TITLE : Groundwater Potential of the Summerdown Area

PROJECT : Omitiomire Copper Project

CLIENT : Craton Mining and Exploration (Pty) Ltd

DATE : 11/12/2023

DOCUMENT NO. : C1022-M67-002

REV. No.	DATE	REVISION DESCRIPTION	PREPARED BY	REVIEWED	APPROVED	CLIENT
1	11/12/2023	Issued to Client	D Sarma	A Simmonds	E Roux	T du Preez
0	16/11/2023	Approved for Use	D Sarma	A Simmonds	E Roux	T du Preez
B	16/11/2023	Issued for Client Review	D Sarma	A Simmonds	E Roux	T du Preez
A	16/11/2023	Issued for Client Review	D Sarma	A Simmonds	E Roux	T du Preez

DOCUMENT AUTHORISATION				
DESCRIPTION	AUTHOR	REVIEWED	APPROVED	CLIENT
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DATE:	11/12/2023	11/12/2023	11/12/2023	
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Table 0-1: Abbreviations

ABBREVIATIONS	
DWA	Department of Water Affairs
DWRM	Directorate of Water Resource Management
EIA	Environmental Impact Assessment
EPL	Exclusive prospecting license
GIS	Geographical Information System
GROWAS	Groundwater information system of the DWA
Hk	Hydraulic conductivity (m/day)
Km	Kilometre
LOM	Life of mine
m	Meter
m amsl	Meter above mean sea level
m bgl	Meter below ground level
m^3	Meter cubed
m^3/day	Meter cubed per day
m^3/h	Meter cubed per hour
m^3/year	Meter cubed per year
Mm^3/year	Million meters cubed per year
mm	Millimetre
MAWLR	Ministry of Agriculture, Water and Land Reform, Government of Namibia
OCP	Omitiomire Copper Project
S	Storage coefficient (-)
SKA	Summerdown Kalahari Aquifer
Ss	Specific storage (m^{-1})

Table 0-2: Glossary of Terms

GLOSSARY OF TERMS	
Aquifer, extent of	The boundaries of the geological unit from which groundwater may be abstracted.
Available drawdown	The depth from the static water table to the main water bearing zone or water strike penetrated by a borehole.
Constant rate test	A pumping test carried out for an extended period at a constant rate. (see "Pumping Test" below)
Dewatering	Decline of the water table or the piezometric head. This may result from pumping rates exceeding the capacity of boreholes.
Discharge	Outflow from the aquifer either naturally or through pumping.
Downhole geophysics	Measurement of physical properties of intercepted geological material down the length of a borehole.
Drawdown	The distance between the static water level and water level during or after pumping in a borehole.
Dry season peak demand	Highest water demand for mining and/or agriculture during the dry season in a year.
Effluent drainage	Surface drainage that receives groundwater (also called gaining stream)
Ephemeral drainage, leakage from	Drainages that experience seasonal flow, following rain events but otherwise remaining dry. Where water from such flow infiltrates the subsurface and recharges underlying groundwater it is referred to as leakage.
Drawdown forecast	Estimate of water level decline due to pumping from an aquifer based on hydraulic characteristics estimated by test pumping and/or groundwater flow modelling.
Groundwater recharge	Inflow of water to the saturated zone of an aquifer due to infiltration of rainwater or leakage from other surface or groundwater bodies.
Hydraulic conductivity	Hydraulic conductivity is the constant of proportionality relating water discharge per unit area of a porous medium under a unit hydraulic gradient according to Darcy's Law. Hydraulic conductivity reflects the ease with which water flows through a porous medium.
Influent drainage	Surface drainage that leaks to the subsurface (also called losing stream)
Isopach	Contours of equal thickness of a sedimentary layer.
Karst, karstification	Subsurface openings created or modified by chemical dissolution, usually of carbonate minerals. The process of karst formation is called karstification.
Life of Mine	Duration for a which a mine is planned to operate.
Non-dry peak period	Highest water demand, for mining or agriculture, during the rainy season in a year.
Pumping test	Pumping test carried out on a borehole at set rate(s) for a pre-defined period (s). Discharge and water level are recorded against time to facilitate the calculation of hydraulic characteristics.
Recovery phase	Period in which the water level recovers (rises) following a step drawdown or constant rate test.

GLOSSARY OF TERMS	
Saturated zone	A level below ground where groundwater occupies all open spaces in an aquifer. The water is at a pressure higher than atmospheric pressure in the saturated zone.
Static water level	The distance from the ground surface to the water table in a borehole under normal, undisturbed, non-pumping conditions.
Step drawdown test	A borehole performance pumping test carried out in usually four to five steps of increasing rate. Each step is for an equal duration.
Storativity	Storativity is a measure of the capacity of an aquifer to store and release water.
Sustainable abstraction	Sustainable abstraction is the rate of groundwater withdrawn from an aquifer at a location and for a known duration with acceptable physical, economic, environmental, social, cultural, institutional, and legal consequences. It considers other existing water demands and possible environmental impacts in assessing available water for use.
Transmissivity	Transmissivity is the product of the hydraulic conductivity and the saturated thickness of the aquifer and is a measure of the overall capacity of the aquifer to transmit water.
Unconfined aquifer	In an unconfined aquifer the water table forms the upper boundary.
Unsaturated zone	The zone between the ground surface and the water table where water and air occupy the open spaces in a porous medium.
Water budget	An account of all inflows (sources) and outflows (sinks) of water to an aquifer is called a water budget. Components of a water budget include water stored in the aquifer, recharge, discharge, pumping etc.

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DISCLAIMER

This report is prepared for exclusive use of Craton Mining and Exploration and Creo Engineering Solutions Pty (Ltd). It records the results of an ongoing groundwater exploration and development project for water supply to the Omitiomire Copper Project. The report is to be used for the purpose stated – to assess the aquifer to sustainably supply the Omitiomire Copper Project with water for the life of mine of eleven years.

The author and Namib Hydrosearch are not responsible for the outcome and conclusions drawn in the context of the proposed abstraction and not liable for any consequences of using the report. The limitations in the study and available data are recorded in the report and may not be limited to those noted. The availability and quality of data, performance of the software and inherent limitations of software determine the quality of the results. All care has been taken to verify the data and use concepts and applications appropriately. The study is carried out on the basis of current scientific understanding of groundwater flow and knowledge of the Summerdown Kalahari Aquifers that may change in the future.

EXECUTIVE SUMMARY

This report, on the groundwater potential of the Summerdown Kalahari Aquifer, forms an integral part of the feasibility study for mining the Omitiomire Copper Project, which is currently being conducted on behalf of Craton Mining and Exploration Limited. Anticipated water demand for the proposed mine, when in full production, will be 2.2 million cubic meter per year.

Existing data and information on the Summerdown Kalahari Aquifer show that, although borehole yields are generally low, there are zones in which relatively high yields have facilitated the successful establishment of several centre-pivot irrigation schemes. Evaluation of surface conditions and drainage, in these higher yielding areas has led to the identification of other, as yet undeveloped areas which could provide sufficient groundwater to sustain the anticipated demand from the OCP mine sustainably.

An initial desktop study identified the most favourable areas for water abstraction and landowners in these areas were therefore approached for access to allow water exploration to be undertaken. Access agreements were signed with the landowners of 7 farms. Fieldwork was restricted to those farms for which access agreements had been obtained.

On one of these farms, Lawriesdale, several boreholes had been drilled by the landowner and preliminary testing had indicated that high yields could be expected. Permission was granted for the project to test pump certain of these boreholes. On other farms, Kismet, Wesselsputs, Welgedacht and Meyerville it was necessary to drill boreholes to conduct such test pumping.

Information on subsurface strata was obtained from downhole geophysical logging in pre-existing boreholes and from lithological logging of newly drilled boreholes as part of the exploration programme. With this information, cross sections have been drawn to illustrate down-gradient changes in the composition of the sediments and explain observed trends.

The evaluation of test pumping data has shown that wellfields on the farms Lawriesdale, Kismet, Meyerville and Ettrick can satisfy the overall water demand of the Omitiomire mine. Dry season peak water demand and maximum water demand in the initial stages of operation of the mine (350 cubic meter per hour) can be met from the identified sources. Preliminary groundwater flow modelling confirms that the supply will be sustainable.

Recommended pumping rates are given for each of the boreholes identified for production use. To maximise the sustainable exploitation of the Summerdown Kalahari Aquifer resource, recommendations are also provided regarding production borehole spacing and water level monitoring in the areas surrounding the wellfields.

Prior to commencement of mining activities, it will be necessary to sign abstraction agreements with landowners and to obtain permits for water abstraction and conveyance from the Ministry of Agriculture, Water and Land Reform to secure the water source.

1 INTRODUCTION

From an assessment of available alternatives for groundwater supply to support mining operations at the Omitiomire Copper Project (OCP), the Summerdown Kalahari Aquifer (SKA) was identified as the most favourable. Location of Summerdown is shown relative to the OCP in **Figure 1-1**. This aquifer currently supplies bulk water for irrigation projects, and exploratory drilling and test-pumping indicate that the SKA resource is able to sustainably meet the water demand of the OCP. Saturated Kalahari sediments that form this aquifer are situated 65km to the east of the OCP extending another 90km further eastwards.

An initial understanding of the aquifer was achieved from existing data sources which enabled identification of areas of higher groundwater potential as targets for field investigation. Groundwater exploration and testing have now been carried out on certain of the targeted farms close to Summerdown and modelling of the results demonstrates that the OCP demand can be met from wellfields on four farms.

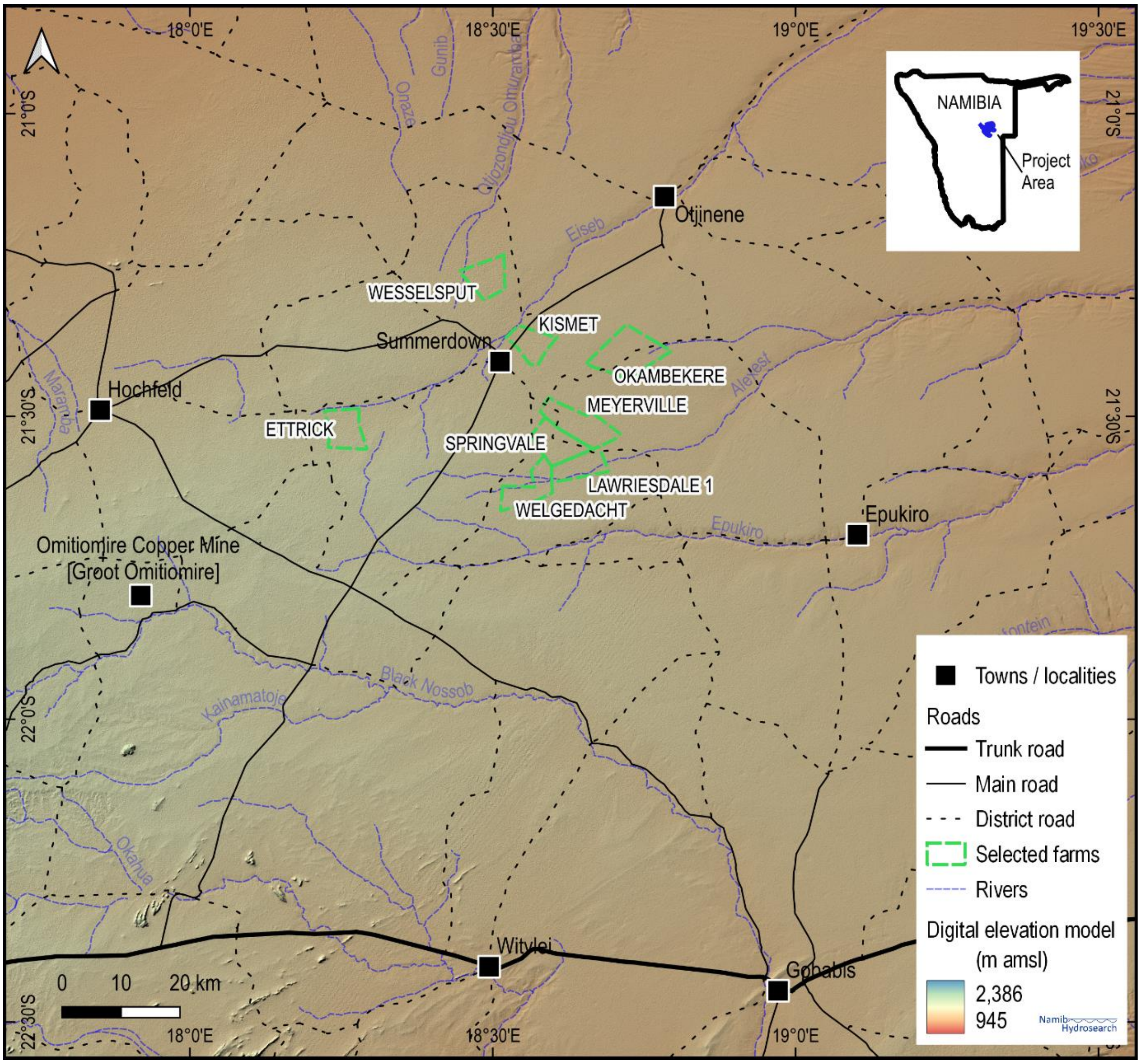

Figure 1-1: Project area location map

Access to the farms for groundwater exploration and testing work was negotiated with landowners. Abstraction agreements with landowners and permits from MAWLR will however still be required prior to development and production.

2 PROJECT WATER REQUIREMENT

The updated water requirement of the Omitiomire Copper Project is 306 m³/h or 2.23Mm³/year (**Table 2-1**). However, for the initial 4 months of the project water demand is expected to be higher at 350m³/h.

Table 2-1: Project bulk water requirement for the Omitiomire Copper Project

Description	Units	Quantity	Comment/Source
Dry season peak demand	m³/hr	306	Reference Doc: C1022-M67-001_Water Supply Basis of Design 07.11.2023
Non-dry peak period	m³/hr	198	
Average demand	m³/hr	252	
Bulk Annual Consumption	m³/year	2,235,515	
Life of Mine	years	11	

3 PHYSICAL SETTING OF THE SUMMERDOWN KALAHARI AQUIFER (SKA)

3.1 Rainfall and hydrology

Water deficit conditions prevail in the Summerdown area most of the year, as potential evapotranspiration rates exceed average rainfall during all months except in January, February, and March. Average rainfall exceeds monthly average potential evapotranspiration in these three months and recharge to the groundwater is therefore expected to occur. The long-term sustainability of the groundwater resource is dependent on seasonal rainfall depth trends over time. Under semi-arid conditions prevalent in Summerdown area, usually above average rainy seasons are required to recharge groundwater and for the water table to recover. It is assumed that rainfall events exceeding 452mm/year (15% higher than mean annual rainfall of 392mm/year) are required for recharge to occur. From rainfall frequency analysis there is an 81% probability of such an event occurring at least once in 5 years. Groundwater recharge events, although episodic, are expected to occur at regular intervals.

The general slope of the area is to the east (**Figure 3-3**) and several larger ephemeral drainages are developed, namely, the Eiseb and the Epukiro (**Figure 3-3**). Smaller ephemeral drainages are present in the interfluvial areas of these rivers and their interaction with groundwater is discussed further in Section 4.

3.2 Geology

Kalahari Group strata of Tertiary age form an unconsolidated to semi-consolidated cover of arenaceous sediments overlying the Damara rocks which are exposed to the west and south.

West of the SKA lies the folded metamorphic strata of the Southern Margin Zone of the Proterozoic Damara Supergroup. From the available mapping of the area Swakop Group rocks including carbonate lithologies are indicated to the west of the SKA (Miller, 1983).

The extent and depth of Kalahari sediments in the area is known from groundwater borehole records in the GROWAS database (a borehole database maintained by the Ministry of Agriculture, Water, and land Reform, MAWLR) and from mineral exploration drilling logs (Eiseb Exploration and Mining, EEM). From the available data an isopach map was generated illustrating Kalahari sediment cover thickness. As depicted by the isopach contours, Kalahari thickness generally increases to the north and east and is shown to exceed 150m in the northeast of the study area (**Figure 3-3**).

3.3 Hydrogeology

The Hydrogeological Map of Namibia (Lohe et al., 2021) classifies the project area as having "moderate potential". More recent information, from drilling and irrigation abstraction, however, suggests that the groundwater potential is actually better than "moderate". Available data confirm that the area is underlain by an unconfined Kalahari aquifer of variable potential.

Existing data (**Figure 3-3**) on the thickness of the Kalahari sediments, static water level and elevation of the ground surface (ALOS Global digital surface model, www.eorc.jaxa.jp) was used to generate a map of saturated Kalahari sediment thickness (**Figure 3-4**).

