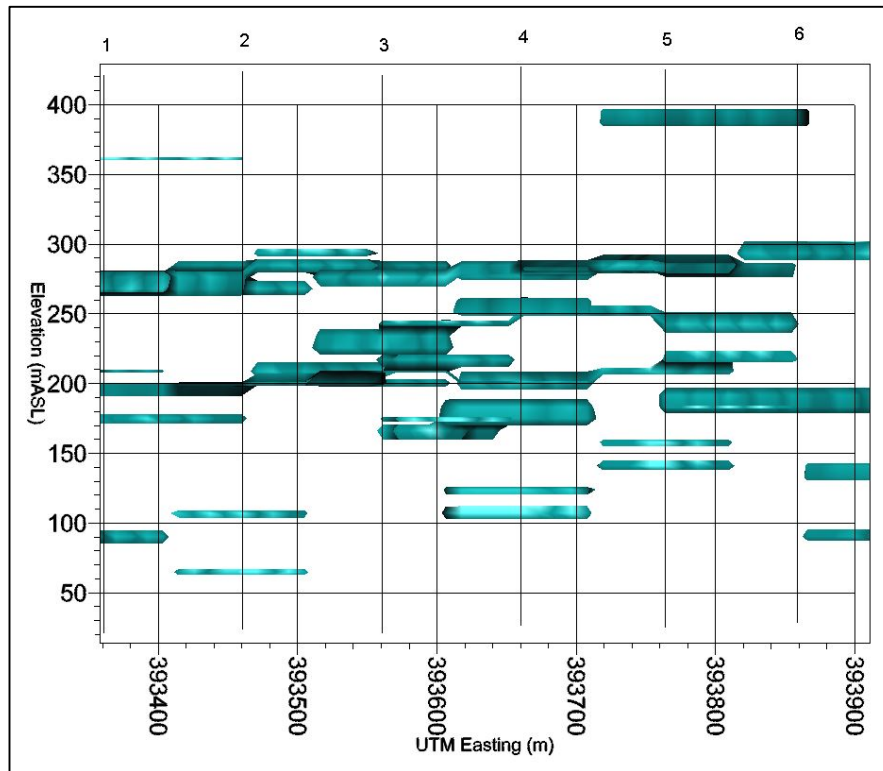


Figure 5. View looking north through the model showing ESKT isosurface @ 50% across survey area to highlight depth of main potential aquifers.

This concentration of elevated hydraulic conductivity response in the lower pale grey sandstone unit appears throughout the model, indicating that the main aquifers encountered in the upper 390m will lie predominantly between 140m to 350m deep. There are minor potential aquifers observed in the upper red-brown sandstone but these are likely to be small perched groundwater systems. They lie above the regional water table, which from the data in bore WT6, lies at a depth of 87m.

Some elevated hydraulic conductivity is also noted in places in the lower 50m of the model, within the claystone, which is strongly correlated with the fracturing response (discussed in detail in Section 3.3). There are also intervals described as *poor to moderately sorted, medium to coarse grained sandstone interbeds up to 0.5m thick*. If these are more extensive in other parts of the area, they may be a possible explanation for the elevated ESKT responses observed in the claystone.

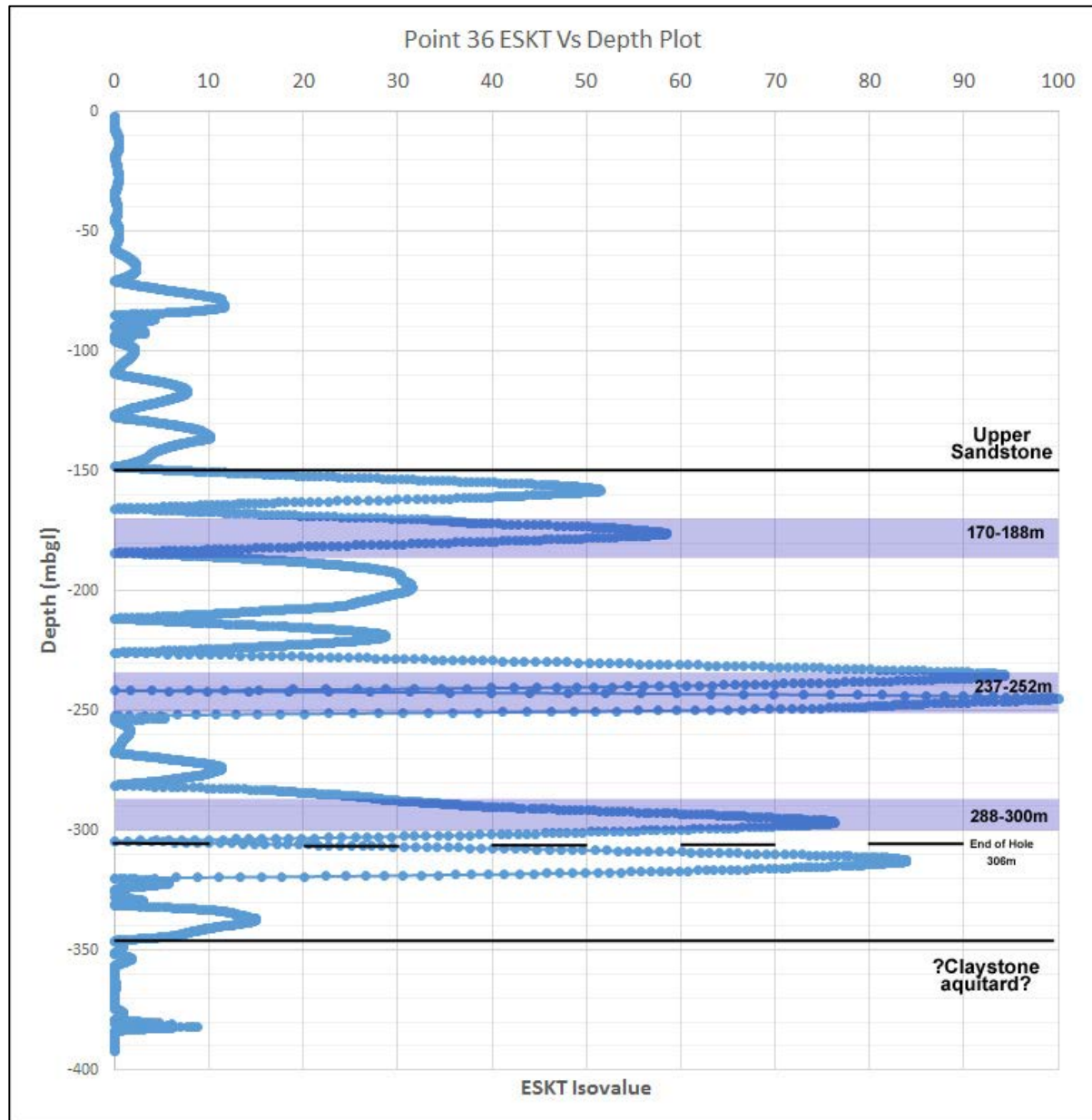


Figure 6. ESKT response Vs Depth Plot for Bore WT6 (Point 36) showing 3 main zones of elevated hydraulic conductivity correlating closely with logged water intercepts

3.1.2 Electro seismic Change in Gradient Tomography

The *Electroseismic Change in Absolute Gradient Tomography* (ESCATG) is used to differentiate absolute electrical changes in rock formation properties (zeta potential), proportional to each other. This method allows the identification of rock formations with similar electrical characteristics. It is also used to distinguish between consolidated rocks and the unconsolidated regolith and surface sediments.

The *Electroseismic Change in Total Gradient Tomography* (ESCTGT) is similar to the ESCATG but is not restricted to absolute values. It is useful for mapping soft materials, soils and weathered lithology as unconsolidated topsoil and transported material will generally exhibit positive zeta potentials.

By setting the isosurface cut-offs to appropriate values the change in gradient tomography allows the delineation of the near-surface weathered horizons and soil profile from the consolidated bedrock. Figure 7 shows the ESCTGT layer (in brown) which models near surface weathered and transported cover. It is relatively consistent over the site and in most places ranges between 8-15m in thickness.

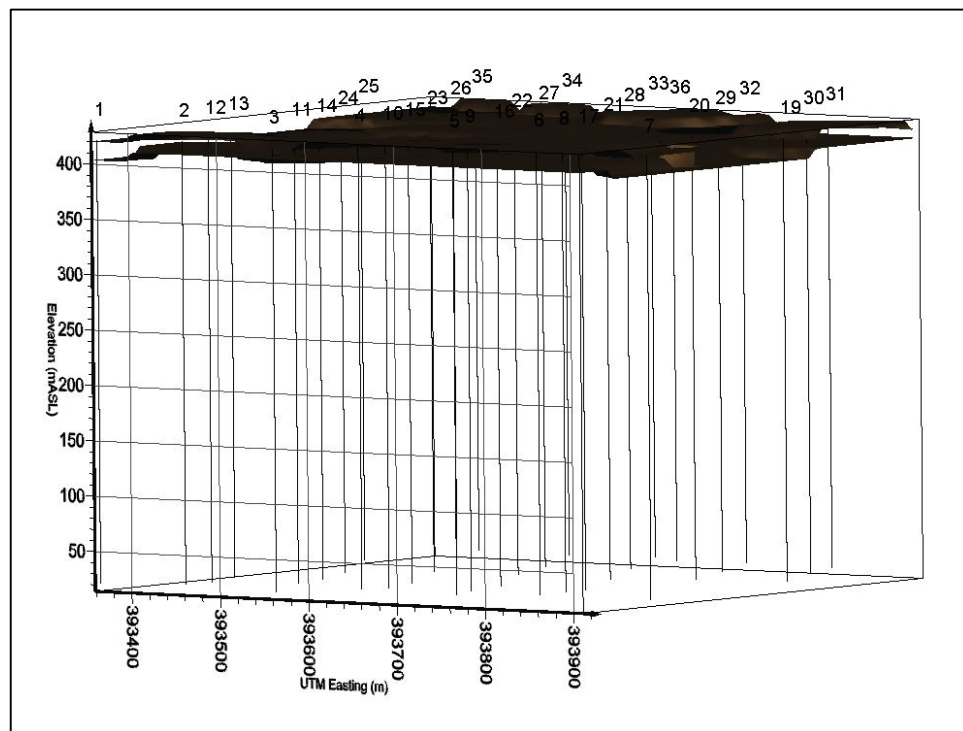


Figure 7. ESCTGT isosurface (@0.0001%) highlighting surface unconsolidated layer across the survey site.

3.1.3 Electro seismic Fracture Tomography

The *electro seismic fracture analysis tomography* (ESFT) is used to reveal inferred fracturing. The ES data is spectrally analysed and specific frequency patterns associated with fracturing are used to identify horizontal fracture planes. The results are used to identify probable secondary permeability features. These fractured zones are generally associated with higher fluid flow rates. Fractures dipping at greater than 30° are not observed directly as they do not generate a strong response from the seismic wave front. Steeply dipping and vertical structure can be inferred from the ESFT results grouping along high angles.

Figure 8 shows the survey area 3D block model with the ESFT isosurface set at 40% overlain on the existing ESKT isosurface at 75%. The fracturing identified is strongly concentrated at depths below 300 m (120 m ASL) and even more so below 340 m depth (80 m ASL) in the claystone unit. Again this matches well with the known geology with the claystone described as *flaky in parts (breaks along bedded laminae)* which would be expected to produce a high ESFT response.

There is little correlation observed between the fracturing and the hydraulic conductivity with them predominantly occurring in isolated intervals. Fracturing response is greatest below the main interval of hydraulic conductivity, in the logged siltstone and claystone intervals.

