FY23 Ministers North SUR Phase 1 Hydrogeological Drilling Completion Report

Jim McDiarmid
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Electronic Approval Record

Author Role	Name
Field Hydrogeologist	Jim McDiarmid/Kristopher Stewart
Reviewer Role	**Name**
Senior Field Hydrogeologist	James Clothier/Mark Musgrave
Approver Role	**Name**
CNPH Strategic Hydrogeologist	Nicholas Quaglia

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Key Stakeholders

The following people have an interest in this document and should be informed of any significant changes to the content.

Position	Name	
CNPH Strategic Hydrogeologist	Nicholas Quaglia	
CNPH Hydrogeology Superintendent	Aine Patterson	
Field Hydrogeology Superintendent	Jon Hanna	
Senior Field Hydrogeologist	Mark Musgrave	
Senior Field Hydrogeologist	James Clothier	

EXECUTIVE SUMMARY

Yandicoogina Gorge is home to locally significant persistent pools and associated groundwater dependant ecosystem (GDE).

The primary objectives of this program were the targeting and installation of four injection bores around the Yandicoogina Gorge to enable supplementing groundwater levels upstream of the Sanders Seep GDE. Pilot hole drilling built upon data collected during the initial phase of drilling in FY20 to determine the viability for a Managed Aquifer Recharge (MAR) scheme at Ministers North.

The technical objective for the program was achieved with the final development yields for three of the four production bores being 20L/s with HMN0042 being significantly higher, at approximately 50L/s. There is good potential for the installed re-injection bore field to mitigate any further impact on the Yandicoogina GDE. Additionally, the network of monitoring bores at Ministers North has been expanded to help with the future groundwater assessments.

Step tests analysis was undertaken on the injection bores and suggest injection rates of 20L/s for HMN0045 and greater than 100L/s for the other three bores is achievable. Viability of these results is uncertain as the suggested rates are outside the ranges tested during the step tests and may be impacted by broader regional aquifer conditions.

Geology was broadly in agreement with the existing geological model for the exception of HMN0042, which intersected Mt McRae shale 22 m deeper than anticipated.

Ground conditions were generally competent across the project area. Two monitoring bores HMN0046 and HMN0047 had to be installed in-rod to achieve technical objective. During the drilling of HMN0042 on the pad of HMN0046, hard ground conditions at surface prevented the DR casing being advanced down to the broken ground at depth. The bore was ultimately installed to meet technical objectives.

Due to DR drilling trying to penetrate hard ground, the program took longer than anticipated and could have been completed more efficient with a conventional drilling rig.

One remaining anomaly in the area is the low yields observed in HMN0024 during the previous drilling campaign, and how an area of lower permeability might impact groundwater flow around the Yandicoogina Gorge.

The Keystone fault does not appear to form a barrier to groundwater flow and may contribute to elevated yields due to increased fracturing observed within its vicinity.

Groundwater chemistry results from the field program and samples taken from production bores where comparable to previous results from the project area. Ground water is low EC, slightly basic pH with slightly dominant Bicarbonate and calcium, suggesting near source recharge water. Two of the pool within the Yandicoogina Gorge show signs of mixing with surface water during the wet season.

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1 INTRODUCTION

This report presents the findings of the **FY23 Ministers North SUR Phase 1** between August and December 2022.

All work was conducted in accordance with the proposal and plan from Nicholas Quaglia (CNPH Strategic Hydrogeologist) dated 12th May 2022 and further revised in accordance with the site conditions.

1.1 Project Purpose

The purpose of this project is the implementation of a re-injection bore field to mitigate any further impact on the Yandicoogina Gorge ground water dependant ecosystem (GDE). The Yandicoogina Gorge GDE has experienced consistent groundwater level declines since ongoing monitoring started in 2019, which has the potential to lead to vegetation degradation and drying of natural water bodies within the gorge. The mechanism of declining water levels is currently uncertain, whether it is due to natural climate cycles or due to mine dewatering, either localised mine dewatering (Yandi operations) or more widespread operations within the region.

Data presented in this report leverages learnings and results from the two previous drilling programs at Ministers North, FY21 Ministers North DEW Phase 1 and Minister's North FY20 Water Supply & Monitoring Drilling.

1.2 Location

Ministers North is a Brockman Iron Formation deposit that is located approximately 32 kilometres East North-east of Mulla Mulla camp, situated between Mining Area C and Yandi.

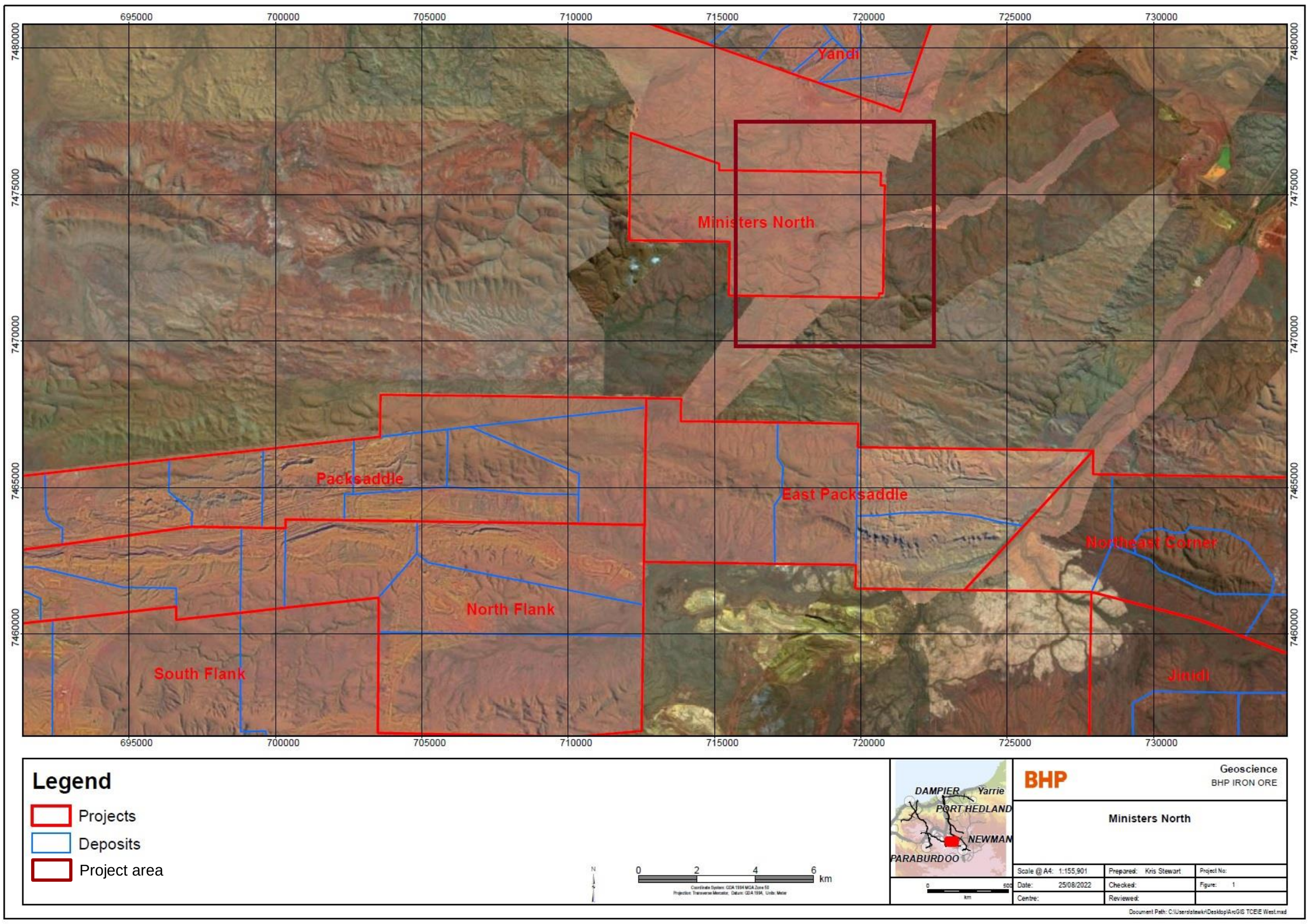

Figure 1: Location Map

1.3 Technical Objective of the Project

The Key Objectives were:

- To augment the existing monitoring network around the Ministers North Project. (4 MB)
- To assess hydrogeological connectivity and injection capacity for MAR. (9 MB)
- To install four large diameter production bores to enable the future implementation of a re-injection bore field to mitigate any further drawdown impact on the Yandicoogina Gorge GDE.

1.3.1 Hydrogeological Setting and Targeting Rationale

The FY23 Ministers North SUR Phase 1 drilling program is proposed to begin the implementation of a re-injection bore field to mitigate drawdown impact on the Yandicoogina Gorge GDE. This program focuses on targets around the western end of the gorge, on the eastern side of the rail line. The scope of work expands on knowledge of the area based on numerous existing frontier piezometers and monitoring bores. Additional holes were planned to expand the monitoring network and replace some failed frontier monitoring points.

Targeting was based on pervious drilling outcomes, including knowledge of fracturing within Joffre Member, Dales Gorge Member and fresh Mt. McRae Shale. Additionally, structurally controlled permeability associated with the Wirriba Anticline was targeted.

A line of re-injection bores is proposed between the possible future mining area at Ministers North and the downstream GDE. This will help supplement declining water levels in the base of the Yandicoogina Gorge and prevent further environmental impact on the GDE.

Program Overview

- The program involves pilot hole drilling, injection bore drilling and test pumping in FY22/23.
- Four regional 50 mm monitoring bores to expand monitoring network.
- Nine investigation Pilot holes for target assessment to be converted into 50 mm monitoring bores.
- Four 304 mm injection bore locations were chosen following completion of the pilot hole program.
- Test pumping will follow production bore installation.
- Pilot holes are focused on the eastern side of the rail line.
- Previous drilling from FY20 and FY21 has informed some potential injection bore targets also.

The scope of work is presented in Table 1, and Targeting Intents and Termination Criteria in Table 2.

Table 1. Scope of Work

Program	No. of holes	Average depth (m)	Total (m)	Gamma	OTV	ATV
Monitoring Bores	13	118.5	1540	N	N	N
Production Bores	4	100	400	N	Y	Y
Hole tracking link – http://csmsdc-gdmp01/HoleTracking/Program/PadDetails/4892						

Table 2. Technical Objective & Termination Criteria

Hydro Pad Name	Planned Hole Name	Planned Depth (m)	Technical Objective	Termination Criteria
MN_FY22_PAD005	HMN0042	100	Injection bore to investigate the viability of MAR to manage the Yandicoogina Gorge.	Planned depth based off findings from monitoring bore HMN0046
MN_FY22_PAD006	HMN0043	100	Injection bore to investigate the viability of MAR to manage the Yandicoogina Gorge.	Planned depth based off findings from monitoring bore HMN0047
MN_FY22_PAD008	HMN0044	100	Injection bore to investigate the viability of MAR to manage the Yandicoogina Gorge.	Planned depth based off findings from monitoring bore HMN0049
MN_FY22_PAD004	HMN0045	50	Injection bore to investigate the viability of MAR to manage the Yandicoogina Gorge.	Planned depth based off findings from monitoring bore HMN0016
MN_FY22_PAD005	HMN0046	100	Investigate the viability of MAR to manage the Yandicoogina Gorge.	Target depth or if ground becomes hard and yield drops off.
MN_FY22_PAD006	HMN0047	100	Investigate the viability of MAR to manage the Yandicoogina Gorge.	Target depth or if ground becomes hard and yield drops off.
MN_FY22_PAD007	HMN0048	100	Investigate the viability of MAR to manage the Yandicoogina Gorge.	Target depth or if ground becomes hard and yield drops off.
MN_FY22_PAD008	HMN0049	120	Investigate the viability of MAR to manage the Yandicoogina Gorge.	Target depth or if ground becomes hard and yield drops off.
MN_FY22_PAD009	HMN0050	120	Investigate the viability of MAR to manage the Yandicoogina Gorge.	Target depth or if ground becomes hard and yield drops off.
MN_FY22_PAD010	HMN0051	150	Investigate the viability of MAR to manage the Yandicoogina Gorge.	Target depth or if ground becomes hard and yield drops off.
MN_FY22_PAD011	HMN0052	150	Investigate the viability of MAR to manage the Yandicoogina Gorge.	Target depth or if ground becomes hard and yield drops off.
MN_FY22_PAD012	HMN0053	150	Investigate the viability of MAR to manage the Yandicoogina Gorge.	Target depth or if ground becomes hard and yield drops off.
MN_FY22_PAD013	HMN0054	100	Regional monitoring location	Target depth or if ground becomes hard and yield drops off.
MN_FY22_PAD014	HMN0055	100	Regional monitoring location	Target depth or if ground becomes hard and yield drops off.
MN_FY22_PAD015	HMN0056	150	Regional monitoring location	Target depth or if ground becomes hard and yield drops off.
MN_FY22_PAD016	HMN0057	100	Investigate the viability of MAR to manage the Yandicoogina Gorge.	Target depth or if ground becomes hard and yield drops off.
MN_FY22_PAD017	HMN0058	100	Regional monitoring location	Target depth or if ground becomes hard and yield drops off.