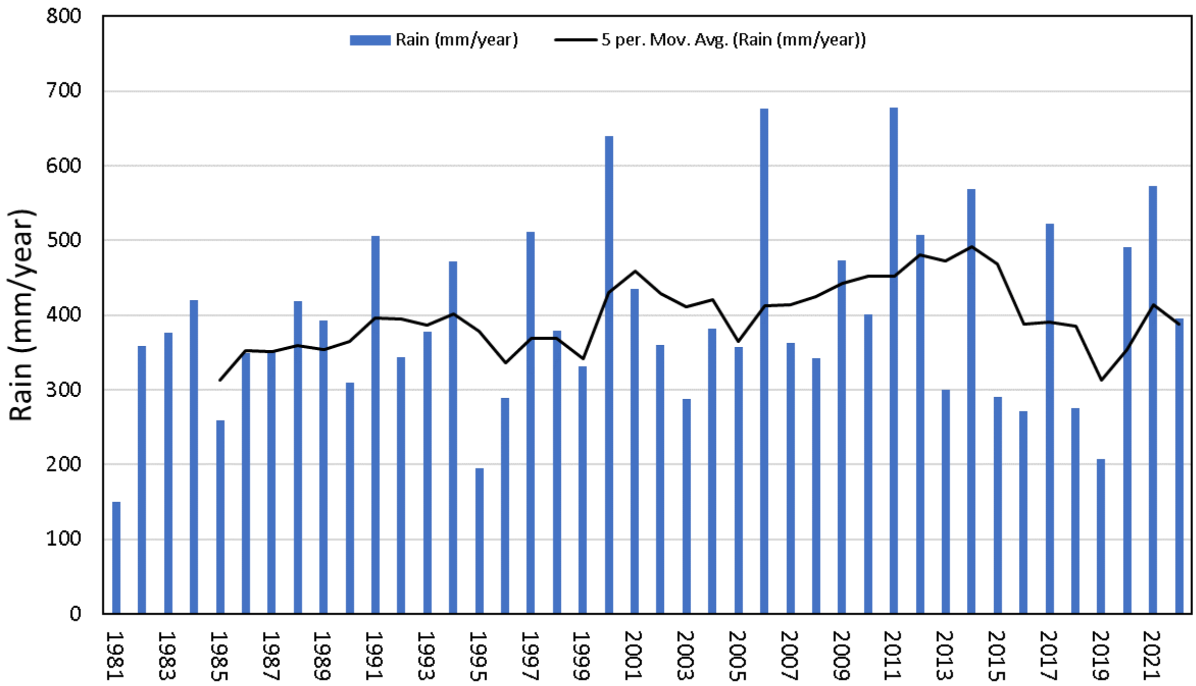

Figure 3-1: Annual rainfall in Summerdown (Funk et al. 2014)

3.3.1 Aquifer delineation

From these data it is seen that the Kalahari aquifer is restricted to an area extending from close to the western margin of the basin eastwards for 80 to 90km (**Figure 3-4**). The aquifer slopes from west to east and saturated thickness of sediments is shown in a cross-section (**Figure 3-5**). Further to the east the Kalahari sediments are dry. The aquifer, as delineated from the data, is shown in **Figure 3-4**.

Water level contours generated from the GROWAS database records (MAWLR, 2022) show that the regional groundwater flow direction is from west to east (**Figure 3-3**) while locally, flow may be towards the ephemeral drainages (e.g., Eiseb, Epukiro). Outflows to the ephemeral drainages are probably lost through evapotranspiration by vegetation along river courses. Historically, a few springs are said to have seasonally discharged groundwater to the Epukiro Omuramba near Du Plessis.

3.3.2 Current abstraction from the SKA

Bulk abstraction from the SKA is for irrigation and records of pumping are available for two farms (Evare and Okambekere) from the Department of Water Affairs. The remaining irrigation farms are identifiable in satellite imagery. Private records collected from individual farmers and the above records indicate that current total water consumption for irrigation is about 4Mm³/year.

Irrigation is carried out using central pivot systems and main crops grown are maize, wheat, and lucerne. Water consumption estimates for two crops per year is about 12,800 m³/year/hectare (Schimper, 2023). Water consumption differs during dry and rainy months, wet summer consumption being about 30% of the dry season demand. Some farmers only practice wet season irrigation thus using substantially less water than the estimate given by Schimper (2023).

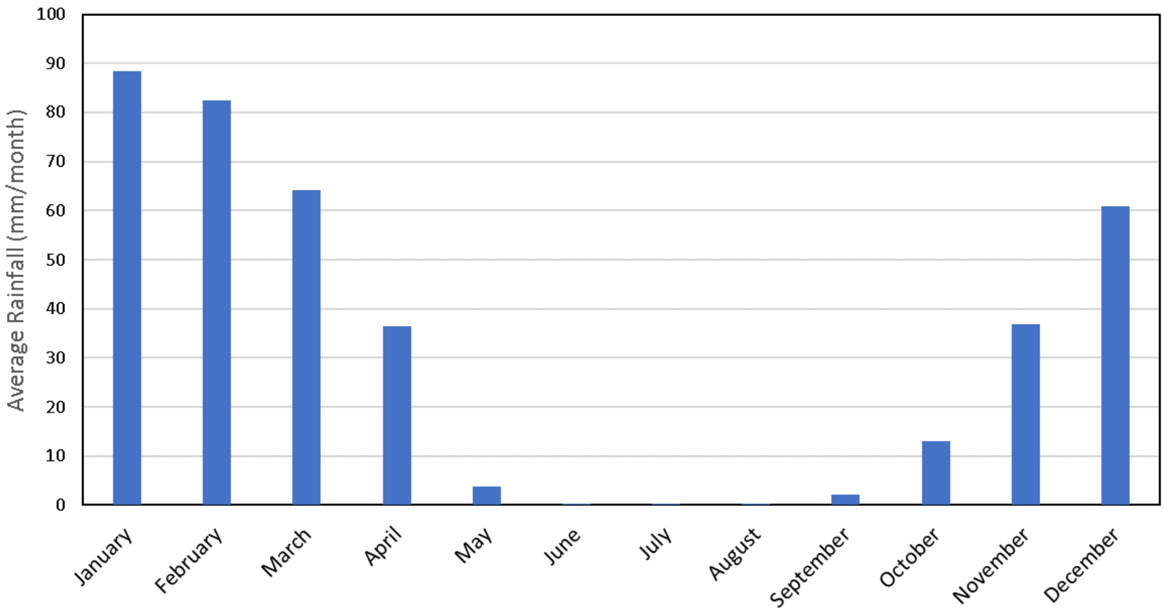

Figure 3-2: Monthly average rainfall (1981-2022)

Groundwater levels in monitored production boreholes in various irrigation schemes have remained stable since records are available from about 2018 (Geo Pollution Technologies, 2021). It should be noted that the monitoring points are often located within the irrigated agricultural fields where return flow is presumably causing local groundwater mounding that influences the measured water levels.

Stock watering and domestic water use from the SKA are relatively small and are not considered bulk usage.

3.3.3 Water quality

The overall groundwater quality sampled from the SKA is Group A (excellent quality water, according to the guidelines for evaluation of drinking water for human consumption, Department of Water Affairs, April 1988). Water quality is discussed further in Section 5.5.

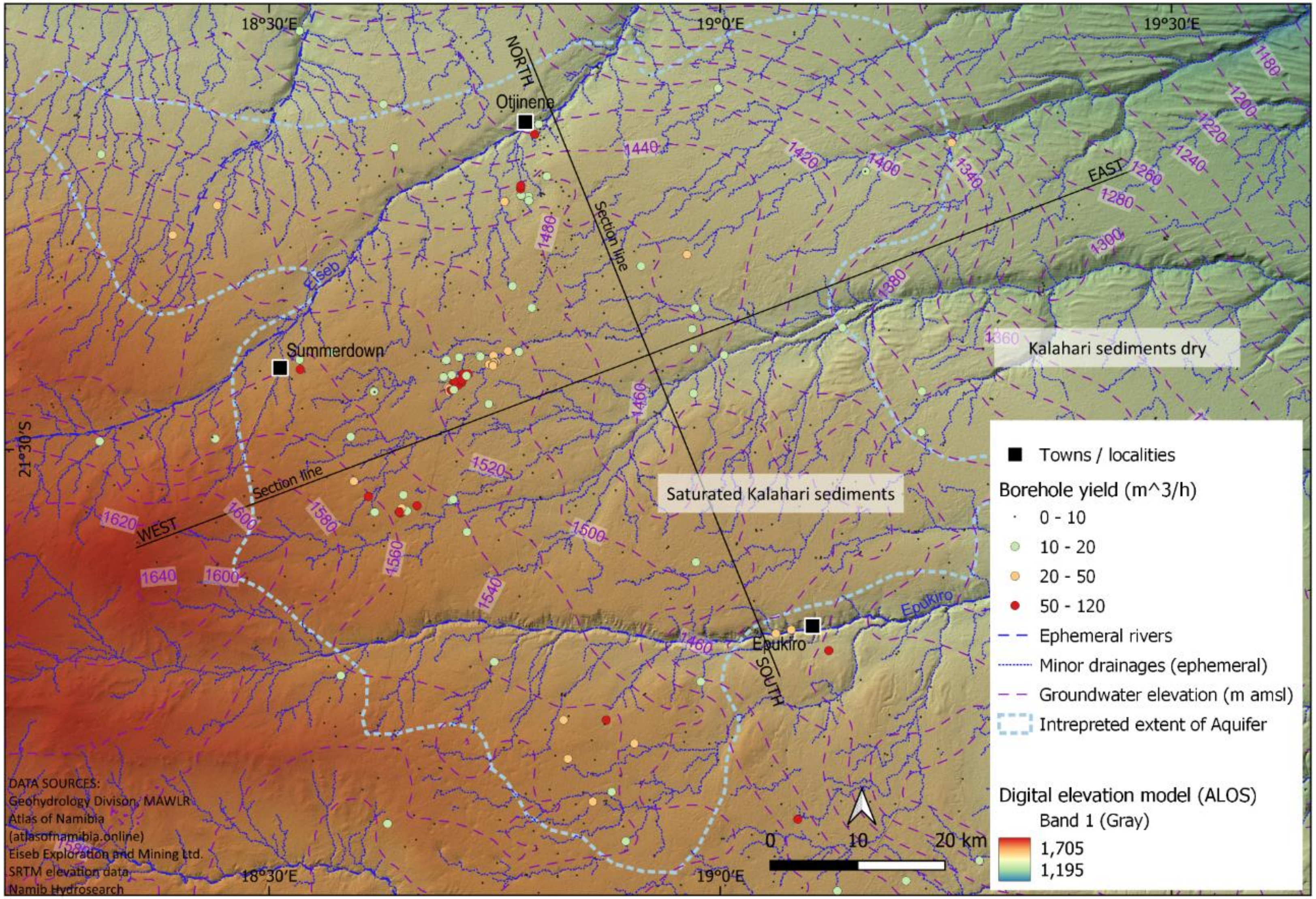

Figure 3-3: The Summerdown Kalahari Aquifer extent, surface drainages, and borehole yields

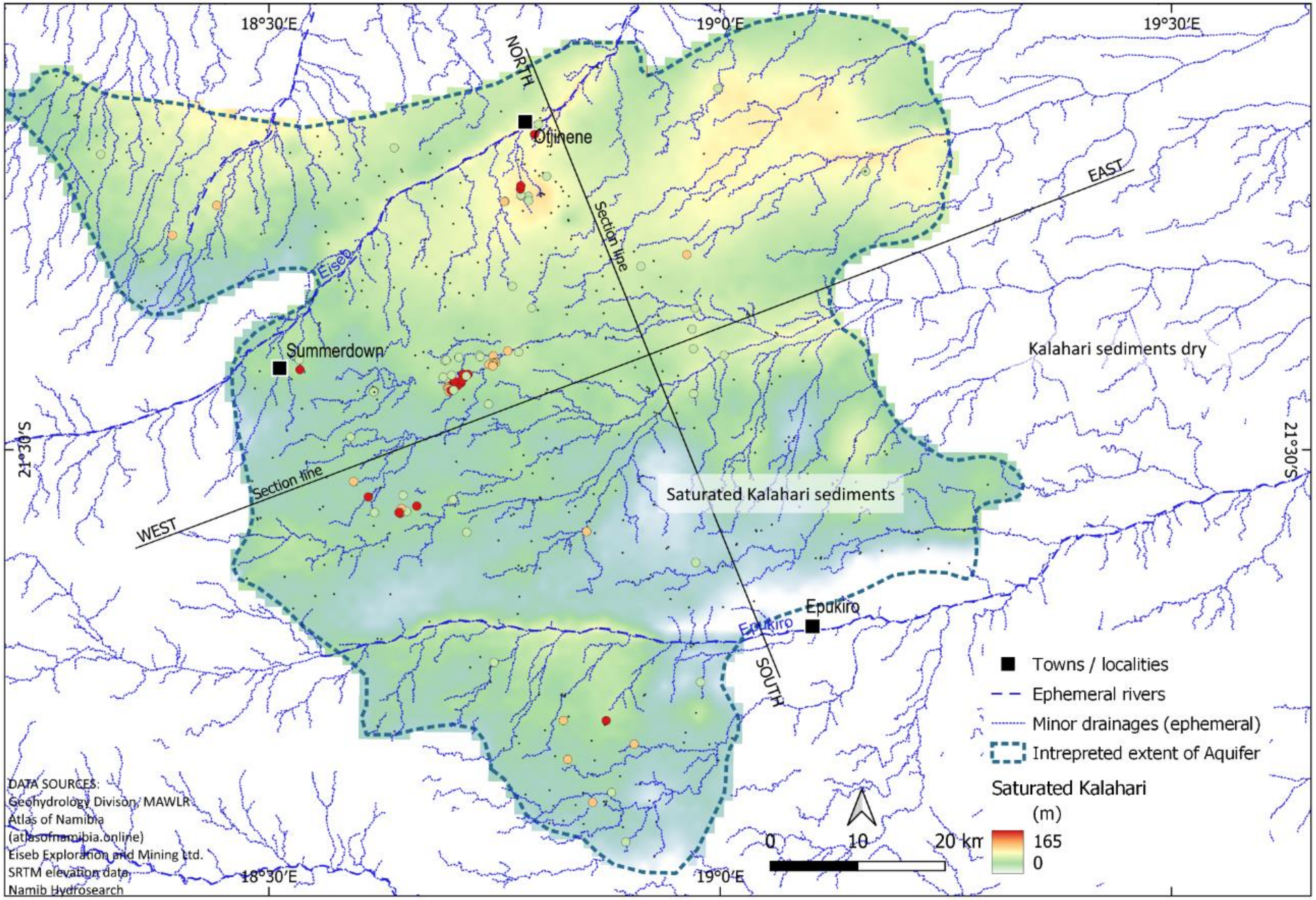

Figure 3-4: Summerdown Kalahari Aquifer extent and saturation

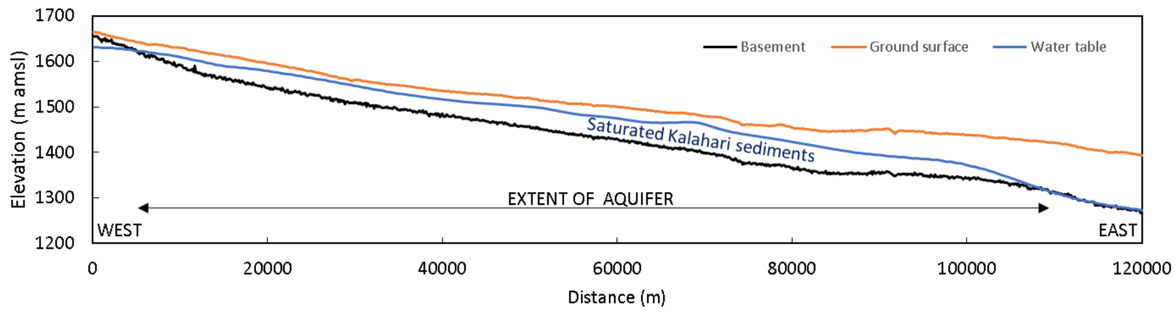

Figure 3-5: West to East cross-section across the Summerdown Kalahari Aquifer showing the extent of the saturated sediments (see Figure 3-4 for section line)

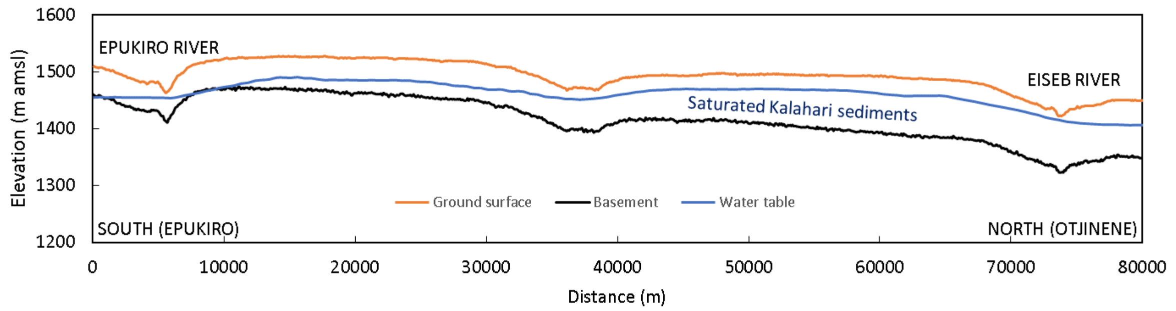

Figure 3-6: South to North cross-section across the Summerdown Kalahari Aquifer showing relationship of the groundwater table to topography and surface drainages (see Figure 3-4 for section line)

4 CONCEPTUAL UNDERSTANDING

Based on interpretation of satellite imagery (MAXAR vivid standard 50 cm, 3 band imagery and Google Earth images), the digital elevation model, borehole information and field observations a conceptual understanding of groundwater occurrence, and therefore areas of potentially higher yield, was derived.

The main points on the extent of the aquifer, origin and groundwater potential are stated below.

1. The Kalahari sediments are thinnest at the western edge of the basin thickening to the east and north. From about 80 to 90km eastwards of the margin the water table passes below the bedrock contact and the sediments are dry, i.e., the Kalahari aquifer is absent. This defines the extent of the Kalahari Aquifer in the east west direction (**Figure 3-4** and **Figure 3-5**).
2. In the north – south direction the interfluvial areas between the Epukiro and Eiseb Rivers have higher groundwater levels and locally the water table slopes towards the rivers (**Figure 3-6**).
3. Borehole yield in the Kalahari Aquifer is highly variable but generally low due to the fine grain-size and resulting low transmissivity of the sediments. No clear relationship is seen between saturated thickness and yield from boreholes.
4. Higher borehole yields are however seen to coincide with the headwaters of certain east and north flowing ephemeral streams. After rainfall these streams apparently receive groundwater, discharged via springs when groundwater levels are high after rainfall

making them thus effluent or gaining streams. Evidentially groundwater is forced to discharge through springs due to restricted or impaired downstream flow caused by the presence of clay rich sediments. This is illustrated in a schematic cross-section (**Figure 4-1**) and in an example (Farm Okambekere, **Figure 4-2**).