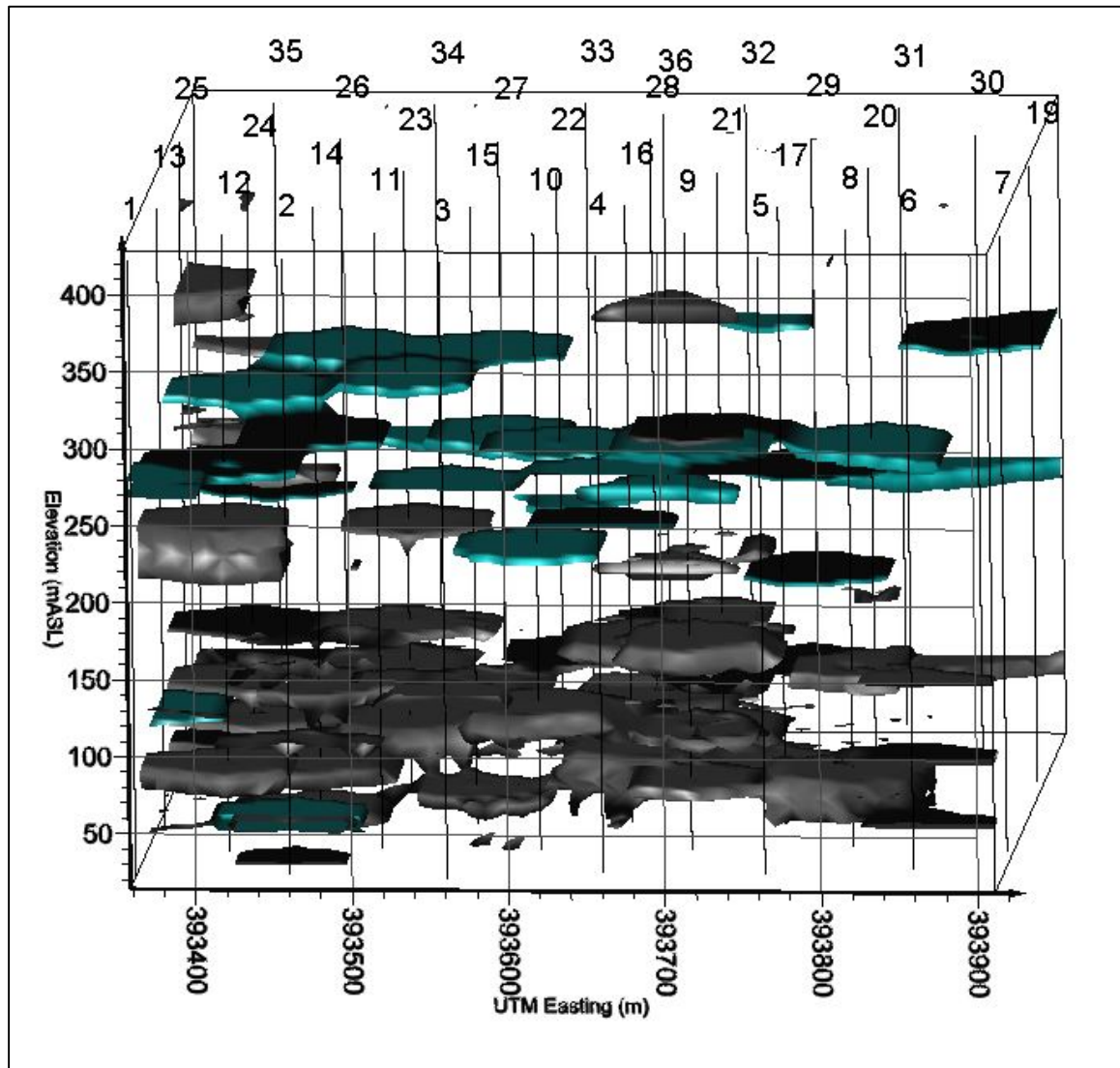


Figure 8. 3d Block Model showing ESFT isosurface (@ 40%) and ESKT isosurface (@75%) to highlight the lack of correlation between the two ES responses

Figure 9 shows an ESFT slice through points 25 – 30 to correspond to the diamond drill core log at Point 26 with the ESKT data along that survey line also shown. At Point 26 there is little fracturing response observed until a depth of 290m (130 m ASL), and a clear interval of high fracturing response from approximately 340m to 380m depth (40 – 80m ASL), which correlates extremely well with an obvious interval in the 3D calliper breakout data from the downhole log. Elevated hydraulic conductivity is observed in correlation with fracturing, with a strong ESKT response seen in the middle of the fractured interval around 380m (40m ASL).

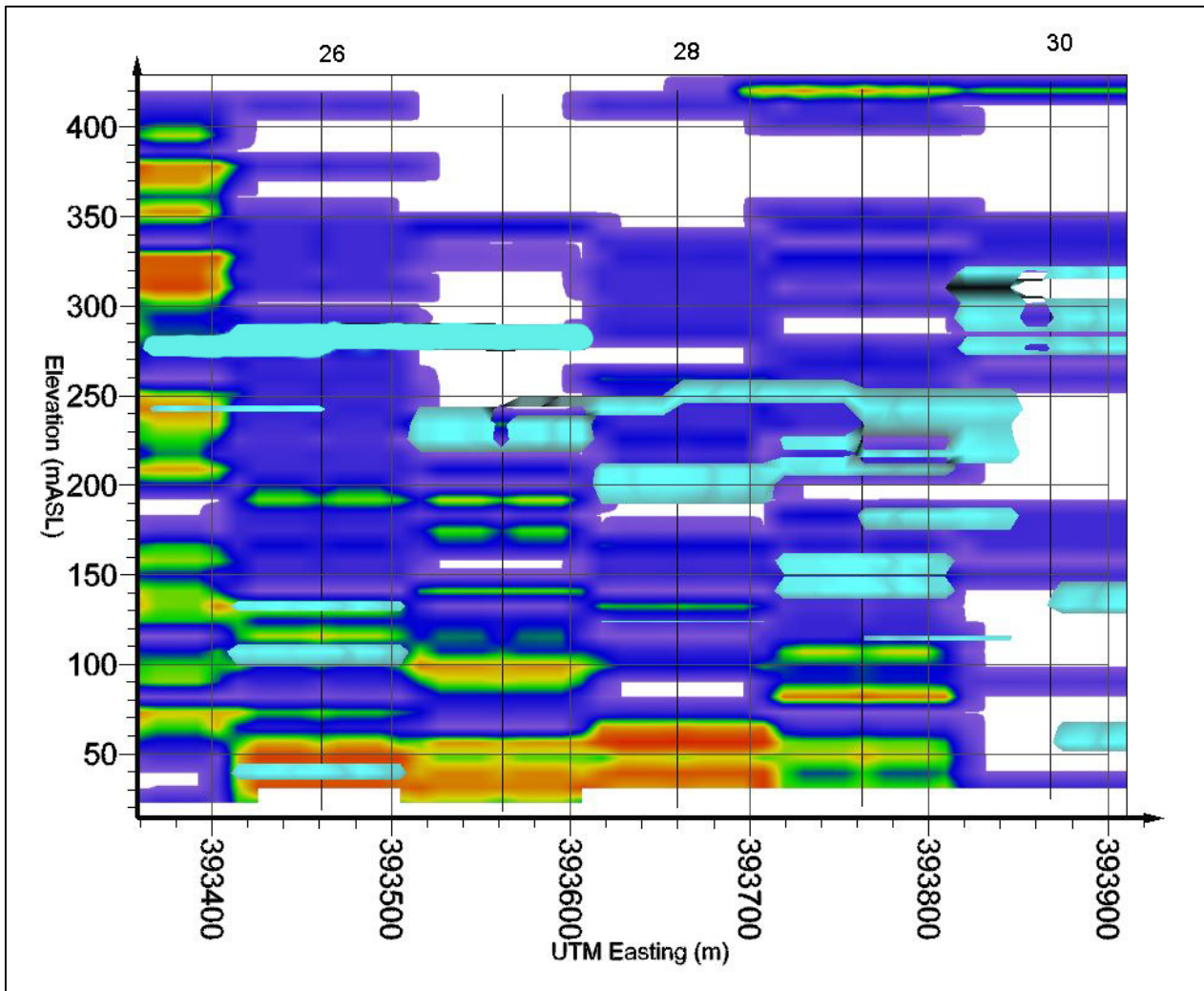


Figure 9. ESFT Section through points 25-30 with ESKT data (@50%) overlain in aqua highlighting strong fracturing response below 100m ASL and high ESKT associated with the fracturing below 60m ASL at Point 26.

Figure 10 shows the raw ESKT data for the core-hole location at Point 26. There is a strong ESKT response at shallow depths (30-50m) and another at 130-150m amongst an otherwise low ESKT response in the upper sandstone. The lower sandstone unit displays a stronger and more variable ESKT response with a significant zone of hydraulic conductivity between 280 and 323m that supports the inferred aquifer at 321m. The claystone unit also exhibits relatively high ESKT, indicating a secondary permeability within the logged bedding plane fractures.

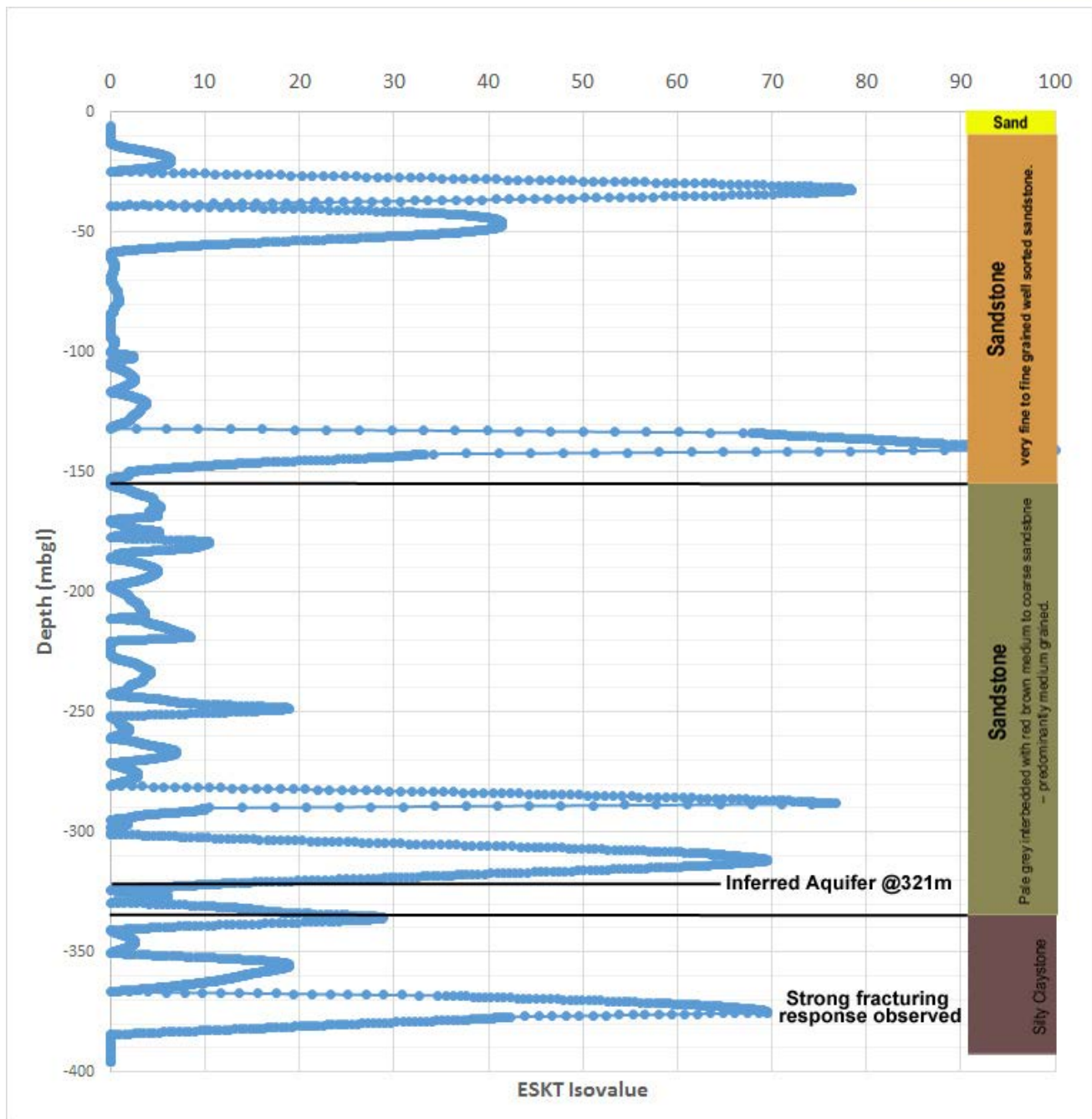


Figure 10. ESKT response Vs Depth plot for Point 26 showing simplified logged geology from the diamond drill hole

3.4 Electro seismic Groundwater Flow Potential

The electro seismic groundwater flow potential tomography (ESGFPT) data indicates an areas potential for groundwater flow. This parameter is determined statistically using data from other ES parameters. It is sensitive to primary and secondary permeability data, as well as water quality and gradient electrical response data. This data is primarily used to find the best location to tap groundwater reserves.

The zones of highest groundwater flow potential are found almost entirely within the areas of elevated hydraulic conductivity already identified. Figure 11 shows the occurrence of groundwater potential overlain on the ESKT data demonstrating the high degree of correlation between the two.