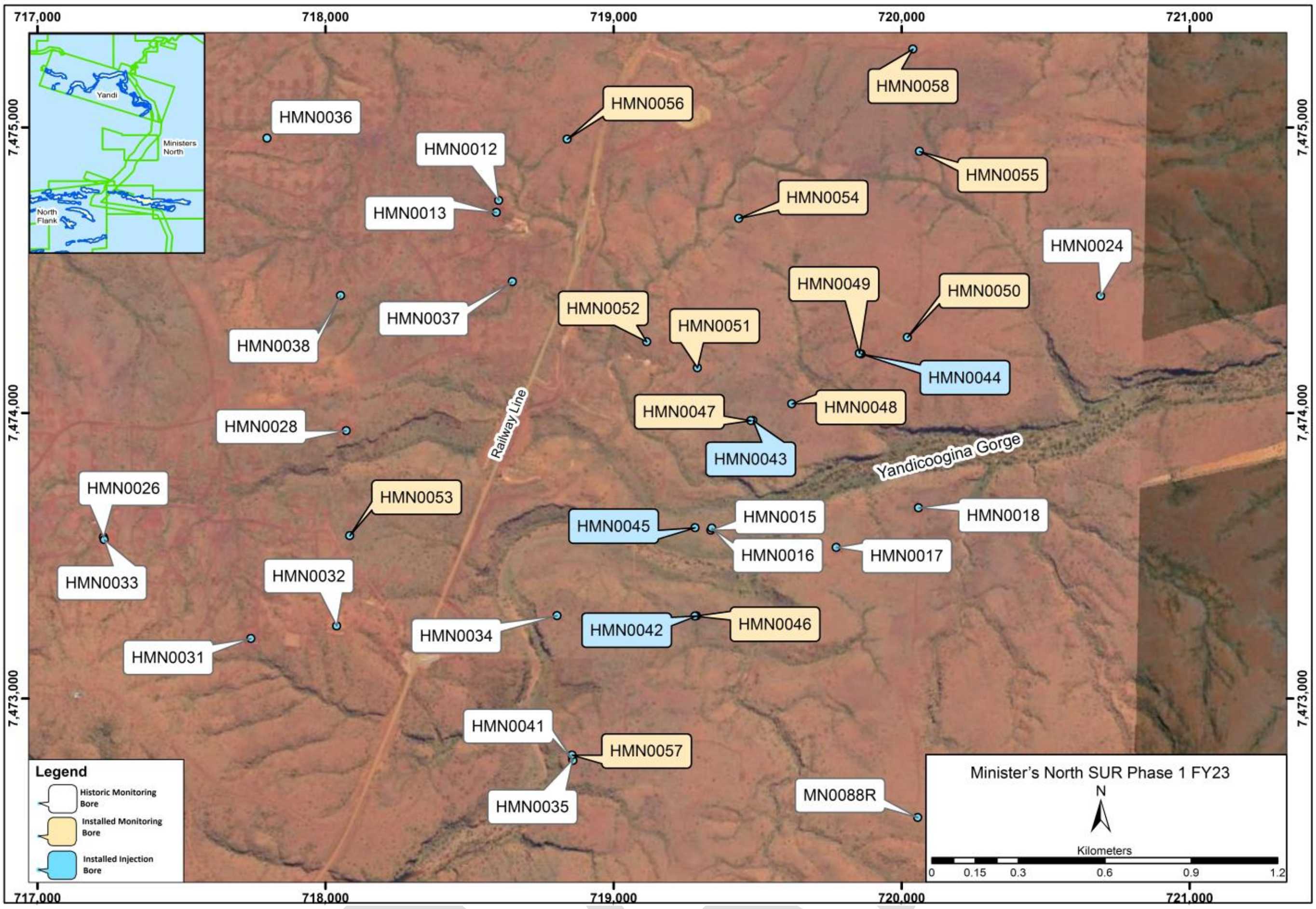

Figure 2. Monitoring and Injection Bore Location Map

2 Geological and Hydrogeological Setting

Ministers North is situated in the northern region of the Hamersley Province which is characterised by mild deformation with open folding. The Ministers North deposit extends approximately 10 km E-W by 5 km N-S and is located 10 km south of Yandi. The deposit covers an E-W-trending, doubly plunging anticline of Brockman Iron Formation (the Wirriba Anticline), which is cored by Mount McRae Shale Formation. The Wirriba Anticline changes from east-west trending in the west to northwest-southeast trending in the eastern end of the deposit (white line in Figure 3). This offset in the anticline coincides with the intersection of the Keystone fault, a low-offset steeply dipping normal fault (Kari & Androszczuk, 2021). Mineralisation occurs predominantly in the Dales Gorge Member of the Brockman Iron Formation. It extends for 6 km N-S and 2 km E-W and to depths of 300 m. A representative cross-section is shown in Figure 4, taken from BHP (2022).

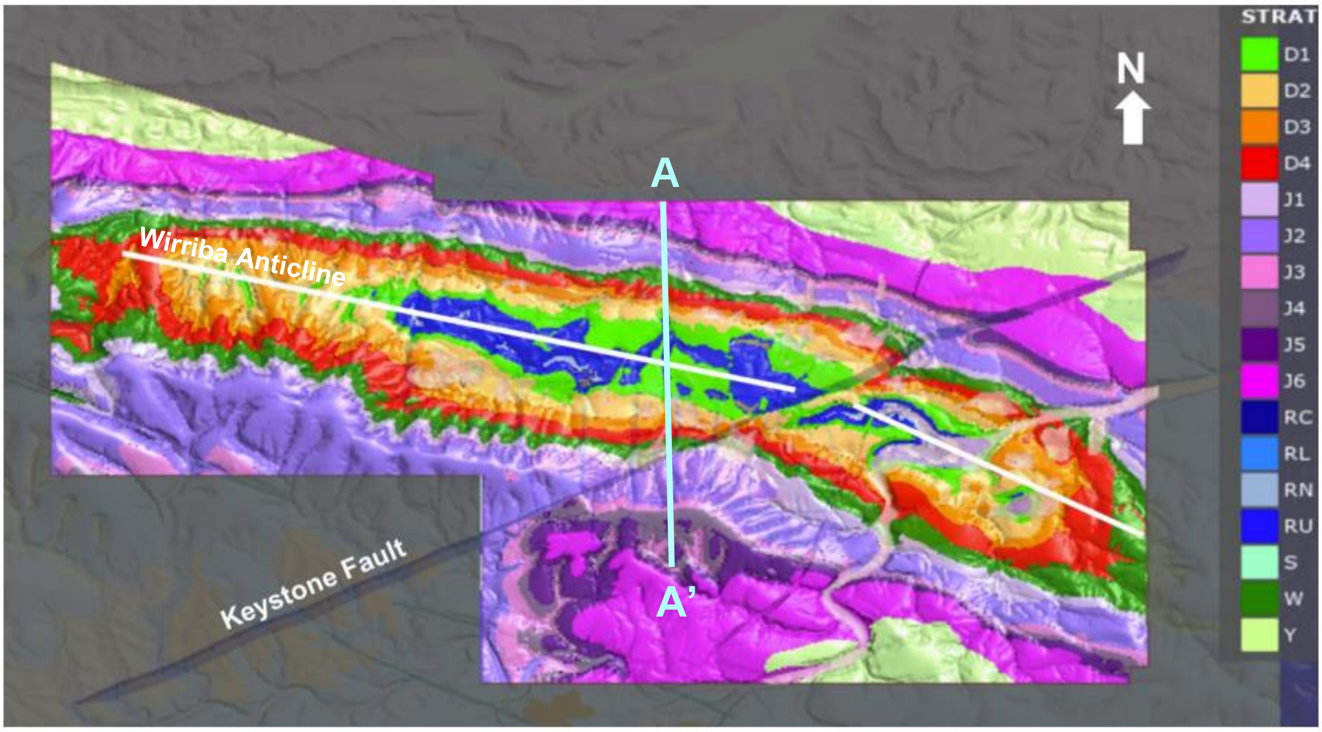

Figure 3. Geological map of the Ministers North Deposit

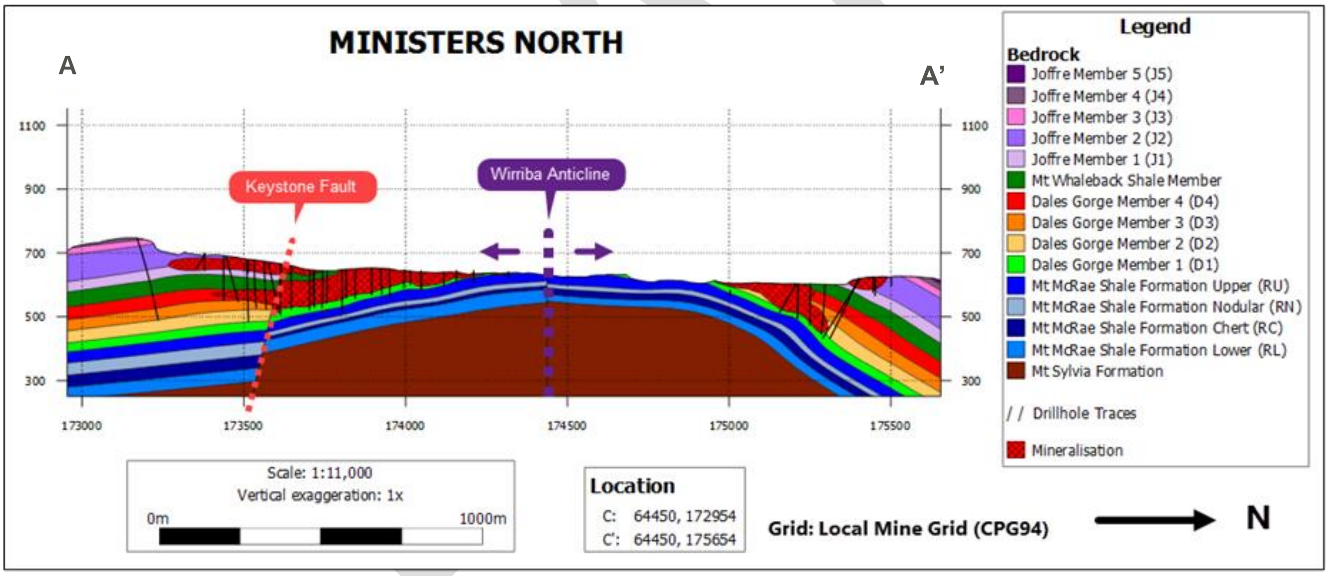

Figure 4: Geological cross-section A-A' through Ministers North (a Brockman deposit) after BHP (2022)

3 Field Program

3.1 Health Safety and Environment

All work undertaken during the hydrogeological drill program was in accordance with existing WAIO Geoscience and Water Planning safety procedures and requirements. The work was executed under PEAHR number 202202282

During the planning phase, technical risks and challenges were highlighted before the execution and appropriate controls were put in place for the duration of the program, as listed below:

Table 3. Risk and constraints for drilling program

Technical Risk	Activity
Fibrous Material	• Fibrous intercept is highly unlikely (Weathered Brockman sequence).
Reactive geology	• Potential for intersecting McRae Shale at the base of a couple of holes, discharge to be contained if fresh pyritic shale encountered. • Captured in hole tracking.
Ground condition	• Potential difficult ground at depth when drilling through weathered dales gorge. • Note that the program area may be inaccessible following significant precipitation events.
Discharge management whilst drilling	• As per current DMP. • High yield anticipated in some locations (note that some RC targets had comments in logs saying the pad was flooded). • Water quality expected to be well within discharge limits. • Locations adjacent to the gorge are close to the Sensitive drainage area, therefore discharge will have to be monitored closely if sump becomes full.
Discharge management whilst test pumping	• DMP for test pumping to be completed following selection of injection bore targets.
Proximity collars	• A minimum step-off distance of 15m from planned and existing EXP collars was incorporated in target planning. • Liaised with earthworks planner to determine closest distance we can get to recently drilled RC collars/ hydro holes.
Other	• 2mm aperture screens required for injection bores • Coarser gravel also required for larger aperture size on screens (>6.4mm)

3.1.1 Safety Events

Material Impact During Movement of Risk Goods – Event number 1000519089. During rig pack set move onto the HMN0053 pad, the operator was unloading equipment from the support truck using a telehandler. Whilst removing a storage cage from the support truck, contact was made with an adjacent gravel hopper resulting in the gravel hopper falling from the offside of the support truck. Mobile plant exclusion zones were in place and no personnel where within the mobile equipment area except the telehandler operator.

Uncontrolled Dropped or Falling Objects – Event number 1000549032. During drilling of HMN0045, the top cap and bearing of the air swivel located on top of the drill head because detached and fell from height. The top bearing of the air swivel, weighing approximately 2.5kg, fell 5.5m landing within the personnel exclusion zone. An investigation was undertaken, and equipment inspected, replaced and re0engineered to prevent future potential falling object incidents.

Steep terrain has previously caused safety concerns at Ministers North and was identified during the planning of the program and earth works where undertaken to ensure all access tracks had been prepared to allow safe access for rig movement in and out of the project area around the Yandicoogina Gorge.

All proximity collars were identified and controlled with no incidents.

3.2 Drilling and Installation

The drilling and completion of the groundwater monitoring bores was carried out in accordance with the WAIO Geoscience Drilling Standards, WAIO Hydrogeology Bore Completion Criteria, and followed a detailed design and specification compliant with the National Uniform Drillers Licencing Committee (NUDLC) 2020, Minimum Construction Requirements for Water Bores in Australia, 4th Edition.

The drilling and installation were undertaken by Ventia DR4 utilising dual rotary (DR) and conventional hammer (CH) drilling methodology between 19th August 2022 and 5th Dec 2022. Target depths of the boreholes were confirmed by the Field Hydrogeologist, as guided by the Target and Termination Criteria (Table 2), on the Draft Bore Plans for each planned bore pre-defined by the program designer. The target depths specified on the Draft Bore Plans were based on the anticipated geology and adjusted accordingly by the Field Hydrogeologist based in the actual geology encountered during drilling.

The target depth of the boreholes was confirmed by the Field Hydrogeologist as guided by the Target and Termination Criteria (Table 3) in the Draft Bore Plans for each planned bore pre-defined by the planning team. The target depths specified on the Draft Bore Plans were based on the anticipated geology and adjusted accordingly by the Field Hydrogeologist based on the actual geology encountered during drilling.

Drill cuttings samples were collected every two metres for detailed geological logging of the lithology, and air lift yields were estimated and recorded at the end of each drill rod (every 6 m). Water quality field parameters including temperature, electrical conductivity (EC) and pH were measured using a calibrated Hanna Instruments multi-parameter water quality meter. End of hole field parameters are given in

Table 5 with downhole variation shown on the hydrogeological bore logs in Appendix I.

Bore casing (screen and blanks) was installed to the depths specified in the Final Bore Plans (for Monitoring bores and Production bores) or sufficiently close to the design depth such that the technical objectives of the bore were achieved.