5. It is probable that spring discharge over a long period has resulted in the precipitation of calcium and magnesium carbonate, which has resulted in the formation of calcrete and/or calcareous sandstone (**Figure 4-2**). With fluctuating groundwater levels, solution cavity formation and possible karstification appear to have occurred locally within the calcrete and calcareous sandstone sections enhancing transmissivity and storativity (**Figure 4-2**).
6. In addition, where thicker, saturated, coarse-grained sand and gravel layers are present in the headwaters of the ephemeral drainage (**Figure 4-1**, A) groundwater yields are high (Farms Lawriesdale, and Springvale) making them favourable targets for further groundwater exploration.
7. In **Figure 4-1**, coarse grained unconsolidated sediments (A) and calcareous sediments (B) are favourable groundwater targets. Further downgradient where finer sediments are present, borehole yields are likely to be low.

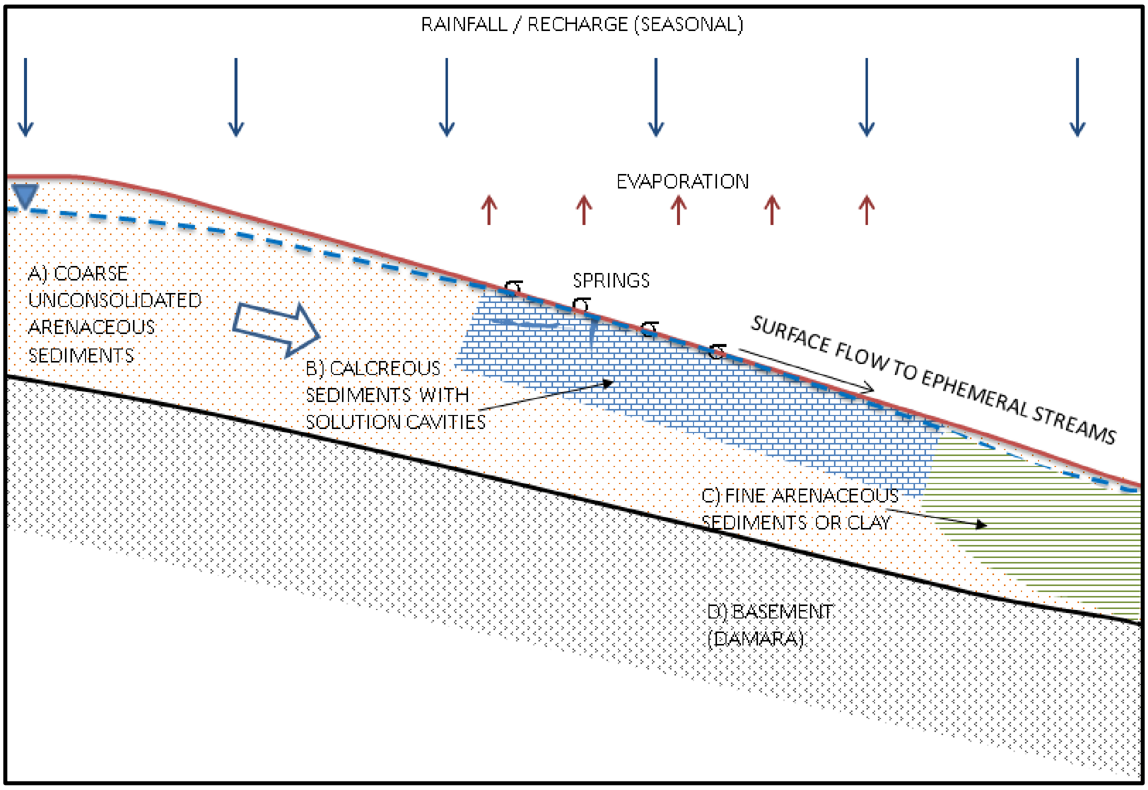

Figure 4-1: Schematic cross-section showing the coarse-grained arenaceous sediments, calcareous sediments and downgradient finer sediments, and potential for higher yielding Kalahari boreholes

Borehole records and water level data show the SKA to be unconfined and thus recharge of groundwater mainly occurs directly from infiltrating rainwater and to a lesser extent through leakage from streambeds during flow in wet summer months. Groundwater elevation is highest in the extreme west due to the slope of the sedimentary basin from west to east and generally higher along the interfluvial areas of the ephemeral drainages.

The unconfined SKA interacts with surface water drainages and in the process, both receives recharge and discharges groundwater. Some of the key processes are:

1. The aquifer in the Summerdown area is situated between the larger east flowing rivers, Epukiro and Eiseb. These larger ephemeral rivers are effluent through most of their reach gaining water. Groundwater naturally drains from the aquifer and is lost through discharge into these rivers, either through evapotranspiration or, occasionally, through springs along the rivers (**Figure 3-4**). Groundwater loss by evapotranspiration as major discharge mechanism in semi-arid to arid climatic conditions is well documented in the Kalahari Basin (Lubczynski, 2009; Lubczynski, 2011; Lekula and Lubczynski, 2019). Groundwater flow in the aquifer is to the east towards the deeper part of the Kalahari basin. At about 80 kms from the western edge of the basin, the Kalahari sediments are not saturated as the water table lies in the underlying bedrock (**Figure 3-5**).
2. In the interfluvial areas of the Eiseb and Epukiro, smaller ephemeral tributary streams are present that often have discontinuous courses. In the upper reaches these streams are influent or leaks to the underlying aquifer. Downstream the rivers are more well defined, and conditions change to effluent receiving groundwater discharge (**Figure 3-4**).

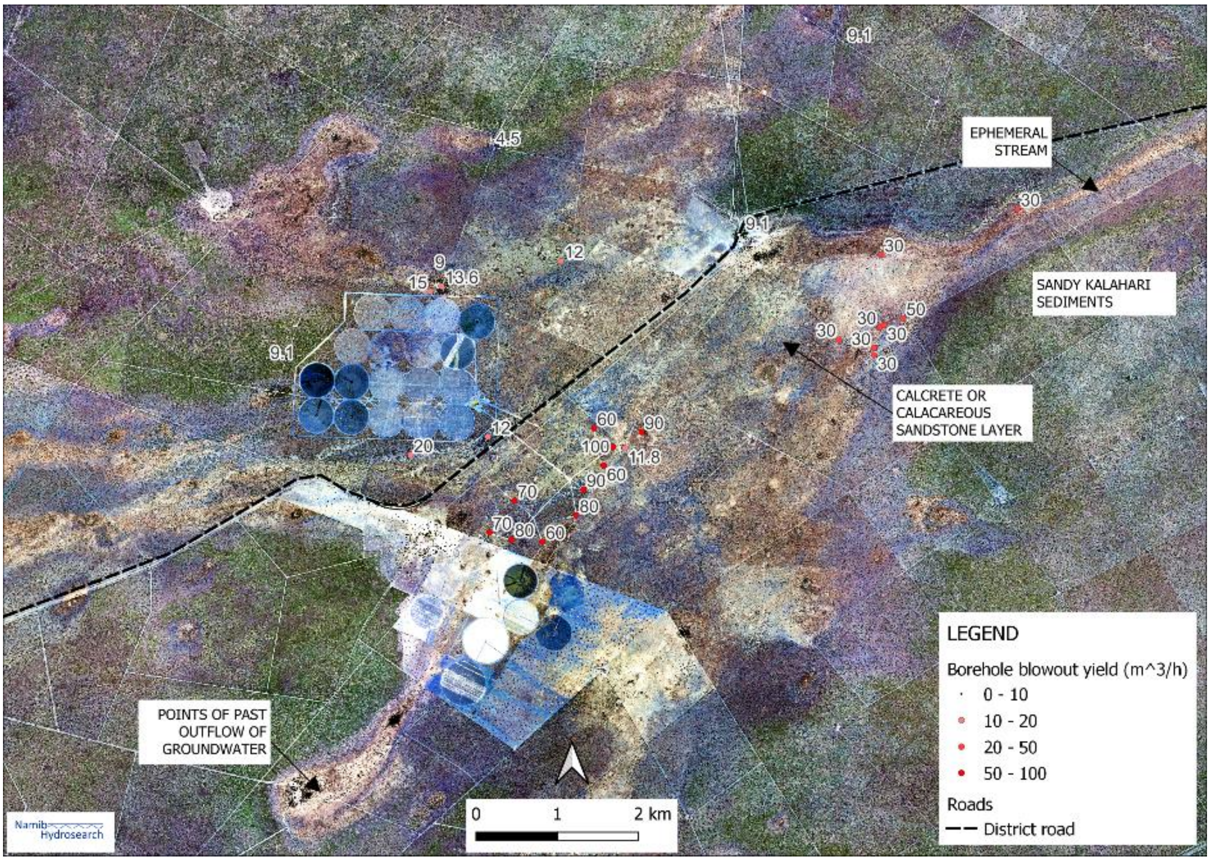

Figure 4-2: An illustration of higher yielding boreholes associated with the calcrete and karst features at the headwaters of an ephemeral stream (Farm Okambekere)

In summary,

- Groundwater originates from rainfall and is naturally discharged through outflow from the SKA to the east and laterally to larger ephemeral rivers.

- Borehole yields are determined by the nature of the aquifer material. Exploitation of the SKA resource requires boreholes to be carefully placed tapping formations with high groundwater transmissive properties e.g., karstified calcrete (carbonate rocks) or the coarse-grained sediments.
- The large extent of saturated Kalahari sediments gives rise to a substantial stored resource in the SKA. As groundwater recharge occurs from rainfall, the high variability of annual rainfall, typical in semi-arid regions, will result in periods of below average recharge which has been factored into planning for the life of mine. In the forecasts made using test pumping data below (Section 6) no recharge has been assumed for a period of 15 years).

5 GROUNDWATER EXPLORATION

5.1 Target selection and access to land

Based on the understanding gained from satellite imagery interpretation, combined with available borehole records, eight initial areas (A to H) of higher groundwater yield potential (targets) were selected for testing. These areas were distinguished by postulated calcrete, possible karst features, shallow groundwater and associated ephemeral drainages. The target areas are shown (**Figure 5-2**).

Targets were followed up with work based on successful access permission negotiations coupled with field visits and further study of higher resolution colour imagery. Fieldwork was restricted to Wesselsputs, Kismet, Lawriesdale and Ettrick.

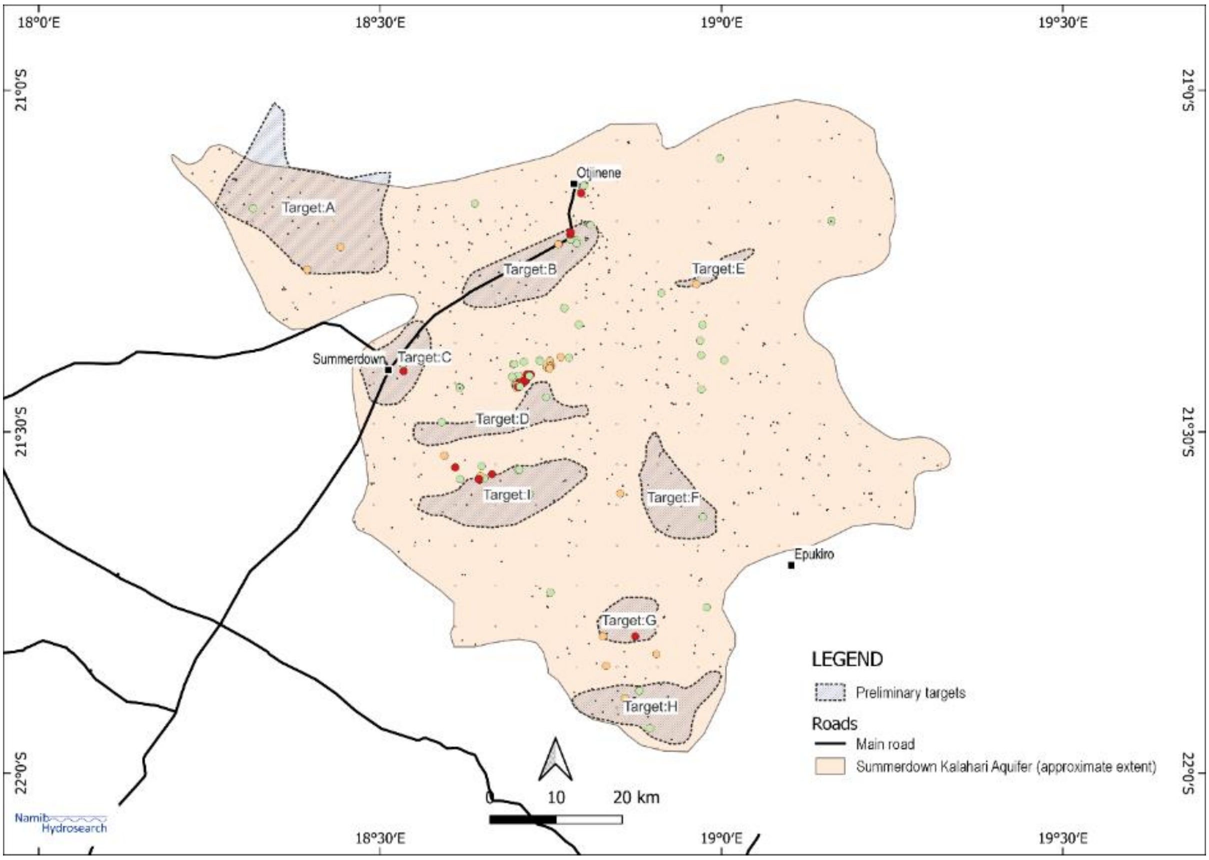

Figure 5-1: Preliminary groundwater exploration targets demarcated in the Summerdown Kalahari Aquifer

5.2 Geophysical surveys

Electromagnetic and resistivity profiling was conducted along lines surveyed over targets on Wesselsput and Kismet. These are shown in **Figure 5-2**.

Evaluation of the success of geologically sited boreholes compared to those sited using geophysical profiles (over geologically selected targets) further geophysical surveys were not deemed necessary over sites prior to drilling on farms Meyerville and Welgedacht.

5.3 Drilling

Exploration drilling (**Figure 5-2**) was carried out using rotary percussion methods to final depth at a nominal diameter of 10". In all boreholes overburden was drilled at nominal 12" and 10" steel surface casing installed. Where boreholes were cased to the bottom the steel casing (nominal 8") was perforated in situ. In some cases, boreholes were left uncased to final depth as the strata was competent. Boreholes selected for production purposes will need to be cased. Boreholes were developed at the end of drilling. Boreholes drilled are shown in **Figure 5-3** and **Figure 5-4**, and are listed in **Table 5-1** below. Borehole logs are given in Appendix A.

Drilling results were satisfactory in Kismet and Meyerville, but yields were lower in Wesselsputs and Welgedacht and further work in these farms was suspended. Further drilling targets may be identified on Kismet and Meyerville if additional resources are required in future.

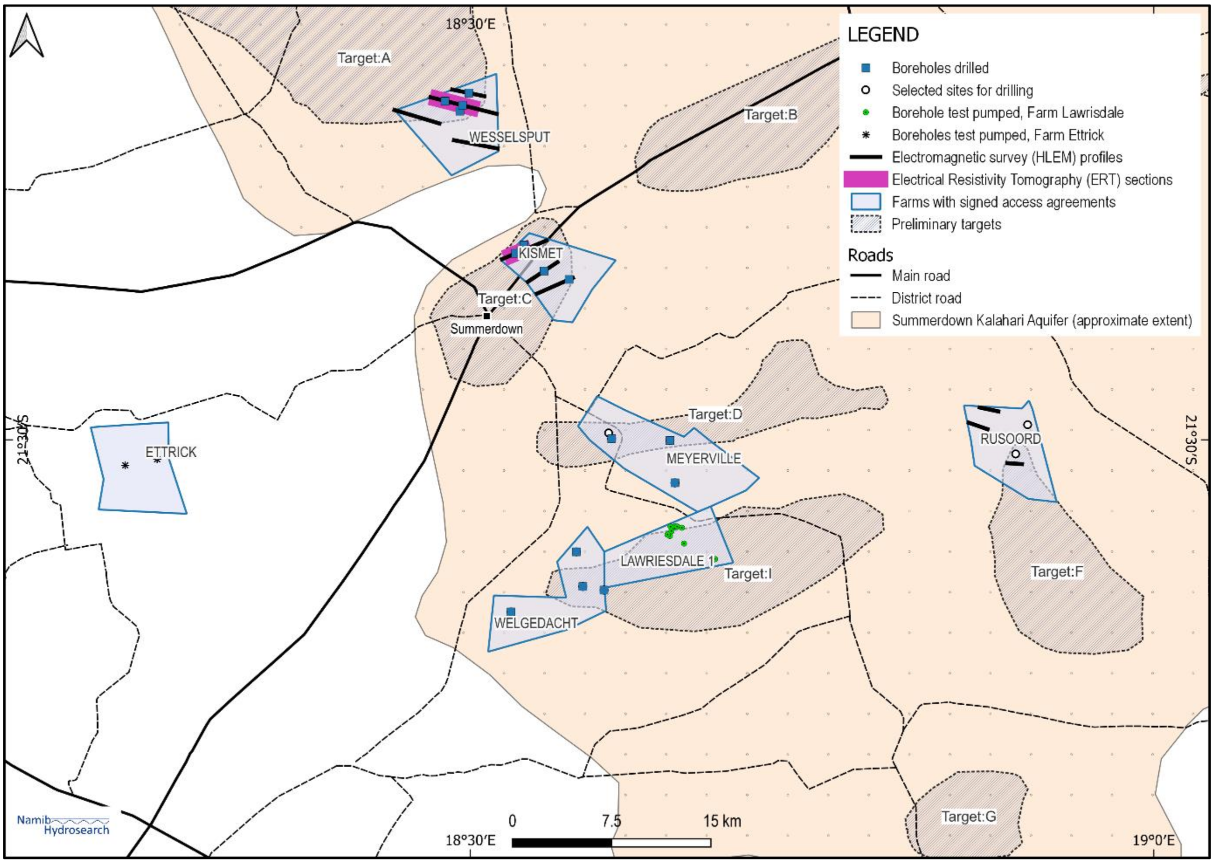

Figure 5-2: Groundwater exploration work carried out in the Summerdown area

Two profiles, drawn using borehole logs for Kismet and Meyerville, are given in Figure 5-5 and Figure 5-6. Water bearing zones are in sand, gravel, calcareous sandstone, and overlying calcrete in the

Kalahari sediments, and rarely at the bedrock contact. In a generally downslope direction increasingly thicker mudstone was encountered in boreholes on Kismet and Meyerville. As expected, groundwater potential is seen to diminish with increasing proportions of mudstone. Grain size of arenaceous sediments is also seen to have an influence on the yield with boreholes drilled in thick gravel layers in Meyerville having the highest yields. The mudstone impedes downstream flow, causing mounding of groundwater, supporting the conceptual model (Section 4).