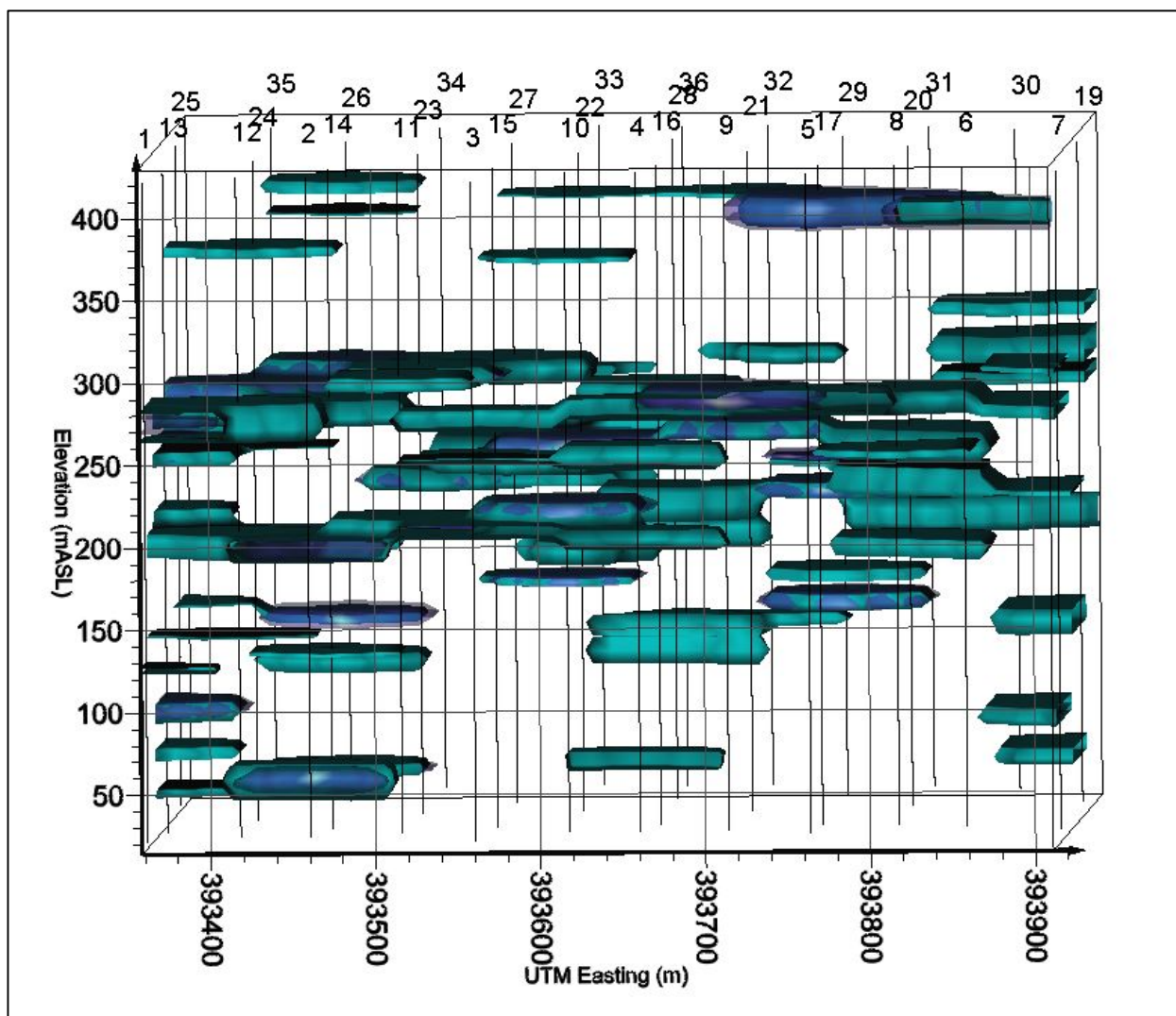


Figure 11. ESGFPT isosurface (@20% in blue) overlain on ESKT isosurface (@50% in cyan) highlighting the strong concentration of groundwater potential in area of highest hydraulic conductivity.

Figure 12 shows data from the Point 36 at bore WT6 comparing the ESKT response with the ESGFPT response.

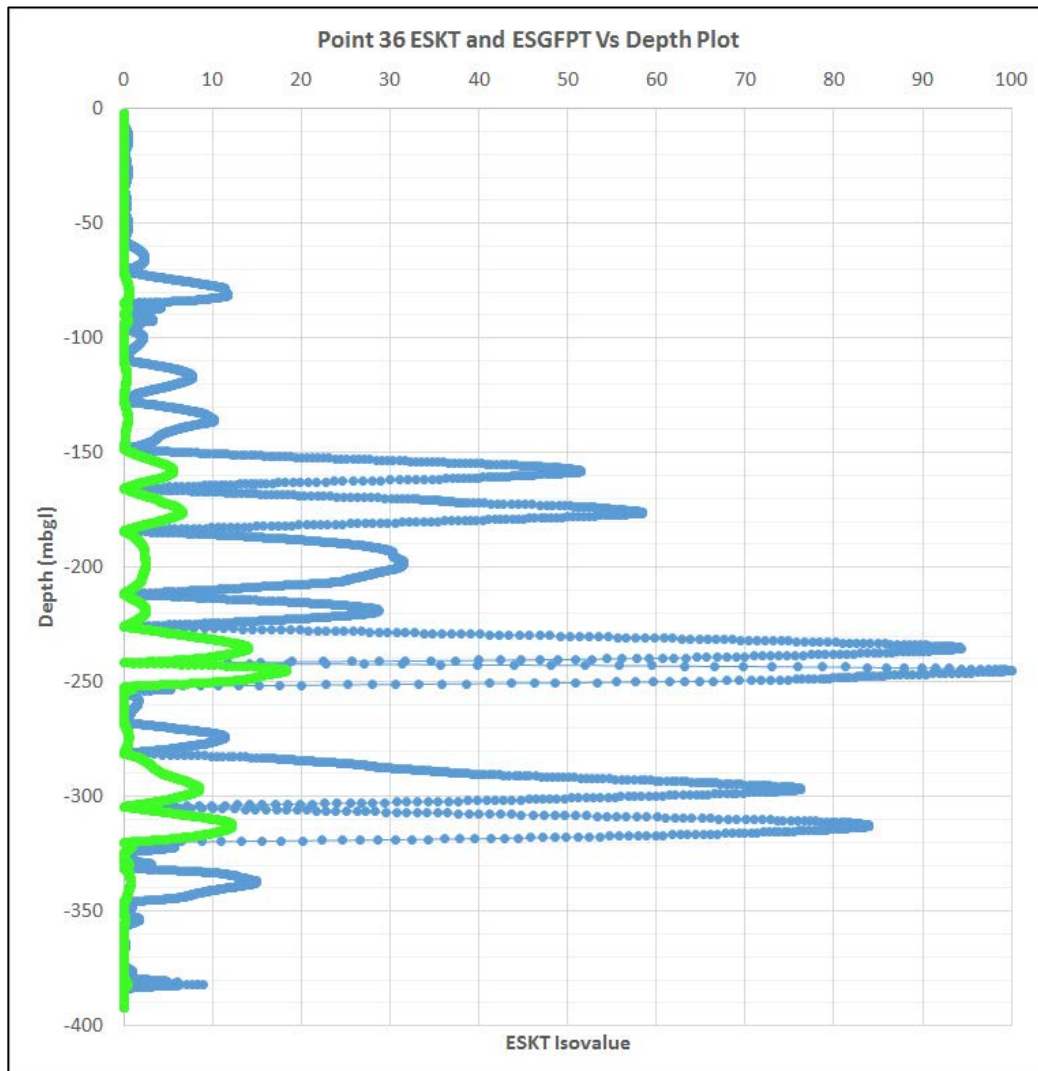


Figure 12. ESKT and ESGFPT vs Depth plot at Point 36 showing strong correlation between modelled groundwater potential and hydraulic conductivity occurrence.

At Point 36, both data sets correlate very closely indicating that groundwater potential is almost entirely contained in the primary permeability of the coarse sediments. No correlation is observed between the fracture tomography and groundwater potential data at the intervals observed indicating that secondary permeability caused by fracturing is not a major factor in aquifer development in the bore.

3.5 Electro seismic Interface Angular Response Tomography

The ES interface tomography data indicate the positions of interfaces between formations with differing electrical and elastic properties. It makes use of the unique interfacial effects generated, by electro seismic conversion, as the pressure wave passes through a formation change. *Electro seismic Interface Angular Response Tomography* (ESIAT) uses the change in the angular gradient of the signal response that occurs at the interface between two rocktypes to determine the position and depth of major geological changes. Figure 13 shows the ESIAT data for a section through points 25 to 30, which includes the core log at Point 26.

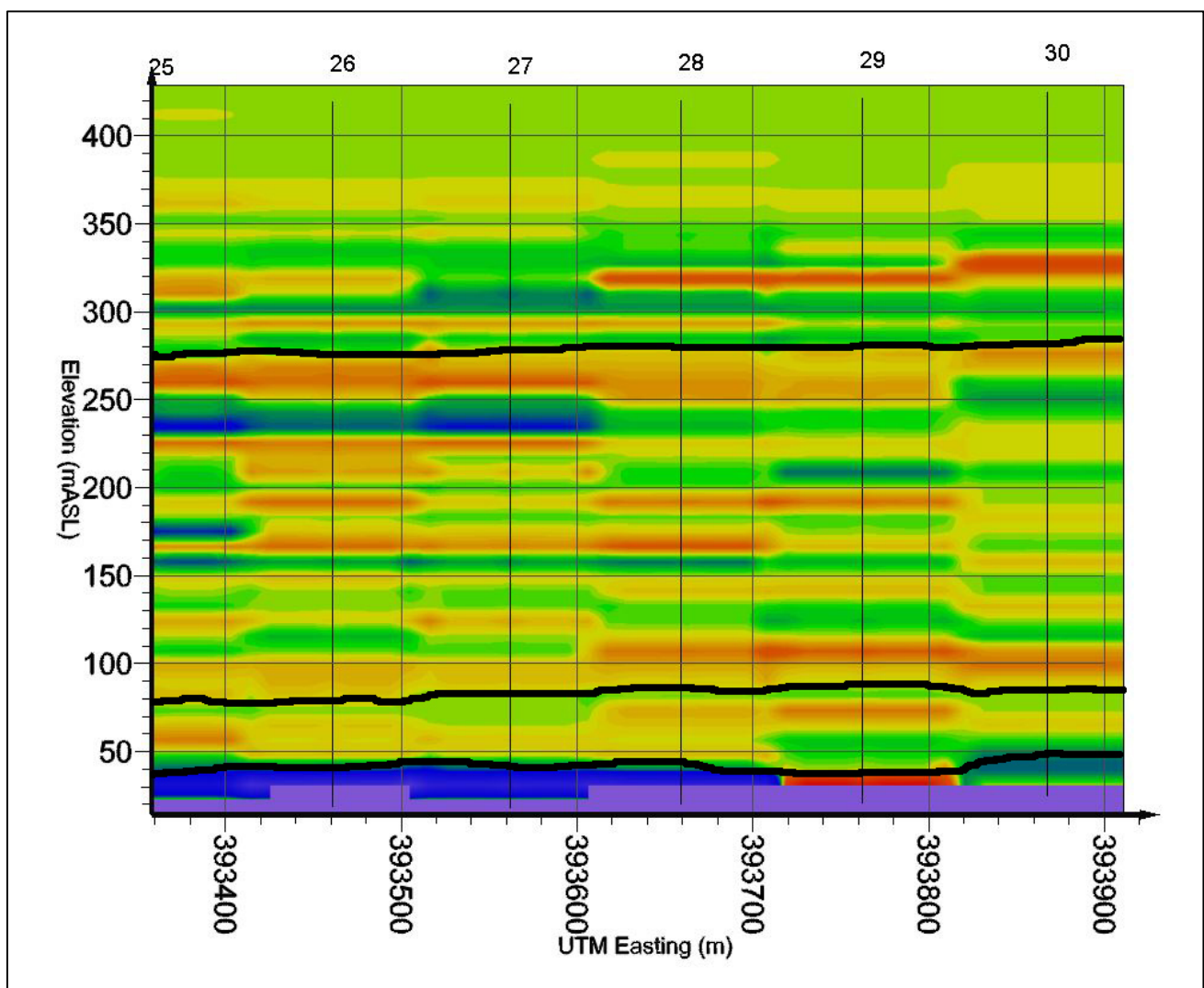


Figure 13. ESIAT Section taken through points 25-30 with major interfaces corresponding to the core log at Point 36 identified.

The interface tomography is picking out a number of prominent interfaces in the model. The most prominent appears to be the logged change in the sandstone at approximately 150m depth (260 – 270m ASL). It also identifies the change to the claystone unit at approximately 340 – 350m depth (70-80m ASL). There is also a very strong interface identified at 380-390m depth at the base of the model that corresponds to the sandstone interval logged at this depth. The three major geological interfaces have been approximated in Figure 13 based on the diamond drill core data at Point 26.

4. Electrotelluric Modelling

Electrotelluric currents are geo-magnetically induced currents that flow through conductive formations in the subsurface. They are primarily created by natural fluctuations in the earth's geo-magnetic field, caused by solar winds. The ET data set describes the variability in conductivity of the formations under a site. The data set does not describe the apparent conductivity of the formations underlying a site as it is only a representation of the potential difference generated by a streaming current as it passes through a conductive medium. The data does indicate a relative variability in conductivity, which can be used to delineate conductive formations, even though the exact conductivity cannot be determined without calibration against a resistivity downhole well log.