Gravel pack and low permeability surface seals were installed at the depths and tolerance as specified in the Final Bore Plan or sufficiently close to the design such that the technical objectives of the bore were achieved. Standard methods of gravel pack and low permeability seal installation were followed by the drilling contractors, including:

Monitoring bores were constructed using Class 25 50 mm NB slotted and blank PVC (Figure 4), using flush-threaded environmental casing. A medium specification gravel (size range 3.2 – 6.4 mm) was poured from hopper at surface into the hole annulus to provide a filter pack, and a 5-meter cement surface seal was placed at surface. Headworks consisted of lockable steel monument and a 0.6 x 0.6 m cement plinth.

Final bore locations were decided towards the end of the monitoring bore drilling phase. Production bore targeting was based on results from the monitoring bore drilling and previous drilling results, selecting the best spatial distribution of high yielding locations to maximise injection potential. Production bores were constructed with 12-inch blank steel bore casing and 2 mm wire wound screens. A coarse specification gravel (size range 6.4 – 12.8 mm) was poured in the hole annulus with a hopper to provide a filter pack, and a minimum 5-metre cement surface seal was placed at surface. Headworks consisted of steel caps and 1 x 1 m cement plinth.

A surface seal was initially not installed in HMN0045 due to unstable ground collapsing into the hole at surface during development. A sucker truck was mobilised to site to clear out the surface material and a 2m seal was able to be installed.

HMN0042 had a 2 m bentonite seal installed form 23 - 25 mbgl and grout seal installed by tremie in place from 23 mbgl to surface. A bentonite seal was placed on top of the gravel pack and allowed to set, to ensure grout does not penetrate the gravel pack envelop. All injection bores require surface seals from surface down to the of the productive zone to ensure water injected under pressure cannot leave the bore via the annulus.

Airlift development of the production bores was carried out until discharge was less than 4 grams of sediment per 20 litres of water. Water samples were collected and submitted to SGS Laboratory for Comprehensive Suite analysis.

The production bores were checked for verticality during the bore development stage, with the drilling contractor attaching a pump dummy (4 m length, 10” diameter) to the drill string as part of the developing tool.

EPIROC conducted downhole survey (ATV/OTV) to ensure casing and screens where in good condition and overall verticality was achieved.

All bores were surveyed by BHP Surveyors to Map Grid Australia (MGA), a grid coordinate system based on the Universal Transverse Mercator projection and the Geocentric Datum of Australia 1994. The bores were also surveyed for ground level and top of casing elevation reduced to mAHD.

Bore construction details and initial standing water levels (SWLs) measured following bore installation are presented in Appendix II

Figure 4. Monitoring bore completion (Left) Production bore completion (Right)

3.2.1 Pad and Access

The initial commencement of this program was delayed due to the difficulty with earthworks in hard ground. Additional earthworks on Steep terrain in and out of Yandicoogina Gorge was undertaken to allow safe access to this area. As the pad clearance was ongoing during drilling, some shifting between different areas of the project was required to ensure the drilling was not impacted.

Due to the exploratory nature of the pilot holes, some initial production bore target’s locations were changed based on the outcomes of the drilling. Once the final production bore locations had been decided, earthworks where mobilised to the area to enlarge the sumps to account for the higher yields from the Production bores.

18 hours of standby was incurred due to leaky sump on HMN0044P due to the sump being built above ground level with loose rocky ground. Earthworks were still in the area and able to quickly dig a secondary sump downhill of the leaking sump.

71 hours of standby was incurred due to sump capacity of HMN0042P. This was primarily due to the bore development producing significantly more water than expected (50 L/s) and producing more fines than expected, taking 27 hours of active development.

3.3 Field Data Collection

During drilling, the following data were collected by the driller and the field hydrogeologist for each bore:

- First water strike (FWS) and all subsequent significant increases in yield.
- Changes in drilling conditions i.e. harder/softer ground/ lost circulation/fractures/voids etc.
- Airlift yield estimates and field water quality measurements (EC, pH & temperature) every six metres and at the end of the hole when readings have stabilised.
- Following the completion of each bore (after 48 hrs), the groundwater static water level was measured by the field hydrogeologist and recorded in the Geobank log.

Figure 5: HMN0042-P and HMN0046-M headworks

4 Field Observations and Results

Figure 6 shows the spatial distribution of yields and water levels and field chemistry. Figure 8 gives geological information collected during the previous three drilling programs at Ministers North. This information was used to determine the best location for the proposed re-injection bores field.

The geological map export form Leapfrog model is shown in Figure 9 and the trace line location of the cross section given in this section.

4.1 Site Hydrogeology and Drilling Conditions

The aquifer at Ministers North is a high transmissive fractured rock aquifer. The current drilling program has shown that the area around the Yandicoogina Gorge is highly fractured, with relative high airlift yields for an unmineralized/ partially mineralised Brockman Formation. Ground conditions are summarised in Table 4 with special distribution given in Figure 8.

Surface cover consisted of soft, loose scree at surface, generally 0 to 8 m deep, but up to 30 m of transported material was encountered at the base of the Yandicoogina Gorge. Care was taken when logging above water level formation as injection into the proposed bores could lead to mounding and rewetting of this formation.

Yields generally increased with depth and correlated well with discrete zones of broken ground. As the ground is generally poorly mineralised around the Yandicoogina Gorge at Ministers North, high yielding mineralised zones such as D4, D2 and J6 were less important in describing permeability in the area. Primarily, formations with elevated yields were observed to have high chert content, namely J1 and D1 units. Additionally fresh Mt McRae shale near the centre of the Wirriba Anticline fold hinge was also observed to host elevated yields.

The Keystone fault does not appear to form a barrier to groundwater flow and may contribute to elevated yields due to increased fracturing observed within its vicinity.

Of note was that the monitoring bores nearest the centre hinge of the Wirriba Anticline and near the lineament of the to the Keystone Fault were observed to have elevated yields (Figure 6). The highest airlift yield (12 L/s) was encountered during the drilling of monitoring bore HMN0053, located on the western side of the rail line. HMN0051 and HMN0052 located which both had airlift yields of 10 L/s.

Black shale was intersected in two monitoring bores and three production bores. Occurrences were all at depth and in bores surrounding the gorge. Ground conditions encountered during this drilling campaign have provided further proof that the Mt McRae Shale is competent and fractured at depth and hosts a significant fractured rock aquifer. High yields (15-20L/s) were observed in all fresh black shale units, particularly within chert rich sequences. The Mt McRae shale does not appear to form a low permeable barrier in the Ministers North area.

All proximity collars were identified and controlled with no incidents.

Fibrous material is of low likelihood at Ministers North due to drilling within the Brockman Dales and Joffre sequences. Magsus measurements were taken to identify the fibrous risk, with appropriate controls put in place where high readings where observed.

Table 4: Airlift Yield and First Water Strike

Hole Name	Yield (Max)	Description of Yield Intersections
HMN0042	50	FWS of 4L/s in hard broken D2 with large (>50mm) chips. Airlift yield increased to 10 L/s associated with bands of soft broken ground. Increase in yield observed in D1: 54 to 72 m competent chert rich BIF with thin bands of broken ground, vugs and iron staining. Yield increased to 15 L/s in chert rich Mt McRae Shale, possible RC or RU from 74 to 88 m fault zone, leached and pitted chert with quartz. RU: 88 to 104 m, fresh black shale with bands of weathered, leached shale and chert. Yield increasing to 20 L/s during drilling and final development yield of 50L/s
HMN0043	20	D2: 34-82 m. Fractures with minor pitting at 42 m and 46 m and FWS of 2 L/s at 50 m. Fractured zone from 54 to 70 m with larger chips, pitted surfaces and mineral build up with airlift yield increasing to 10 L/s. Competent BIF from 70 to 82 m with minor fracture at 76 m increasing yield to 12 L/s. D1: 82 to 104 m. Increasingly fractured at depth, with yield increasing from 15 L/s at 94 m to 20 L/s at 104 m. Final development yield of 20 L/s.
HMN0044	20	J2: 28 to 68 m. Competent ground with minor Fracture zones above water table at 52 56 m and FWS of 0.5 L/s at 60 m. J1: 68 to 104 m. Yield increased through two discrete fracture zones. 74 to 80 m, broken ground with dissolution features increased yield to 6L/s and 94 to 104 m, larger subrounded chips with pitted surfaces increasing yield to 20 L/s. Final development yield of 20 L/s.
HMN0045	20	Transported sediments from 0 to 30 m with very large (>100mm) subrounded cobbles and clay rich fines. FWS of 8 L/s at 20 m, increasing to 10 L/s by 28 m. RU: 30 to 40 m slightly weathered platy black shale with no increase in airlift yield. RC: 40 to 50 m, fresh chert rich shale, slower drilling with airlift increasing to 15 L/s. Final airlift development of 20 L/s.
HMN0046	20	Hard ground from 24 m, in D2 to 52 m, slightly weathered poorly mineralised BIF. FWS of 2 L/s at 32 m, increasing to 6 L/s in jointed BIF at 42 m. D1 from 52 to 72 m intersected chert rich BIF with yield increase to 8 L/s in broken section between 58 and 64 m. Mt McRae Shale was encountered from 72 to 104 m with leached broken zone between 74 and 88 m increasing yield to 10L/s.
HMN0047	7	FWS of 0.5 L/s at 56 m in D2: 30 to 82 m. Yield increased to 5 L/ at 66 to 72 m jointing and breakage along bedding with minor staining and vuggy pitted surface on some chips. D1: 82 to 102 m Slight increases associated with vuggy broken chert and minor staining at 92 m (6 L/s) and 102 m (7 L/s).
HMN0048	5	FWS at 56 m at base of D4. D3: 58 to 80 m. Yield increased to 2 L/s in friable mineralised BIF from 72 to 78 m, and 3 L/s on the D3:D2 contact. D2: 80 to 100 m hard competent ground, fracture zone from 91 to 92 m increased yield to 5L/s.
HMN0049	5	J1: 40 to 80 m with broken ground from 40 to 52 m and FWS of 1L/s at 62 m. Yield increased to 3 L/s in small fracture zone from 66 to 68 m. Fractured whaleback from 80 to 90 m with large chips, pitted surfaces and increase in yield to 5 L/s. No increase in yield from 90 to 120 m in fresh unmineralized BIF.
HMN0050	4	J3: 40 to 66 m vuggy porous chips with orange staining and small cavity at 40 m. J2: 66 to 102 m fresh unmineralized BIF with FWS at 86 m of 2 L/s increasing to 4 L/s by 98 m with minor alteration and surface pitting. J1 hard fresh Biff with no increase in yield to depth.
HMN0051	10	FWS of 2 L/s at 62 m, soft shale band at top of D3. D3: 56 to 94 m increase in yields at discrete fracture zones, chert quartz and shale at 84 to 86 m (3 L/s) and 90 to 94 m (4 L/s). D2: 94 to 132 m, yield increased with depth associated with fracture zones at 104 to 110 m (5 L/s), 118 to 120 m (7 L/s) and 124 to 130 m (8 L/s). D1: 132 to 142 m, alteration and dissolution of haematite, vuggy chips with iron staining and yield increasing to 10 L/s
HMN0052	10	D4: 36 to 86 m, broken ground with red staining and FWS of 0.5 L/s at base. 66 to 70 m shale and vuggy BIF increasing yield to 4 L/s. Fracture with leached vuggy iron-stained surfaces at 74 to 82 m increased yield to 7 L/s. Fracture in D3: 102-106 m yield 8 L/s intercepted vuggy chips with iron staining at base. Broken ground in D2 124 to 134 m dissolution features and alteration yield 9 L/s. Fractured D1 from 142 to 152 m with rough fracture plains and yield increased to 10 L/s.
HMN0053	12	FWS of 2 L/s at 94 m in D1. Loss of returns from 98 to 110 m in Mt McRae shale while drilling open hole required DR to be advanced before airlift yield returned. Yield increased form 3 L/s at 116 m to 10 L/s at 128 m through soft broken ground. Yield then increased to 12 L/s when going open hole at 140 m. Large pyrite nodules (75 mm) in McRae.
HMN0054	6	J3 above water table from 38 to 44 m with vuggy chips and surface staining. J2: 50 to 104 m. FWS of 0.1 L/s at 62 m. Yield increased to 5 L/s at 80 m due to broken ground/ fracture zone at 62 to 80 m with abundant porous and pitted chips. Minor yield increase to 6 L/s associated with fracture at 97 to 98 m.
HMN0055	5	FWS of 2 L/s at 68 m with yield increasing to 5 L/s at 80 m associated with friable broken ground at 64 to 76 m. J4: 80 to 104 m, no increase in yield.

Hole Name	Yield (Max)	Description of Yield Intersections
HMN0056	8	J2: 32 to 104 m. Chips with minor surface staining at with FWS at 66 m. Minor leaching and surface staining with shales 74 to 78 m and yield increasing to 2 L/s. Yield increased to 6 L/s at discrete fracture from 82 to 84 m with vuggy leached BIF. Fracture zone from 90 to 94 m with increase in yield to 8 L/s, staining and mineral build up on surfaces.
HMN0057	5	D4: 34 to 74 m, friable magnetic BIF from 42 to 50 m with FWS of 2 L/s at 52 m. Fracture zone from 60 to 64 m with vuggy chert and iron staining. Yields initially declining before increasing up to 5 L/s at base of unit. D3: 74 to 104 m. Broken and vuggy below 84 m. Prospective ground with no increase in yield observed, likely due to loss of air to the formation.
HMN0058	3	Broken ground 40 to 58 m in Yandicoogina Shale above water table. J6: 68 to 98 m. FWS of 2 L/s at 68 m on contract of weathered cherts and fresh magnetic BIF. Minor yield increase to 3L/s with chips becoming larger (10 to 20 mm) from 84 m. Very high Magsus of 530 but no fibres observed.

4.2 Field Groundwater Quality and Water Level Measurements

Water quality and water level measurements taken in the field are summarised in Table 5 below. Field water chemistry measurements agree with historical results from the area, being slightly alkaline (pH 7.9 to 8.9) with low EC values (244 to 681 us/cm).