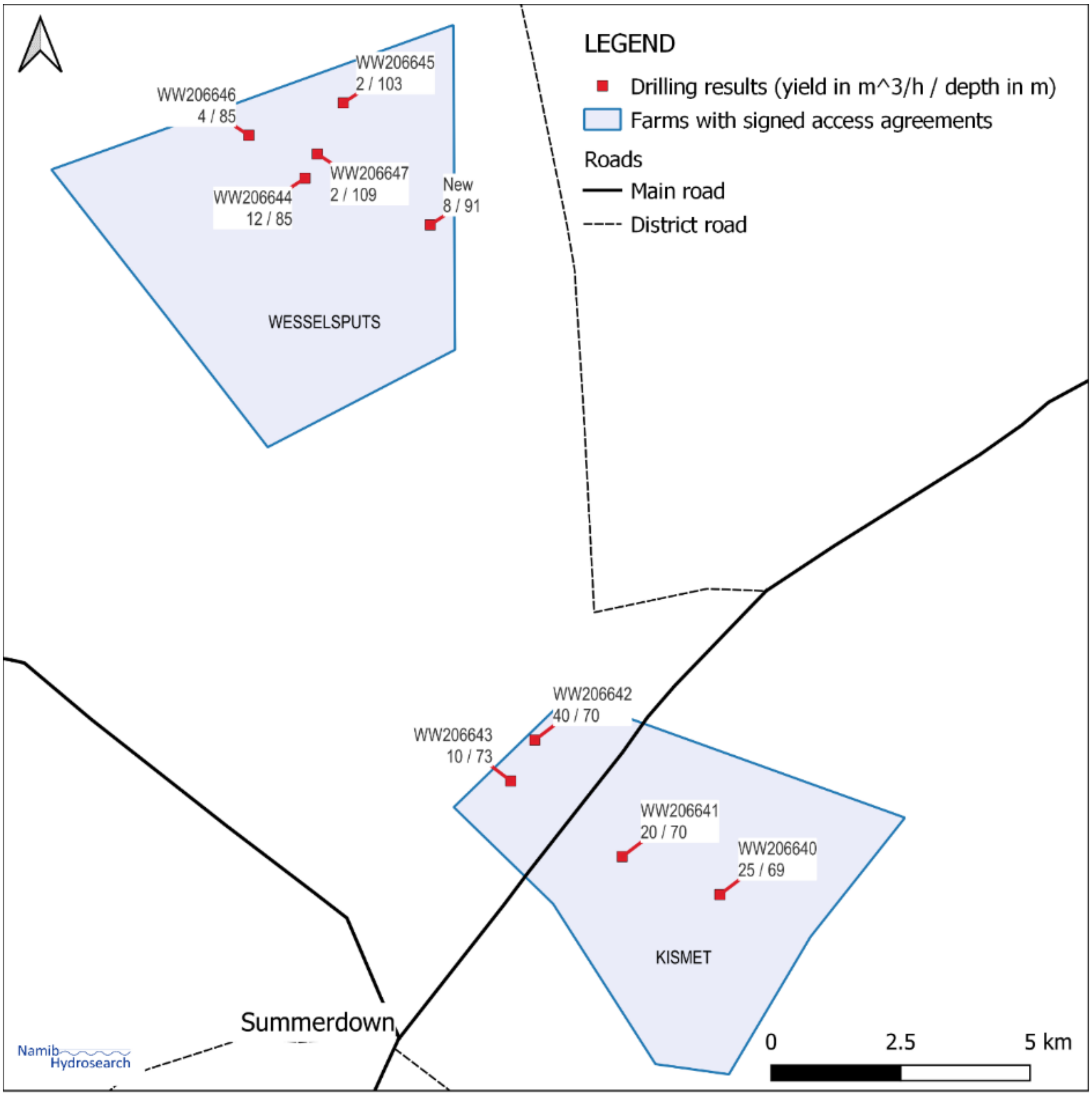

Figure 5-3: Drilling results on farms Kismet and Wesselsputs

Figure 5 12: Drilling results on farms Kismet and Wesselsputs

Higher yields in boreholes are seen to be attributed to the thickness of coarser material (coarse sand and gravel) intersected below the water table. On Kismet where the calcrete and sand section are 40 to 50 m thick in boreholes WW206640 and WW206641 (**Figure 5-5**) blow out yields were found to be high (25 and 20m^3/h respectively). To the northwest, subsequent boreholes were drilled through thick clay/mudstone and consequently sustainable borehole yields are lower. It should be noted that in borehole WW206642, a shallow water strike in a thin calcrete horizon resulted in a high blowout yield

(40m³/h) which, due to the limited saturated thickness, is considered unsustainable under production pumping. Similarly, on Wesselsputs, the sandy/calcrete layer is less than 25 m thick with a higher proportion of mudstone and consequently yields are significantly lower.

Boreholes drilled on Meyerville encountered coarse unconsolidated sand and gravel to a maximum depth of 42m followed by mudstone. These sediments are followed by mudstone. Drilling was carried out to the top of the mudstone fully penetrating the aquifer unit. As on Kismet and Wesselsputs, sand and gravel thickness determined the yield achieved in each borehole. Successful borehole had blowout yields of 25, 50 and 60m³/h. Higher yields are attributed to the thickness of coarser material (coarse sand and gravel) in these boreholes. A higher proportion of mudstone is however present downslope (north) towards the ephemeral drainage where yields are lower (6.5m³/h).

On Welgedacht, due to a deeper water table, limited thickness of saturated sand is present in WW206761 resulting in a low yield. Other boreholes (WW206762 to WW206764) were drilling closer to an ephemeral drainage where coarse sediments (sand and gravel) are mixed with fine material (mud) and yields from the Welgedacht boreholes were low (**Figure 5-4**).

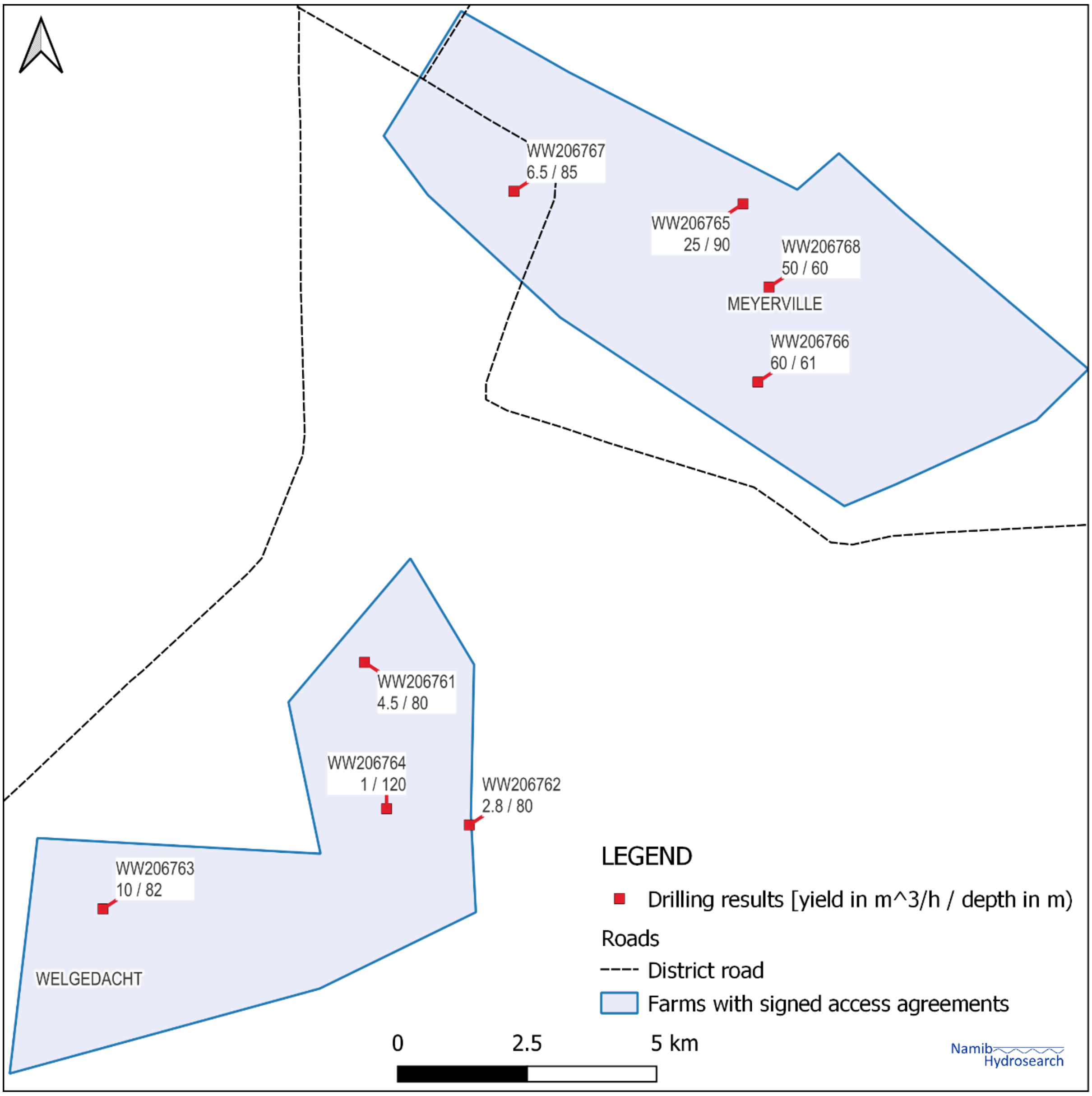

Figure 5-4: Drilling results on farms Welgedacht and Meyerville

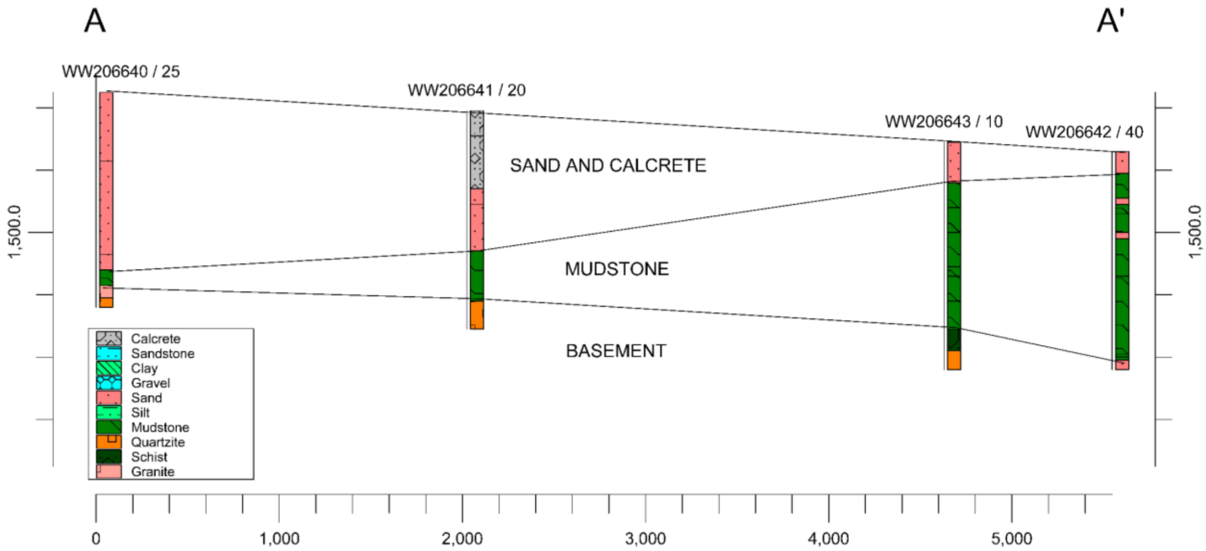

Figure 5-5: SE-NW (A-A') cross-section showing lithology intercepted in boreholes on Farm Kismet. Borehole numbers and blowout yield are indicated for each borehole

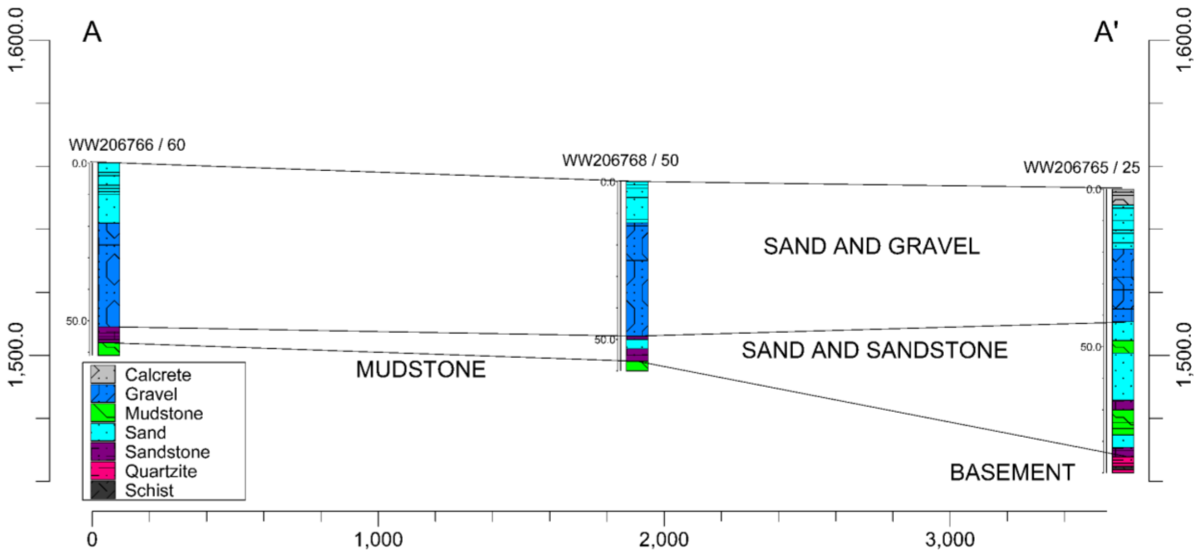

Figure 5-6: S-N (A-A') cross-section showing lithology intercepted in boreholes on Farm Meyerville. Borehole numbers and blowout yield are indicated for each borehole

Table 5-1: Summary information of boreholes drilled

Farm	Site No	Drilling date	Borehole No	Latitude WGS 84	Longitude WGS94	Elevation (m amsl)	Depth	Blow out yield (m^3/h)	Static water level (m bgl)
Kismet	K04	26/07/2023	WW206640	S 21.38275°	E 018.57229°	1444	69.0	25	11.18
Kismet	K03	09/08/2023	WW206641	S 21.37653°	E 018.55396°	1545	70.0	20	5.18
Kismet	K05	10/08/2023	WW206642	S 21.35655°	E 018.53720°	1441	70.0	40	4.22
Kismet	K01	15/08/2023	WW206643	S 21.36377°	E 018.83289°	1530	73.0	10	4.78
Wesselsputs	W03	25/08/2023	WW206644	S 21.25951°	E 018.49213°	1543	85.0	12	-0.50
Wesselsputs	W04	28/08/2023	WW206645	S 21.24624°	E 018.49888°	1515	103.0	2	3.24
Wesselsputs	W01	30/08/2023	WW206646	S 21.25227°	E 018.48149°	1508	85.0	4	4.92
Wesselsputs	W02	30/08/2023	WW206647	S 21.25526°	E 018.49434°	1513	109.0	2	1.53
Wesselsputs	New (Home)	31/08/2023	-	S 21.26717°	E 018.51559°	1520	91.0	8	4.36
Wegedacht	W1	14/11/2023	WW206761	S 21.58197°	E 018.57757°	1586	80.0	4.5	21.29
Wegedacht	W2	15/11/2023	WW206762	S 21.60990°	E 018.59781°	1577	80.0	2.8	9.70
Wegedacht	W3	16/11/2023	WW206763	S 21.62600°	E 018.52980°	1597	82.0	10	11.2
Wegedacht	W4	16/11/2023	WW206764	S 21.60740°	E 018.58230°	1583	120.0	1	-
Meyerville	M4	22/11/2023	WW206765	S 21.50051°	E 018.64615°	1553	90.0	25	9.40
Meyerville	M3	23/11/2023	WW206766	S 21.53150°	E 018.64969°	1561	61.0	60	15.60
Meyerville	M2	24/11/2023	WW206767	S 21.49924°	E 018.60339°	1560	85.0	6.5	
Meyerville	M5	25/11/2023	WW206768	S 21.51491°	E 018.65136°	1555	60.0	50	12.50

NOTE:
Borehole logs are given in Appendix A.