The ET data set is generated by frequency analysis of the background noise on the site, during the data recording, to a maximum frequency of 10Hz. The frequency domain data is analysed for amplitude to determine the variability of conductivity for the formations at specific depths under the site. This data set is not linear in resolution. Resolution decreases exponentially from surface level to depth. It is very important that interpretations of conductive formations at depth consider this lower vertical resolution limitation.

The ET modelling is a completely separate geophysical technique to ES and where similarities are identified in both data sets, it allows a high degree of confidence in the modelled result as it has been arrived at via two separate geophysical techniques.

4.1 Electrotelluric Interface Tomography

The ET data shows excellent agreement with the ES data and models the major geological boundaries very clearly based on the change in electrical conductivity. Figure 14 shows the *Electrotelluric Interface Tomography* (ETIT) for the E-W slice through points 25-30. The ETIT data set describes the position and depths of interface indicators that occur at the boundaries between two geological units with differing variability in their electrical conductivity

The ETIT data recognizes two major changes at depth. The first of these occurs at a depth of approximately 210 - 250m, with multiple interfaces recognized within that interval. The core log does not indicate a major change at that depth but does note the *"187-222m interval has common to abundant claystone and siltstone laminae and interbeds"*. The second interface occurs at a depth of approximately 340m corresponding to the claystone unit. The boundaries drawn on the units in Figure 13 are copied directly from the ESIAT data presented in Figure 12. While the change at 154m between the sandstone is not observed, the claystone unit at 343m fits the data perfectly suggesting there is extremely good correlation between the ES and ET data sets.

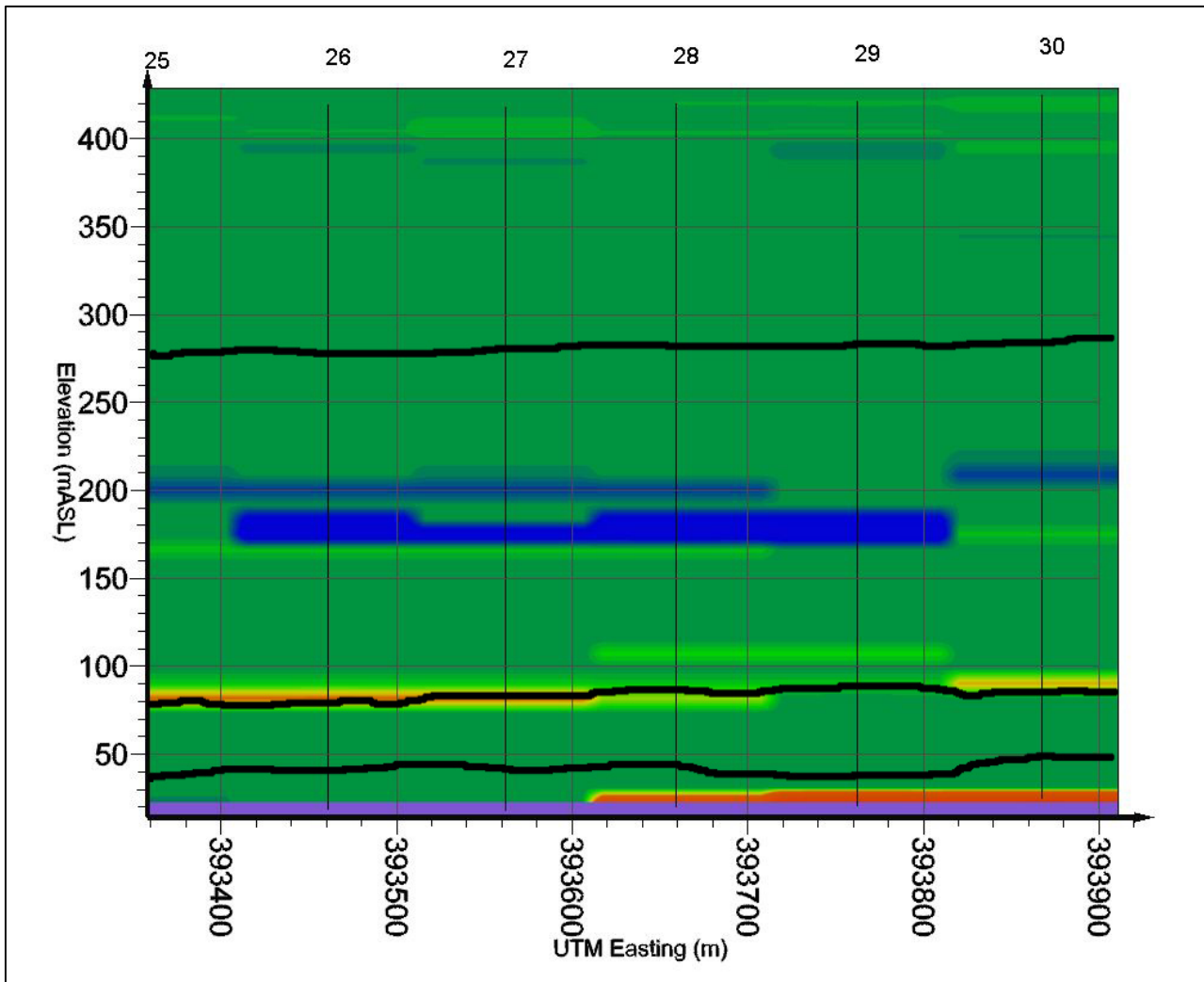


Figure 14. ETIT Section through points 25-30 with logged geological boundaries marked and major ET response observed in the 170 – 210m ASL horizon.

Figure 15 shows another E-W slice through points 7 – 12, 300m south of the slice in Figure 13, with very little change observed. The depths of the major interfaces are virtually identical confirming the geology is flat-lying over the survey area.

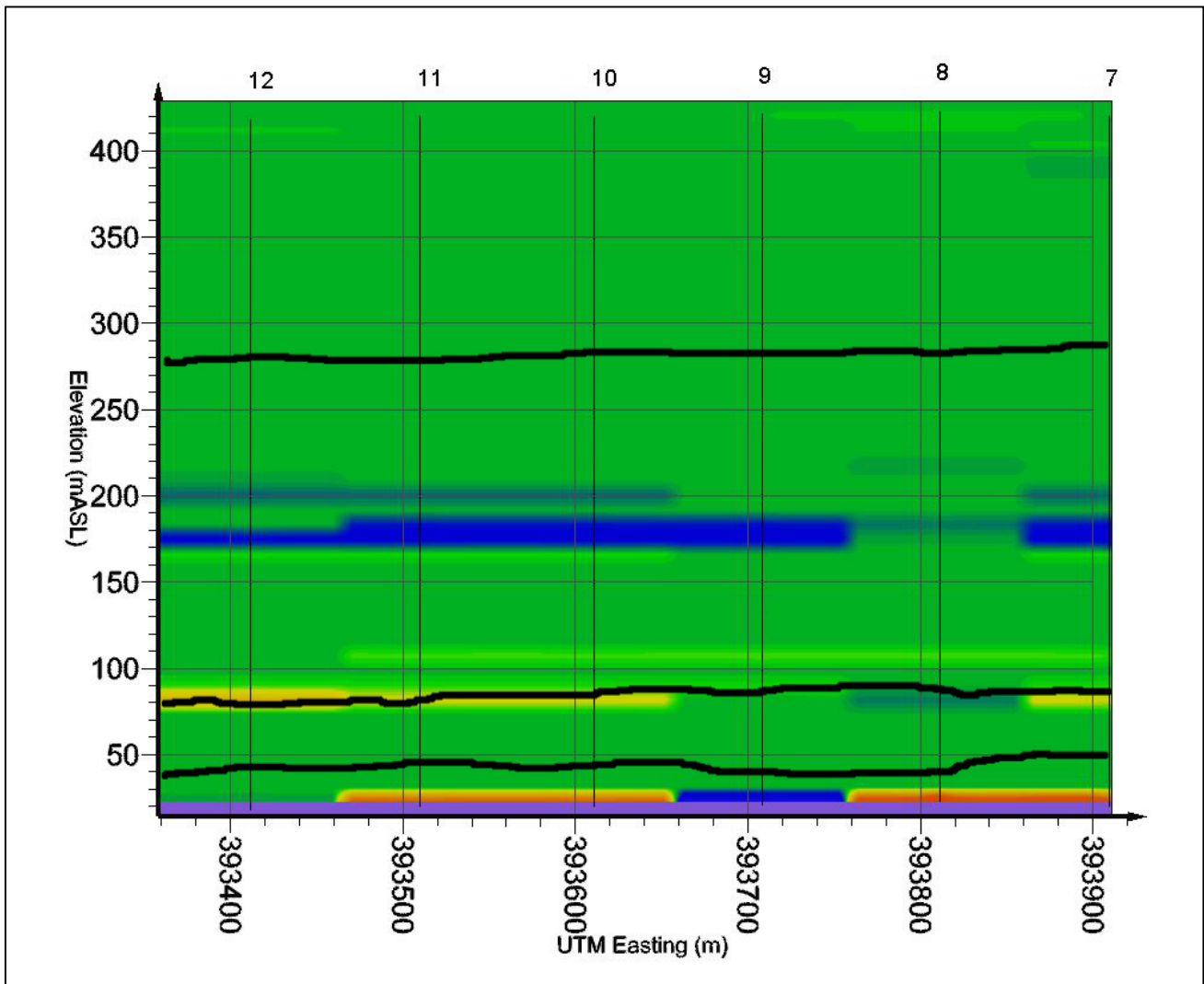


Figure 15. ETIT Section through points 7 - 12 with logged geological boundaries marked.

Figure 16 gives a more complete picture of the overall data in the 3D model. It plots the ESKT hydraulic conductivity data at an isovalue of 60% with a face render of the ETIT data that picks out the main interfaces identified. The ETIT data identifies a strong change at the base of the zone where hydraulic conductivity is highest at a depth of approximately 220 – 260m (200 – 160m ASL). The strongest change is identified in the 240 – 260m depth interval (180 – 160m ASL). There is no clear indication in the core log of a major change in geology at this point, but both the ES and ET data sets identify a definite change in response at this depth. It is also at this depth (252m or 173m ASL)) where the base of the second aquifer in bore WT6 (Point 36) is observed. At Point 36, the high ESKT zone where the aquifer is located is immediately above the ETIT interface, suggesting it represents an aquitard unit underlying it.

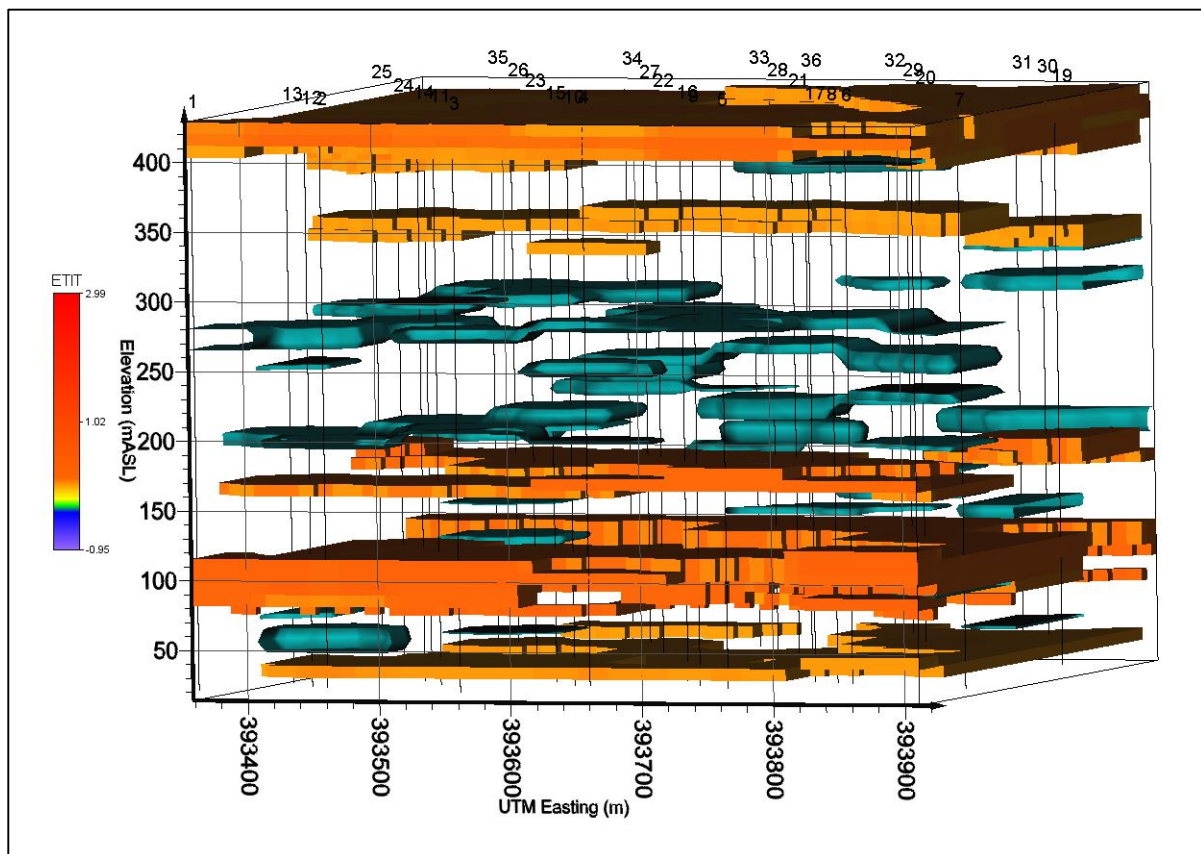


Figure 16. ESKT isosurface (@60%) plotted in cyan with major ETIT interfaces.