Previously work (RPS, 2021) undertaken at Ministers North has shown that water levels are relatively flat across the project area. Water levels obtained for the recently installed bores are generally between 561.12 and 561.34 mAHD except for HMN0053 (560.28 mAHD). HMN0044 (561.69 mAHD) was also slightly higher and disagrees with the monitoring bore HMN0049 (561.12 mAHD) on the same pad. These two anomalies are possibly due to incorrect top of casing elevation reading, or the water level had not fully recovered after drilling when taken.

Water level distribution is shown in Figure 6. The previous static water levels from bores drilled during the 2020 (RPS, 2020) campaign show static water levels around 1.5 m higher than water levels taken in during the current drilling program. No clear water level flow direction can be ascertained due to the ongoing declining water levels seen across the Ministers North project area.

A round of water level dipping was undertaken on 16th February 2023 to obtain a snapshot of water levels surrounding the gorge to enable accurate water table mapping (Figure 7). A 561 mAHD contour was drawn on the map to delineate higher and lower water levels.

Generally, water levels are higher in the West and south and drop to the North-east. Water levels where within 30cm of 561 mAHD with some minor variations between holes likely due to accuracy of elevation data. During February 2023, the gorge does not appear to be a key driver in ground water level, however only one monitoring point is located within the gorge.

Water levels within the Yandicoogina Pools have reported elevation of between 556 and 558 mAHD. If the pools elevation is correct, they are 2 to 4 meters below the elevation of the regional aquifer and are unlikely to have a good hydraulic connection. Further investigation would be needed to determine if groundwater is outflowing to the fluvial sediments in the vicinity of HMN0045 and being transmitted through the fluvial deposits to the pools or the seeps along the Gorge walls downstream of HMN0024 are draining into the pools.

Keystone fault does not appear to act as a barrier to groundwater flow. The enhanced permeability halo of fractured rock south of the fault may act as a preferential conduit to water flow form the project area, with water levels decreasing along the strike of the fault to the North-West.

Table 5: Summary of Groundwater Quality and Water Level Field Measurements

Hole Name	FWS (mBGL)	Last EC (us/cm)	Last pH	Last Temp (ºC)	TOC RL (AHD)	SWL (mBTOC)	Water Level (mAHD)
HMN0042	35	422	7.97	31.3	589.64	28.48	561.16
HMN0043	44	492	8.76	33.4	607.41	46.17	561.24
HMN0044	60	617	8.39	31.1	621.50	59.81	561.69
HMN0045	20	517	8.25	29.6	569.56	8.37	561.19
HMN0046	36	431	8.6	30.0	590.02	29.03	561.17
HMN0047	56	604	8.8	28.5	607.66	46.32	561.34
HMN0048	56	591	8.8	24.7	607.76	46.48	561.28
HMN0049	62	558	8.8	28.5	621.77	60.65	561.12
HMN0050	86	600	8.7	24.0	634.65	73.50	561.15
HMN0051	62	565	8.8	25.7	606.41	45.14	561.27
HMN0052	44	681	8.8	28.0	606.45	45.24	561.21
HMN0053	94	570	8.9	26.9	653.57	93.29	560.28
HMN0054	62	545	8.9	26.1	614.77	53.59	561.18
HMN0055	68	355	8.4	25.3	616.34	55.05	561.29
HMN0056	66	559	8.7	33.6	621.19	59.86	561.33
HMN0057	52	244	8.3	25.7	612.19	51.03	561.16
HMN0058	68	630	8.7	24.5	626.38	65.16	561.22

4.3 Hydrogeological Cross Sections

The line of monitoring bores on the eastern edge of the project area are significant, shown in Figure 10, as theses bores are the closest to the pools within the Yandicoogina gorge. Water levels within the gorge are of concern due to the permanent pools which are of environmental and heritage significance. The undertaken drilling program extended the monitoring network to the north across the Keystone Fault and found that water levels were flat across this structure. Airlift yields decrease to the north, with the lowest yields (3 L/s) in the J6 and Yandicoogina shale units in HMN0058. Monitoring bores drilled in the vicinity of the mapped keystone fault in this area did not see an increase in yield relative to surrounding bores. Water levels form the monitoring bores projected across the Yandicoogina Gorge outcrop in the walls of the gorge, a situation substantiated by the presence of seeps in the walls of the gorge at some locations. As the elevations of the pools are below the projected water levels in this area, it is likely that they are at least partially fed by groundwater flow.

Two re-injection bore locations were chosen on the northern edge of the Yandicoogina gorge (HMN0043 and HMN0044) due to airlift yields in monitoring bores HMN0049 (5 L/s) and HMN0047 (7 L/s). Figure 11 gives a cross section through the bores along the northern wall of the Yandicoogina gorge looking Southeast. Yields generally decrease from west to east with HMN0047 (7 L/s) on the west of the line through HMN0048 (5 L/s) located between the two higher yielding monitoring bores drilled as injection bore to HMN0050 (4 L/s) on the eastern edge of the higher yielding zone. Monitoring bore HMN0024, located furthest east recorded an airlift yield of 0.1 L/s with the low yields in HMN0025 being attributed to intersected very hard, un-mineralised J5 and J6 units.

Figure 12 shows the down hole yields from the re-injection bore HMN0045 in relation to the alluvial deposits at the base of the Yandicoogina gorge and the nearby monitoring bores HMN0015 and HMN0016. Downhole yields were very similar with the 15L/s in both HMN0016 and HMN0045 recorded during drilling, with development yields of 20

L/s in the re-injection bore. Logged sediments where up to 20m deeper in the drilled holes relative to the geological model, suggesting the aquifer contained within the transported material at the base of the gorge and its transport water through the area. The interconnection between the sub-cropping hard rock aquifers and the transported sediment is not well understood and will be improved by the aquifer testing of the injection bore HMN0045.

Figure 13 shows the relationship between the existing model and HMN0042 and HMN0045. Interpretation of the Dales Gorge from the drilling results in this area differ from the geological model, with the Dales Gorge units being significantly deeper than in the geological model. Airlift yields where high during drilling of the monitoring bore HMN0046 (10 L/s) and the reinjection bore HMN0042 (20 L/s) despite of significant air loss to the formation and coming up nearby RC holes and the monitoring bore HMN0046. Development yields from HMN0042 were estimated as being more than 50 L/s which suggest the presence of enhanced permeability compared to nearby bore. A possible fault zone nearby with significant off set is possible with extensive broken ground noted from 74 to 88m during drilling and would explain the localised elevated yields.

The area of highest airlift yields during the monitoring bore drilling was HMN0051 and HMN0052. Figure 14 shows a cross section through the Keystone Fault in relation to the high yielding production bore HMN0013 and the two highest (10 L/s) monitoring bores HMN0051 and HMN0053 looking north. This area was prospective as a location for re-injection bores due to the high yields, but the proximity of the elevated permeability associated with the Keystone fault in this area was not beneficial. This area was deemed to have too good of a hydraulic connection to the ore body to the north, and as such any water injected into this location would likely run north towards the proposed mining area instead of supporting water levels around Yandicoogina gorge.

4.4 Notes on Conceptual Hydrogeological Model

Some clarification remarks based on observations from the drilling programs conducted at Ministers North on the interaction of groundwater with the pools at the base of the Yandicoogina Gorge are made.

Pool persistence along the side of a hills or in gorges is commonly associated with groundwater discharge into the stream channel over a low-permeability geological layer. As the aquifer pinches out against low permeable units, the aquifers vertical thickness reduces to zero forcing groundwater out of the aquifer, forming pools and recharging overlying sediments. This mechanism has been identified as driving regional groundwater discharge to streams across the Pilbara (Bourke et all, 2023).

Water flows from the aquifer to the fluvial system are likely limited to the East by the Yandicoogina Shale Member and low transmissivity unmineralized J6 unit of the Joffrey Member (HMN0024).

Current groundwater levels are between 2 and 4 meters above the current pool water elevations. In the area of the pool’s, groundwater historically exiting the aquifer as seeps along the walls of the gorge, likely at the contact of the fractured BIF and low permeable shale units. Current state of the groundwater seeps needs clarification.

The pools are located within the channel sediments which overlay low permeable shale bedrock The interchange of groundwater and surface water is occurring at some point upstream of the pools where the fluvial sediment is in direct contact with the more permeable fractured rock aquifer. The exact location of this interaction could be seasonally variable dependant on the groundwater levels within the aquifer and stage of the river / recharge from rainfall events.

The Keystone Fault is also proposed as a potential structural control of groundwater loss from the system as the regional water table appears to dip the North-East in line with the fault trace. Further accurate mapping of water levels through different stages of the seasonal water level cycle could clarify direction of water flow.

The whaleback shale units intersected in HMN0049 consisted of fractured chert with ample evidence of fracturing suggesting that this unit does not function as an impermeable layer or barrier to flow in the vicinity of the Yandicoogina Gorge.

The pyrite bearing carbonate shale units at the core of the Wirriba Anticline are chert rich, fresh and highly fractured. There is a potential for contamination of the aquifer with elevated sulphate bearing groundwater through remobilising pyrite contained within the rock if oxygen is added to the system through aerated injection water.