5.4 Test Pumping

Boreholes drilled during the project in Farms Kismet, Wesselsputs and Meyerville (project boreholes), and selected boreholes in Farms Lawriesdale and Ettrick (existing boreholes) were subjected to step drawdown tests (SDT) and constant rate tests (CRT). The information on the tests is summarised in **Table 5-2**. Drawdown and water level recovery data interpretation provide insight into the type of aquifer, estimates of hydraulic properties and aquifer boundary conditions. In the absence of monitored observation boreholes during the tests, aquifer storativity and specific yield could not be uniquely estimated during this exploration programme.

Table 5-2: Summary information of boreholes test pumped

Borehole	Farm	Type of test	Pumping duration (hour)	Average pumping rate (m³/h)				Maximum drawdown (m)	Recovery duration (hour)	Recovery percentage	Remarks
WW206641	Kismet	SDT, 4 steps of 1 hour	4	9	15	25	29	47.31	4	100%	
WW206641	Kismet	CRT	24	25				27.58	24	99%	
WW206640	Kismet	SDT, 4 steps of 1 hour	4	10	20	31	31	29.55	4	100%	
WW206640	Kismet	CRT	24	28				12.11		100%	
WW206642	Kismet	SDT, 4 steps of 1 hour	4	11	15	19	23	45.57	4	97%	
WW206642	Kismet	CRT	24	16				31.36	24	96%	
NEW1	Lawriesdale	SDT, 4 steps of 1 hour	4	5	10	15	17	32.25	4	100%	
NEW1	Lawriesdale	CRT	12	15				21.36	12	99%	
P01	Lawriesdale	SDT, 4 steps of 1 hour	4	15	23	29	31	26.59	4	99%	
P01	Lawriesdale	CRT	44	30				29.01	48	98%	
P04	Lawriesdale	SDT, 4 steps of 1 hour	4	15	20	24	23	37.36	4	100%	
P04	Lawriesdale	CRT	12	24				38.19	12	100%	
P08	Lawriesdale	SDT, 4 steps of 1 hour	4	15	20	25	27	26.43	4	100%	
P08	Lawriesdale	CRT	24	21				16.02	24	100%	
P10	Lawriesdale	SDT, 4 steps of 1 hour	4	35	41	48	55	25	4	100%	
P10	Lawriesdale	CRT	48	51				25.21	24	100%	
P14	Lawriesdale	SDT, 4 steps of 1 hour	4	7	14	21	28	29.27	4	100%	
P14	Lawriesdale	CRT	48	25				29.67	48	99%	
P15	Lawriesdale	SDT, 4 steps of 1 hour	3.5	7	14	21	27	36.53	4	99%	Test terminated at 3h30min, water level at pump intake
P15	Lawriesdale	CRT	48	20				14.27	48	96%	
P16	Lawriesdale	SDT, 4 steps of 1 hour	4	12	25	37	42	31.44	4	100%	
P16	Lawriesdale	CRT	24	30				20.9	24	99%	
P17	Lawriesdale	SDT, 4 steps of 1 hour	4	40	51	60	73	30.46	4	99%	
P17	Lawriesdale	CRT	72	65				43.22	72	99%	
P18	Lawriesdale	SDT, 4 steps of 1 hour	4	15	30	45	50	42.82	4	100%	
P18	Lawriesdale	CRT	12	35				12.32	12	97%	
P19	Lawriesdale	SDT, 4 steps of 1 hour	4	15	26	35	45	20.26	4	99%	
P19	Lawriesdale	CRT	12	40				17.06	12	98%	
Ettrick 1	Ettrick	SDT, 4 steps of 1 hour	4	20	31	41	51	13.12	4	99%	
Ettrick 1	Ettrick	CRT	48	50				15.28	48	97%	
Ettrick 4	Ettrick	SDT, 4 steps of 1 hour	2.17	11	16	19	-	22.02	4	100%	Test terminated at 2h10min, water level at pump intake
Ettrick 4	Ettrick	CRT	24	16				12.46	44	100%	
WW206766	Meyerville	SDT, 4 steps of 1 hour	4	31	50	61	82	13.13	4	99%	
WW206766	Meyerville	CRT	48	60				9.6	48	98%	
WW206765	Meyerville	SDT, 4 steps of 1 hour	4	10	16	21	28	11.52	4	98%	
WW206765	Meyerville	CRT	24	26				5.33	24	94%	
WW206768	Meyerville	SDT, 4 steps of 1 hour	4	31	50	61	82	33.19	4	99%	
WW206768	Meyerville	CRT	48	55				21.03	48	-	Recovery monitoring ongoing

NOTE: CRT – Constant rate test; SDT – Step drawdown test

During the tests electrical submersible pumps were used and flow was controlled through a variable frequency drive. Pumping rate was monitored using an electromagnetic flow meter, verified by periodically recording the time required to fill a container of known volume, and by using a 90-degree V-notch weir. Water level was measured manually using electric dippers. Recovery of water level was monitored to the same period as constant rate test duration. Recovery of 94% to 100% was achieved after the constant rate tests.

5.4.1 Project boreholes

Three of the four project boreholes drilled on Farm Kismet were tested (**Figure 5-7**). These are WW206640, WW206641 and WW206642 (**Table 5-2**). The fourth borehole had a lower blowout yield of 10 m^3/h and was not tested. Similarly, on Farm Meyerville, three of the four boreholes were tested (Figure 5-8). These were WW206765, WW206766 and WW206768.

5.4.2 Existing boreholes – Farms Lawriesdale and Ettrick

Much drilling had been conducted over Lawriesdale over the past few years by the landowner and all indications pointed to high yields and good potential for wellfield development. Agreement was reached with the landowner to carry out test pumping of certain of the boreholes (**Figure 5-9**) which negated the need for drilling on this farm.

Recent drilling carried out in Farm Ettrick by the landowner targeting weathered bedrock (Damara Supergroup) rocks encountered high yields. Two of the highest yielding boreholes (**Figure 5-10**) were test pumped.

On Farm Lawriesdale, information on intercepted lithology and water bearing zones in boreholes is lacking. Downhole logging was therefore carried out of the uncased lower part of the boreholes being tested. Logging data included downhole optical scans, gamma, deep and shallow formation conductivity, and fluid temperature and conductivity. From these data the aquifer was interpreted to be of uniform thickness consisting mainly of orange to brown sandstone for the first 40 m. Clay content increases below this depth to the contact with the basement (Damara Supergroup) at about 60m. The plotted data is given in Appendix B.

5.5 Step drawdown tests

Step drawdown tests (SDT) are variable discharge tests where a borehole is pumped at increasing rates for short periods (4 steps of 1 hour duration in this project). The purpose of the tests generally is to determine the yield and efficiency of the borehole. The purpose of the SDT in the current project were to determine the appropriate yield for the constant rate test, particularly in the case of existing boreholes where information on depth to water bearing zones are not available.

5.6 Constant rate tests

Constant rate tests were carried out (**Table 5-2**) at set pumping rates for a relatively long duration (12 hours to 72 hours). Drawdown, or the difference between the pretest static water level and the pumping water level, is recorded with time. Flow characteristics are interpreted using diagnostic plots and hydraulic parameters are estimated based on applicable hydraulic test solutions. In addition, the tests provide an indication of flow barriers or dewatering of water bearing zones.

Constant rate tests were interpreted by curve matching technique using AQTESOLV Pro software (Duffield, 2007). Aquifer response is typically unconfined as seen from the early Theis type response, followed by stabilisation of drawdown in intermediate time and late time Theis-curve response (Kruseman and de Ridder, 1994). Drawdown derivatives show a characteristic dip at intermediate time further confirming the type of aquifer as unconfined, which is consistent with the drilling information.

Aquifer parameters were estimated using the Moench solution for unconfined aquifers (Moench, 1997). Projections for production pumping were modelled using the estimated parameter. An example of interpretation carried out is given in **Figure 5-11**. **Figure 6-1** gives an example of projection made to 15 years at the production rate.