4.2 Electrotelluric Interface Angular Response Tomography

The *Electrotelluric Interface Angular Response Tomography* (ETIAT) data represents the change in angular gradient in the variability of electrical conductivity that occurs at the interface between two rock types with differing electrical properties. This data is dependent on the amplitude of the response in front and behind the interface. However, changes in formations with similar electrical conductivities will have similar angular gradient change responses. This allows for the characterization of interfaces between independent sounding locations.

Figure 17 shows the ETIAT data again through Points 25-30, and again shows excellent correlation to the known geological boundaries. There is a significant horizon between 150m to 240m depth where little change is observed in the ETIAT data and this corresponds strongly to the zone of highest hydraulic conductivity identified in the ES data.

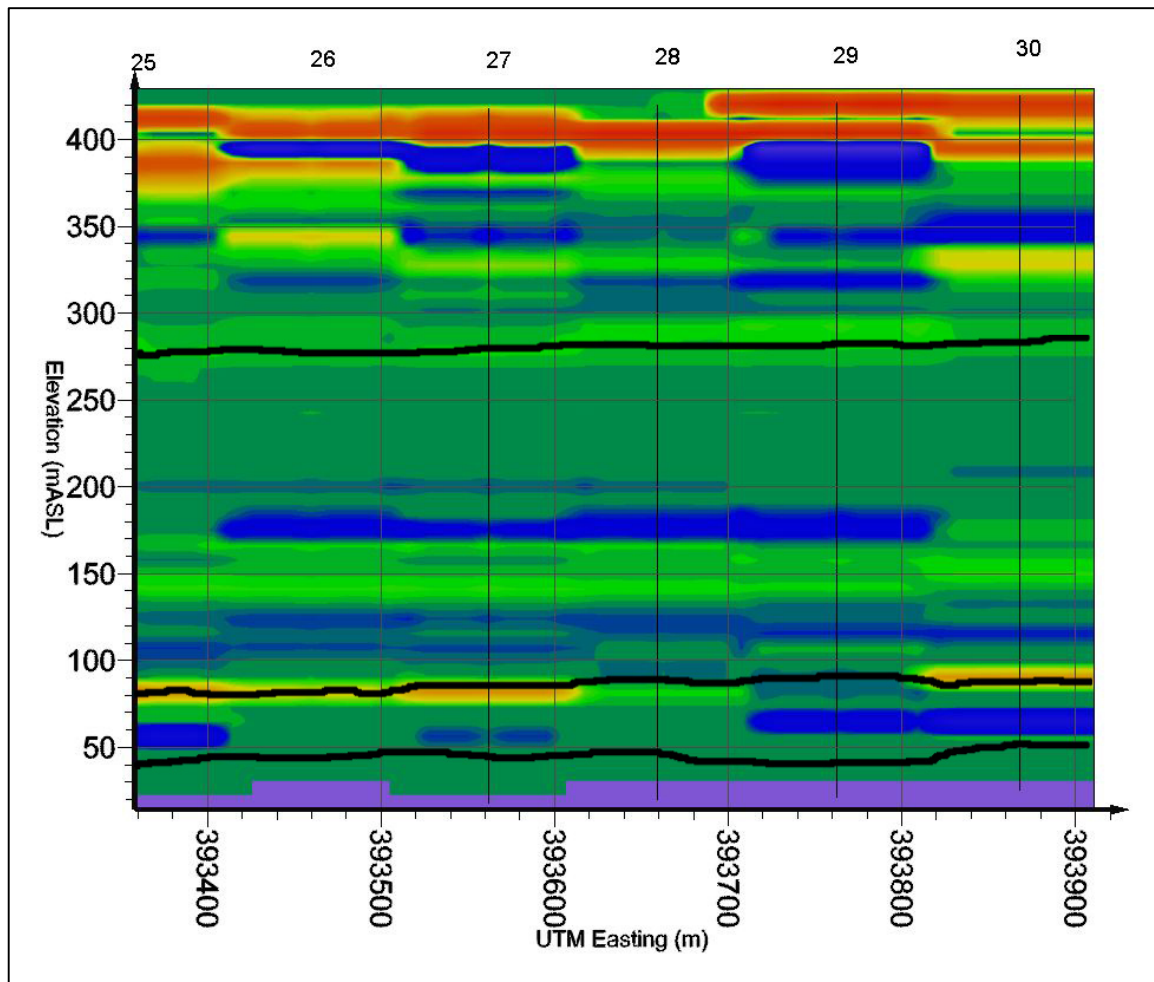


Figure 17. ETIAT Slice through point 25 – 30 with major ES interfaces marked.

Figure 18 shows the ESKT data for the whole survey area overlain on the same ETIAT slice through points 25-30 with the hydraulic conductivity clearly concentrated in the horizon between 130m to 230m deep (190 – 290m ASL). The strong interface at approximately 240m depth (180m ASL) appears at the base of the main zone of high hydraulic conductivity. At this point there is a significant change in the ET response with multiple interfaces recognized below 240m depth (180m ASL).

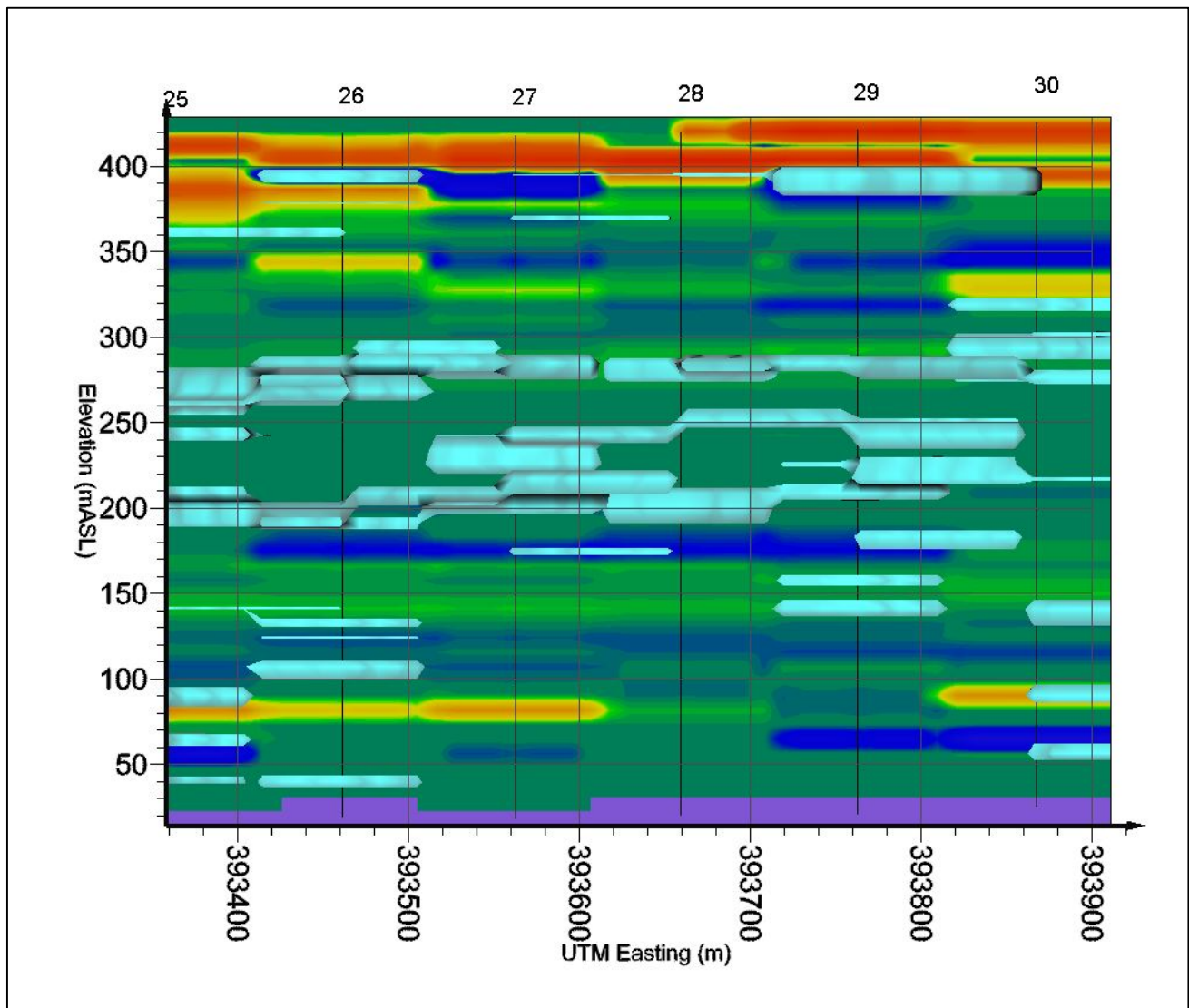


Figure 18. ESKT data (@40% in aqua) overlain on ETIAT slice through Points 25-30 showing correlation of hydraulic conductivity to a broad horizon of low ETIAT response between 190 – 300m ASL.

Survey Conclusions

Groundwater potential in the survey area is strongly correlated to primary permeability occurring in horizontal sandstone aquifers. From a depth of approximately 140 m to 260 m there appears to be zones of inter -connected hydraulic conductivity demonstrating the aquifers inner heterogeneity. Less extensive areas of hydraulic conductivity continue to the claystone boundary at a depth of approximately 350m, with generally only a very low ESKT response below this depth. Some elevated ESKT responses are observed below 350m depth where it is strongly correlated to the bedding plane fractures indicated by the ESFT.

Correlating this information to the logged geology, indicates the major aquifer systems observed in the survey area are all contained within the lower sandstone unit (*Pale grey sandstone - interbedded with red brown medium to coarse sandstone*). The log is not detailed enough to correlate the exact aquifer units, but additional work on the core log may be able to identify the aquifer's host rocks.

Hydraulic conductivity and potential aquifers are not laterally extensive across the whole survey area. Groundwater appears to be located in discrete zones of relative high hydraulic conductivity at varying depth throughout the lower sandstone unit, particularly towards the base of the unit where they are less extensive.

Groundwater recharge does not appear to be strongly reliant on local infiltration with the majority of recharge most likely remote to the site. The lack of hydraulic conductivity observed in the upper 140m and the depth of the water table suggest that the near surface is relatively dry with little surface recharge to the deeper aquifers locally. Give the local desert climate and lack of apparent surface recharge, groundwater in the system is likely to be ancient.

Recommended Reading

Fourie, F.D., 2003, *Application of Electroseismic Techniques to Geohydrological Investigations in Karoo Rocks*, PhD thesis, University of the Free State, Bloemfontein, South Africa.

Frenkel, J., 1944, On the Theory of Seismic and Seismoelectric Phenomena in Moist Soil. *Journal of Physics*, 8, 230-241.

Haartsen, M. W. and Pride, S. R., 1997, *Electroseismic Waves from Point Sources in Layered Media*. *Journal of Geophysical Research*.

Shaw, D.J., 1992, *Introduction to Colloid and Surface Chemistry*, Fourth Edition.

Appendix 1. Details of Survey Point Locations

Table A.1 Survey point co-ordinates (WGS84) and elevation.