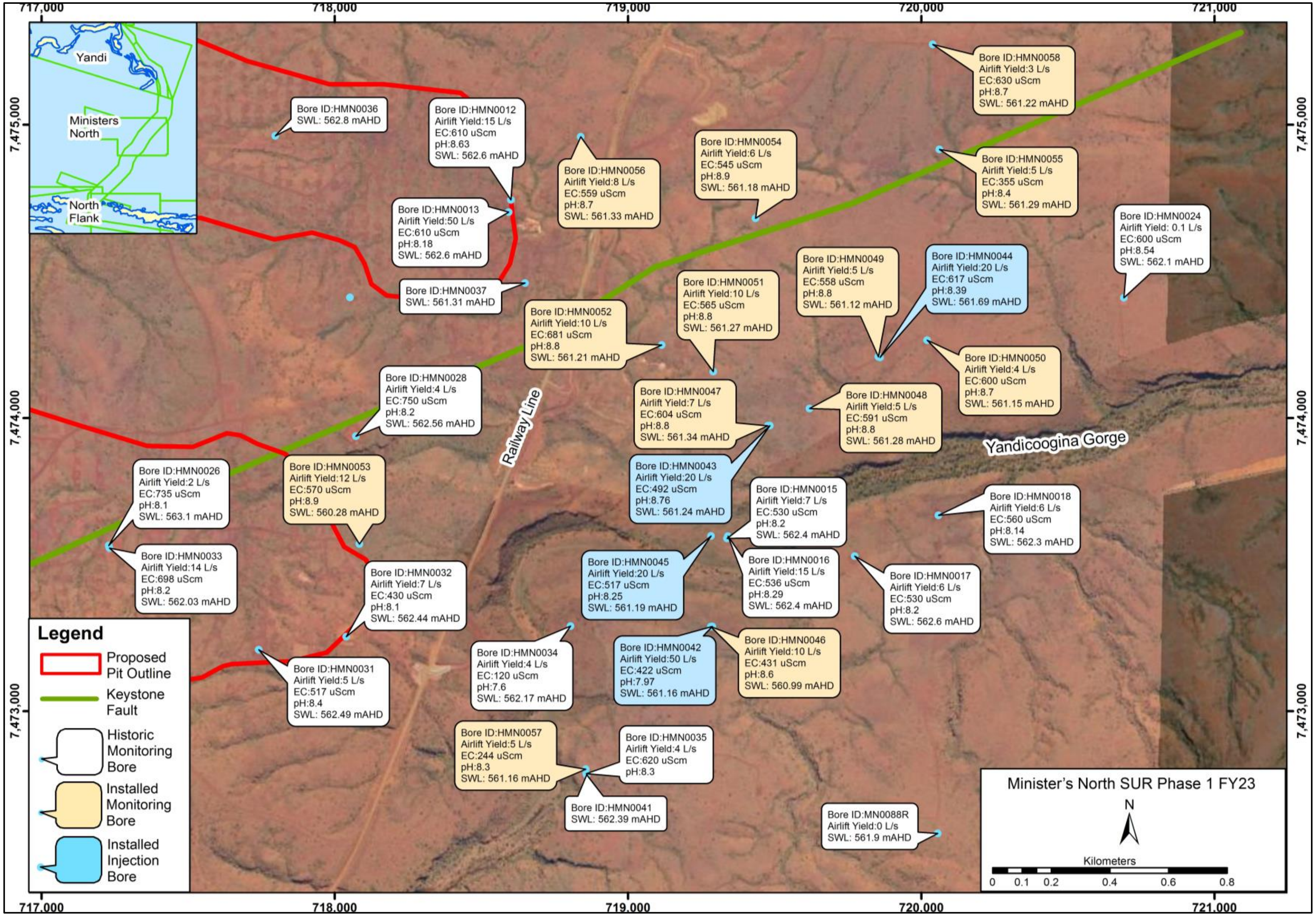

Figure 6: Summary of Field Observations at time of drilling

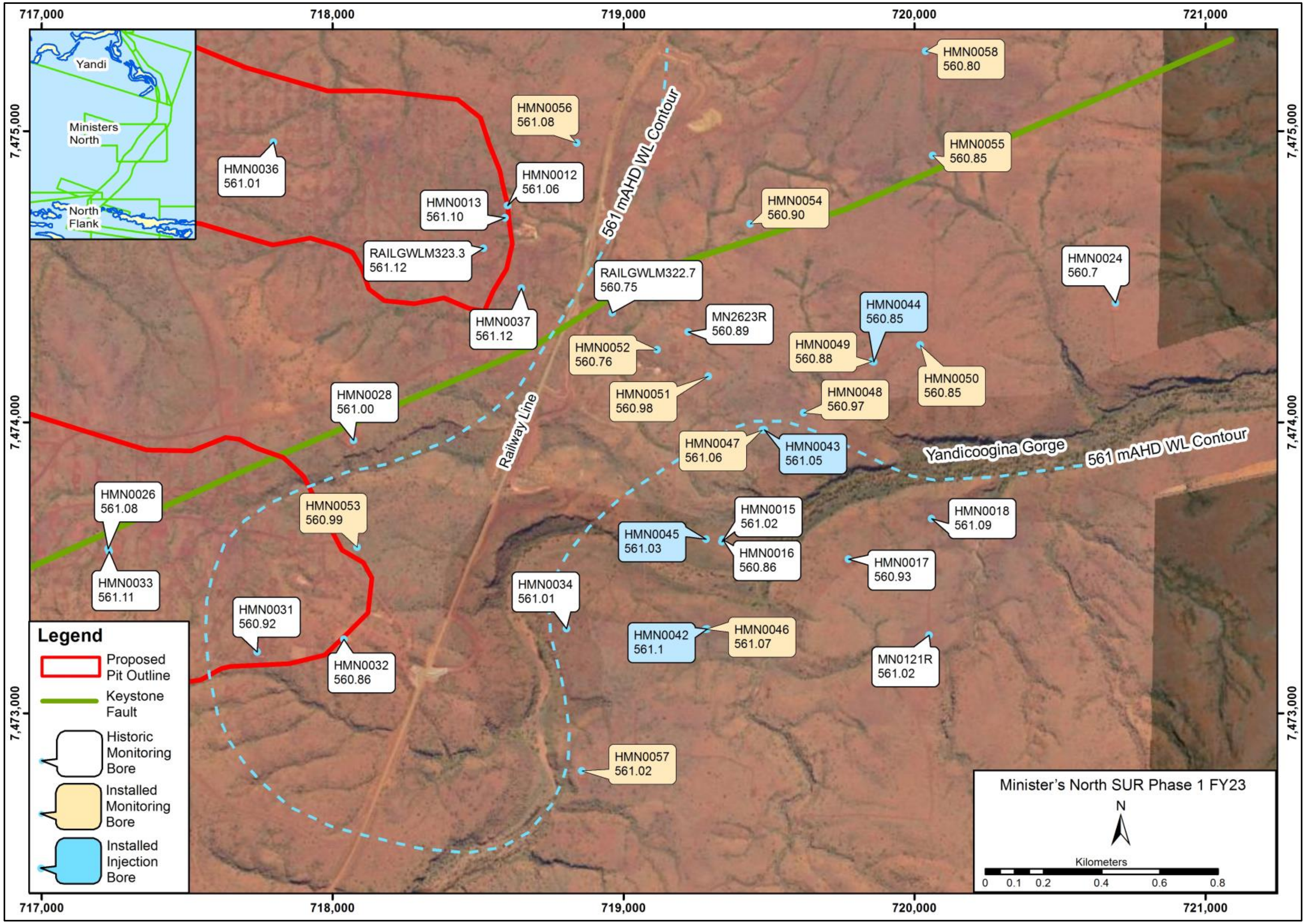

Figure 7: Ministers North water level in mAHD taken on 16th Febuary 2023

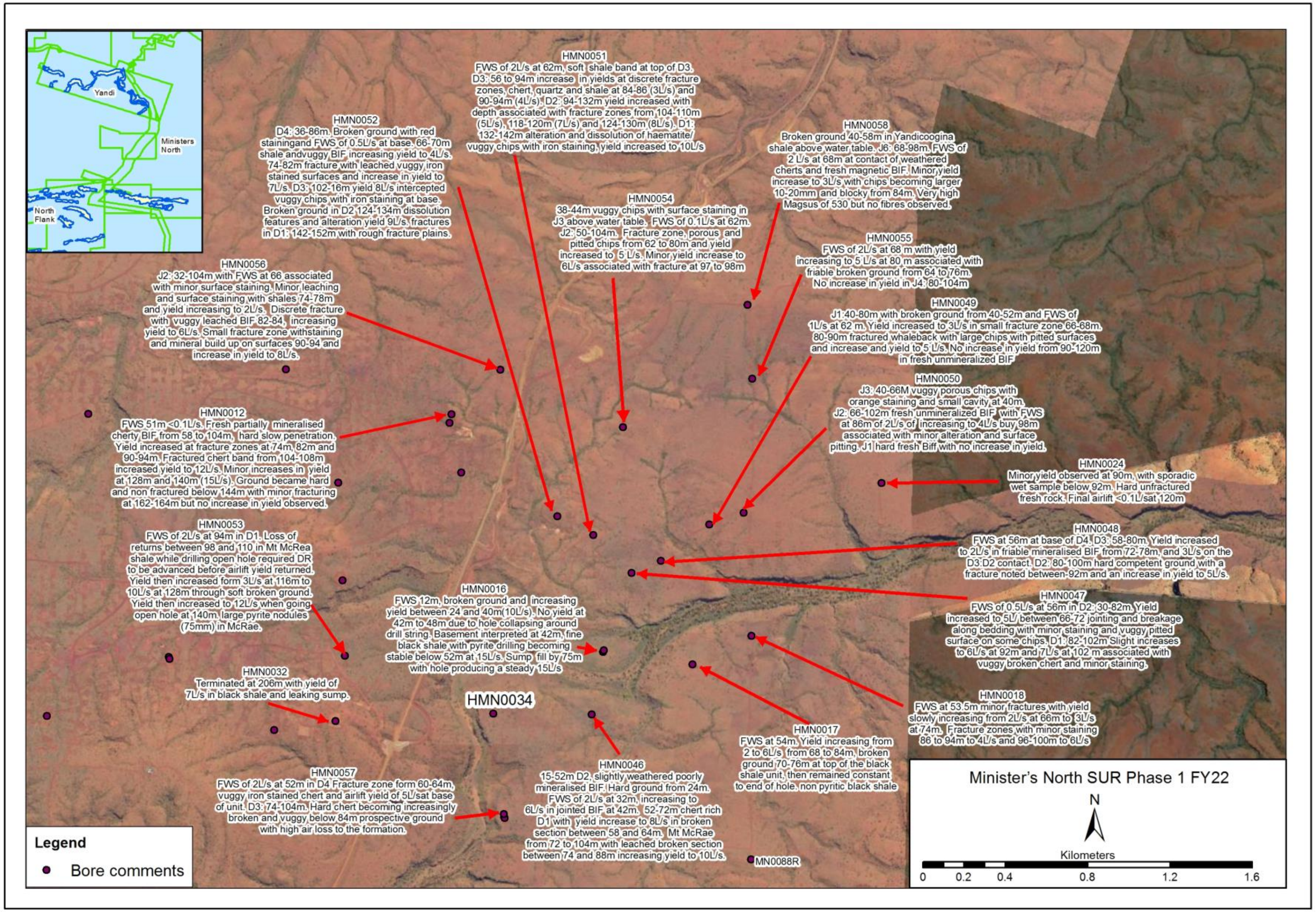

Figure 8: Distribution of hydrogeological information to help siting the re-injection bores