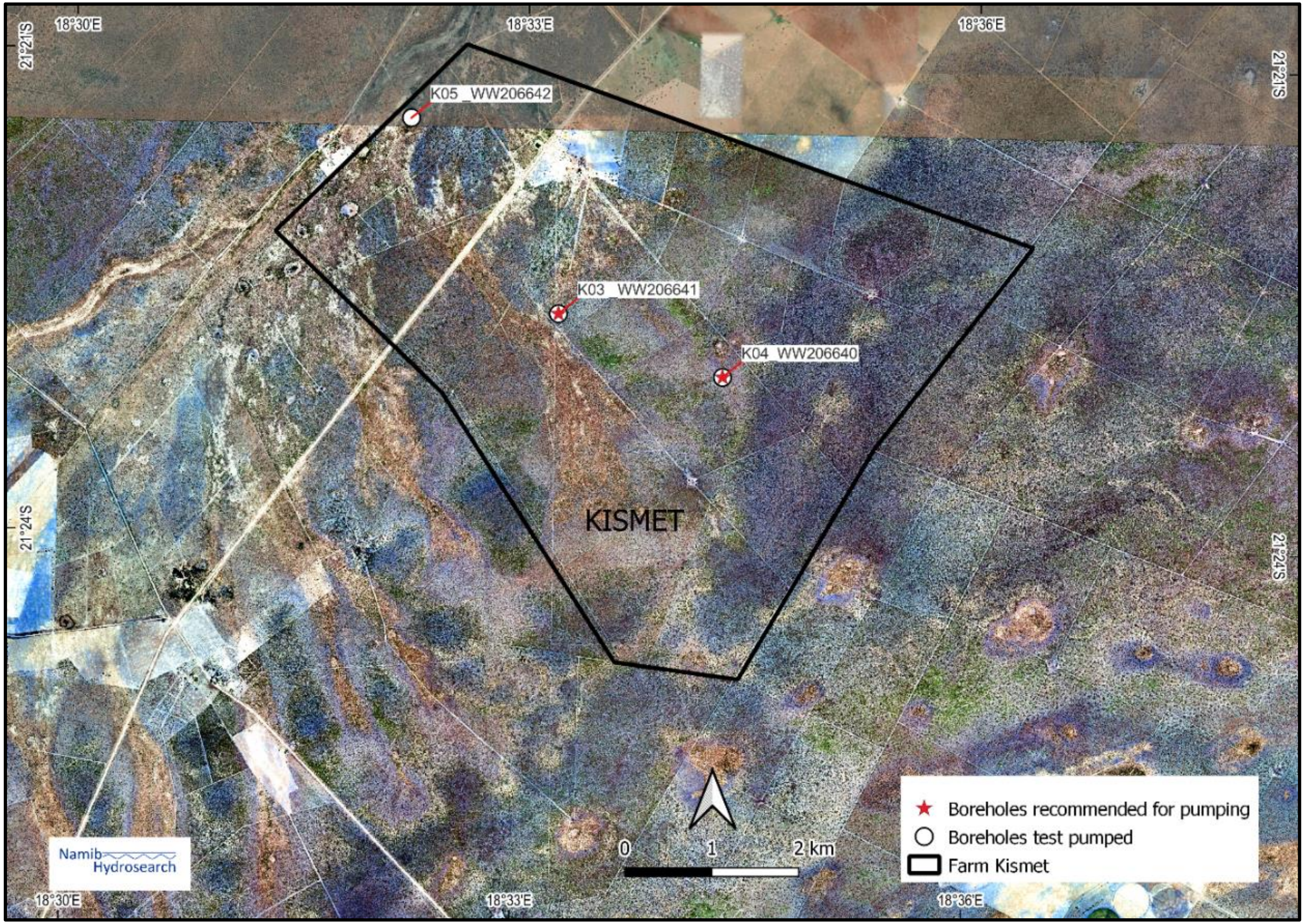

Figure 5-7: Locations of tested boreholes in Farm Kismet

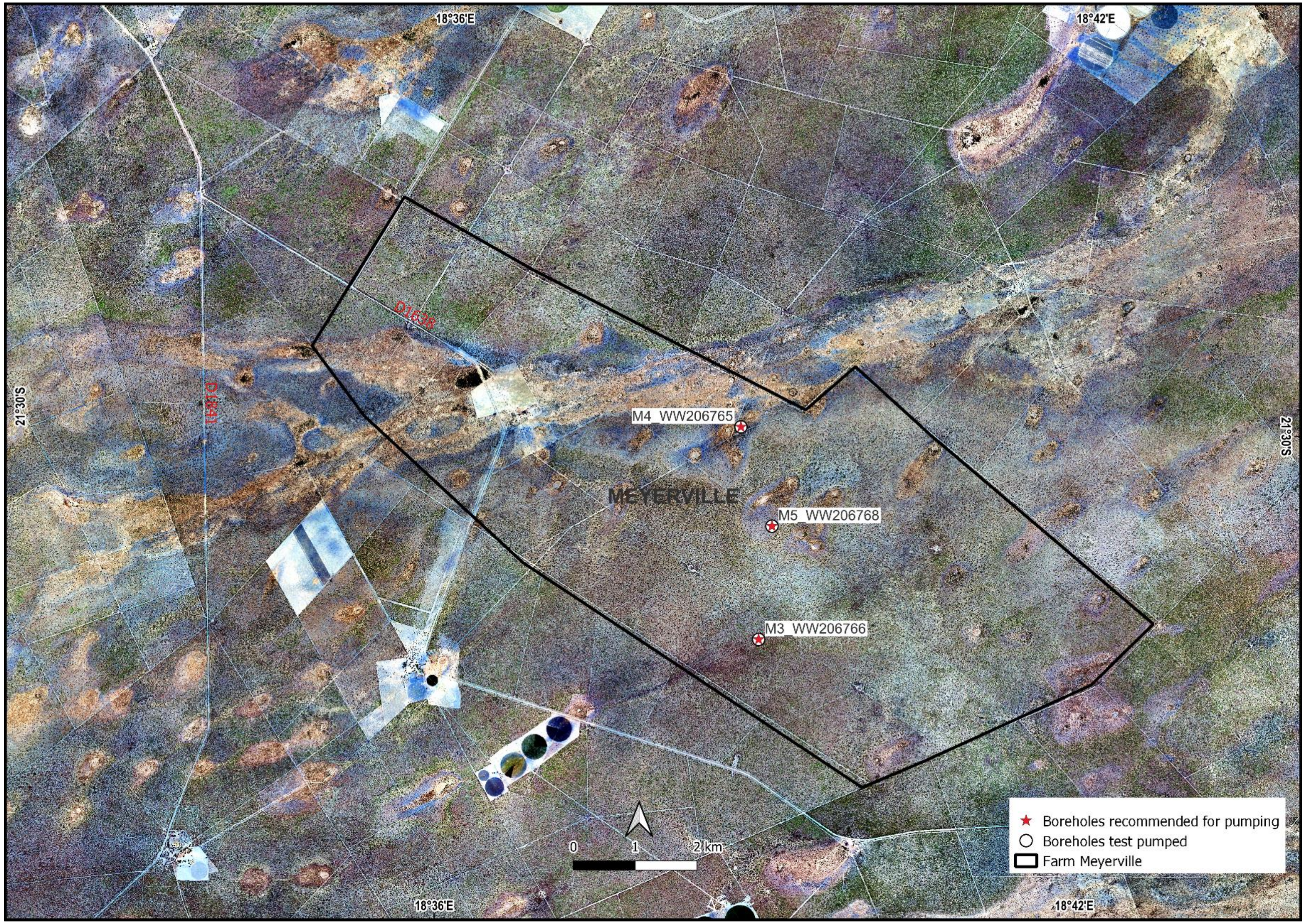

Figure 5-8: Locations of tested boreholes in Farm Meyerville

Figure 5-9: Locations of tested boreholes in Farm Lawriesdale

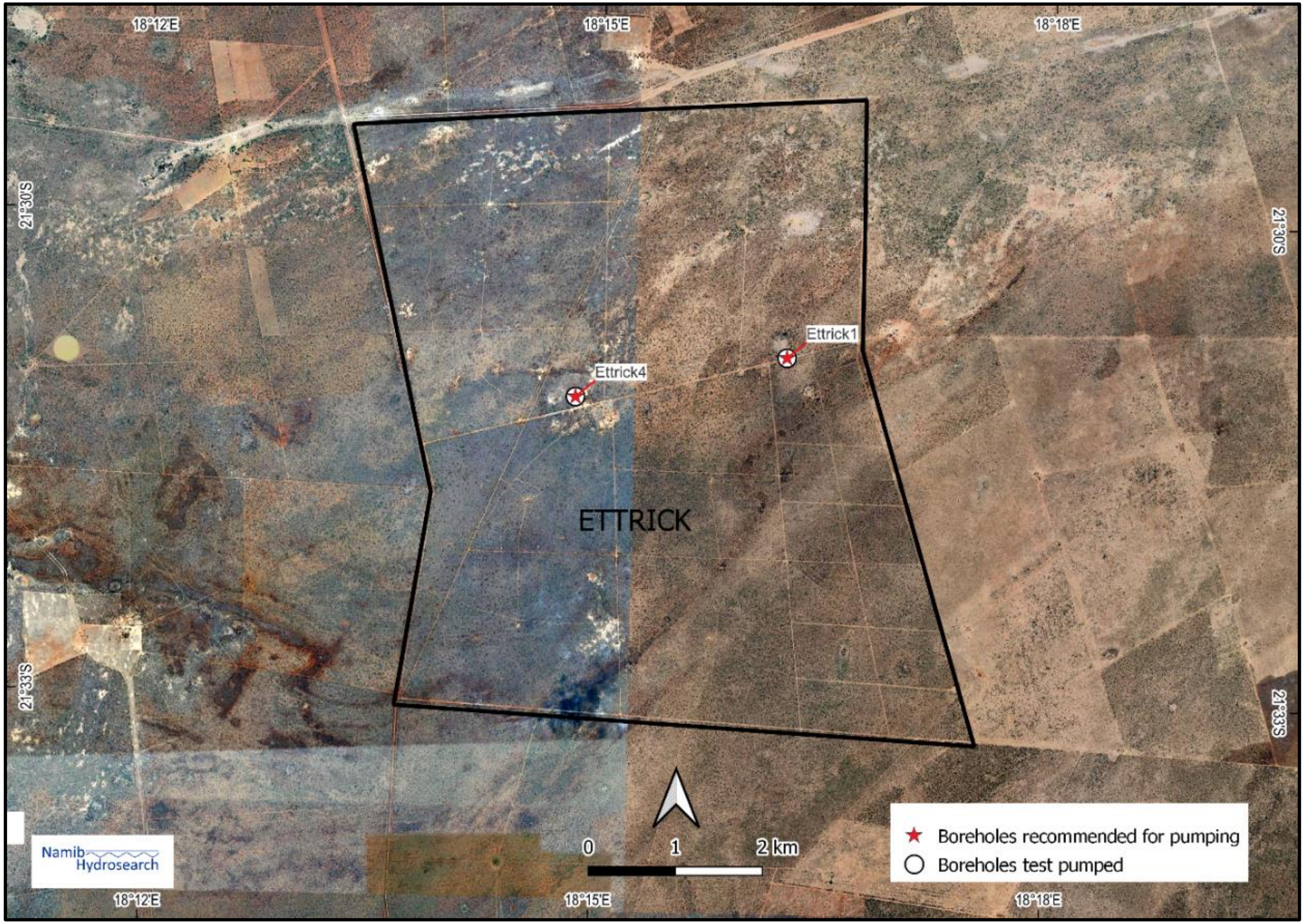

Figure 5-10: Locations of tested boreholes in Farm Ettrick

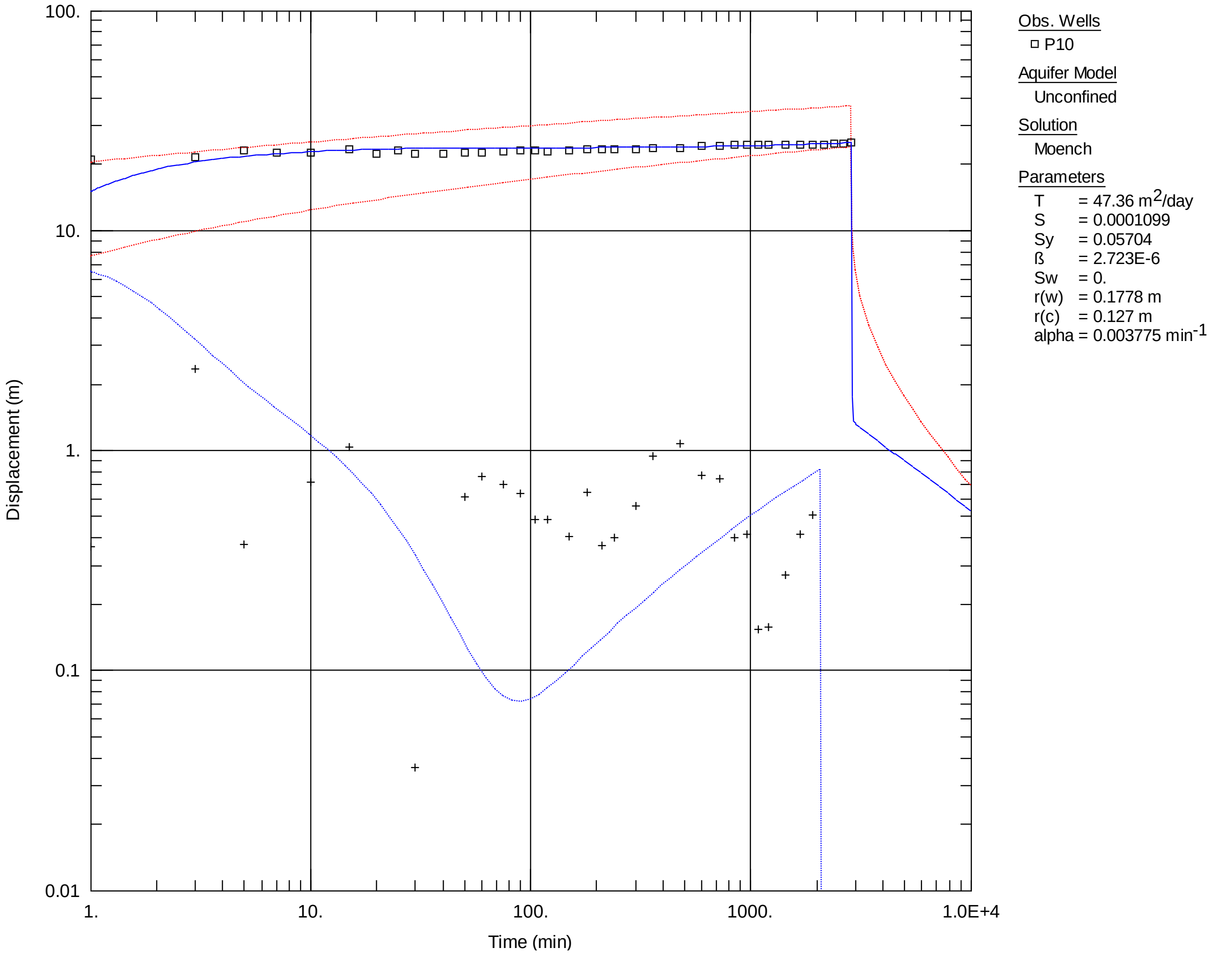

Figure 5-11: Interpretation of constant rate test time-drawdown data (borehole P10) and estimated parameters using curve fitting technique (blue line – fitted curve, red dashed lines – early and late Theis curves, blue dashed line – drawdown derivative)

6 GROUNDWATER RESOURCE EVALUATION

Estimated aquifer properties from test pumping interpretation were used to calculate production pumping rates from each borehole. Modelled pumping rates were adjusted so that forecasted water levels do not exceed the 'available drawdown', or the depth from the static water level to the main water bearing zone in the borehole. When pumping water level exceeds the available drawdown there is risk of dewatering of the borehole and the pumping becoming unsustainable. Two conditions were therefore considered while projecting a modelled drawdown curve:

a) Forecast of long term (15 year) water level decline due to pumping assuming no recharge in this period.

b) Available drawdown is not exceeded, as estimated from borehole records and interpretation of step drawdown and constant rate tests.

Projected drawdown due to pumping of borehole P10 is graphically shown in **Figure 6-1**. The projections made on the other boreholes are given in Appendix C and recommended pumping rates are given in **Table 7-1**.

Sixteen boreholes are recommended for production (**Table 7-1**) and the total water available from the boreholes is 7,635 m³/day (382 m³/hour, pumping 20 hours per day). This meets the water demand and the short-term initial water requirement. Pump installation parameters are included in **Table 7-1**.

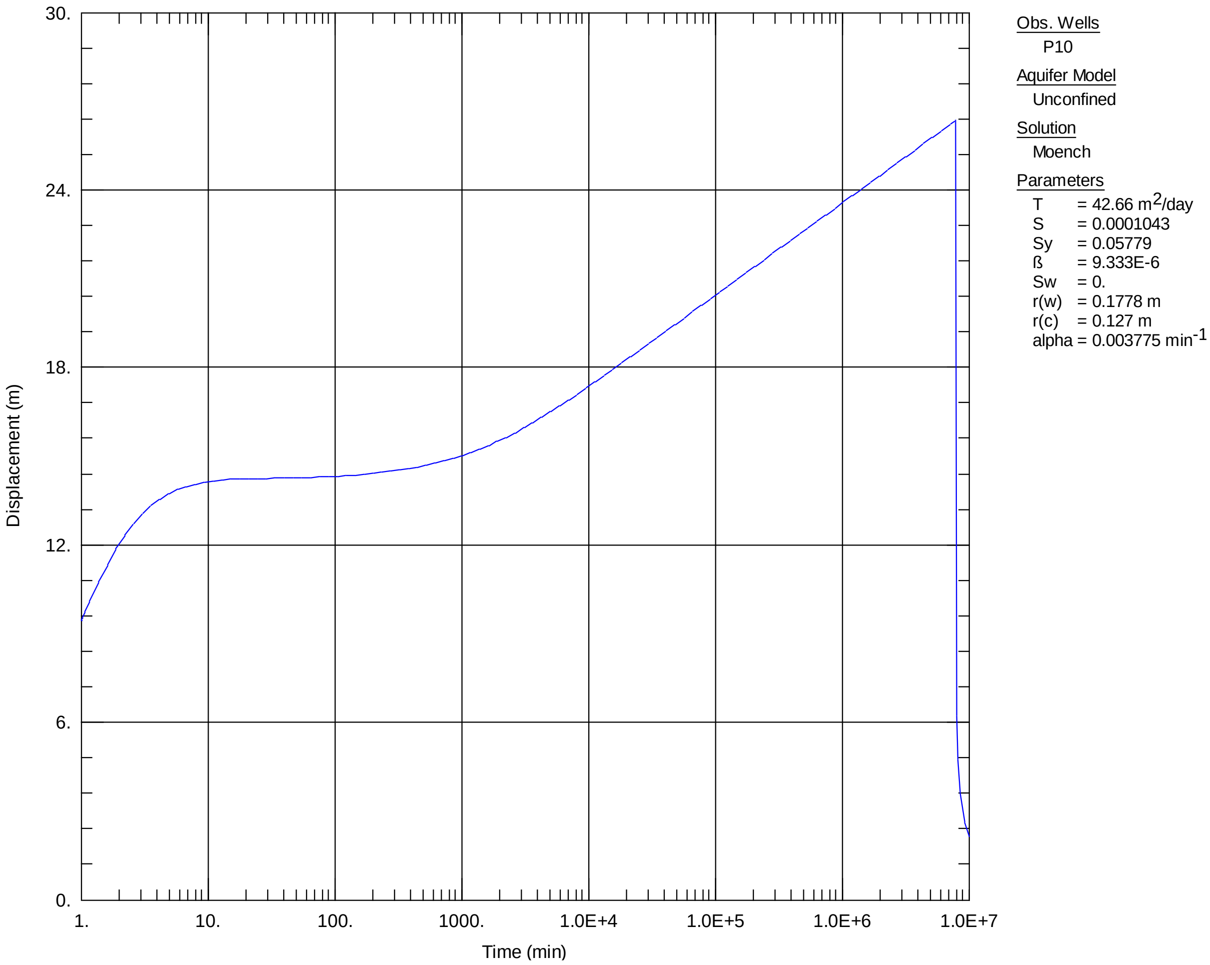

Figure 6-1: Projection of drawdown to 15 years using the estimated parameters and no recharge

7 WATER POINT SURVEY AND BASELINE WATER QUALITY

A water point survey was carried out as part of the study to record current static water levels in boreholes, documentation of abstraction practises on each farm and collection of any historical records of rainfall and irrigation before the commencement of abstraction. Collected data is to be used as a base-line record against which any future changes can be measured. This data will be used as a starting point for subsequent monitoring activities and to generate data for a groundwater flow transient model to estimate the inflow and outflow from the aquifer including recharge and change in stored volume. A steady state model was developed using the data and us discussed in Section 8. In order to determine the potential of the SKA to support the proposed mining operation it is essential that recharge and water demand are well understood.

The farms covered by the survey are shown in **Figure 7-1**. One representative water sample was taken from each farm visited.

Water quality data received from the analytical laboratory are within Group A (excellent quality water, according to the guidelines for evaluation of drinking water for human consumption, Department of Water Affairs, April 1988). Available analyses reports are given in Appendix D.

Table 7-1: Calculated recommended yield from interpretation of test pumping data

Borehole	Farm	Latitude	Longitude	X (UTM WGS84, Zone 33)	Y (UTM WGS84, Zone 33)	Z (m amsl)	Blowout Yield (m^3/h)	Depth (m)	Static water level (m)	Water bearing zone from DH logging	Available Dawdown (m)	Transmissivity (m^2/day)	Storativity	Specific Yield	Borehole diameter (inch)	Recommended Yield (m^3/day)	Recommended Yield (m^3/h) for 20 hours	Pump installation depth (m)	Currently Equipped	Remarks
NEW1	Lawrisdale	-21.56676	18.64721	877,788	7,610,702	1,574.2	12	61	22.3	22-40	9	13.3	1.00E-04	16%	8"	100	5	60	No	Not recommmended for pumping
P01	Lawrisdale	-21.56339	18.64970	878,055	7,611,069	1,572.2	60	60	19.7	20-50	15	24.0	2.90E-05	4%	8"	225	11	60	Yes	
P04	Lawrisdale	-21.56363	18.64658	877,731	7,611,050	1,572.4	60	77	23.1	23-60	18.5	14.3	4.15E-05	5%	8"	150	8	60	Yes	Not recommmended for pumping
P08	Lawrisdale	-21.56938	18.64428	877,478	7,610,418	1,572.2	49	67	25.8	26-46	20	21.7	7.32E-04	8%	8"	300	15	60	Yes	
P10	Lawrisdale	-21.57033	18.64606	877,659	7,610,308	1,571.1	67	79	25.9	26-60	26	42.7	1.04E-04	6%	10"	725	36	65	Yes	
P14	Lawrisdale	-21.56352	18.65128	878,219	7,611,050	1,569.5	60	62	16.5	17-62	20	18.6	3.26E-03	5%	8"	250	13	60	No	
P15	Lawrisdale	-21.56436	18.65479	878,581	7,610,948	1,565.4	60	60	10.4	10-30	15	33.0	9.83E-05	6%	8"	325	16	60	No	main water strike at 30 m
P16	Lawrisdale	-21.57578	18.65657	878,735	7,609,678	1,564.1	40	128	10.7	10-70	28	43.7	5.00E-03	14%	8"	600	30	60	No	Drilled to basement
P17	Lawrisdale	-21.58731	18.67802	880,929	7,608,348	1,562.9	67	66	6.5	6-52	22	21.5	3.77E-05	24%	8"	400	20	60	No	
P18	Lawrisdale	-21.58729	18.67900	881,031	7,608,348	1,562.8	55	65	6.2	6-55	20	51.0	8.63E-04	19%	8"	700	35	60	No	
P19	Lawrisdale	-21.58841	18.67716	880,837	7,608,229	1,563.6	50	77	7.0	6-56	25	48.9	1.44E-04	7%	8"	775	39	60	No	
WW206641	Kismet	-21.37653	18.55396	868,599	7,632,009	1,539.0	20	70	5.8	15-30	22	21.2	3.24E-05	4%	8"	300	15	50	No	
WW206640	Kismet	-21.38275	18.57229	870,487	7,631,277	1,545.0	25	69	11.9	17-30	5.1	22.5	3.16E-04	9%	8"	300	15	50	No	
WW206642	Kismet	-21.35655	18.53720	866,909	7,634,263	1,526.0	40	70	2.9	10-20	20	10.2	8.92E-03	5%	8"	150	8	50	No	Borehole collapsed, to be cleaned, retested & reassess yield. Not recommmended for pumping
Ettrick1	Ettrick	-21.51426	18.27085	838,893	7,617,386	1,606.0	50	40	10.0	10-40	15	118.0	2.00E-03	3%	8"	675	34	38	No	
Ettrick4	Ettrick	-21.51869	18.24747	836,459	7,616,946	1,608.0	50	37	10.5	10-30	12	37.4	3.07E-05	6%	8"	200	10	35	No	
WW206765	Meyerville	-21.50051	18.64615	877,850	7,618,047	1,553.0	25	90	9.4	10-48	8	116.9	2.72E-03	4%	8"	560	28	60	No	
WW206766	Meyerville	-21.53150	18.64969	878,137	7,614,604	1,561.0	60	61	15.6	26-57	10.3	131.8	1.54E-03	30%	8"	850	43	55	No	
WW206768	Meyerville	-21.51491	18.65136	878,353	7,616,438	1,555.0	50	60	11.2	23-55	11.8	61.8	1.05E-03	8%	8"	450	23	55	No	