Point	Latitude	Longitude	Elevation(m)
1	-24.79716	133.94499	421
2	-24.79720	133.94597	424
3	-24.79718	133.94696	421
4	-24.79722	133.94795	427
5	-24.79718	133.94897	425
6	-24.79719	133.94991	429
7	-24.79631	133.95042	420
8	-24.79628	133.94945	423
9	-24.79632	133.94843	421
10	-24.79627	133.94747	420
11	-24.79628	133.94647	420
12	-24.79627	133.94550	418
13	-24.79536	133.94501	414
14	-24.79537	133.94600	416
15	-24.79537	133.94699	416
16	-24.79536	133.94797	417
17	-24.79539	133.94894	417
18	-24.79540	133.94992	419
19	-24.79449	133.95045	424
20	-24.79449	133.94943	422
21	-24.79448	133.94847	419
22	-24.79450	133.94746	419
23	-24.79446	133.94649	418
24	-24.79446	133.94550	414
25	-24.79357	133.94499	417
26	-24.79356	133.94601	419
27	-24.79358	133.94701	418
28	-24.79359	133.94797	420
29	-24.79359	133.94899	421
30	-24.79366	133.95003	425
31	-24.79267	133.94946	420
32	-24.79265	133.94849	421
33	-24.79266	133.94748	422
34	-24.79267	133.94653	421
35	-24.79265	133.94551	421
36	-24.79300	133.94800	423

Appendix 2. The Electro seismic Effect

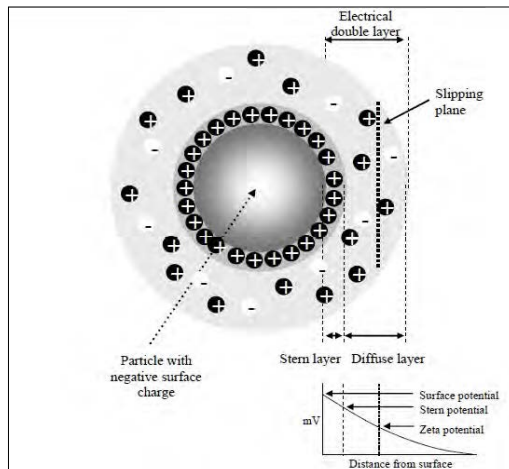


Figure A.1. The Electric Double Layer
([http://www.escubed.co.uk/sites/default/files/zeta_potential_\(an013\)_streaming_potential.pdf](http://www.escubed.co.uk/sites/default/files/zeta_potential_(an013)_streaming_potential.pdf))

A charge distribution at the interface between a mineral grain and fluid is organised on the molecular scale, and is referred to as the electrical double layer (Fig. A1). The fluid's molecules arranged next to the mineral's surface, are disrupted and mobilised as the compression wave from the hammer blow passes. The relative motion caused between mineral and fluid leads to small scale electric currents with associated and detectable electromagnetic fields. The resulting ES signal can then be related to how relative movement of the matrix and water (dynamic permeability) and the strength of electrical attraction between the mineral and the fluid (zeta potential). Different fluids located in the same rock type will inherently produce differing ES responses, as does different geological materials with the same water quality throughout. The differences are discernible and the 3D maps that are produced form the basis for the analysis of groundwater flow paths.

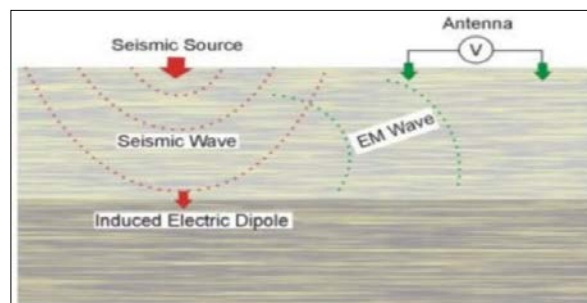


Figure A2. Seismic wave crossing an interface generating an electromagnetic wave

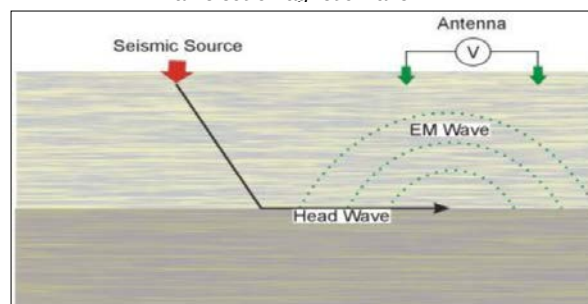


Figure A3. Head wave travelling along an interface generating an electromagnetic wave

Appendix 3. Electro seismic Modelling and Investigation

The descriptions following refer to the electro seismic data discussed in the results section.

3.1 Hydraulic Conductivity Tomography

The electro seismic hydraulic conductivity tomography (**ESKT**) is an indicative measure of hydraulic conductivity (K in Darcy's Law), or the ease at which a fluid, water in this case, can flow through a porous medium. It is expressed as a velocity, usually in units of metres/day, or otherwise stated as how far a fluid will move through a medium over a certain amount of time under gravity or a hydraulic gradient. No data exists in the study area at this stage which can be used to calibrate this and other hydrogeological parameters. The results shown are displayed in relative terms, where a value of 100% is assigned to the highest hydraulic conductivity and 0% is the lowest of the values detected during ES survey. Since these values are relative it is possible that the material with a relative value = 100% could have low hydraulic conductivity in absolute terms. The data can easily be linearly calibrated to a known value at any sounding point at any depth on the model.

3.2 Electro seismic Coupling Coefficient Tomography

The electro seismic coupling coefficient tomography data (**ESCCT**) is representative of the electrical characteristics that define the conversion efficiency between the seismic waves to electrical field. The ESCCT data is expressed as a percentage of conversion. The data can be used as indicators for salinity and temperature variations within an aquifer system. (The parameter is also sensitive to other factors such as pH and viscosity). In groundwater studies ESCCT data can differentiate water quality or type variations and is useful for defining aquifer systems with different feed systems.

3.3 Electro seismic Change in Absolute Gradient Tomography

The electro seismic change in absolute gradient tomography (**ESCAGT**) data is used to differentiate absolute electrical changes in rock formation properties, proportional to each other. This method allows the user to discern formations of similar electrical characteristics and when used in conjunction with the ESIT and electro seismic change in total response tomography (see below), provides deeper insight into the geological and lithological information for subsurface formations. It is also used to support the delineation of subsurface faulting and intrusive formations not from an interface standpoint but rather from an absolute electrical standpoint.

3.4 Electroseismic Change in Total Gradient Tomography

The electroseismic change in total gradient tomography (**ESCTGT**) is used to differentiate total electrical changes in rock formation properties, proportional to each other. (This differs from parameter ESCAGT which measures the absolute electrical change). This method allows the user to discern formations of similar electrical characteristics and when used in conjunction with the ESIT and ESCAGT, provides deeper insight into the geological and lithological information for subsurface formations. It is also used to support the delineation of subsurface faulting and intrusive formations not from an interface standpoint but rather from a total electrical standpoint.

3.5 Electroseismic Groundwater Flow Potential Tomography

The electroseismic groundwater flow potential tomography (**ESGFPT**) data indicates the areas under the site with the highest flow rate potential. This data incorporates primary and secondary permeability data as well as ESCCT and gradient electrical response data to determine the areas of highest probability of groundwater flow. This data is primarily used to find the best location to tap a groundwater reserve.

3.6 Electroseismic Interface Tomography

Interface tomography (**ESIT**) indicates the positions of interfaces between different rock types and also between layers of unconsolidated materials with different electrical and elastic properties. It makes use of the interface effects generated by electroseismic responses as the pressure wave passes through a resistive interface between different geological materials. This data can be used to determine if there are large geological shifts such as faults. Furthermore, the interface tomography results indicate positive (red) and negative (blue) interface changes. Interface response polarities indicate the type of fluids and rock involved in the generation of the ES response. Similar rock types generate similar polarity responses thus indicating stratification boundaries. Information from this parameter is often interpreted in combination with information from parameters ESIAT and ESIANT as discussed below.

3.7 Interface Angular Gradient Tomography (ESIAT)

This parameter augments information about the interfaces between geological materials as detected using parameter ESIT. A geological interface does not necessarily imply a change in the types or properties of the geological materials involved. Interfaces between materials with similar electrical and elastic responses will show similar angular gradient responses. Detection of similarities is important to prevent misleading interpretations. When differences are detected the results are useful for showing the depths and positions of major geological changes such as changes in the lithology, major faulting or the presence of intrusive lithology.

3.8 Normalised Interface Angular Gradient Tomography (ESIANT)

Statistical data are often skewed due to sample sizes or a few anomalous values. Normalisation accommodates data transformation to reduce the skewness in the data for comparison purposes. The parameter, ESIANT reflects the outcome of such adjustments to

the results of parameter ESIAT discussed above. It is enhancement of the latter parameter and used for the same purpose to obtain information about the interfaces between geological materials. A geological interface does not necessarily imply a change in the types or properties of the geological materials involved. Interfaces between materials with similar electrical and elastic responses will show similar angular gradient responses. Normalisation sometimes serves to enhance this information. When differences are detected the results are useful for showing the depths and positions of major geological changes such as changes in the lithology, major faulting or the presence of intrusive lithology.

3.9 Fracture Tomography (ESFT)

The electroseismic data is spectrally analysed and specific frequency patterns associated with fracturing are used to infer fracturing with depth. The results are used to show larger secondary permeability within a primary permeability aquifer. These fractured zones are associated with higher fluid flow rates.

3.10 Electrotelluric Tomography (ET)

This data provides further information with which to delineate lithological changes and geological formations with similar characteristics by identifying the variability in conductivity in the subsurface material. The data resolution changes exponentially with depth. The interpretation requires a process of systematically changing the isosurface values until the structures become apparent at various depths.

3.11 Electrotelluric Interface Tomography (ETIT)

This data provides an enhancement of parameter ET by focussing on the differences in the variability of the electrical conductivity within geological materials. The ETIT data set describes the position and depths of interface indicators that occur at the boundaries between two geological units with differing electrical conductivity variability. This data allows for the delineation of ET generated interface data.

3.12 Electrotelluric Interface Angular Response Tomography (ETIAT)

The ETIAT data represents the change in angular gradient of electrical conductivity variability that occurs at the interface between two formations with differing electrical properties. The data allows for the characterization of interfaces between independent sounding locations. This will allow for the correlation of inter-point interfaces to determine the position and depth of major geological changes.

Appendix 4. Electrotelluric Geophysics

Electrotelluric currents are geo-magnetically induced currents that flow through conductive formations in the subsurface. They are primarily created by natural fluctuations in the earth's geo-magnetic field, caused by solar winds. These currents are generally very low in frequency, Less than 0.1Hz, however lightning in the earth's atmosphere also causes high frequency telluric currents to be induced in the subsurface. The lower the frequency of the geomagnetic field disruption the deeper the EM field can penetrate into the subsurface, to create a telluric current. Thus the frequency of the detected electrotelluric current is directly proportional to its depth.

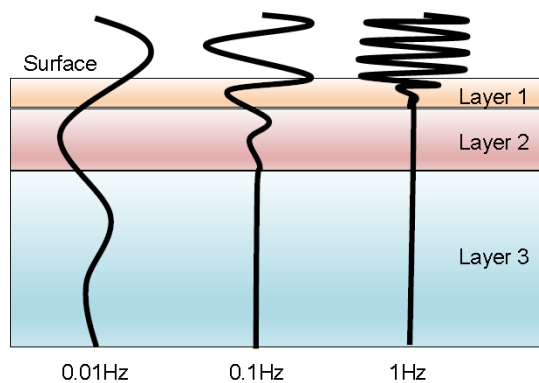


Figure 1 - Electrotelluric Frequency dependence

4.1 Theory of Operation

The depth to which a particular frequency can penetrate the subsurface is known as the skin depth, and is determined by the frequency of the EM field and the resistivity of the surface. This is shown in the equation below.

$$\delta = \sqrt{\frac{2\rho}{\omega\mu}}$$

Where:

- δ : is skin depth
- ρ : is the ground resistivity
- ω : is the angular frequency of the telluric current
- μ : is the magnetic permeability

Electrotelluric geophysics makes use of this frequency to depth dependence to allow for the calculation of the strength of a telluric current at any given depth.

The strength of a particular telluric current frequency is determined by calculating the Fourier transform of the recorded frequency spectrum at a sounding location as shown in Figure 2.

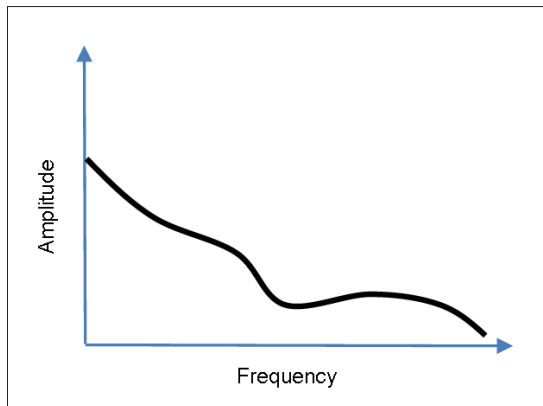


Figure 2 - ET Frequency domain

This in effect shows the electrical conductivity variability within a formation at any given depth.