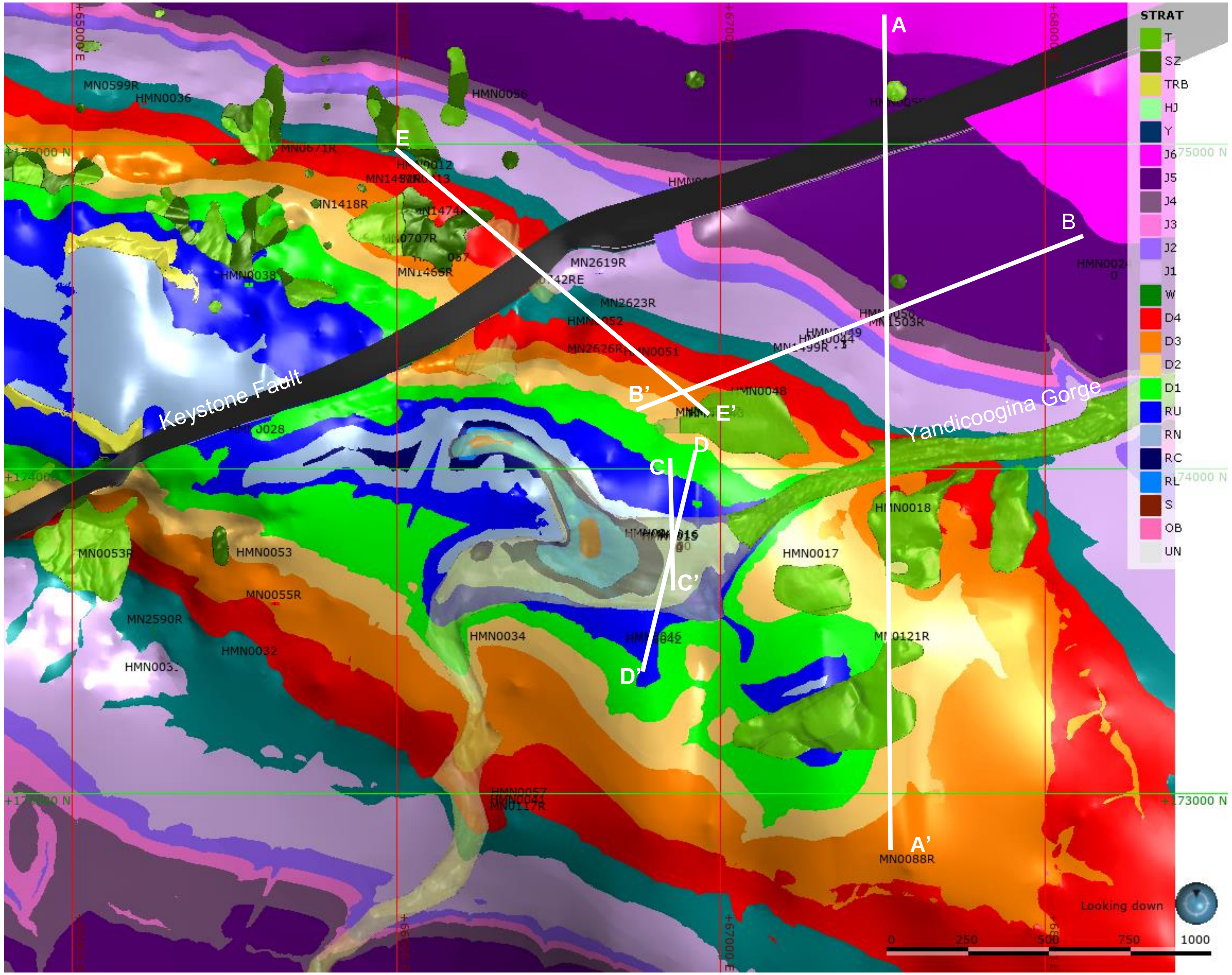

Figure 9: Geological map export form Leapfrog model

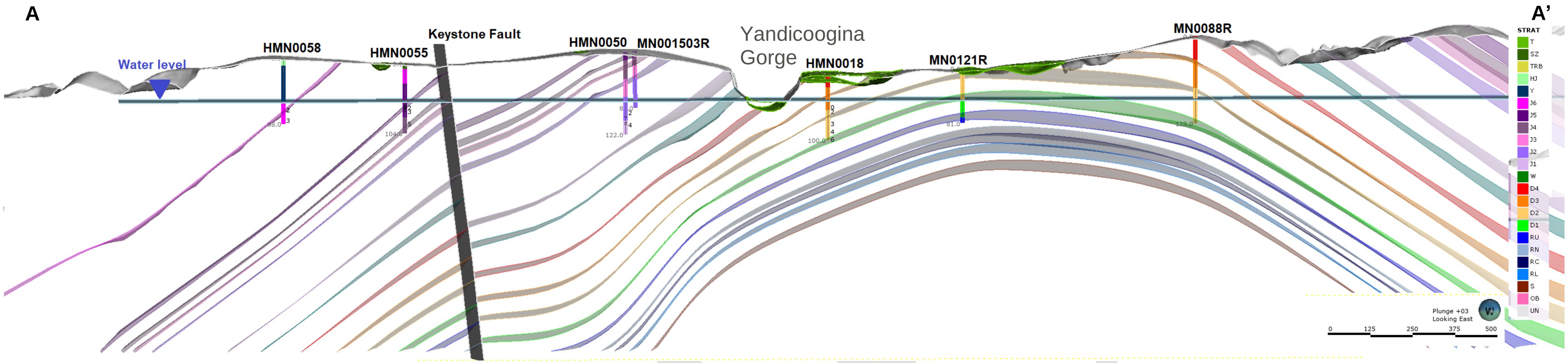

Figure 10: Most Easterly line of monitoring bores looking East

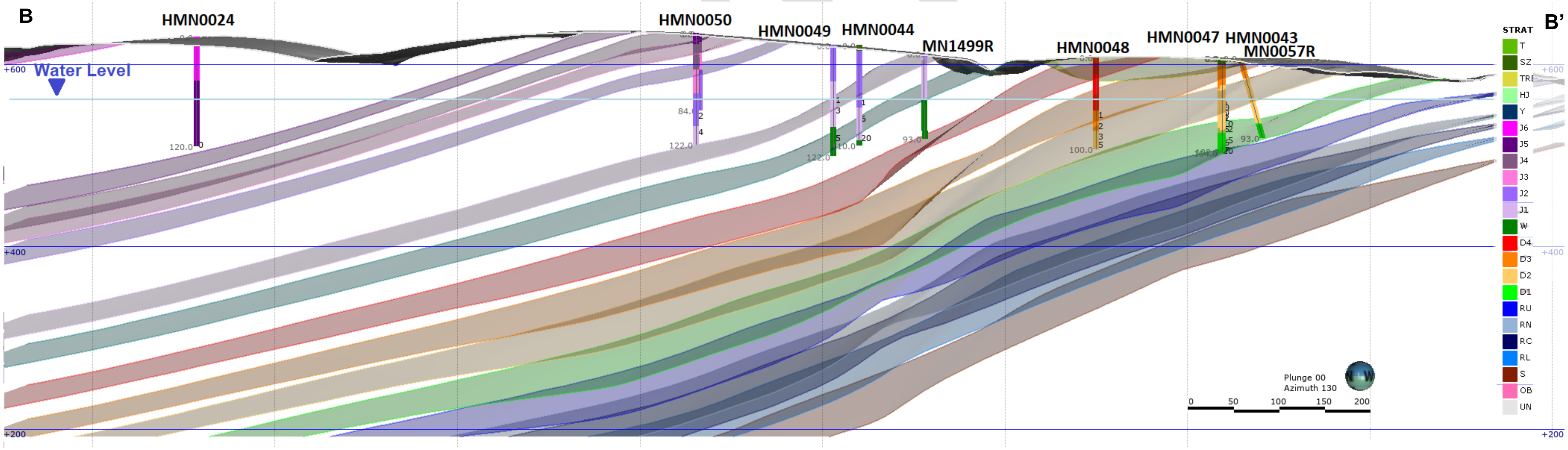

Figure 11: Northern wall of the gorge looking Southeast

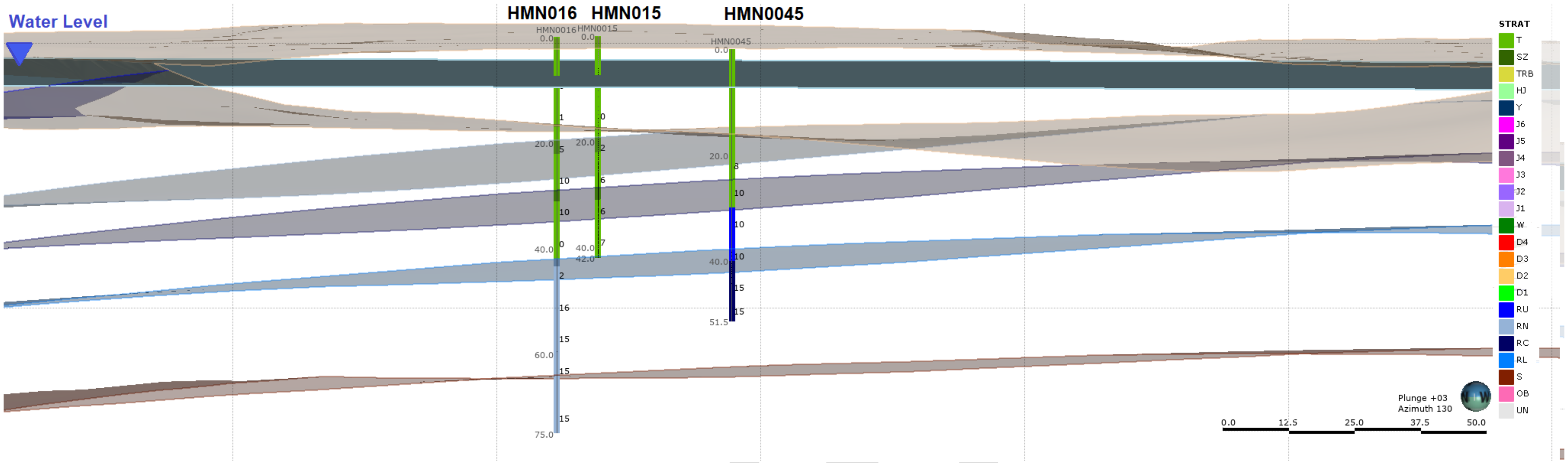

Figure 12: HMN0045 looking east

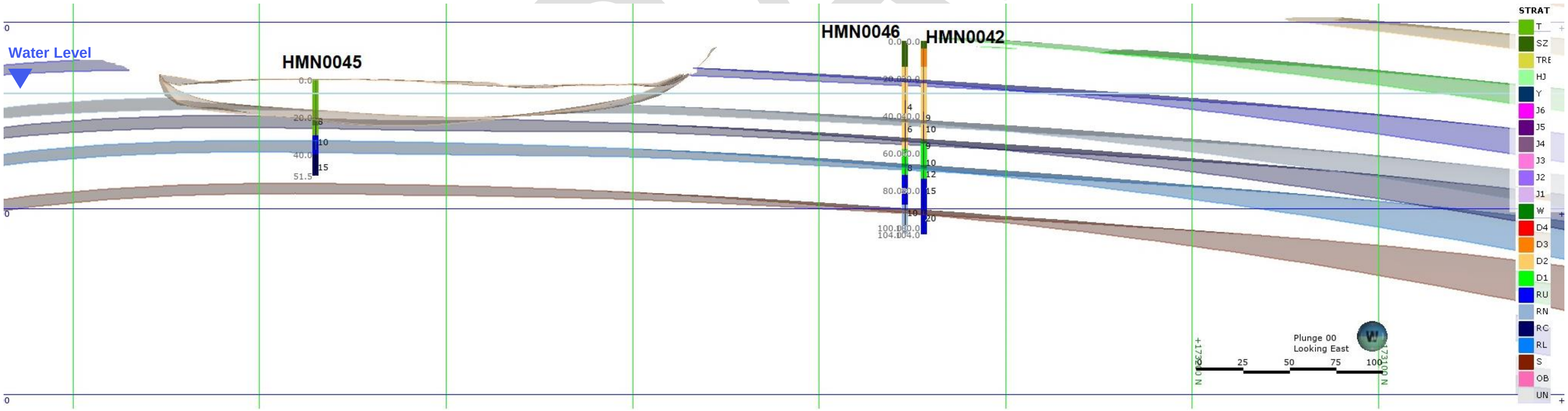

Figure 13: Production bores HMN0045 and HMN0042 looking east

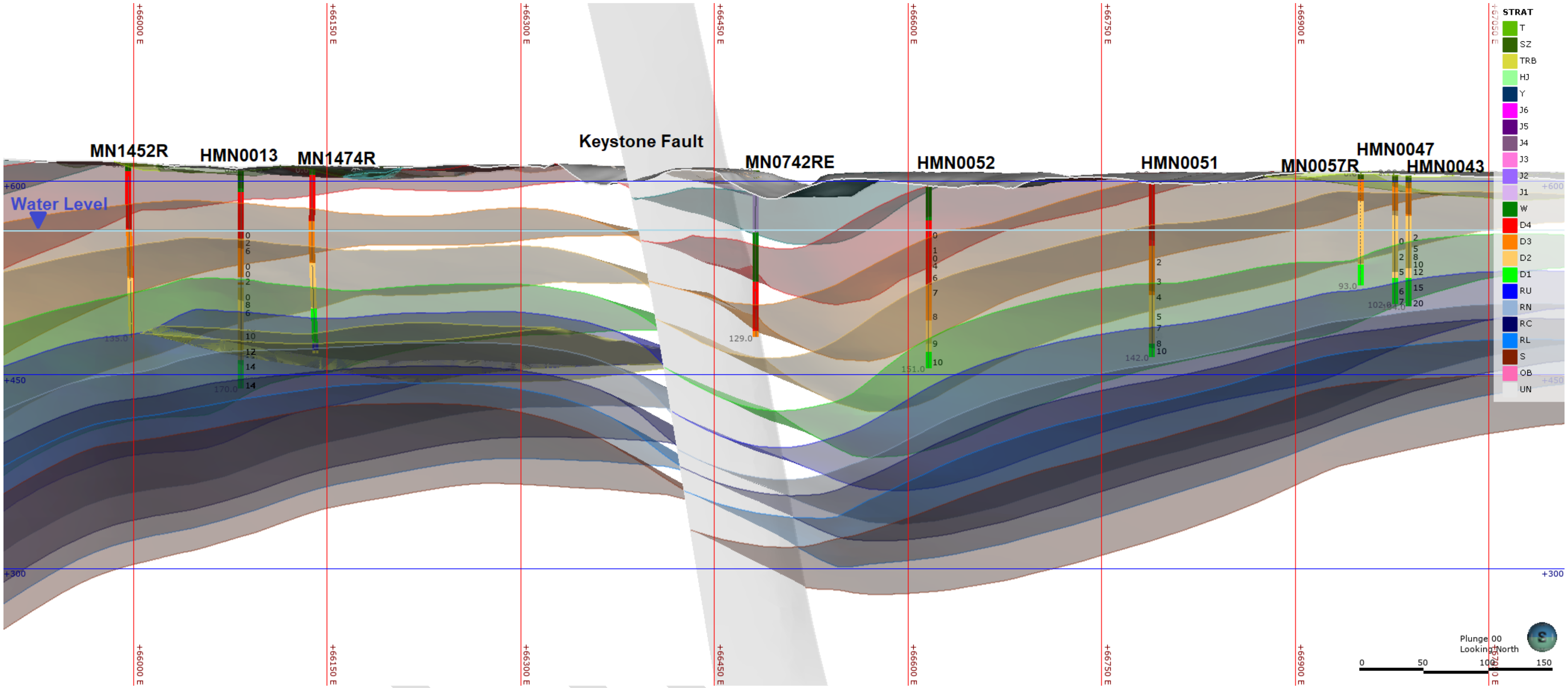

Figure 14: Crossing the Keystone fault through HMN0013, HMN0052 and HMN0053 looking north

5 Hydrochemistry Analysis

Groundwater samples were collected from each production bore at the end of the bore development process and were submitted to SGS Laboratory for comprehensive suite analysis. The SGS test certificates are available in ioWater.

- Tested groundwater is fresh with EC between 430 and 640 µS/cm.
- The pH levels recorded were also relatively consistent throughout the program and ranged from 7.7 to 8.5.
- No laboratory samples were taken from monitoring bores.

RAILGWLM323.3P is a production bore located near HMN0013 on the west of the railway line and has been used to provide water for railway and road construction/maintenance and drill programs in the area. RAILGWLM323.3P has 10 full suite samples taken between 2013 and 2021 with no change in the water quality being observed during this time. Abstraction form Ministers north has since stopped operation due concerns of the impact of declining water levels on the pools within the Yandicoogina gorge.

Water typing was undertaken and compared to the recently drilled bores to all other results taken from Ministers North. Figure 15 shows all samples are grouped in the bicarbonate dominated recharge water zone. This is in keeping with the generally low TDS and conceptual understanding that the groundwater aquifer at Ministers North is near source.

Two rounds of sampling were undertaken from four pools (YC1 Upstream to YC4 Downstream) within the Yandicoogina Gorge and are compared to samples taken from production bores (Figure 16). The samples were taken at the end of the dry season (October) and end of the wet season (April). Most samples represent the same groundwater type as the production bores, however the April 2021 sample taken form Pool 1 (YC1) shows the imprint of mixing or dissolution. Sulphate (So_4) is also elevated in the end of wet season in YC1 and YC2 sampling locations. These locations have likely been affected by mixing with a different source water, namely surface water inflow form the upstream catchment. The source of sulphate is potentially interaction with pyrite hosted in the black shale source rock of the cobbles, which form the alluvial sediments at the base of the gorge. Additionally, all samples taken from the pools during the April 2021 sampling event have slightly elevated EC and lower pH than samples taken during the dry season or from the production bores.

Laboratory analysis results are summarised in Table 6 and figures 15 to 17 below:

Table 6: Laboratory Analysis Results

		CATIONS					ANIONS				WQ DATA		
Sample ID	Date	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	Fe mg/L	CO3 mg/L	HCO3 mg/L	SO4 mg/L	Cl mg/L	pH pH units	EC µS/cm	TDS mg/L
HMN0042P	05/12/22	21	5.2	37	17	<0.005	0.0	200	18	30	8.1	430	250
HMN0043P	28/10/22	25	6.8	44	20	<0.005	0.0	240	20	31	8.3	500	260
HMN0044P	06/11/22	31	9.2	37	22	<0.005	0.0	240	29	39	8.4	550	290
HMN0045P	19/11/22	13	3.4	24	12	<0.005	0.0	210	32	45	8.0	470	280
HMN0003P	12/07/20	33	8.3	37	26	<0.005	0.0	230	27	50	8.1	550	290
HMN0013P	10/12/21	30	9.7	46	24	<0.005	0.0	280	29	41	8.5	600	330
HMN0033P	12/07/20	47	7.9	40	26	<0.005	0.0	210	50	75	7.8	640	380
RAILGWLM323.3P	29/10/13	30	10	51	26	0.008	0.0	270	28	41		600	340
RAILGWLM323.3P	08/05/14	33	9.9	47	25	0.08	0.0	280	26	41		600	360
RAILGWLM323.3P	17/07/14	24	8.1	38	20	0.085	0.0	270	29	41	8.2	590	360

		CATIONS					ANIONS				WQ DATA		
Sample ID	Date	Na	K	Ca	Mg	Fe	CO3	HCO3	SO4	Cl	pH	EC	TDS
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	pH units	µS/cm	mg/L
RAILGWLM323.3P	25/07/18	32	9.6	51	25	<0.005	0.0	270	28	42	7.7	590	320
RAILGWLM323.3P	29/11/18	32	9.7	49	25	<0.005	0.0	290	28	40	8.1	580	320
RAILGWLM323.3P	17/05/19	31	9.6	51	26	<0.005	0.0	280	27	43	7.7	590	340
RAILGWLM323.3P	28/05/20	31	9.9	50	25	<0.005	0.0	290	28	41	8	600	330
RAILGWLM323.3P	25/11/20	28	9.6	46	23	<0.005	0.0	290	29	40		640	370
RAILGWLM323.3P	12/05/21	31	9.5	51	24	<0.005	0.0	290	28	37		570	330
RAILGWLM323.3P	18/11/21	33	9.6	49	25	<0.005	0.0	290	29	41		540	310
RAILGWLM322.7P	29/10/13	35	9.3	46	26	<0.005	0.0	240	33	52		600	340
RAILGWLM322.7P	8/05/14	38	9.2	45	26	0.1	0.0	260	31	56		630	380
RAILGWLM322.7P	17/07/14	27	7.2	34	20	0.1	0.0	250	37	57	8	630	380
Pool 1 YC1	01/10/20	37	10.5	46	30	0.434	0.0	243	27	38	7.3	592	338*
Pool 1 YC1	18/04/21	39	12.5	57	33	0.166	0.0	202	102	48	6.6	729	416*
Pool 2 YC2	01/10/20	35	10.4	44	27	0.085	0.0	228	26	34	7.3	552	315*
Pool 2 YC2	18/04/21	38	12	58	33	0.268	0.0	222	81	44	6.9	673	384*
Pool 3 YC3	02/10/20	51	11.2	44	29	0.017	0.0	268	29	44	7.3	684	391*
Pool 3 YC3	17/04/21	51	12.4	56	35	0.062	0.0	265	48	48	7.2	776	443*
Pool 4 YC4	02/10/20	51	11.5	43	29	0.026	0.0	248	29	46	7.7	627	358*
Pool 4 YC4	17/04/21	43	11.6	47	30	0.078	0.0	249	24	45	6.9	661	377*

Note: * TDS derived from electrical conductivity conversion factor of 0.5711 given in Figure 17.