Total yield (borehole with yield > 10 m^3/h) 382 m^3/h

Total yield (boreholes with yield > 10 m^3/h) 7,635 m^3/day

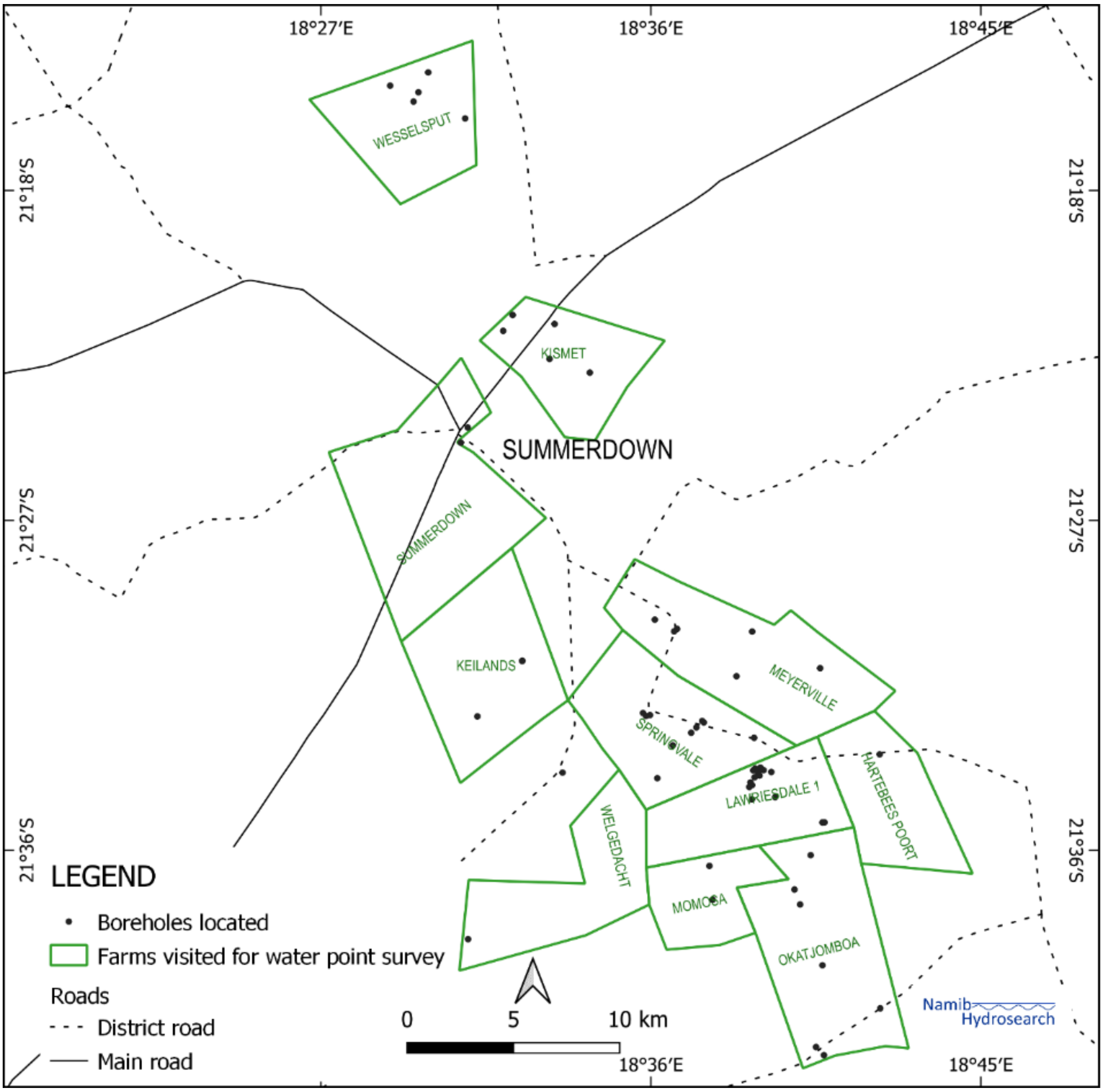

Figure 7-1: Farms visited for water point survey

8 GROUNDWATER FLOW MODELLING

Long term monitoring data (groundwater levels and abstraction) are not available for the existing bulk water schemes ruling out the application of a transient model with which to evaluate recharge and abstraction scenarios. A steady state model was therefore constructed to assess the water budget of the western part of the SKA, targeted for supply to the OCP. As the model was built using limited available data generated during the project, the results must be considered preliminary.

Hydrogeological data and information available for the model are commented on as follows:

1. Available drilling data and Kalahari isopachs were used to estimate the extent of the Summerdown Kalahari Aquifer (SKA). This model domain covers the western part of the SKA (**Figure 8-1**) based on the aquifer limits delineated (Section 3.3.1) and availability of groundwater level data. To the east, the model boundary was placed far away enough not to have any direct influence on the target areas (farms).

2. Hydraulic conductivity values from the boreholes that were test pumped (Section 5.4).

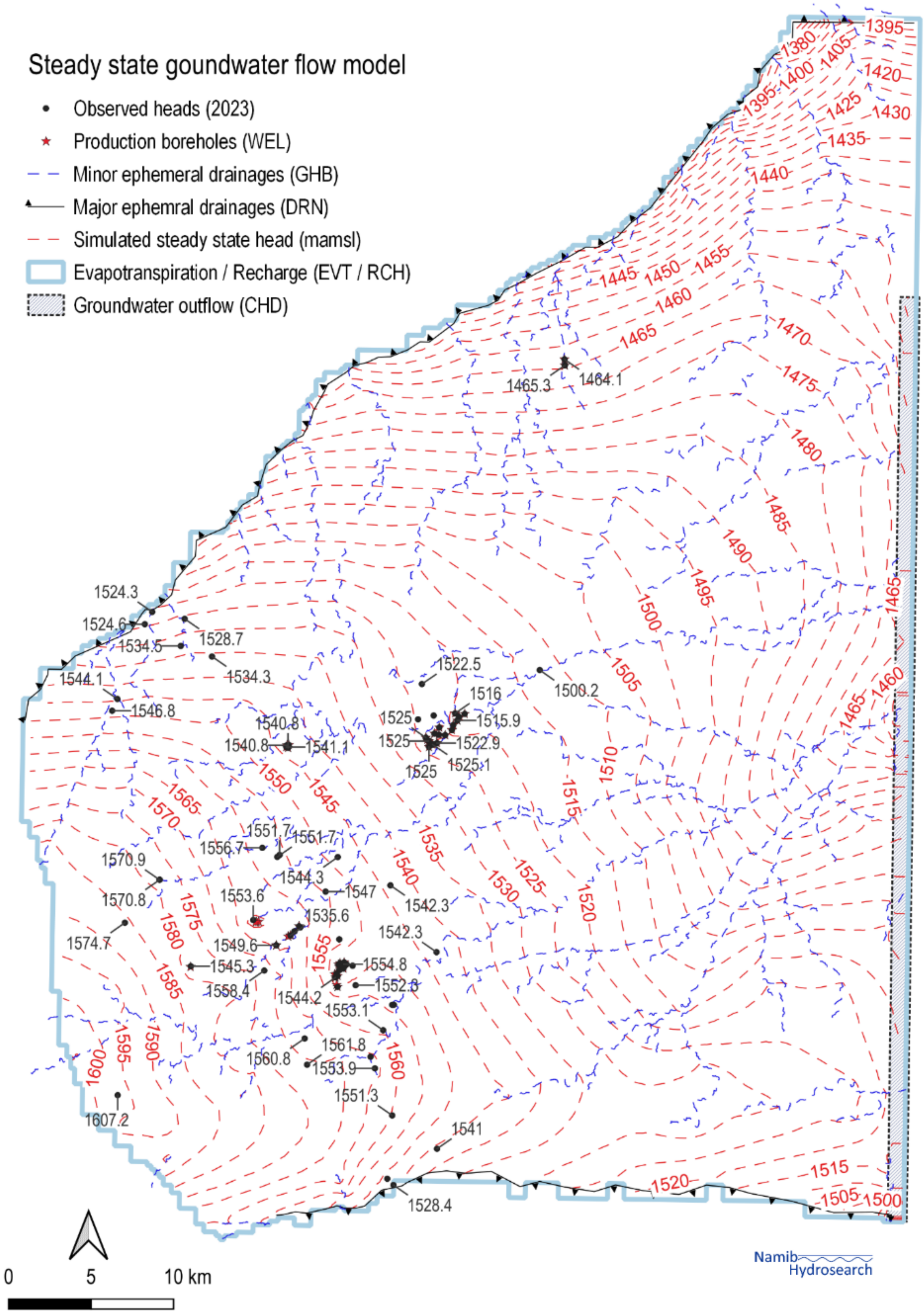

Figure 8-1: Steady state groundwater flow model of the western part of the Summerdown Kalahari Aquifer. The model domain, hydraulic boundaries, observations and simulated heads are shown

3. Observed groundwater levels measured during the water point survey (hydrocensus) carried out in October and November of 2023 (Section 7). A few earlier groundwater levels were also taken from reports (Geopollution Solutions, 2021).
4. Average annual evapotranspiration rates for the area from the online Moderate Resolution Imaging Spectroradiometer (MODIS) database (Running et al., 2021).
5. Bulk annual pumping rates where available were provided by DWA (farms Okambekere, Evare, Okasondana) while others were estimated from the size of irrigated fields as evident from satellite imagery and the average rate of water use for common crops using central pivots.
6. Direct diffuse recharge and flow in the ephemeral drainages occurs during the wet season. The sustainability of the aquifer therefore is dependent on the frequency and intensity of rainfall and consequent recharge events. For projecting drawdown into the future average rainfall conditions were assumed to continue unchanged in the model.

Hydraulic boundaries (recharge and discharge) were individually simulated using appropriate packages setup for the model as follows (**Figure 8-2**):

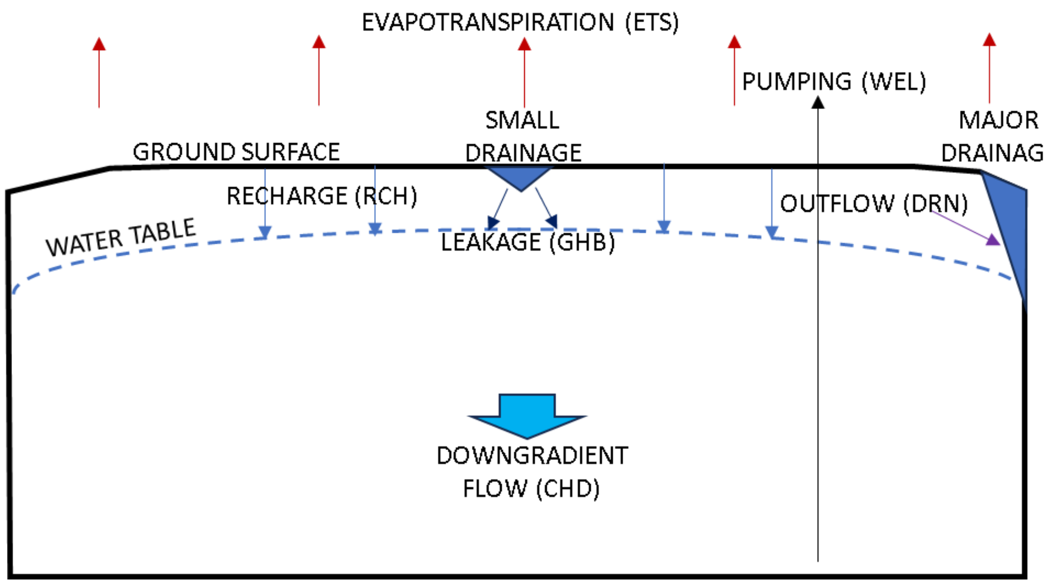

Figure 8-2: Various hydraulic boundaries used in the model is illustrated with schematic NS cross-section across the model domain

1. As the aquifer is unconfined, i.e., the aquifer has no low permeability layer overlying it, aerial recharge was assigned to the entire model domain using the Recharge Package and adding water directly to the saturated zone of the aquifer. During the model calibration process, recharge flux was estimated.
2. Leakage from small ephemeral drainages is evident from a slight mounding of the groundwater table. Particularly in the upper reaches these drainages are seen to be influent. A head dependent boundary, the General Head Boundary Package (GHB), was applied to simulate leakage. Leakage to the aquifer occurs where the groundwater heads are below the assigned GHB head.
3. Discharge from the saturated zone of the aquifer occurs by evapotranspiration and is simulated using the Evapotranspiration Segments (ETS) Package. Evapotranspiration is set to decrease linearly with depth and to cease at a depth of 25 m below the top of the model

(ground surface). The parameters used are based on previous work done in the Kalahari Basin (Lekula and Lubczynski 2019).

4. Along the southern and northern boundaries of the model, discharge from the aquifer occurs by evapotranspiration from the shallow groundwater table along the incised valleys of the larger ephemeral drainages, Epukiro and Eiseb. To simulate this loss of water along the river channels, the Drain (DRN) Package was used (**Figure 8-2**).
5. Applying averaged annual pumping rates abstraction from the aquifer was simulated using the WEL Package.

Initial values for hydraulic conductivity used in model calibration were from locations where boreholes were test pumped as discussed above (Section 5.4). Although the steady state model was calibrated with acceptable levels of error (**Figure 8-3**) some of the simulated heads varied from the observed groundwater levels, possibly due to the influence of unaccounted for pumping. The overall fit of measured to simulated heads is, however, considered acceptable (**Figure 8-3** and **Figure 8-4**).

The summary of model inflow and outflow volumetric rates or water budget (**Figure 8-5**) are reasonable. The water budget (**Figure 8-5**) shows that direct diffuse recharge and leakage from ephemeral drainage are important in replenishing the aquifer while evapotranspiration is the primary means of water discharge.