In order to calculate the actual formation apparent resistivity, the magnetic field component at the right angle to the electric field must be integrated using the equation:

$$\rho_a = 0.2\tau \left(\frac{E_x}{H_y} \right)^2$$

Where:

- ρ_a : is the apparent resistivity
- τ : $2 \pi / \omega$
- E_x : is the Electric Field component
- H_y : is the magnetic field component

Electrotelluric methods are useful at delineating lithological structures at great depth. They are also useful at providing calibration information to the electroseismic data in terms of seismic velocity estimation.

When correlated against electroseismic data, they can provide deeper insight into the nature of the electroseismic response interpretations.

Appendix 5. Electro seismic Interpretation parameters, assumptions and limitations.

5.1 Parameters

All ES investigations produce data sets which are relative by definition. These relativities include:

- 1) Depth estimates are relative to the applied seismic velocity models utilised while producing an ES model.
- 2) Hydraulic parameters are relative to the applied calibration data used to create a model.
- 3) Geological parameters such as formation conductivity and chemical composition affect the ES data being interpreted.
- 4) Electro seismic interpretations are relative and subject to the geological context of the site being investigated.

Thus all the ES response data is considered to be relative to the site geological and hydrogeological composition.

5.2 Assumptions

As such, assumptions must be made when interpreting ES data sets. These include but are not limited to:

- The site geology at each survey point is assumed to be of similar seismic velocity parameters. This is not always the case as slight variations in geological formation density, porosity, compressibility and stratification are always present. This results in slight variations in the seismic velocity profiles between each unique ES sounding location even if the geology is similar. Statistically, these variations can be up to 25% of the base velocity model for the site. As such, any interpretation of the depth estimates for ES responses must account and compensate for these potential depth estimate variations. In most cases, the unique seismic velocity profile for each survey point generally can't be known, a general seismic velocity model is applied to all the survey points in a project. This may produce some variations in the interpreted depth of the resultant ES responses.
- ES data sets are vertical data sets, describing the geology and hydrogeology of the site directly under the survey point. As such, ES survey point lateral resolution plays a significant role in the size and dimensions of the near vertical geological structures and features that be delineated or interpreted by ES data sets.
- Even though the vertical resolution of an ES sounding is relatively high, with samples being taken every 8 to 12cm vertical depth depending on the velocity model used, it is important to note that a great deal of raw resolution is lost during the processing of the data. This is due to filtering and smoothing constraints applied to the data sets. As such, it is practically not possible to accurately delineate geological features thinner than 1m in thickness.

- ES data sets for 2D and 3D interpretations rely heavily on interpolation to describe the correlation between geological and hydrological features. As interpolation parameters are set to default values that assume that the geological setting of any particular site is mostly stratified in a horizontal or near horizontal plain, these interpolation strategies should always be considered when interpreting complex geologies.
- In the case of un-calibrated hydrological data interpretations, it must be understood that all ES hydrological data is subjective and relative to the maximum recorded ES response values. These data sets must be considered with reference to the geological setup of the site. For example, a low permeability formation such as granite generally does not host high permeability, or hydraulic conductivity, or aquifers. There may be slight variations in the hydraulic conductivity or permeability in the makeup of such geologies. However, a relative ES interpretation of such geology may be misinterpreted as a high permeability aquifer. The best way to avoid these misinterpretations is to calibrate the model to the hydrological parameters of a known well that resides within the same geology as the survey site.
- ES methods cannot predict the groundwater yield that an interpreted aquifer will produce. Any estimates of groundwater flow potential, discussed in this ES study report, are merely an indicator of where the best interpreted location is for groundwater flow.
- ES data cannot currently determine the porosity of a formation.
- The ES processing and interpretation workflow assumes that data collected in the field was done on surface soil and sediment conditions of similar characteristics. It assumes that the site soil conditions are uniform in moisture content, electrical conductivity and soil composition. It is also assumed that the ES electrode placement and recorder settings were conducted in exactly the same manner for each sounding and that noise sources were removed as far as possible. The seismic source energy is also assumed to be consistent in strength, for every seismic event generated to produce a recorded ES conversion.
- It is assumed that the ES survey was done in the lowest noise location possible and that all possible extraneous sources of seismic noise were eliminated from the site before surveying commenced.
- Any electrical noise sources such as power line noise is assumed to be consistent in frequency and amplitude and produces odd and even harmonics that can be predictably filtered out. Any other types of electrical noise sources such as electric fences are assumed to have been removed from the site.
- Fracture indicators can be generated by interfacial responses, ferrite, quart or sulphide bearing geological features. Any interpretation of possible bedding plain fractures must be done cautiously. Any other possible geological features that may have caused such fracture indications must be considered.

- ES data interpretations and calibrations rely heavily on the correctness and relevance of the geological and hydrological data provided for the investigation site. If incorrect data is provided, then it is possible that incorrect results and interpretations of the ES data may result.
- Strong geological interfacial seismic reflectors may cause mirrored ghosting effects in an ES survey. This is due to a strong geological reflector re-bounding the injected seismic wave which then re-passes through geological features on its way back to the surface. This causes what appears to be a mirror image of the ES data with depth. As such, known strong geological seismic reflectors should always be considered when interpreting ES data set.
- ES methods cannot determine the depth of the static water table at a survey point. As such, any permeable formations indicated on ES data sets that reside above the static water table, must be considered as poor aquifers that do not contribute to groundwater flow or yield.
- ES Methods cannot differentiate between fully and partially saturated aquifers. As such, ES methods cannot determine if an aquifer has been partially dewatered or if an aquifer is fully saturated. Even if an aquifer has been depleted, there is still water within the aquifer which allows an Electro-seismic conversion to take place which describes the permeability of the aquifer and the pore space fluid characteristics. However, it will not indicate whether the aquifer is productive or not. With this in mind, all aquifers delineated by ES methods are assumed to be fully saturated and capable of yielding groundwater.

5.3 Limitations

As there are a number of assumptions made using ES methods to estimate and interpret the geology and geohydrology of a site, the results presented as well as the interpretations made, in this report, cannot be guaranteed to be absolutely correct. ES data can only provide an estimated insight into the geological and hydrogeological makeup of a study site based on the information available.

The behaviour of groundwater is complex. Our conclusions are based upon the analytical data presented in this report and our technical experience. Future advances in regard to the understanding of groundwater and its behaviour, and changes in regulations affecting its management, would impact on our conclusions regarding its potential presence on this site. Where conditions encountered at the site are subsequently found to differ significantly from those anticipated in this report, Geo9 must be notified of any such findings and be provided with an opportunity to review the data provided.

Appendix 6. Core Log CH001A

HOLE ID: CH001A		HOLE LOCATION: 7257512mN (GDA94 MGAz53) 393461mE	Drilled by: Mitchell Rig 26	
Date Spudded: 13/12/2013		Date Completed: 5/1/2014	Total Depth: 1094.66	Logged by: Bruce Wilson
From (m)	To (m)	Description: Elevation 425m ASL	Comments:	Graphic Log
0	6	SAND: Red ochre dune sands - unconsolidated		
6	9.3	SAPROLITIC SANDSTONE: red brown mottled pale grey clay rich very fine to fine grained clayey sandstone		
9.3	154.5	SANDSTONE: Red brown, ochre, brown, pale grey, grey sandstone. Mottled, banded, blotchy, spotted, banded very fine to fine grained well sorted sandstone. Firm to hard well cemented with clay matrix, Sporadic calcitic cemented beds/ laminae in parts. Grains are predominantly quartz with mica, lithics and black opaque minerals in parts. Silty laminae in places grading to siltstone interbeds. Bedding thickness ranges from mm scale to decimetre scale – repetitive. Siltstone laminae/interbeds increasing towards bottom of sequence.		
154.5	334.5	SANDSTONE: Pale grey interbedded with red brown medium to coarse sandstone – predominantly medium grained. 187-222m interval has common to abundant claystone and siltstone laminae and interbeds. Occasional inferred aquifers at natural partings in core with coarse grains – e.g. 321m. Some narrow soft clay bands (see geotech log). Becoming finer with depth, grades to siltstone (red brown) in places. Some grey units several metres thick.	Aquifer? 321m	
334.5	343.5	INTERBEDDED SILTSTONE AND SANDSTONE: Predominantly red brown to brown interbedded siltstone and very fine to fine grained sandstone with common clay filled vughs/flattened voids. Core commonly breaks at vugh/void locations. Some soft sediment deformation textures. Calcite cement and vugh lining is common in places. Vughs could be bioturbational. Grades to claystone beds in parts.	Clay filled voids in places Vughy with clay filled cavities – breaks easily	

HOLE ID: CH001A		HOLE LOCATION: 7257512mN (GDA94 MGAz53) 393461mE	Drilled by: Mitchell Rig 26	
Date Spudded: 13/12/2013		Date Completed: 5/1/2014	Total Depth: 1094.66	Logged by: Bruce Wilson
From (m)	To (m)	Description: Elevation 425m ASL	Comments:	Graphic Log
343.5	390	SILTY CLAYSTONE: Red chocolate brown; mottled, spotted and banded medium bluish grey in parts. Homogenous textured claystone. Flaky in parts – breaks along bedded laminae. Very hard in parts. Thin (<5cm) beds of angular to sub angular clasts which form a sedimentary breccia in places. Occasional thin interbeds of medium grained sandstone. From 352-357m greenish bands of claystone and soft plastic clay occur to several cm. Core discs and is sub-fissile. Assumes a banded texture. Some off-white bands. Vertical/discordant calcite veins from 361-363m. Becoming tightly banded and calcitic 359-373m. Sandstone interbeds to 0.5m (medium – coarse grained, poor to moderate sorting) begin at 370m and continue to base of unit. Fossil rich bed 0.15m thick consisting of mollusc shell fragments (dolomitised) at 377.3m	Rich red chocolate colour – noticeable colour change Purplish in parts Green bands from 352m with some soft plastic clay (smectite?)	
390	453	SANDSTONE interbedded with SILTSTONE: greenish grey, grey, off white, dark grey interbedded sandstone and dolomitic siltstone/dolostone. Distinct “camouflage” texture as seen in previous hole. Beds from mm scale to decimetre scale. Sandstone is predominantly very fine to fine grained and firm to very hard. Siltstone is dolomitic. Bed disruption due to bioturbation is common. Sandstone becomes proportionately more dominant with depth. Well cemented with probable dolomite and silica cement. Sandstone is predominantly well rounded very fine to fine quartz grains with some lithics and common black opaque stringers. Becoming more massive in placed with depth; medium grain size and well sorted quartz grains more common with depth. Black very fine grained carbonaceous rich bands in places with silty interbeds. Some dark grey siltstone beds to 1m thick. Pebble dyke/breccia 0.3m thick at 432m – contains disseminated pyrite. Narrow breccia bands in places thereafter to 442.5m. Good inferred porosity in strongly disked zone 446-447.6m. Worm burrows becoming more distinct with depth.	Fossils, bioturbation and distinct ‘camouflage’ texture or pattern Siltstone around 429m as in CH003 Breccia as in CH003 Possible aquifer at 446m	

HOLE ID: CH001A		HOLE LOCATION: 7257512mN (GDA94 MGAz53) 393461mE	Drilled by: Mitchell Rig 26	
Date Spudded: 13/12/2013		Date Completed: 5/1/2014	Total Depth: 1094.66	Logged by: Bruce Wilson
From (m)	To (m)	Description: Elevation 425m ASL	Comments:	Graphic Log
453	502.2	SANDSTONE with interbedded SILTSTONE: Generally as above with a colour change in the camouflage pattern to a more reddish brown overtone. Arguably more siltstone interbeds. Some worm burrows are vughy. Mottled red brown with greenish pale grey blotches and bands. Pale grey green relatively homogenous fine to coarse grained sandstone unit with multiple/ drill breaks/discs/biscuits from 481.6-490m possible aquifer zone. 493-501.3m is predominantly coarse red brown (hematite stained), rounded and well cemented quartz grains – minor bioturbation and relatively homogenous. This may be a basal sandstone unit. Interbedded with banded siltstone in final metre. Overall a non to weakly calcareous unit.	Colour change to predominantly red brown Possible aquifer zone 481-490m Generally non-calcareous	
502.2	607	SILTSTONE: banded/laminated multi-coloured (brown, green, blue, grey, yellow) siltstone. The initial finely laminated (mm scale) siltstone beds are calcareous – probably calcitic cement. Intermittent fine to medium grained sandstone beds (decimetre down to cm scale). Becoming weakly to non-calcareous with depth – probably becoming dolomitic as cement is hard and carbonitic in appearance. Interbedded dark red brown clastic siltstone with paler grey/green/blue dolostone/dolomitic siltstone – paler units are harder. Minor bioturbation in places. Dolomite patches, blebs and nodules appear at approximately 572.5m, narrow veins concordant with bedding also begin. Occasional discordant dolomite veins. From approximately 555m crystalline dolomite becomes apparent.	Calcareous initially Becomes dolomitic with depth “dolomite/ dolostone has arrived” Dolomite veining appears 555m. 568.8m orange salt like mineral (not halite) in a narrow (<1cm) band. Could be stained dolomite	