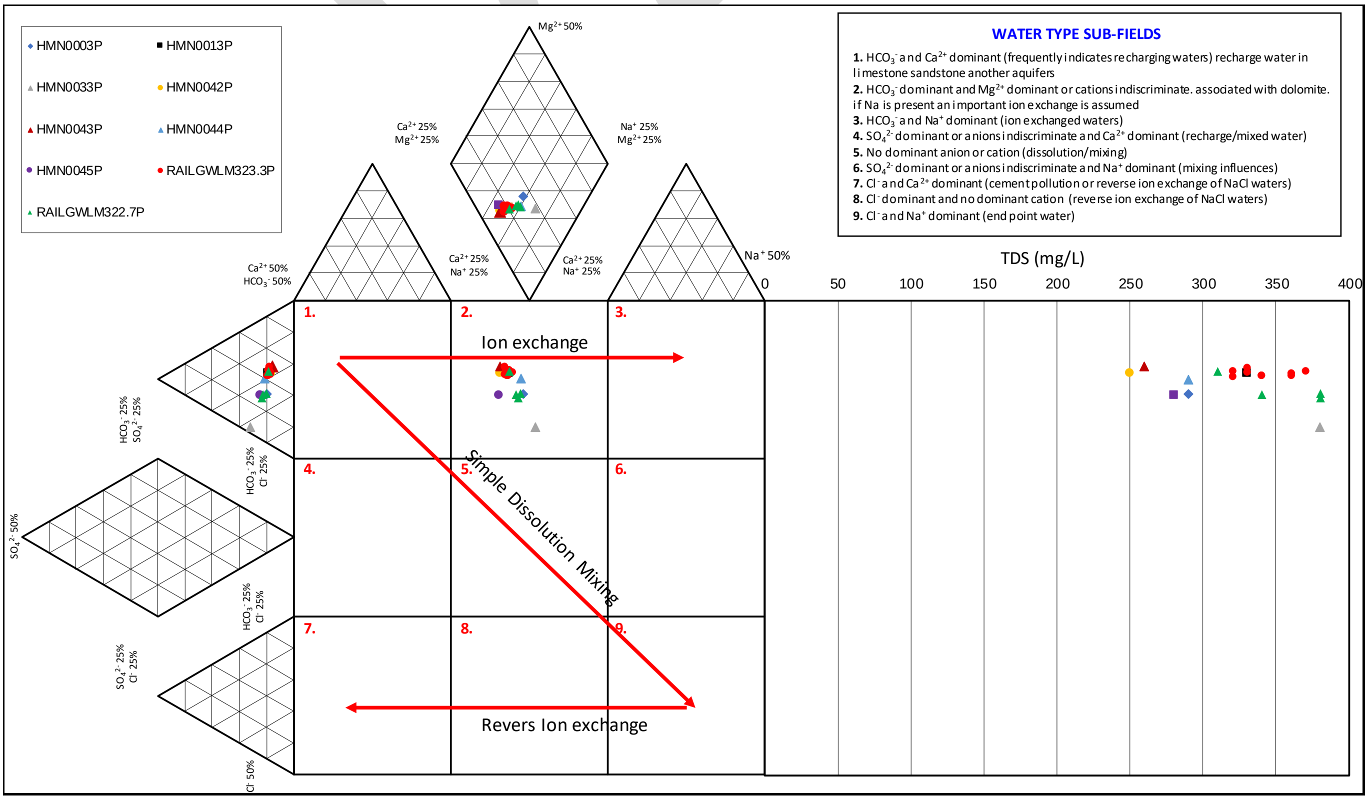

Figure 15: Expanded Durov Diagram for all Production Bore Water Samples

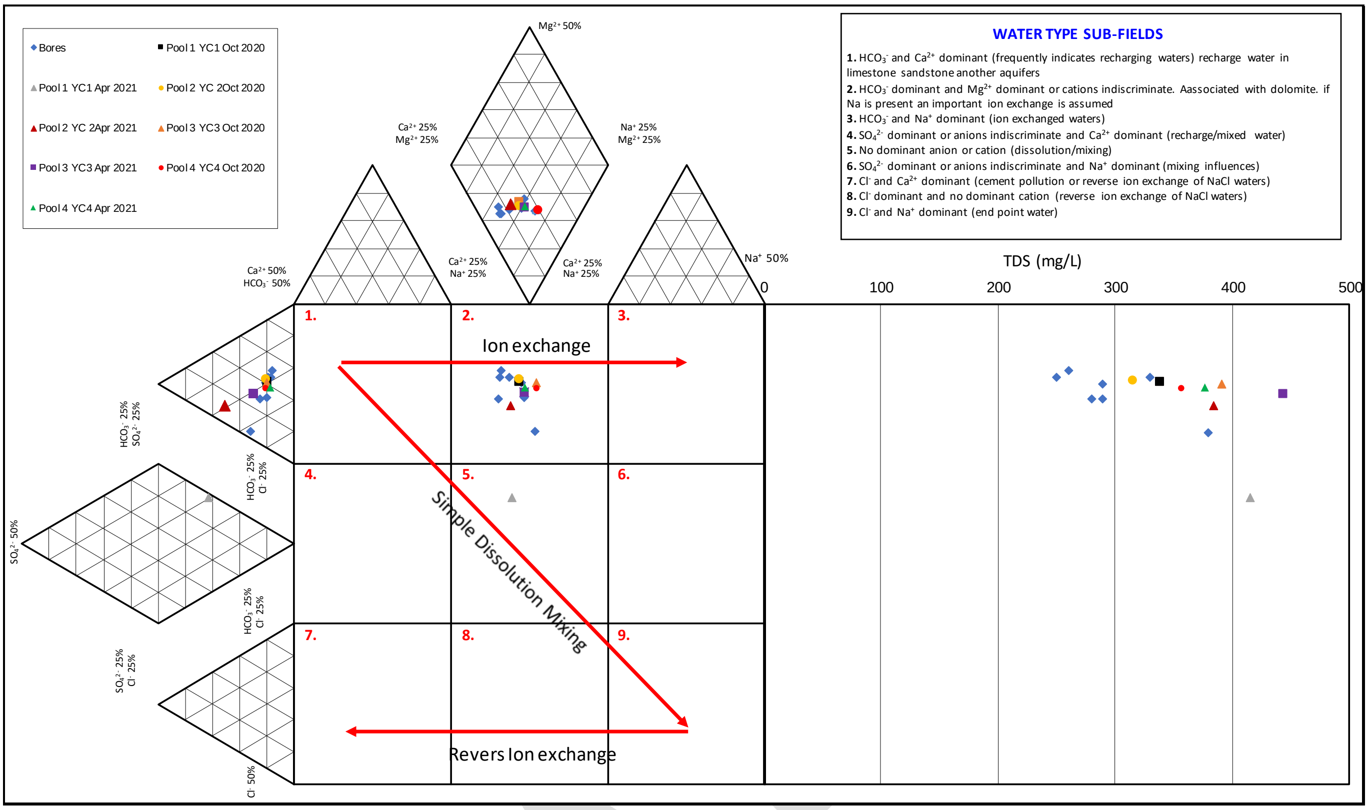

Figure 16: Expanded Durov Diagram for all Yandicoogina Pool Water Samples

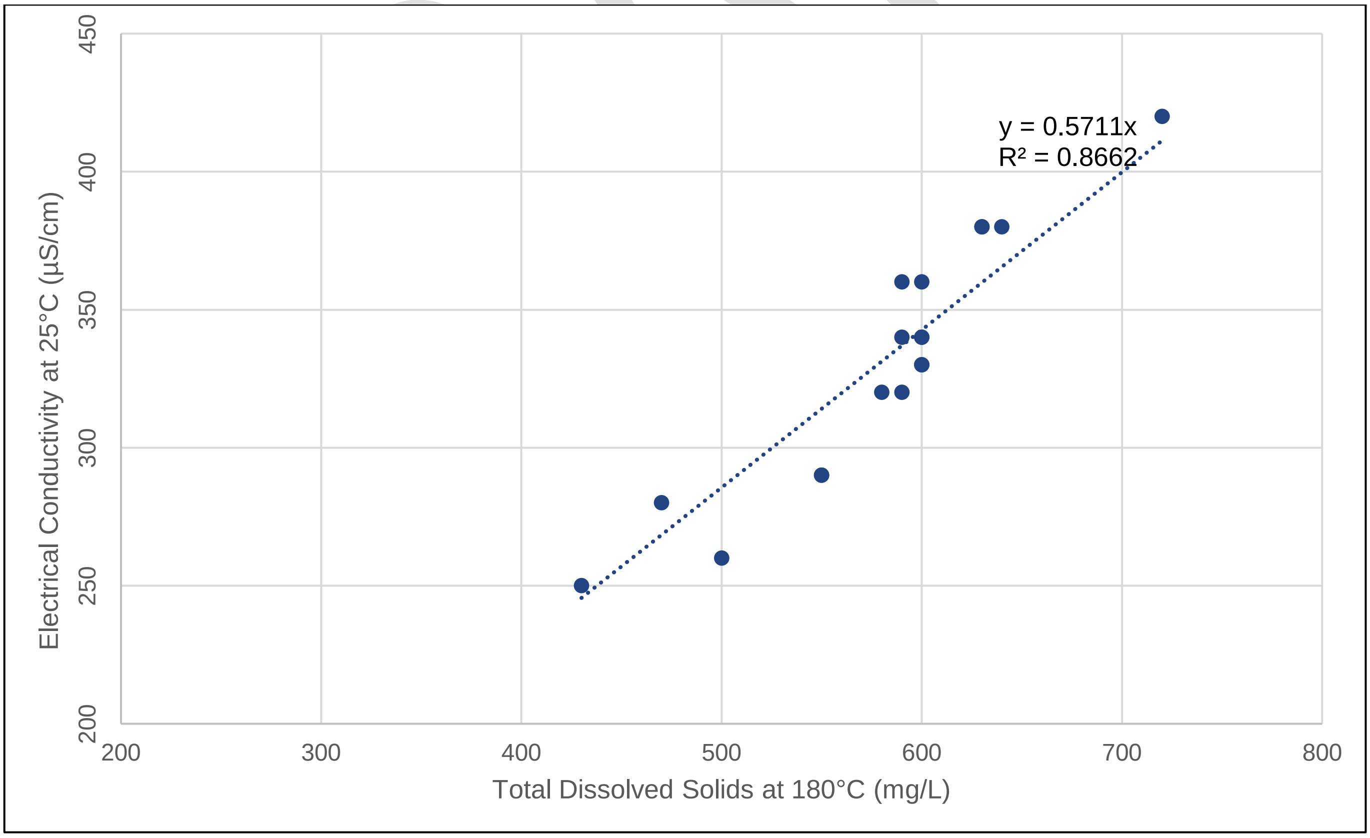

Figure 17: Electrical conductivity to TDS for Ministers North to establish convertion ratio

6 Step Test Analysis

Step rate aquifer testing was conducted on all four production bores with four steps at rates between 30 and 80L/s, depending on outcome of initial calibration. Long term pumping test where unable to be conducted due to PEHAR discharge restrictions and concerns of impacts on the regional aquifer and local pools form extended pumping. As such, an attempt to determine transmissivity and storage values was undertaken utilised the step rate data. Analysis was undertaken using the Theis step rate method which applies to confined aquifers and may not be ideal for the aquifer conditions found at Ministers North. Analysis results are given in table 7 below.

Maximum injection rate was estimated based on the calculated transmissivity of the aquifer and injecting at a given rate over 1 year period. The available head above the water to within a nominal 10 m of surface was used to determine the available mounding potential. The exception was HMN0045 which was assigned a limit at ground level as this bore is located within the reiver bed where groundwater and surface water interface. Environmental considerations such as local tree root depth and potential impact on the nearby Yandicoogina Gorge GDE will need to be factored in to determine the safe available mounding height for operation of the injection field.

Overall, the aquifer has been found to be high transmissivity with relatively low storage storativity, which is similar to previous work conducted to the west of the rail line within the proposed Ministers North pit shell (RPS, 2021).

The maximum rate of 80L/s for HMN0042 was limited by pump capacity, with very little drawdown seen during the step test. Monitoring data from the nearby monitoring bore (HMN0046) had different water levels between the manual dips and the downhole logger leading to poor fit during the aqtesolv analysis, with water levels in the monitoring bore being very responsive (maximum Drawdown of 0.8 m). The production bore HMN0042 only experience 2.4m of drawdown at 80 L/s indicating the aquifer was not fully stressed during the test, and significant upside in potential pumping rates is present.

Bore efficiency was calculated for each step. HMN0042 and HMN0045 were relatively low suggesting the bore was not fully developed or experienced high inflow velocities. In fractured rock aquifers poor bore performance can be due to water coming from discrete fractures causing localised, higher than expected inflow velocities within the aquifer. As the calculated maximum injection rate is significantly above the tested step rates for three of the production bores, it is likely to overestimate the potential injection rate.

Only two steps were completed in HMN0044 as the two sumps available for water to be pumped into failed to contain the water and the test was terminated to prevent breach of the PEHAR conditions.

Assumptions made are that is that mounding will occur as a mirror of drawdown and long-term injection rates could be similar to the short-term test rates. Due to the high conductivities observed in the bore this could be a reasonable assumption. The presence of boundary effects on the aquifer have not been tested and may drastically change the hydraulic response behaviour of long-term injection.

Table 7: results of Step rate test analysis

Hole Name	Step	Step Rates (L/s)	Drawdown (m)	Apparent Efficiency (Ew %)	Transmissivity (m^2/day)	Storativity (S)	Maximum Injection Rate (L/s)
HMN0042	1	50	1.03	24	12800	$1.8*10^{-5}$	200+ *
	2	60	1.37	21			
	3	70	1.91	19			
	4	80	2.41	17			
HMN0043	1	30	2.35	70	3200	$4.2*10^{-6}$	140*
	2	40	3.51	63			
	3	50	4.80	58			
	4	60	6.24	53			
HMN0044	1	40	5.34	75	680	$1.9*10^{-4}$	120*
	2	50	7.21	70			
HMN0045	1	35.0	11.27	8.7	530	$5.2*10^{-8}$	23
	2	37.5	13.20	8.0			
	3	40.0	15.22	7.6			
	4	42.5	17.48	7.1			

Note: * Calculated injection rate is far outside step rates

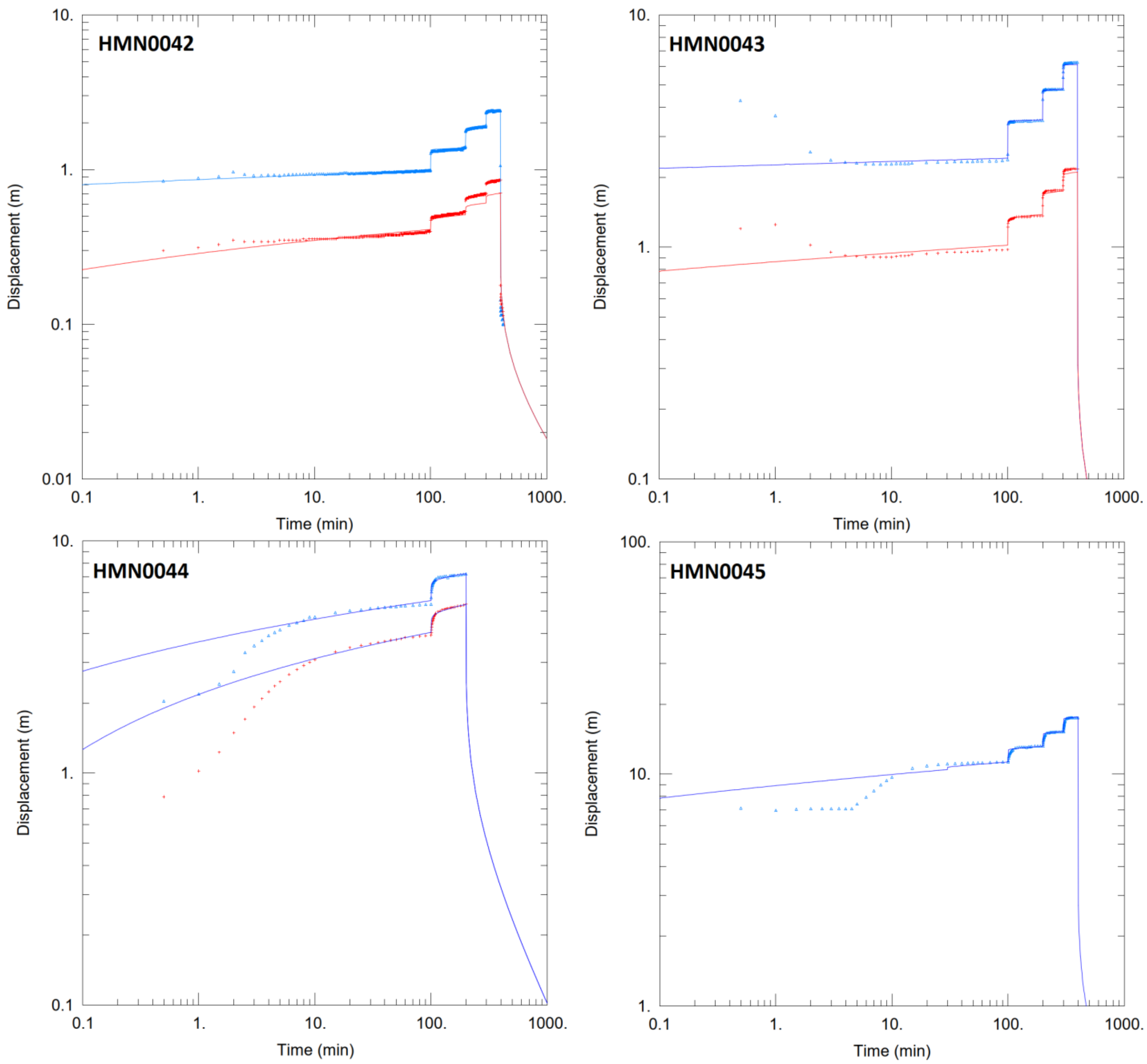

Figure 18: Graphs of Theis Confined Step Rate Test Analysis

7 DRILLING PERFORMANCE ASSESSMENT

7.1 Drilling Execution Risks

As the drilling contractor was a Dual Rotary (DR) rig, significant depth of hard, near surface ground was drilled DR leading to slower than expected completion rates. The monitoring bore casing of HMN0057 and HMN0046 was installed in-rod due to intersecting broken ground at depth. This was allowed for in the design of the program with thinner, threaded PN25 PVC casing and could have been readily achievable without controlling surface material with DR casing.

The two bores monitoring bores where DR casing was advanced deep where HMN0053 (130 m) and HMN0055 (80 m). This was due to encountering unstable formation, leading to the DR casing being reamed to depth. While this did allow the monitoring bore casing to be installed in a clean open hole, it is likely conventional drilling would have been able to drill to depth without issue and the initialisation completed in rod.

The injection bore HMN0042 was installed on the same pad as HMN0046. As the monitoring bore showed poor ground conditions at depth, the drillers attempted to ream down 18" DR casing through the hard formation. This resulted in very slow penetration rate and 12 shifts to get the DR casing down to 44 mbgl. The decision was them made to drill open hole to complete the bore. The hole was over drilled by 4 metres, but boggy ground did not allow further over drilling and the production casing was installed 5 metres short of target depth. This bore met its technical objective and due to the high development yield (50 L/s) will provide sufficient injection capacity in this area.

HMN0045 was drilled at the base of the Yandicoogina Gorge and intercepted deep loose material with cobble sized chips coming out of the Discharge Control Unit (DCU), as well as having a near surface water levels. During bore development the outside of the bore blew out and was stabilised with gravel pack to prevent further blow out and rig instability. This could have been prevented by cementing in larger diameter surface casing to the top of the desired screened section. As the annulus was filled to surface with gravel pack, no seal was installed. Ventia plan to rectify this situation in the coming quarter by removing the gravel down to 5m and installing a surface seal.

7.2 Drilling Completion Performance

Monitoring bores were completed in an average of 7 shift and 19 shifts for the production bores. All bores were completed and met the technical objective. As mentioned, some delays were experienced due to discharge management and safety incidents. Additionally, DR drilling through hard ground was a significant contribution to slower than expected completion rate.

8 CONCLUSIONS

The drilling program resulted in the successful construction of thirteen monitoring bores and four injection bores at Ministers North. All bores reached their technical objectives and the project as a hole was successful. The primary objectives of this program to build upon the data collected in previous drilling programs and drill a series of pilot and production bores to determine the viability for a MAR scheme at ministers North, was achieved.

Significant fracturing is present across the project area, with airlift yields increasing significantly from monitoring bore to production bore. Airlift yields as low as 5 L/s encountered in the monitoring bore HMN0049 where targeted for successful injection bore locations yielding 20L/s. This is in keeping with transmissivities of 400 to 2,000 M^2/Day from the aquifer test conducted in HMN0033 on the western side of the rail line (RPS, 2021).

There is good potential for a re-injection bore field to mitigate any further impact on the Yandicoogina Gorge GDE. Maximum injection rates have been calculated but likely overestimate the injection potential due to limitations in the testing methodology.

The Mt McRae shale does not appear to form a low permeable barrier in the Ministers north area.

Keystone fault does not appear to act as a groundwater barrier to groundwater flow and may act as a preferential conduit to water flow form the project area to the North-East.

Water levels within Monitoring bores remain constant across the project area and are currently above the given elevation of the Yandicoogina Gorge pools. Flow pathways from the regional aquifer to the sediments at the base of the Yandicoogina Gorge may already be impacted by declining water levels and needs further clarification.

9 RECOMMENDATIONS

This project could have been completed in a timelier manner utilising conventional hammer drilling methods for the monitoring bore drilling portion. Two production bores (MHN0042 and HMN0045) had some stability issues during drilling which were able to be overcome with DR drill rig.

All injection bores should have annulus seals from surface down to the top of the productive zone to ensure water injected under pressure cannot leave the bore via the annuals. This minimises the risk of mounding and can allow for greater efficiency and higher injection rates. HMN0045 surface seal was only installed to 2 m, which should be factored in when planning injection rates.

The low permeable ground around HMN0024 encountered during the previous drilling program remains an outlier, with no significant yield observed (<0.1L/s). As this bore is located on the eastern edge of the tenement boundary, more investigation of a possibly aquifer boundary in this area could help understand groundwater flow pathways from the proposed mining area to the ponds in the Yandicoogina Gorge.

As water levels at Ministers' North are impacted by seasonal recharge, periods of loss from the aquifer to the river and from the river to the aquifer are expected. Additional maps of water levels could be created from either existing monitoring data or future monitoring events to see how the water table behaves throughout the dry and wet season to see if the direction of groundwater flow changes.

Measured water levels remain above the given elevations for the pools and the flow pathways from the regional aquifer to the pools is poorly understood and further investigation is warranted. Current yield and elevation of the seepage zone along the Gorge wall should be mapped and factored into the conceptual model of how flow groundwater interacts with the alluvium in the Gorge.

10 REFERENCES

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Appendix I Bore Hydrogeology Log

Appendix II Bore construction information.

Bore ID	East (MGA94_50)	North (MGA94_50)	Ground RL (mAHD)	EOH (mbgl)	Hole Strat	Comments	Fallback (mbgl)	Gravel Pack (mbgl)	Seals (mbgl)	Slot Min (mbgl)	Slot Max (mbgl)	Yield (Max L/s)	Last EC (us/cm)	Last pH	Screened Unit	TOC RL (mAHD)	Stick up (m)	SWL (mbgl)	SWL (mAHD)
HMN0042	719287.5	7473289.3	589.29	104	D3, D2, D1, RU	Chosen based on HMN0046	95.5 - 104	25 – 95.5	0 - 25	47.5	95.5	50	422	7.97	D2, D1, RU	589.64	0.35	28.48	561.16
HMN0043	719483.9	7473973.9	607.11	104	D3, D2, D1	Chosen based on HMN0047	103.5 - 104	5 – 103.5	0 - 5	58	100	20	492	8.76	D2, D1	607.41	0.31	46.17	561.24
HMN0044	719859.7	7474206.7	621.23	116	J3, J2, J1, W	Chosen based on HMN0049	105 - 110	5 - 105	0 - 5	57	105	20	617	8.39	J2, J1, W	621.50	0.27	59.81	561.69
HMN0045	719283.3	7473597.8	569.22	51.5	T, RU, RC	Chosen based on HMN0016		2 - 51.5	0 - 2	15.5	51.5	20	517	8.25	T, R	569.57	0.35	8.37	561.19
HMN0046	719282.6	7473288.6	589.35	104	D2, D1, RU	Fallback to 92m. Casing installed in-rod.	92 - 104	5 - 92	0 - 5	23	101	10	431	8.6	D2, D1, R	590.20	0.85	29.03	560.99
HMN0047	719477.1	7473973.1	606.95	102	SZ, D3, D2, D1			5 - 102	0 - 5	40	100	7	604	8.8	D2, D1	607.66	0.66	45.66	561.34
HMN0048	719620	7474032.8	607.36	100	D4, D3, D2			5 - 100	0 - 5	40	100	5	591	8.8	D4, D3, D2	607.76	0.23	46.25	561.28
HMN0049	719854.9	7474209.8	621.09	122	J2, J1, W, D1			5 - 122	0 - 5	36	120	5	558	8.8	J1, W, D1	321.77	0.52	60.13	261.12
HMN0050	720020.3	7474265.9	634.04	122	J5, J4, J3, J2, J1			5 - 122	0 - 5	36	120	4	600	8.7	J4, J3, J2, J1	634.65	0.58	72.92	561.15
HMN0051	719291.5	7474158.7	605.72	142	SZ, D4, D3, D2, D1			5 - 142	0 - 5	40	142	10	565	8.8	D4, D3, D2, D1	606.41	0.59	44.55	561.27
HMN0052	719119.8	7474256.7	605.74	151	SZ, W, D4, D3, D2, D1			5 - 151	0 - 5	37	151	10	681	8.8	D4, D3, D2, D1	606.45	0.67	44.57	561.21
HMN0053	718088.2	7473558.9	652.97	151	D3, D2, D1, RU, RC, RL	Broken ground 73-98m in D1 and 122-130m in RC. FWS 94m.		5 - 151	0 - 5	78	150	12	570	8.9	D1, RU, RC, RN	653.57	0.61	92.68	559.96
HMN0054	719435.6	7474681	614.11	104	SZ, J5, J4, J3, J2			5 - 104	0 - 5	40	100	6	545	8.9	J2	614.77	0.61	52.98	561.18
HMN0055	720063.0	7474916.1	615.67	104	SZ, J6, J5, J4			5 - 104	0 - 5	40	100	5	355	8.4	J5, J4	616.34	0.65	54.4	561.29
HMN0056	718836.4	7474959.3	620.44	110	SZ, J3, J2, J1	Hole terminated short of target depth due to discharge management/ leaky sump.		5 - 110	0 - 5	74	110	8	559	8.7	J2, J1	621.19	0.69	59.17	561.33
HMN0057	718863.5	7472807.7	611.27	104	SZ, W, D3, D4, D3	Fallback to 92m. Casing installed in-rod.	101 - 104	5 - 101	0 - 5	11	101	5	244	8.3	W, D4, D3	612.24	0.93	50.1	561.21
HMN0058	720039.9	7475274.6	625.77	98	HJ, Y, J6	High magsus between 68 and 98 mbgl (530 SI E-3) no fibrous material observed.		5 - 98	0 - 5	38	98	3	620	8.7	Y, J6	626.38	0.66	64.5	561.22