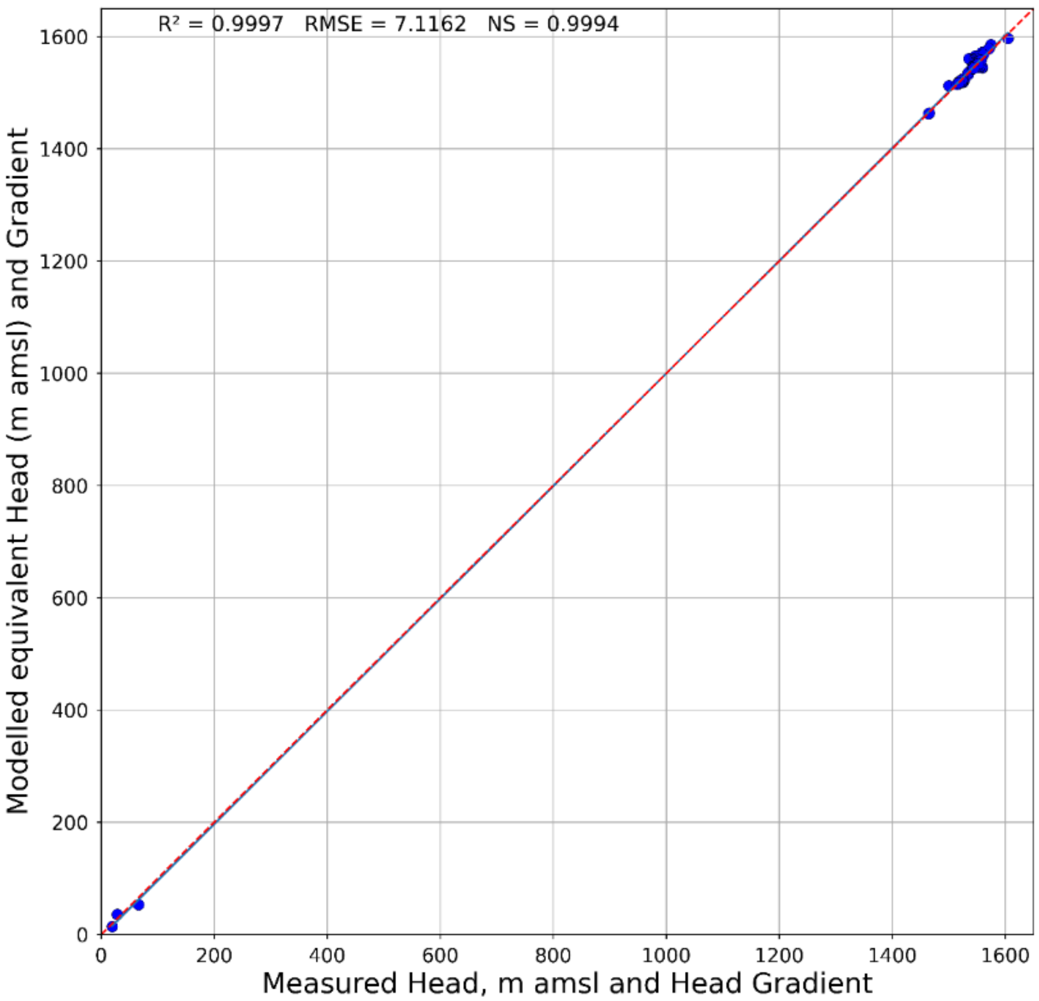

Figure 8-3: Plot of measured versus simulated heads and head gradients

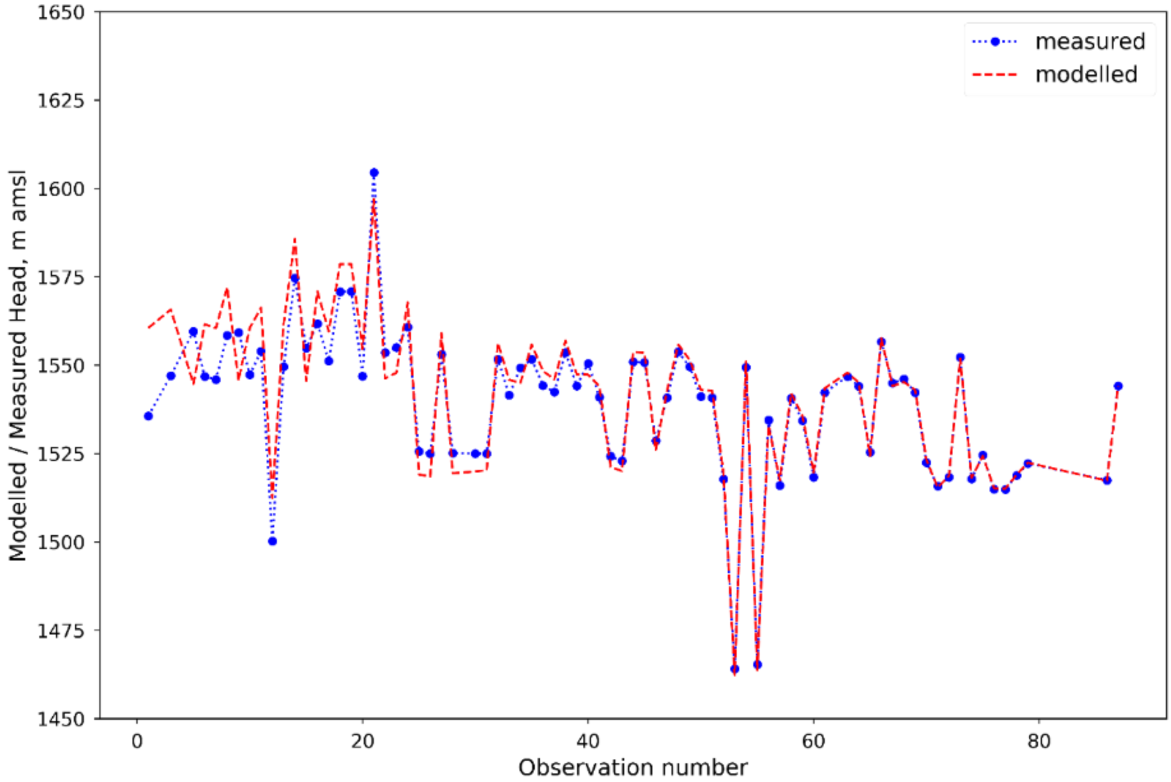

Figure 8-4: Comparison of measured and simulated heads

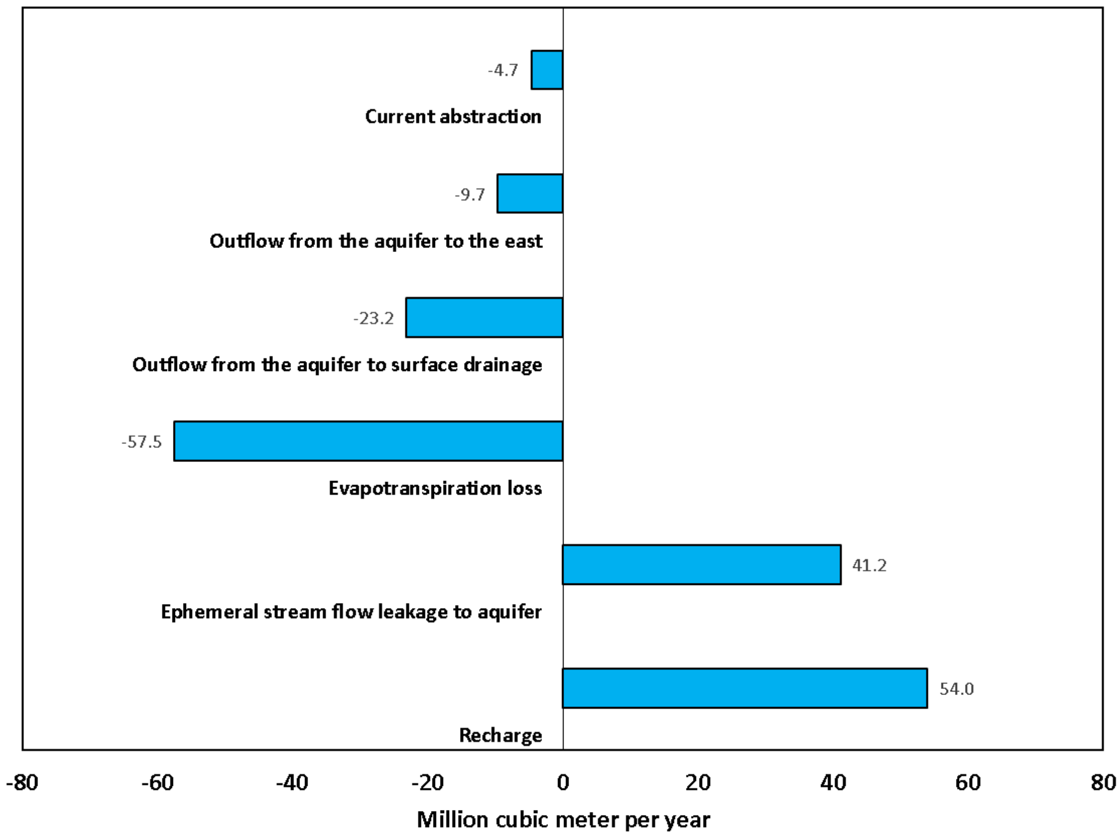

Figure 8-5: Water budget of the steady state model

Key results of the model, including the long-term average water budget, are discussed below.

1. Hydraulic conductivity of the aquifer, within the model domain, varies from 0.1 to 3.35 m/day, which is in the same range as the values calculated from test pumping (0.98 m/day average).
2. Steady state recharge to the aquifer occurs through direct recharge from rainfall (54 Mm^3/year) and through leakage during flow in the smaller ephemeral drainages (41 Mm^3/year).
3. Discharge from the aquifer is accounted for by loss through evapotranspiration (57 Mm^3/year), outflow to Epukiro and Eiseb Rivers (23 Mm^3/year), down gradient flow (9.7 Mm^3/year) and bulk abstraction (4.9 Mm^3/year).
4. The balance or net average inflow to the aquifer, including recharge and stream leakage, is therefore 8% of the mean annual rainfall of 390mm/year.

8.1 Drawdown forecast

Bulk abstraction of groundwater will cause an initial reduction of aquifer storage and a decline of the water table. Over an extended period of time, total bulk pumping for irrigation and supply to the OCP will reduce natural losses from the aquifer (evapotranspiration, outflows), and a new equilibrium will be established.

Peak OCP demand will require a 30% increase (1.41Mm^3/year) in abstraction from the aquifer compared to the current annual pumping. In this scenario it is assumed that all pumped water from Farm Lawriesdale will be supplied to the OCP and that, on this farm, irrigation activity will cease. Additional pumping from farms Meyerville, Kismet and Ettrick will satisfy this increase. Total bulk abstraction for irrigation and mine supply (6.1 Mm^3/year) will therefore be 6.4% of the current average inflow to the aquifer.

The steady state projection (**Figure 8-6**), represents a worst-case scenario, showing localised drawdown in all farms. On the farm Lawriesdale, where certain of the production boreholes are closely spaced, the projected drawdown is of the order of 17 m. It is therefore recommended that two of the production boreholes on Lawriesdale (P18 and P19) should be replaced with new boreholes spaced adequately (minimum spacing of 1 km) to avoid high local drawdown.

On farms Meyerville and Kismet however, production pumping will only result in a maximum drawdown of 7m and 3m respectively. This is considered reasonable as the impact of drawdown is local.

Under current recharge conditions and provided that conservative recommended pumping rates have been maintained, the groundwater table will recover after pumping is stopped at the end of the mine life. With the current steady state model, it is however not possible estimate the amount of time that will be required for water levels to return to pre-mine levels.

It must be borne in mind that where the pumping rate is unsustainably high, steady state conditions will not be achieved and the aquifer will dewater. For this reason, recommended pumping rates and regimes must be adhered to at all times and where demand exceeds supply additional boreholes should be established rather than unsustainably increasing abstraction from the existing supply boreholes.

Influence of neighbouring bulk pumping for irrigation is included in the model assuming that the same rate of pumping as estimated for 2023 is continued. However, additional development of irrigation schemes is likely to have an influence on the available resource and is discussed below. In terms of the new legislation (Section 9) where farmers intend to establish new irrigation schemes, they will have to apply for permits from the Department of Water Affairs. Such permits will have to take cognisance of existing abstraction for which permits will have already been issued.

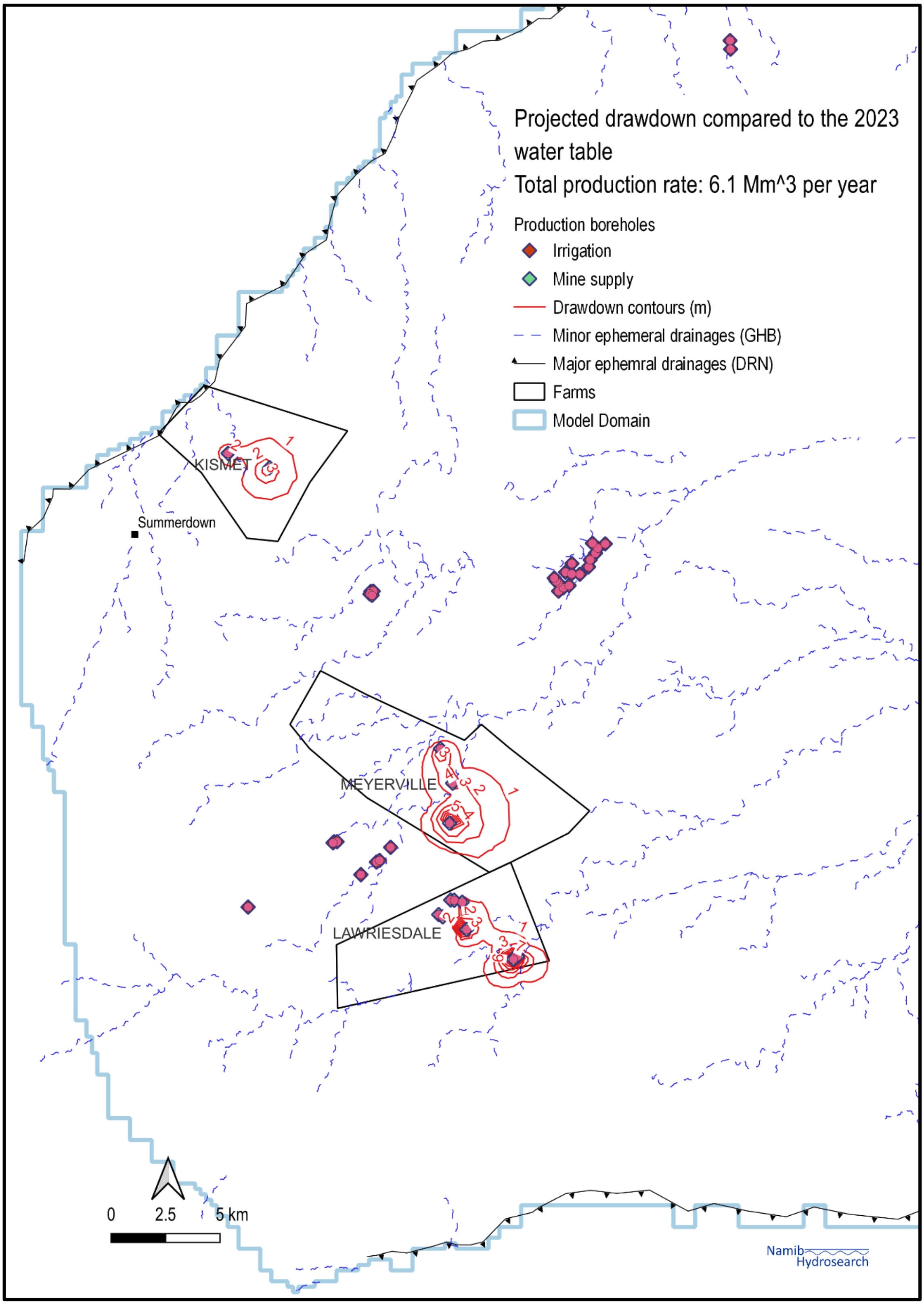

Figure 8-6: Steady state drawdown calculated at project boreholes and bulk irrigation abstraction points

9 DISCUSSION OF RESULTS

An early conceptualisation of the SKA facilitated the identification of a number of areas deemed favourable for groundwater exploration. it was not possible to conduct exploration over some of the best of these areas, as certain farmers were unwilling to negotiate access agreements. Work was therefore confined to favourable targets on farms where access had been secured. Notwithstanding this limitation, results from test pumping, both pre-existing and newly drilled (project) boreholes, indicates that the OCP water demand will be met by the boreholes on farms Lawriesdale, Meyerville, Kismet and Ettrick.

During the early stages of this project possible regional resources and recharge were quantified. These used assumed values for aquifer thickness, specific yield, annual rainfall, and recharge percent to generate preliminary estimates of the stored volume and annual recharge (3.0 billion m^3 and approximately 30 million m^3/year respectively). This project has however established that certain of the values and parameters assumed in the regional estimation were either overly conservative (recharge rate) or optimistic (extent of aquifer). The exploration project better defined the productive sections of the aquifer and enhanced the conceptual understanding. Water supply for the OCP cannot however be quantified from a regional estimate but requires a detailed study of the aquifer within and immediately surrounding the proposed wellfield(s).

Constant rate test pumping shows that 382m^3/h can be achieved from 16 boreholes (**Table 7-1**). The water demand for the initial stages of mine operation of 350m^3/h can be met from the boreholes identified. A preliminary steady state model indicates that the required water demand to the OCP can be met from the SKA and that this abstraction will have a limited overall impact.

To increase the confidence in sustainably abstracting sufficient water to meet the OCP demand it is of paramount importance to further confirm the annual recharge to the system. Attempts to use historical groundwater level monitoring data from irrigations schemes to estimate recharge was found to be complicated by suspected irrigation return flow (seepage below irrigated fields). Groundwater levels are influenced by a resultant mounding of infiltrated water as monitoring boreholes are located close to irrigated fields.

The risks involved in abstraction from the SKA and mitigation measures are discussed below:

1. Risk of impact the overall sustainability of the aquifer due to establishment of unregulated groundwater abstraction schemes in the SKA. New irrigation schemes are being planned or setup in the Summerdown area due to the high groundwater supply potential of the area. Realising the risk of overexploitation, the newly promulgated (August 2023) Water Resources Management Act (2013) included the SKA is as a Sub-terranean Water Control area for better management of the resource. Pumping will thus be regulated by permits issued by the Ministry of Agriculture, Water and Land Reform (MAWLR). Applications for an abstraction permit will therefore be made on the basis of the current study for the identified resource of 382m^3/h. Permitted abstraction schemes will therefore be legally protected from the impacts of additional withdrawal.
2. Risk of impact due to pumping from the SKA for supply to the OCP. The SKA has not been investigated in detail in the past. Much of the understanding gained is based on the current investigation of the western part of the aquifer. Risk arises due to the propensity of droughts in a semi-arid country and a general lack of long-term groundwater monitoring data. A conservative approach has therefore been adopted to calculating abstraction rates by

assuming that no recharge occurs to the aquifer for 15 years. The rainfall frequency analysis indicates a high probability (81%) of occurrence of recharge events at least once in 5 years (Section 3.1). However, a lack of long-term groundwater monitoring data precludes a detailed analysis of such events. Monitoring of groundwater levels, pumping rates and rainfall will be vitally important for continual management of the resource.

3. Risk of affecting water quality of the aquifer. Water quality analysis from all the boreholes sampled are of Group A – excellent quality water according to guidelines for the evaluation of drinking water for human consumption, DWA, Namibia, April 1988 (Appendix D). The SKA is vulnerable to pollution as it is an unconfined aquifer (open to the ground surface) with a shallow water table. Pollution may come from fertilizers and pesticides applied in irrigation farms, accidental dumping of hazardous material such as fuels, and wrong disposal of human and animal waste. With development of the water resources the risk of pollution increases requiring periodic sampling and analysis and identification of pollution sources. Baseline water quality sampling was carried out during the water point survey and from boreholes drilled and test pumped. The data is presented in Appendix D and will be used as baseline reference for any change recorded in the future.

10 RECOMMENDATIONS

The following recommendations are made for further development and management of the groundwater resource.

10.1 Negotiation of access to land for production

Negotiation with landowners to secure abstraction agreements should begin very early in the mine development phase as this is a critical aspect for success.

10.2 Sustainable abstraction of groundwater

- Boreholes identified in **Table 7-1** be equipped and connected to supply pipelines for supply to the proposed OCP mine
- Any new production boreholes are adequately spaced (more than 1 km) to avoid local high drawdown. On the farm Lawriesdale two of the existing boreholes (P18 and P19) are to be replaced as they are too close to a high yielding borehole P17.
- A network of monitoring boreholes be identified in order to observe the behaviour of the SKA under production conditions. If necessary new monitoring boreholes are to be drilled. A preliminary list of monitoring boreholes is given in **Table 10-1** below.
- In the first year of production monitoring should be on a monthly basis extending the time interval to bi-annual thereafter.
- Based on the behaviour of the aquifer under production conditions pumping rates and regimes should be adjusted to achieve an even response

10.3 Protection of the wellfield area

The boreholes are vulnerable to pollutants at surface as the aquifer is unconfined and the water table is shallow. The area around the production boreholes, set at 500 m radius, should be protected from pollutants at surface. These would include fertilizers, pesticides, animal kraals, storage of hazardous materials including fuels, and wastewater disposal.

10.4 Monitoring of yield, groundwater levels

Recording of weekly abstraction volumes using a totalizing flowmeter and weekly groundwater levels is recommended. Analyses of the data on a yearly basis can identify any problems with the operation of a borehole, unsustainable pumping rates and quantify recharge rates to the aquifer. Onsite rainfall monitoring is also recommended. Numerical groundwater flow models in the scale of individual wellfields (e.g., Meyerville and Lawriesdale) should be built to evaluate recharge.

10.5 Recharge evaluation and additional resource

The steady state model discussed above gives a fundamental understanding of groundwater flow and budget of the western part of the SKA. This model must be updated and with additional groundwater level information, verified bulk abstraction rates and recharge estimates to increase the reliability of resource quantification and sustainable abstraction rates. In addition, a transient flow model must be developed at a stage when sufficient monitoring data is collected (two to three years after start of production pumping). For security of water supply and avoiding high localised drawdown, additional exploration for groundwater should be carried out on adjacent properties.

Table 10-1: List of boreholes for monitoring of groundwater level

Farm	Monitoring borehole
Lawriesdale	New1, P04, P19
Kismet	K1 (WW206643)
Meyerville	M2 (WW206767)

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APPENDIX A - BOREHOLE DRILLING LOGS

APPENDIX B - DOWNHOLE GEOPHYSICAL LOGS, LAWRIESDALE FARM

APPENDIX C - TEST PUMPING INTERPRETATION AND SUPPLY PROJECTIONS

APPENDIX D - WATER QUALITY ANALYSES