HOLE ID: CH001A		HOLE LOCATION: 7257512mN (GDA94 MGAz53) 393461mE	Drilled by: Mitchell Rig 26	
Date Spudded:13/12/2013		Date Completed:5/1/2014	Total Depth:1094.66	Logged by: Bruce Wilson
From (m)	To (m)	Description:Elevation 425m ASL	Comments:	Graphic Log
607	772.1	SILTSTONE: Interbedded red brown and pale bluish grey units. Red brown is siltstone and pale unit is dolostone. Only occasional multi-coloured laminae – predominantly decimetre scale and repetitive beds. Common dolomite blotches, veins (discordant) and laminae (concordant), probably 1-5% of core mass. Red brown clastic siltstone grades to very fine grained siltstone in parts. Minor calcareous laminae in parts. Chert nodules appear 672.5m. Natural breaks/fractures occur along narrow dark stylolites in dolostone. Dolostone beds become hard/partially silicified with depth. Approximately 728m fractured dolostone with chert and dolomite fracture fill. Fairly homogeneous red brown siltstone 720.5-725m	Interbedded siltstone and dolostone (dolomitic siltstone) Jay Creek Limestone? Brecciated dolostone at 633.5m (0.5m wide) in a red siltstone matrix Chert is banded and agate-like in places Possible marker bed 720.5-725m	
772.1	780.75	SILTY CLAYSTONE: Dark grey to medium grey finely laminated claystone very similar in texture and colour to 720-726m interval in CH003. Anhydrite blotches to 2cm diameter abundant in final 1.5m. Secondary gypsum growth post drilling (worm like fibrous crystals).	Coarse, bladed anhydrite and secondary gypsum common	
780.75	825.3	SILTSTONE: red brown to dark brown laminated siltstone grading to silty claystone; micaceous in part. Interbedded with pale grey dolostone – homogeneous and finely bedded in parts – some coarse anhydrite crystal clusters/aggregates visible in dolostone 10cm chert at 799.8m – fractured; also a large nodule at 807.4m. Appearance of vughy fractures in dolostone at 807.4m, halite (orange and coarsely crystalline) appears as fracture fill at 811.5m. vughy red siltstone with halite matrix in parts 818-825.3m	Halite at 811.5m	
825.3	860.5	HALITE: mid brown, reddish brown, translucent, coarsely crystalline secondary halite with skeletal residual dolostone and pitted and irregularly bedded anhydrite, dolostone mix. 75-80%+ halite. Commonly red brown with siltstone fragments. Very similar textures to CH003. (Hydrocarbon (oil) shows in salt 834.3-835; 840.25-840.75; 849m. introduced from drillers in core barrel). Clean looking salt intervals at 843.5-844.6m and 846.1-848m	Dark grey brown oil/hydrocarbon coating and inclusions 834m, 840m, 849m – introduced by drillers halite	

HOLE ID: CH001A		HOLE LOCATION: 7257512mN (GDA94 MGAz53) 393461mE	Drilled by: Mitchell Rig 26	
Date Spudded:13/12/2013		Date Completed:5/1/2014	Total Depth:1094.66	Logged by: Bruce Wilson
From (m)	To (m)	Description:Elevation 425m ASL	Comments:	Graphic Log
860.5	870.9	LIMESTONE/DOLOMITIC SILTSTONE: pale grey, buff to beige to mid grey, finely laminated, open cavities concordant to bedding; fractured in parts (discordant to bedding) grades to fine calcareous claystone in parts. Common halite fracture fill. Oily bituminous fluid (hydrocarbon) oozing from fractures and vughs in places across the unit. Common coarse anhydrite crystals in groundmass in part.	Limestone, dolomitic at top then grades to limestone Oil/bitumen shows (legitimate)	
870.9	882.8	HALITE: as above (825-826) with common swirling and pitted anhydritic dolostone interbeds and inclusions.	Halite	
882.8	887.4	LIMESTONE: as above (860-870) 0.2m milled/rounded limestone breccia with halite matrix support at beginning of sequence. Oil shows	Limestone Oil Show	
887.4	1079.5	HALITE: as above, dirty with dolostone bands and anhydritic in part. Cleanish halite from: 889.4-891.3m; 900-901m; 914.3-915.3m; 956-957m; 1012.2-1014m. Calcareous insolubles (limestone fragments and matrix fill) common past 900m. Coarse halite crystals (cm scale) with common anhydrite, dolomite calcitic siltstone and silt. Dolostone band 15cm wide at 978.1m and 957m salt impregnated dolomite 966.7-968.5. Reddish pink haematite staining of halite common in parts. Becoming sandy and silty at base of unit.	Mud loss at 893.4m – no returns, regained after hole was treated. Below 1000m salt becomes progressively dirtier/siltier compared to upper section	
1079.5	1083.4	HALITIC SANDSTONE: Red brown, beige to grey swirls in part. Silty salty sandstone with swirling dolostone and anhydrite inclusions/vertical beds. Sand and silt content increases to > 75%. Poorly sorted very fine to coarse quartz and lithic grains with silty and halite matrix. Halite impregnation and occasional bands.	Rapid transition to sandy/silty layer	
1083.4	1086	HALITE: Dirty reddish brown, translucent coarsely crystalline halite with 0.5m relatively pure but hematite stained interval.	Halite – re-entry	
1086	1090.4	SANDY LIMESTONE/CALCAREOUS SANDSTONE: Pale to medium grey banded and finely bedded limestone grading to a calcareous sandstone/siltstone with depth. Becoming possibly more dolomitic with depth. Chert nodules at start of unit. Fractured with halite fracture fill (orange) and concordant bands (also orange as well as acicular and translucent). Limestone changes to very fine and fine grey, well sorted calcareous sandstone which grades to calcareous siltstone in parts. A limey unit.	Limestone unit	
1090.4	1091.8	SANDSTONE: Mid grey homogenous very fine to fine, well sorted silty sandstone grading to siltstone. Calcareous and probably dolomitic cement. “halite veins”	Calcareous sandstone with halite stockworks	



HOLE ID: CH001A		HOLE LOCATION: 7257512mN (GDA94 MGAz53) 393461mE	Drilled by: Mitchell Rig 26	
Date Spudded:13/12/2013		Date Completed:5/1/2014	Total Depth:1094.66	Logged by: Bruce Wilson
From (m)	To (m)	Description:Elevation 425m ASL	Comments:	Graphic Log
1091.8	1092.4	BRECCIA: Rounded clasts of pale grey calcareous sandstone and red brown silty sandstone in a halite matrix support.		
1092.4	1094.66	SANDSTONE: Red brown very fine to fine grained sandstone with a silty matrix. Grades to siltstone. Salt bands/veins to 5cm (1 band per metre).		



Appendix 7. Drillers Log Bore WT6

THE NORTHERN TERRITORY OF AUSTRALIA

APPROVED FORM 21 (25/01/2011)

STATEMENT OF BORE

As per Water Regulations (2009)

WT 6.

Name of Owner: <u>Tellus Holdings</u>				Registration No.: RN19194			
Location/Address: <u>Chandler Salt Mine</u>				BC Permit No: _____			
Intended Use: _____							
GPS Location:		Zone: <u>53</u>	GDA94 ☒ Other: ☐	Specify: _____	Easting: <u>393693</u>	Northing: <u>7257560</u>	

From	To	Particulars of Strata	Name of Drilling Company: <u>Diverse Resources Group P/L</u>				
0	2	Bouldery Loose Topsoil	Name of Driller: <u>Paul Juett</u>				
			Name of supervising driller <u>Paul Juett</u>				
2	7	Soft Redish Sandstone	Date Commenced: <u>20-07-15</u>				
			Date Completed: <u>27-07-15</u>				
7	306	Red Sandstone	Depth Drilled: <u>306</u> (m)				
			Completion Depth: <u>306 / 194</u> (m)				
			METHOD OF DRILLING				
			Other ☐	Auger ☐	Rev. Circ. ☐	Rotary Air ☒	Rotary Mud ☐
			Specify: <u>D.H.H</u>				
			HOLE DIAMETER		DRILLING FLUID		
			From (m)	To (m)	Dia. (mm)	Type	
			0	11.4	230	Air - Blade	
			11.4	288	220	Air - Hammer	
			288	306	141	Air - Hammer	

PARTICULARS OF CASING				PARTICULARS OF PERFORATIONS OR SCREEN STRINGS				
From	To	Dia (ID)	Type	From	To	Dia (ID)	Aperture	Type
.+6	11.4	253	Steel					
Pieso 1				170	188	25	1	Slotted
0	170	25	PVC					
188	194	25	PVCcap					
Pieso 2								
0	237	50	PVC	237	252	288-300	1	Slotted plus 6m Sump & Cap

Casing Suspended: Yes ☐ No ☐		Top of Packer Set at: _____ (m)	
Method: _____		Length of Packer: _____ (m)	
Height of Casing above GL: _____ (m)		Method of Packer Connection: _____	

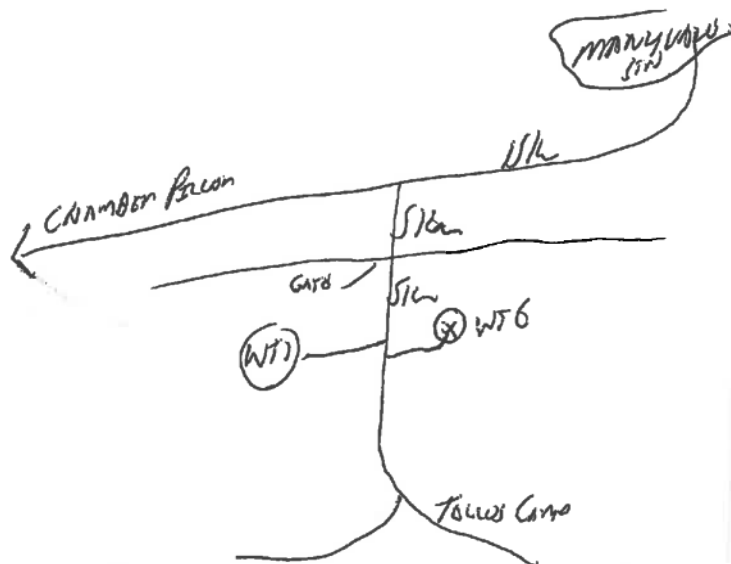
CEMENTING/GRAVEL PACKING			WATER BEARING BEDS							
From	To	Type	Depth (m)	Yield	SWL	Duration	Quality	EC	pH	Bottle No.
0	11.4	Grout	0	173	2	While Drilling				
11.4	163	Cuttings		237	5					
163	165	Bentonite		288	15	87.2	1	Salt	14,000	7.8
165	220	Gravel								RN19194
220	222	Bentonite								
222	306	Gravel								

STRATA / WATER SAMPLES		Completion Yield: <u>15+</u> (L/s)		Method: <u>Air</u>		Duration: <u>1</u>	
Have been ☐ Will be ☒		Completion SWL from GL: <u>87.2</u>				Depth of Lift: <u>306</u>	
Left at: <u>Alice Springs</u>							

NOTE: No company advertising is to be imprinted on this certificate apart from where requested.

LOCATION SKETCH OF BORE RN: RN19194

LOCATION DESCRIPTION OF BORE



25

km

NW ☐North ☐NE ☐West ☐

East ☐SW ☒South ☐SE ☐

OF:

Maryvale Station

1.3 km East of WT1

FINAL CONSTRUCTION STATUS

Capped



Casing Pulled



Left for Obs.



Abandoned



Equipped



Backfilled



Other



ADDITIONAL INFORMATION ABOUT THE BORE: (Include any information which may assist for future reference)

Note: The holder of the NT licence shall submit the form to the Department within 28 days of completion of any works.

I certify that the information contained above is true and correct, and that I have complied with the bore licensing requirements and conditions of the Bore Construction Permit as issued if a Bore Construction Permit was required.

Paul Juett

121

Date

28-07-15

Name and licence number of driller:

Signature and licence number of licensed driller:

FOR OFFICIAL USE ONLY

How Located:

GPS



TST



Survey



Hand Plotted



Other



DESCRIPTION OF PROPERTY:

Rural



Mineral



Pastoral



Reserve



VCL



Other



Lease No:

Lot No:

Hundred of:

Portion No:

Section No:

Town of:

Class of Bore:

Town



Domestic



Investigation



Agriculture



Mineral



Pastoral



Other



Use of Bore:

Production



Investigation



Irrigation



Observation



Monitoring



Roads



None



Grid Reference:

AMG



Clark



Zone:

Scale:

Easting:

Latitude:

Map Name:

Northing:

Longitude:

Index Map Number:

Date Registered:

Bore Plotted on the map?

Yes ☐No ☐

Dept Officer:

Signature:

Remarks: