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Follow-up Hydrogeological Assessment for the Proposed De Wittekrans Coal Mine

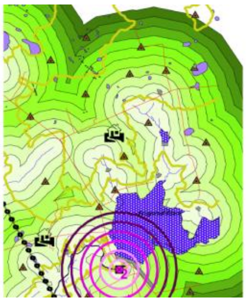
Version –2 – DRAFT FOR DISCUSSION ONLY

Aug 2010

For:

GCS Project Number: 09-532

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19 August 2010

GCS Environmental Unit

ATTENTION: Magdalena von Ronge

Please find attached the updated DRAFT Hydrogeological report for the De Wittekrans Section.

Please do not hesitate to contact us should you require any additional information.

Best regards,

Pieter Labuschagne

GCS Project Hydrogeologist

Follow-up Hydrogeological Assessment

Mashala Resources – Proposed De Wittekrans Coal Mine

Version - Final DRAFT

19 August 2010

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1 Introduction and Overview

This document acts as a follow-up hydrogeological assessment for the proposed De-Wittekrans Coal Mine. The initial and basic hydrogeological assessment for the proposed project was conducted in the 2nd quarter of 2009. The outcome of the hydrogeological study was documented and included in the EIA/EMP (environmental impact assessment / environmental management plan) which was submitted to the Authorities and I&APs (interested and affected parties). Subsequently to review by the various parties a sequence of discussion meetings were held and feedback documentation was supplied.

The following supplies a summary list of the main queries in terms of the hydrogeological section of the EIA/EMP; interpreted from the original; the original list can be obtained from GCS (Pty) Ltd or Mashala Resources:

Table 1-1: Query List with document reference

Identified Issues by I&APs	**Report Reference**
Aspects regarding Groundwater Quality from DMR:	
a) Point 2: Potential development of AMD (Acid Mine Drainage) and impact on the environment. Need to supply mitigation measures and the potential cost thereof.	Discussed in Section 2, mitigation proposed in Sections 6 and 7 if applicable.
b) Point 6: Potential of decant into the Klein Olifants River with potential of AMD kept in mind. Need to supply mitigation measures and the potential cost thereof.	Decant discussed in Section 4 and proposed in Sections 6 and 7 if applicable.
Aspects regarding Groundwater Quantity and Quality from I&APs:	
c) Point 11: Potential impact on levels and quality of the boreholes and fountains.	Section 3.3.2
d) Point 12: Impact of opencast on the quality of the river.	Section 5
e) Point 13: "Farmer utilises approximately **20 000 to 30 000 l/day** (20 to 30 m3/day). How long during/after mining will water levels return to normal?"	Section 3.3.2
f) Point 14: "How will the boreholes situated adjacent the Klein Olifants River be impacted on?"	Section 3.3.2
g) Point 16: "Will boreholes dry up during the mining of the second layer of coal?"	Section 3.3.2
h) Point 26: Explain predicted decant quantity better.	Section 4
i) Point 28 and 29: I&APs had a comment on the calculation of rainwater recharge into rehabilitated opencast pits – this aspect will be confirmed.	Section 3.4
j) Point 31: Relook at decant and mitigation.	Section 4
k) Point 34: Water management of water in pits after closure must be confirmed.	Pits will be filled and rehabilitated (N/A)
l) Point 36: Water flow from different elevations will be discussed in particular the 'vlei/wetland" and the mining elevations.	Section 3.3.2
m) Point 47: Impact on Klein Olifants River?	Section 3.3.2 and 5
n) Point 69: Mitigation of groundwater?	Section 6
o) Point 79: Describe "residual impacts."	Section 6
p) Point 81: Residue deposits and associated impacts on groundwater.	Section 6
q) Point 83: Decant volumes must be specified.	Section 4
r) Point 95: Issues regarding AMD must be addressed.	Section 2
s) Point 101: Confirm opencast mining and impacts on Klien Olifants River system.	Section 3.3.2
Feedback **Report from Geluksdraai Trust**, JHJ van Vuren, 25 Aug 2009. The feedback letter report highlights the following:	

t) Geluksdraai Trust owns the Bosmanshoek 235, the southern tip of the indicated mining area. There are two boreholes on the farm and will be included in this assessment report to identify any particular impacts and issues.	Section 3.3.2

1.1 Scope and objectives

***NOTE**: It is important to study the original 2009 groundwater report in conjunction with this report to read up on specific field work and baseline data which will not necessarily be repeated in this document.*

The main objectives of this follow-up assessment are:

i. To address the points raised above (Table 1-1) regarding potential groundwater quantity and quality issues;

ii. To include new data in terms of ABA (acid base accounting) analyses;

iii. To update the hydrogeological assessment according to new and updated mine and surface infrastructure plans, and

iv. Supply more information on mitigation and associated cost.

1.2 Explanation of new mine plan

Further technical studies were undertaken by Mashala Resources since the feedback sessions and certain aspects of the proposed mine plan was changed; it is therefore important to note that this hydrogeological follow-up assessment will be based on a different mine plan and additional geological and hydrogeological data.

It can be seen from Figure 1-1 that the proposed open cast mine blocks significantly decreases in size and only three blocks will be opencast mined; this will have a positive impact on long-term groundwater behaviour in comparison to the larger open cast blocks proposed in 2009 (initial assessment). The underground mine sections will also decrease and a primary North and South Underground mine will be developed with only 1 adit / box cut system for each section.

Figure 1-2 and Figure 1-3 show the C-lower coal seam dimensions in terms of depth and elevation respectively. It is evident from Figure 1-2 that mining will be more shallower towards the central portion of the De Wittekrans lease area and deeper in the north and south; open cast mining will therefore occur at shallower depths (0-30m) and underground mining at deeper depths (>30m).

Underground mining will follow the traditional board-and-pillar method and the pillar ratio will be according to set geotechnical sound standards to prevent roof-fall and subsidence after mine closure. Open cast mining will be according to the role-over method where pit rehabilitation will be concurrently towards the high-wall direction.

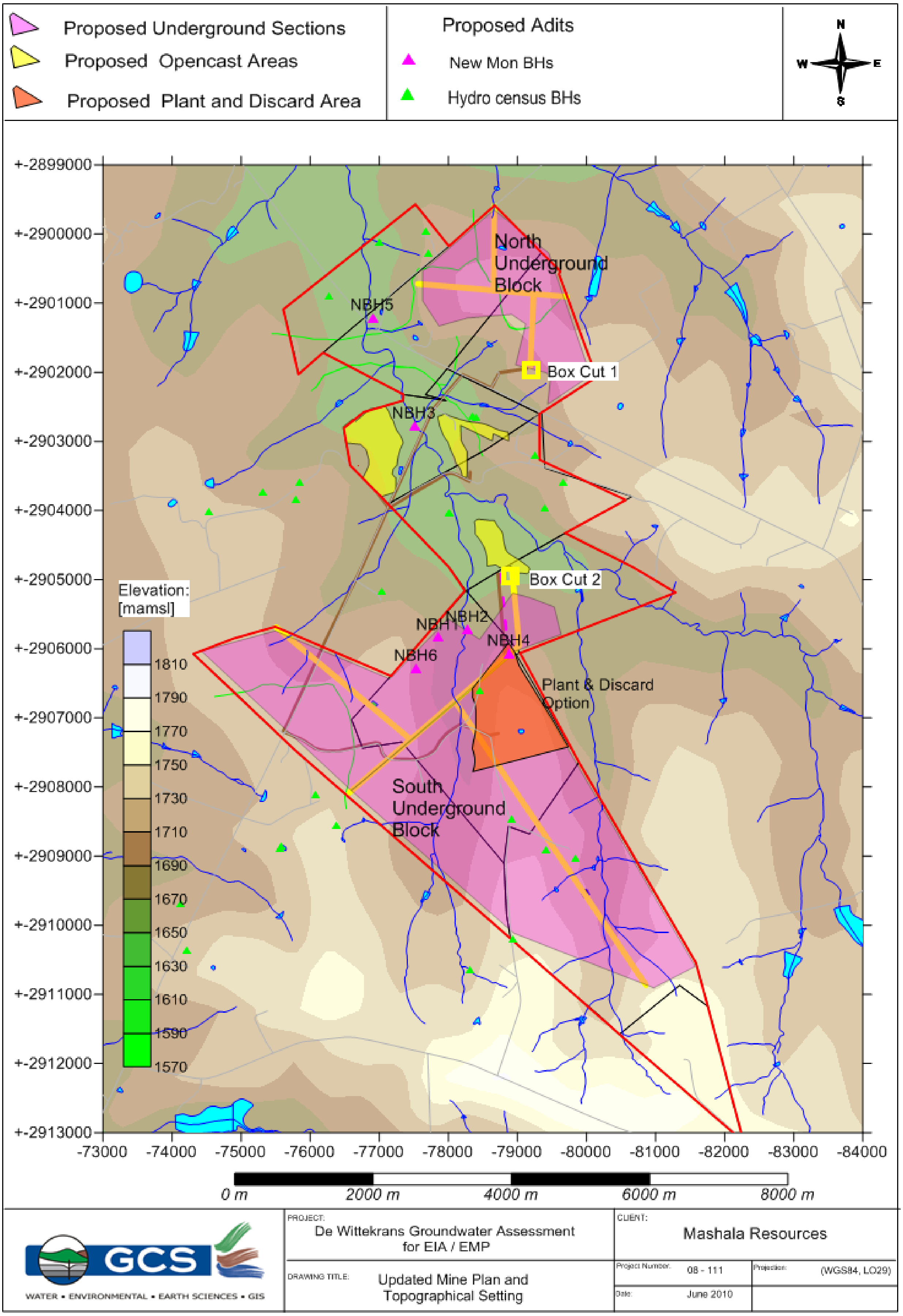


Figure 1-1: Updated Mine Plan for the proposed De-Wittekrans Coal Mine

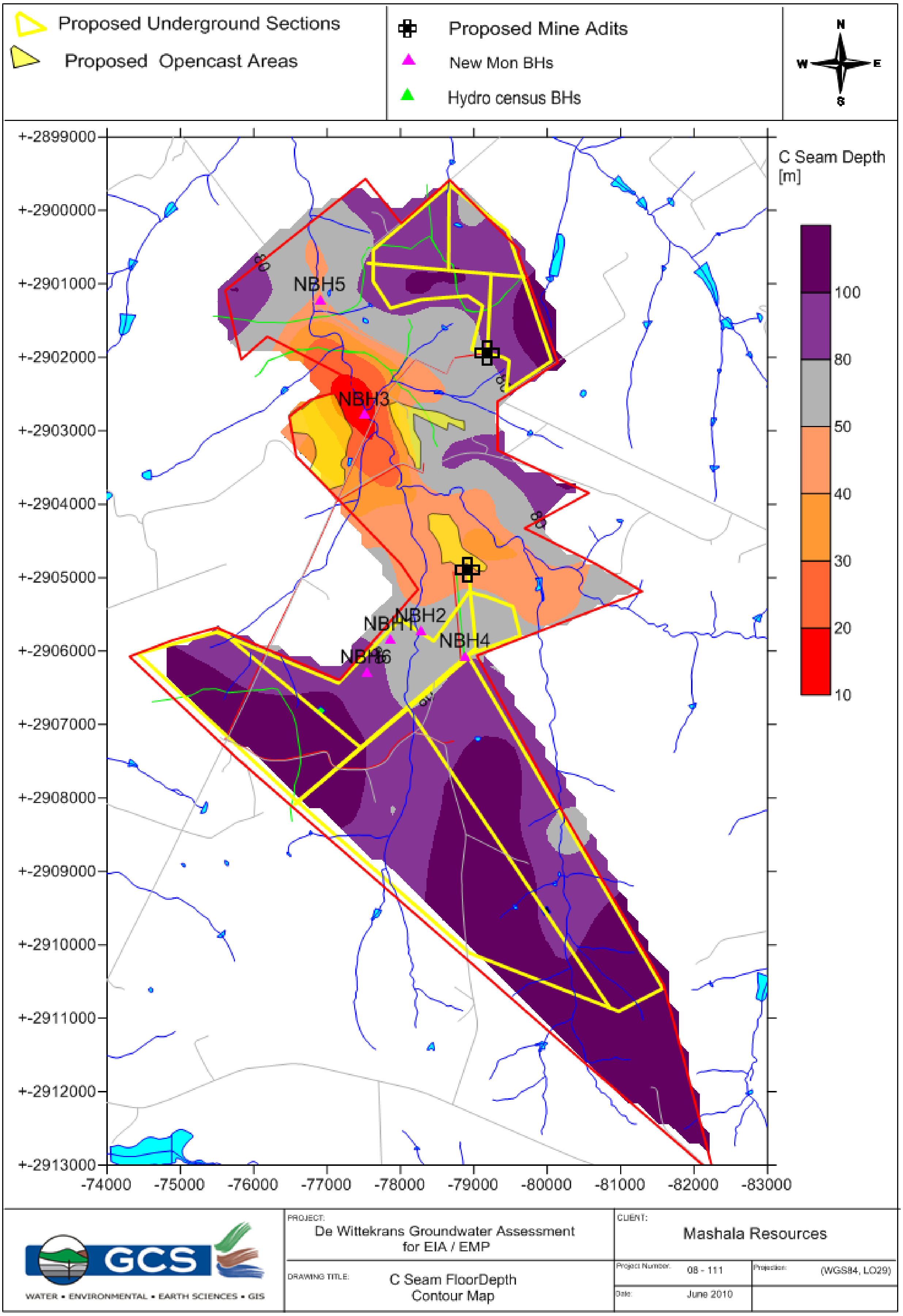


Figure 1-2: C Lower Coal Seam Depth and maximum depth of mining at De Wittekrans

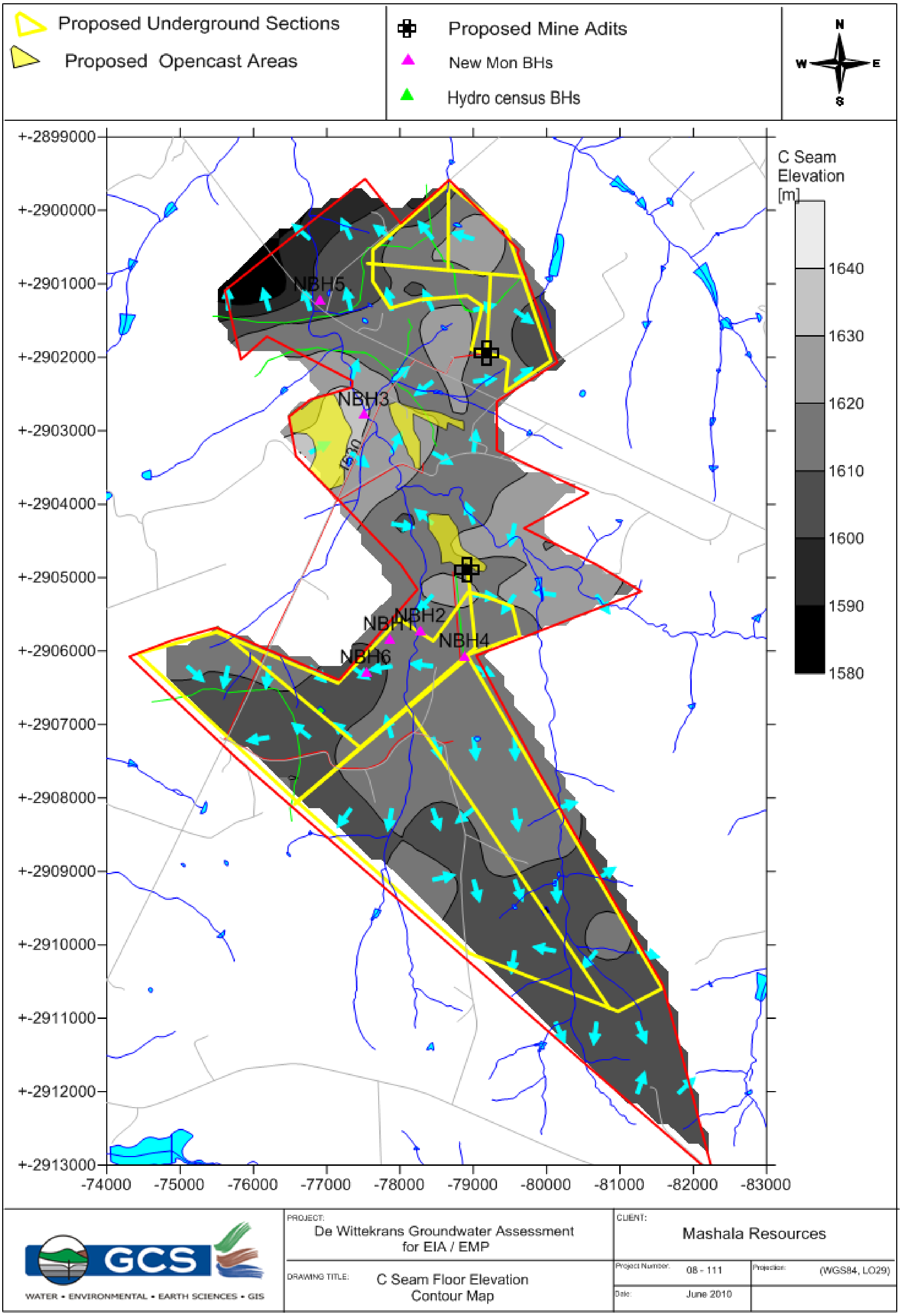


Figure 1-3: C Lower Coal Seam Elevation Contours and probable water flow in underground workings

2 *Preliminary Acid Generation Characterisation*

Rock chip samples were obtained from the drilling cuts during the air percussion drilling of the monitoring boreholes. Samples were obtained from boreholes NBH3 and NBH5; the samples were submitted to the IGS analytical laboratory (Institute for Groundwater Studies, University of the Free State, Bloemfontein). The tests performed were: acid base accounting (ABA), net acid generation (NAG), and aqueous extraction.

Eleven soil/rock samples were collected from De Wittekrans colliery in order to characterise the samples in terms of their potential to generate acidity. The samples were taken from the floor, roof, overburden and hanging walls. The sample names and positions are given below.

Table 2-1: Sample Descriptions

Sample ID	Sample Description
GCS1	NBH3: 31m, Coal Roof
GCS2a	NBH3: 32m, Coal Layer
GCS1a	NBH3: 35m, Coal Layer
GCS2	NBH3: 37m, Coal Floor
GCS3	NBH5: 27m, overburden sandstone
GCS4	NBH5: 37m, Hanging wall
GCS3a	NBH5: 38m, Coal Layer
GCS4a	NBH5: 40m, Coal Layer
GCS5	NBH5: 41m, Coal Layer Floor
GCS6	NBH5: 48m, Coal Layer
GCS7	NBH5: 51m, Coal Floor

2.1 Overview

2.1.1 Acid Base Accounting

Acid base accounting is a screening analytical procedure that provides values to help assess the acid-producing and acid-neutralising potential of underground pillar, floor and hanging wall, waste rock and/or tailings in order to predict post-mining water quality. In this procedure, the amount of acid-producing rock is compared with the amount of acid-neutralising rock, and a prediction of the water quality at the site (whether acid or alkaline) is obtained. The values that are compared are called the acid potential (AP), and the neutralising potential (NP). The comparison may be the difference between the two values, called the net neutralising potential (NNP) or the ratio of the two values, called the neutralisation potential ratio (NPR), as shown below:

Net neutralisation potential NNP = NP – AP

Neutralisation potential ratio $NPR = \frac{NP}{AP}$

Below are two tables showing the comparison ranges.

Table 2-2: ***Net neutralising potential (NNP)***

NNP = NP – AP	Acid generating potential
< -20	Likely to be acid generating
Between -20 and 20	Uncertain range
>20	Not likely to be acid generating

Table 2-3: ***Neutralisation potential ratio (NPR)***

NPR = $\frac{NP}{AP}$	Acid generating potential
< 1	Likely
1 - 2	Possible
2 - 4	Low
> 4	Unlikely

Note that the terms “open” and “closed” are sometimes used in acid base accounting. These terms refer to an assumption about whether the neutralisation reaction is open or closed to the atmosphere. Neutralisation reactions generate carbon dioxide (CO2). If the reaction is “closed” to the atmosphere this CO2 will not escape, but instead will generate extra carbonic acid, thus adding to the AP. A reaction that is “open” will lose this extra CO2 and will thus contain less acidity.

2.1.2 Net Acid Generation

The net acid generation (NAG) test is used to estimate the acid generation potential of a sample. It involves the complete oxidation of the sulphides in a sample by hydrogen peroxide. As acid is produced during the oxidation, it is neutralised by carbonates and other acid-neutralising minerals within the sample. The final pH in the complete oxidation is an indication of the acid generating potential of the sample, as shown in the table below.

Table 2-4: ***NAG***

Final pH	Acid generating potential
pH ≤ 2.5	Moderate to strong acid generating potential
2.5 < pH < 5	Low risk of being acid generating
5 ≤ pH	Non acid generating

The amount of sulphate generated is also measured at the end of the complete oxidation. It is measured in kg/t, i.e. kg of sulphate produced per tonne of rock.

2.1.3 Element enrichment

One element enrichment test was performed, namely: Aqueous extraction- This procedure indicates which chemical constituents may be solubilised by deionised water.

2.2 Results

2.2.1 Acid base accounting

The ABA testing results are summarised in Table 2-5.

- The ABA results indicate that samples GCS1 and GCS2a are highly likely to be acid generating, presenting the B seam coal roof (hanging wall) and coal seam itself.
- Samples GCS3 and GCS6 are likely not to be acid generating.
- The rest of the samples fall into the uncertain range: GCS4a has a lower likelihood of producing acid, while GCS1a, GCS2, GCS4, GCS3a, GCS5 and GCS7 have a higher likelihood of acid generation.

*Table 2-5: **Acid base accounting results (kg/t CaCO3 where applicable)***

Lab number	Sample	Acid Potential (Open)	Acid Potential (Closed)	Neutralising Potential	NNP (Open)	NNP (Closed)	NRP (Open)	NRP (Closed)
GCS1	NBH3: 31m, Coal Roof	34.824	69.647	10.453	-24.4	-59.2	0.300	0.150
GCS2a	NBH3: 32m, Coal Layer	48.430	96.870	21.906	-26.5	-75.0	0.452	0.226
GCS1a	NBH3: 35m, Coal Layer	26.927	53.854	34.533	7.6	-19.3	1.282	0.641
GCS2	NBH3: 37m, Coal Floor	12.433	24.865	16.421	4.0	-8.4	1.321	0.660
GCS3	NBH5: 27m, overburden sandstone	7.706	15.412	37.846	30.1	22.4	4.911	2.456
GCS4	NBH5: 37m, Hangingwall	15.390	30.780	16.973	1.6	-13.8	1.103	0.551
GCS3a	NBH5: 38m, Coal Layer	21.979	43.958	40.846	18.9	-3.1	1.858	0.929
GCS4a	NBH5: 40m, Coal Layer	7.906	15.813	31.497	23.6	15.7	3.984	1.992
GCS5	NBH5: 41m, Floor Coal Layer	22.380	44.760	25.219	2.8	-19.5	1.127	0.563
GCS6	NBH5: 48m, Coal Layer	15.938	31.877	68.585	52.6	36.7	4.303	2.152
GCS7	NBH5: 51m, Coal Floor	10.943	21.886	15.904	5.0	-6.0	1.453	0.727
Unlikely acid generating					≥ 20	≥ 20	≥ 4	≥ 4
Uncertain					-20 to 20	-20 to 20	1 to 4	1 to 4
Likely acid generating					≤ -20	≤ -20	≤ 1	≤ 1

Net acid generation

Results of the net acid generation (NAG) test are shown in Table 2-6.

Table 2-6: *Table of NAG results*

Lab number	Sample ID	Final pH	SO_4 released (kg/t)
GCS1	NBH3: 31m, Coal Roof	2.52	33.4306
GCS2a	NBH3: 32m, Coal Layer	1.25	46.5000
GCS1a	NBH3: 35m, Coal Layer	2.27	28.8500
GCS2	NBH3: 37m, Coal Floor	2.15	11.9353
GCS3	NBH5: 27m, overburden sandstone	5.91	7.3979
GCS4	NBH5: 37m, Hangingwall	3.65	14.7743
GCS3a	NBH5: 38m, Coal Layer	3.87	21.1000
GCS4a	NBH5: 40m, Coal Layer	4.29	7.5900
GCS5	NBH5: 41m, Coal Layer	2.34	21.4847
GCS6	NBH5: 48m, Coal Layer	5.62	15.3009
GCS7	NBH5: 51m, Coal Floor	2.99	10.5051
Unlikely acid generating		≥ 5.0	
Uncertain		2.5 to 5.0	
Likely acid generating		≤ 2.5	

Based on the final pH values, samples GCS3 and GCS6 are unlikely to be acid generating, while samples GCS2a, GCS1a and GCS2 and GCS5 are likely to be acid generating. The samples GCS1, GCS4, GCS3a, GCS4a and GCS7 fall into the uncertain range.

It should be noted however, that even though a sample (eg. GCS1) falls into the uncertain range, the amount of sulphate generated can be quite high. This highlights the fact that these tests should be treated as a guide, and not as a definitive prediction.

2.2.2 Aqueous extraction

The results of the aqueous extraction are shown below.

Table 2-7: *Water soluble constituents*

Lab number	Samples	Initial pH	SO_4 (kg/t)
GCS1	NBH3: 31m, Coal Roof	8.35	0.5898
GCS2a	NBH3: 32m, Coal Layer	7.49	1.1000
GCS1a	NBH3: 35m, Coal Layer	7.79	1.0700
GCS2	NBH3: 37m, Coal Floor	7.85	0.4827
GCS3	NBH5: 27m, overburden sandstone	8.25	0.2690
GCS4	NBH5: 37m, Hangingwall	7.74	0.4275
GCS3a	NBH5: 38m, Coal Layer	7.94	0.5800

GCS4a	NBH5: 40m, Coal Layer	7.85	0.4500
GCS5	NBH5: 41m, Coal Layer	7.77	0.9338
GCS6	NBH5: 48m, Coal Layer	8.09	0.5921
GCS7	NBH5: 51m, Coal Floor	7.76	0.1392

As shown in Table 2-7, the samples with the highest sulphate concentration are GCS2a and GCS1a associated with the B Coal Seam. Sulphate is the product of weathering (oxidation) that is stored in the rock. This concentration is an indication of the amount of stored sulphate in the sample, not a prediction of future acid generating potential. Samples with the lowest concentration of stored sulphate are GCS3 and GCS7.

Table 2-8 shows the water soluble constituents of seven of the samples. The samples with the highest amount of leachable salts are GCS1, GCS2 and GCS5.

Table 2-8: Water soluble constituents (kg/t)

Samples	TDS	Al	Fe	Mn	Ca	Mg	Na	K	Cl	S
GCS1, NBH3: 31m, Coal Roof	1.521	0.0028	0.0014	0.0004	0.0750	0.0237	0.1290	0.2690	0.0844	0.5898
GCS2, NBH3: 37m, Coal Floor	1.638	0.0026	0.0006	0.0003	0.2320	0.0430	0.0880	0.1450	0.1200	0.4827
GCS3, NBH5: 27m, Overburden	0.885	0.0026	0.0012	0.0001	0.0514	0.0133	0.0940	0.1360	0.0359	0.2690
GCS4, NBH5: 37m, Hangingwall	1.389	0.0026	0.0012	0.0002	0.1630	0.0496	0.1100	0.1580	0.0231	0.4275
GCS 5, NBH5: 41m, Coal	1.588	0.0015	0.0005	0.0003	0.1970	0.0465	0.1170	0.1240	0.0343	0.9338
GCS 6, NBH5: 48m, Coal	1.345	0.0028	0.0014	0.0002	0.1860	0.0448	0.0972	0.0702	0.0222	0.5921
GCS 7, NBH5: 51m, Coal Floor	1.326	0.0051	0.0010	0.0002	0.1540	0.0262	0.1610	0.0770	0.0261	0.1392

2.3 Conclusions

The ABA results indicate that GCS1 and GCS2a are highly likely to be acid generating. Samples GCS3 and GCS6 are likely not to be acid generating. The rest of the samples fall into the uncertain range: GCS4a has a lower likelihood of producing acid, while GCS1a, GCS2, GCS4, GCS3a, GCS5 and GCS7 have a higher likelihood of acid generation.

Based on the final pH values, samples GCS3 and GCS6 are unlikely to be acid generating, while samples GCS2a, GCS1a and GCS2 and GCS5 are likely to be acid generating. The samples GCS1, GCS4, GCS3a, GCS4a and GCS7 fall into the uncertain range.

There is a definite risk in certain areas in terms of future long-term acid mine drainage conditions.

The test work done during this assessment must be regarded as preliminary and for indication purposes only. It is recommended that follow-up testing work be conducted and more detail be supplied accordingly.

- More detailed characterisations of the samples should include a study to ascertain the mineralogy, followed by kinetic studies to ascertain the likely rate of acid generation. Based on these results, mitigation measures can be investigated.
- It is also important to consider all hydrogeological components; in other words consider depth of proposed underground workings, possible rate of filling of water after closure, groundwater flow velocity, etc. It is not good practice to just look at ABA in isolation but rather consider all other factors that may influence quality as well as quantity of groundwater.

3 Updated Groundwater Quantity Assessment

3.1 Overview

The following section will supply an updated assessment on **water quantity aspects** and how mining activities can potentially impact on groundwater quantity.

The numerical model was adjusted after research was done on typical groundwater inflow rates into similar underground and opencast mines in the Bethal/Hendrina/Ermelo Coal Field. It was discovered at other mines in the area that if underground mining activities is deeper than 50 to 70 m limited impacts occur within the upper weathered aquifer. It was apparent during the hydrocensus that most farm boreholes were drilled in the weathered zone at depths average around 15 to 35 m. Hodgson presented the following in his initial work on the Mpumalanga Coal Field and associated groundwater inflow (WRC Report 291/1/98):

> Influx rates of water into underground bord-and-pillar areas are usually low. Water seeps are usually present in the coalface of new development. These dry up as mining progresses. The vertical hydraulic conductivity of the over- and underlying sediments is too low to convey significant amounts of water into underground mines. Sub-vertical fissures that yield water for a limited period (weeks rather than months) may be intersected on occasion. In exceptional cases, a sustained but low flow of groundwater may be intersected. Instances where coal mining had to stop for a length of time because of groundwater influx are almost non-existing.
>
> The accurate quantification of groundwater influx into bord-and-pillar workings is difficult, if not impossible. A vast number of depressions in the coal floor exist where water accumulates before reporting to central facilities. Water on the coal seam is usually only notable when it interferes with mining. The data sited in this report on influx of water into bord-and-pillar areas are 28 years of observations in collieries.
>
> In theory, influx into bord-and-pillar areas should depend on the area of a mine. This correlation is demonstrated in Figure 3-1.

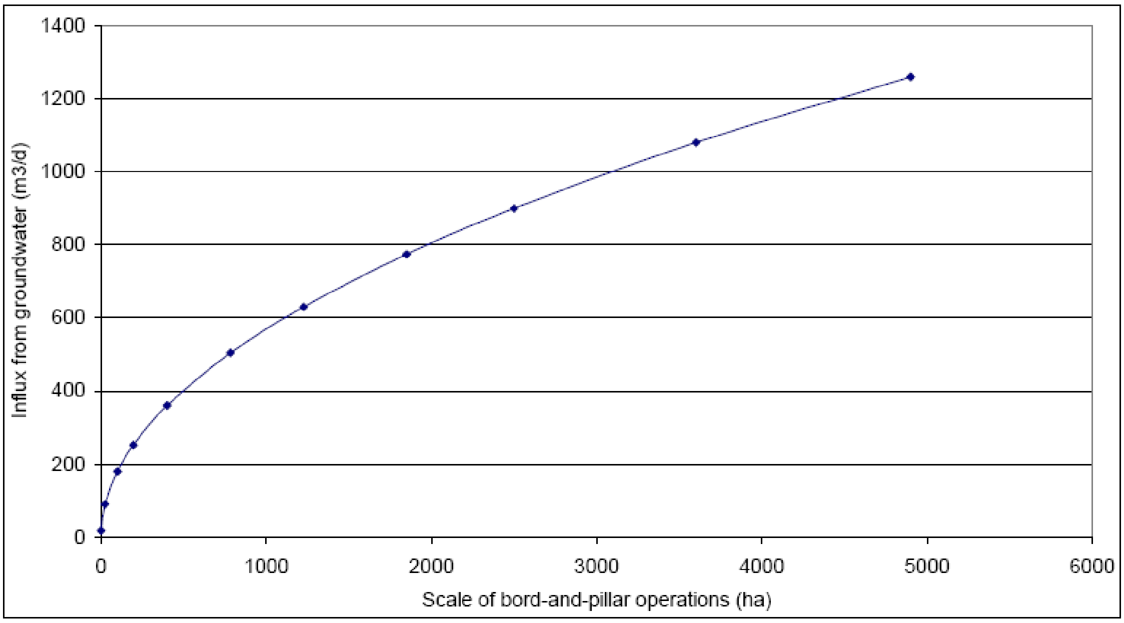


Figure 3-1: Empirical relationship between the area mined by bord-and-pillar methods and water influx for an average mining depth of 60 m (Hodgson, 1995).

In reality, influx is also dependent on mining depth. A sliding scale to incorporate the depth of mining is suggested in Table 3-1.

Table 3-1: Anticipated recharge to bord-and-pillar mining in the Mpumalanga Area (Hodgson, 1995)

Description	Recharge as a % of annual rainfall
Influx into bord-and-pillar mining > 100 m	1.0
Influx into bord-and-pillar mining 60 - 100 m	1.5
Influx into bord-and-pillar mining 30 - 60 m	2.0
Influx into bord-and-pillar mining 15 - 30 m	2.5
Influx into bord-and-pillar mining < 15 m	4 - 6
Recharge to undisturbed Karoo sediments	3.0

By applying the above for the proposed underground mining sections it can be seen from the following table (Table 3-2) that approximately 500 m^3/day can recharge into the underground workings if the total void area of the C seam is considered. If Figure 3-1 is considered approximately 700 m^3/day can recharge into a 1600 ha underground mine (South UG Mine) and approximately 200 m^3/day for a 310 ha mine (proposed North UG Mine). This supplies an order of magnitude of propable recharge after closure if the total void is considered.

Table 3-2: Theoretical underground inflow rates according to the Hodgson guideline

Mining Block	Approx Depth (m)	Area (m2)	% Recharge	Rainfall (m)	Annual Inflow (m3)	Daily (m3)	l/sec
UG South	60 - 100	16 033 840.0	1.5%	0.71	170 760.40	467.84	5.4
UG North	45 - 110	3 114 353.0	1.7%	0.71	37 590.24	102.99	1.2
Total Area (Ha)		**1 914.8**				**570.82**	**6.6**

3.2 Application of the De Wittekrans Proposed mining activities

The numerical groundwater model, that was developed in 2009 using the Visual Modflow software, was updated with the new mine plan and de-water simulation applied. It is important to note that the extent of the proposed opencast pits, applied in the updating of the numerical model, is much smaller (when comparing to the original 2009 mine plan), (refer to Figure 1-1 above). The underground workings will also be smaller with only two primary sections; a South and a North Block respectively will be minded from two adits, one for each. The model simulations were based on the C Lower Coal Seam.

The updated mine plan were planned to be a safe distance away from surface streams and it can be expected that a much smaller impact on regional groundwater flow will occur due to smaller de-watering zones if compared to the 2009 groundwater impact assessment.

It is important to note that no specific mine progress plan was available during the time of this numerical simulations. An interim progress plan was applied based on year-to-year anticipated mine development and progress (refer to Figure 3-2).

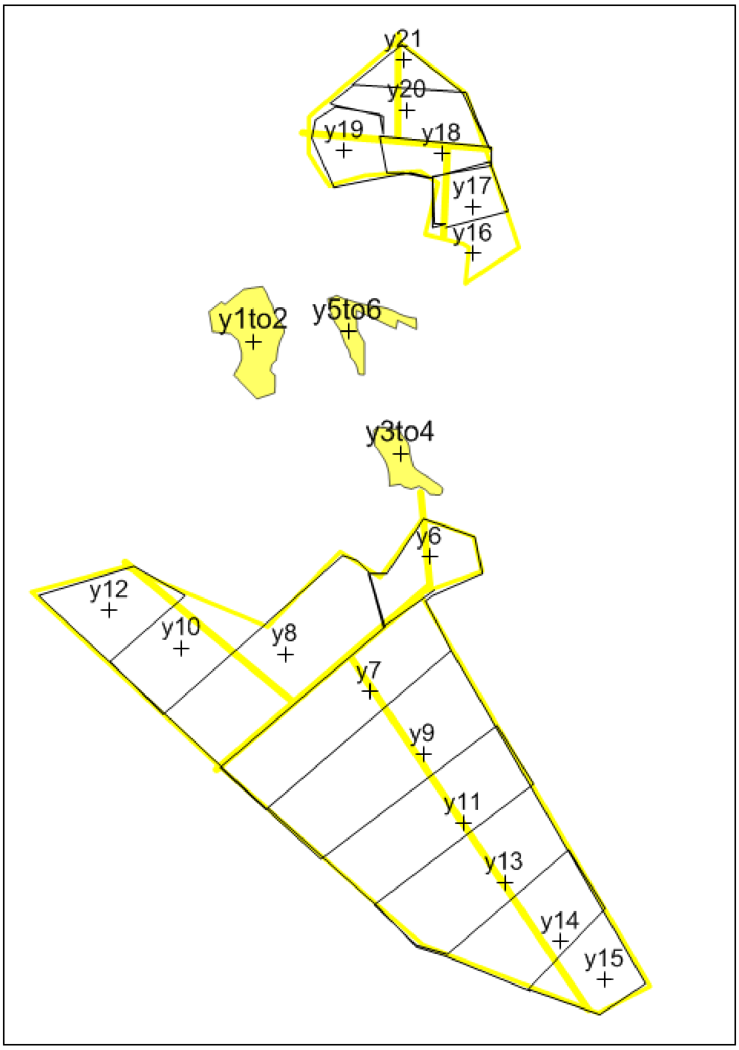


Figure 3-2: Mine progress plan applied

3.3 De-watering Assessment

3.3.1 Cone of depression over life of mine

The dewatering of the proposed opencast and underground mining development was simulated using drain nodes. These nodes allow the setting of a reference level to which the mining area will be dewatered over a specified time period. The level was determined by applying the coal floor elevation data for the C-Lower Seam. The transmissivity allowed for the drain nodes was adjusted within the range of hydraulic parameters obtained from the pump testing data but also according to predicted recharge rates (as per Table 3-2).

The results of the flow model dewatering simulations can be viewed as follows:

- Figure 3-3: 6 Years after mining has started; opencast mining completed and rehabilitated in progress at Block 3. Underground mining will start now at the South Mine Block.
- Figure 3-4: 16 Years after mining has started; Underground mining is completed at the South Block and in the process of recharging. Mining will commence now at the smaller North Block.
- Figure 3-5: 21 Years after mining has started and the life of mine has been reached. Mine closure and final rehabilitation will commence. This can be regarded as the maximum zone of

influence caused by the mine de-watering activities. The 1 m drawdown contour line indicates the zone of influence around the mining area. It can be seen that the zone of influence on groundwater levels ranges between 200 m and 800 m around the mining area.

It can be seen from the model predictions that the opencast mining activities will have a more direct impact on the weathered aquifer in terms of de-watering and recharge. Underground mining will occur at depths >30m; this implies mining below sandstone and shale layers that is less weathered and more impermeable. It is therefore suggested that the impact on surface water flow and shallow base-flow will be less.

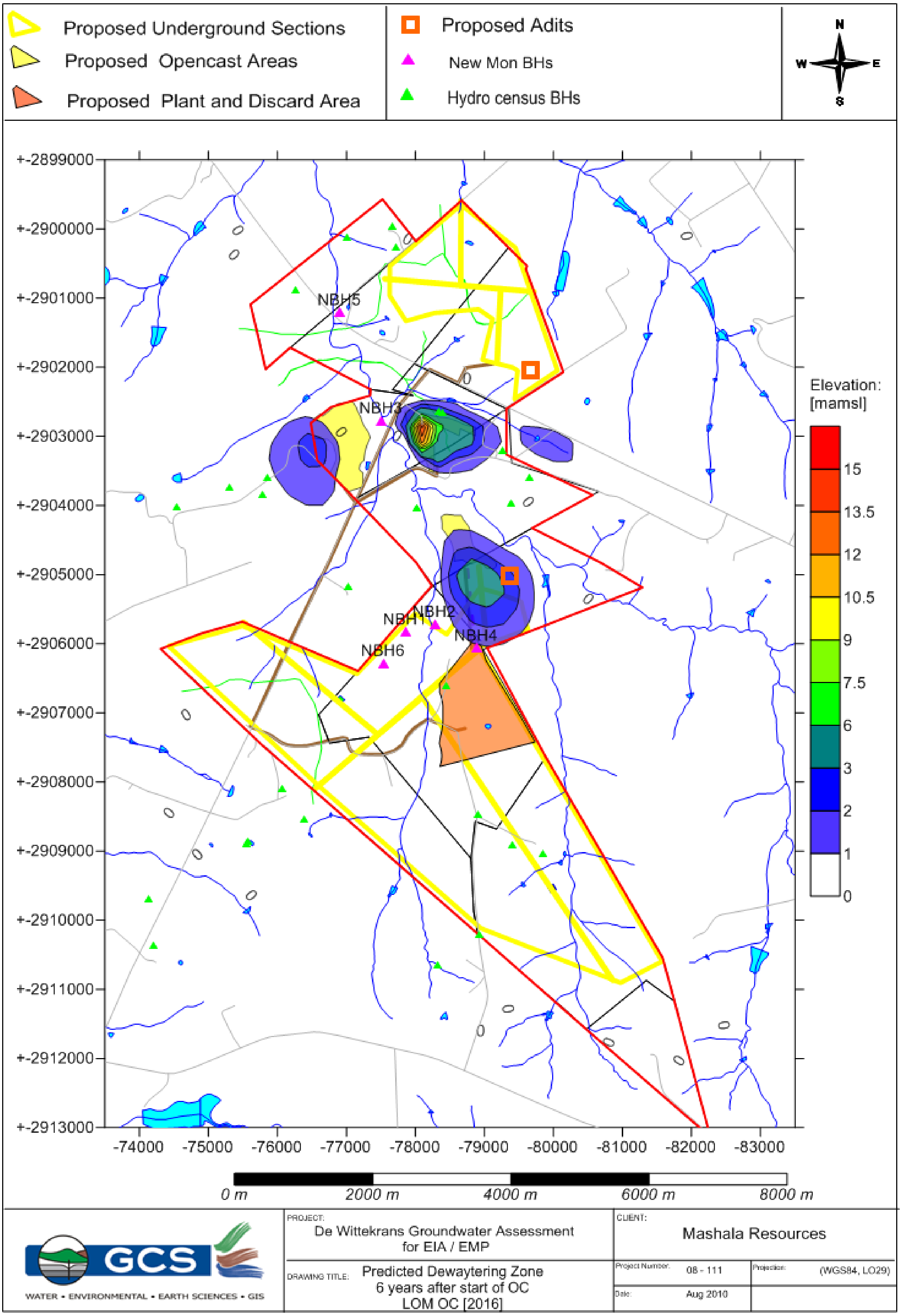


Figure 3-3: Zone of de-watering 7 years after start of opencast mining

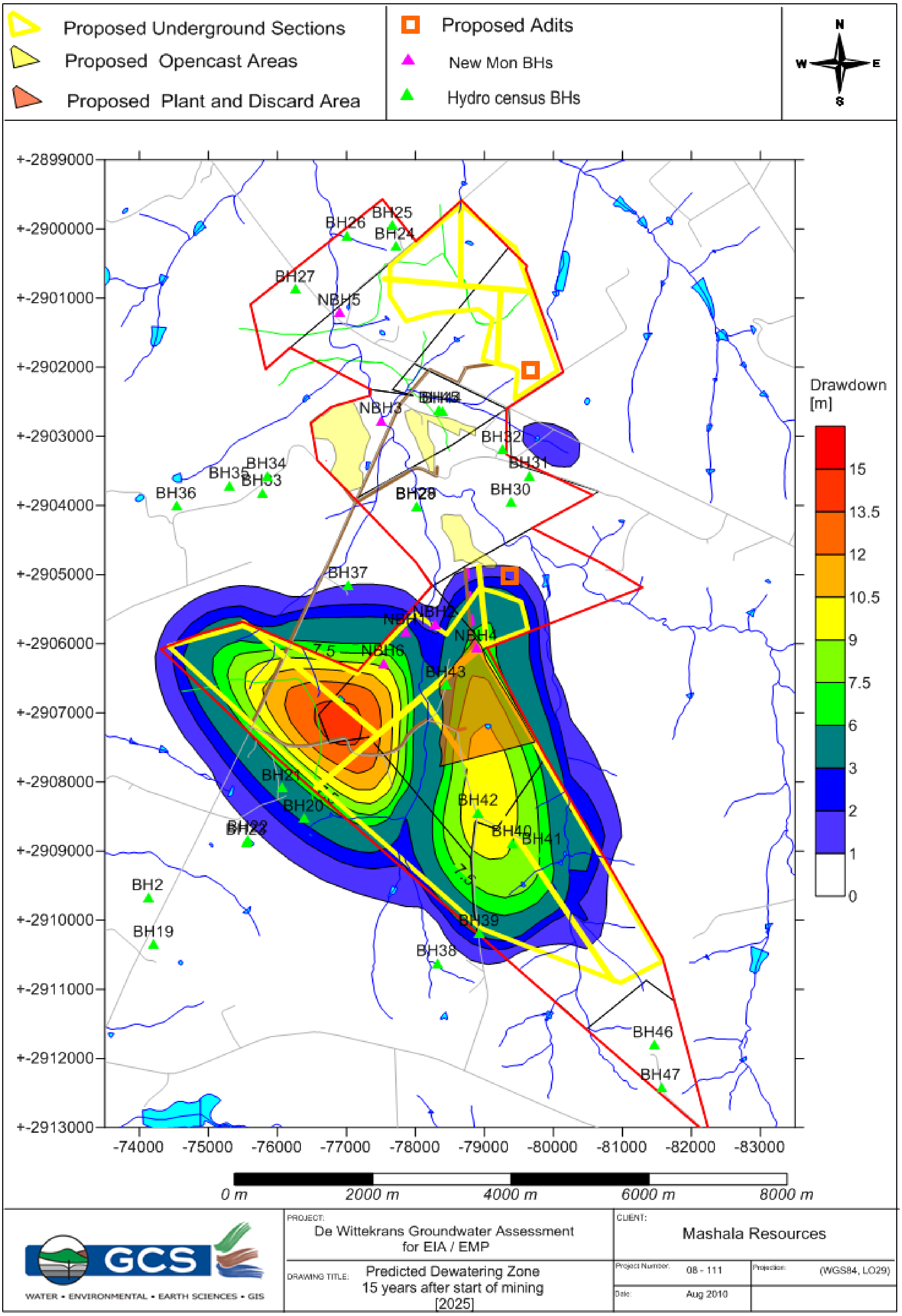


Figure 3-4: Zone of de-watering after 15 years

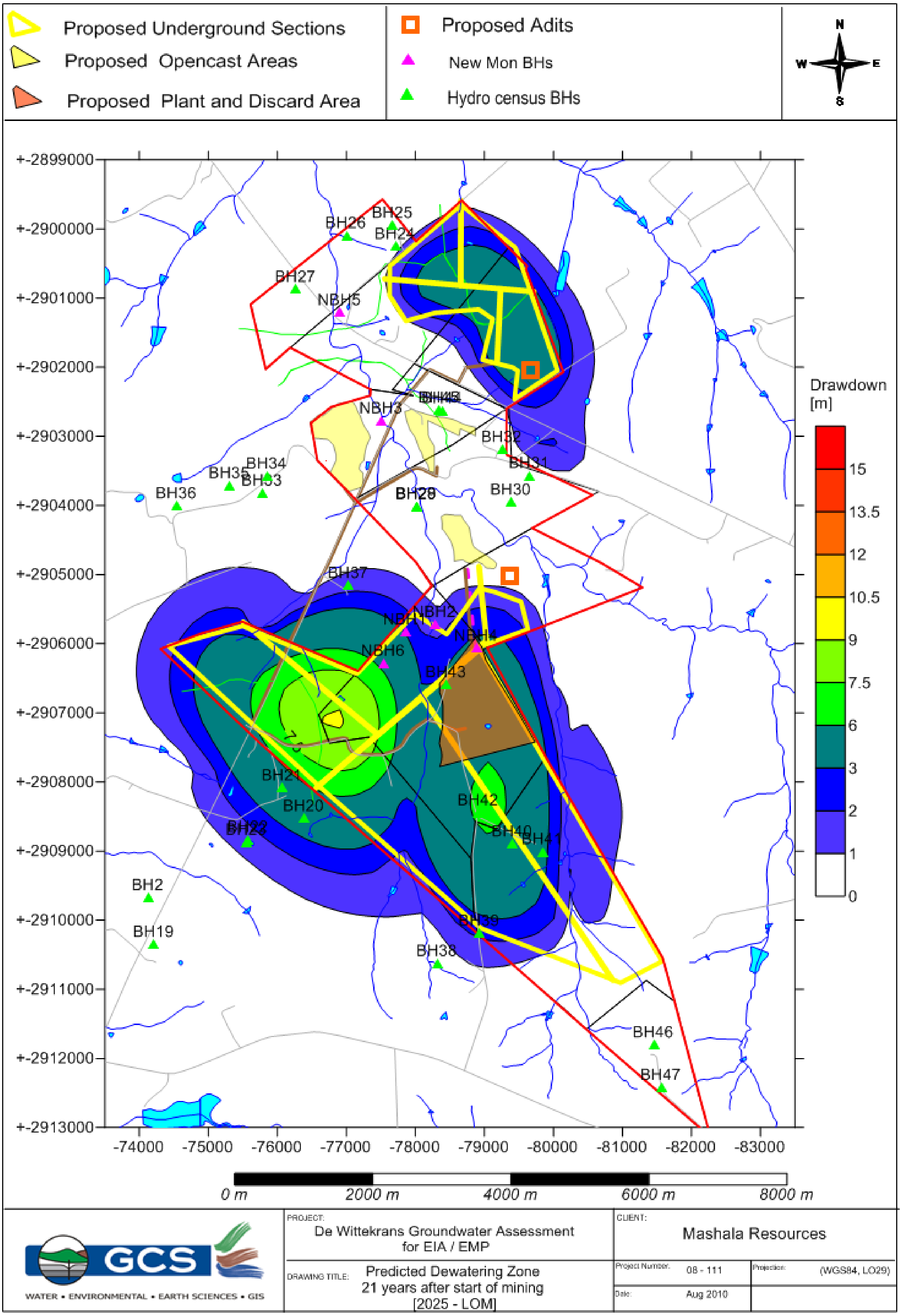


Figure 3-5: *Zone of de-watering after 21 years and life of mine*

3.3.2 Impact on groundwater boreholes, streams and fountains in the proposed zone of influence of the mine

During the hydro-census 45 sites were visited (refer to **Appendix A** of this document and the 2009 Groundwater Assessment for more information) with identification numbers BH1 to BH45. About 18 of these sites are at the Knapdaar Area which is situated more to the south west and the rest in and around the De Wittekrans project area. Most of these sites represents active boreholes equipped with wind pumps or small submersible pumps and used for domestic and stock watering. No big scale irrigation or water supply schemes were identified.

During the feedback meetings Mr. Van Vuren suggest that the two boreholes on his farm must also be included, those are situated in the south with borehole identification numbers BH46 and BH47 (refer to Figure 3-3).

The following supplies more detail on specific borehole impacts in terms of possible groundwater level decrease during mining.

Northern Mine Section:

Figure 3-6 showing a map of the northern farm boreholes; it can be seen that 12 sites were visited during the 2009 hydro-census which represent 11 boreholes and 1 spring. Figure 3-7 shows a time series plot of predicted drawdown in the boreholes; it can be seen that the drawdown in the boreholes range between 2.5 and 0.5 m from the static regional groundwater level. The degree of drawdown depends on the distance away from the proposed mining activities. The regional drawdown cone will be recovered 50% approximately 5 years after mining has stopped and 100% approximately 20 years after mining has stopped.

Only one spring was identified located on Mr. De Lange's farm, this will be impacted on since it is located directly next to the proposed opencast Block 2 (refer to Figure 3-6).

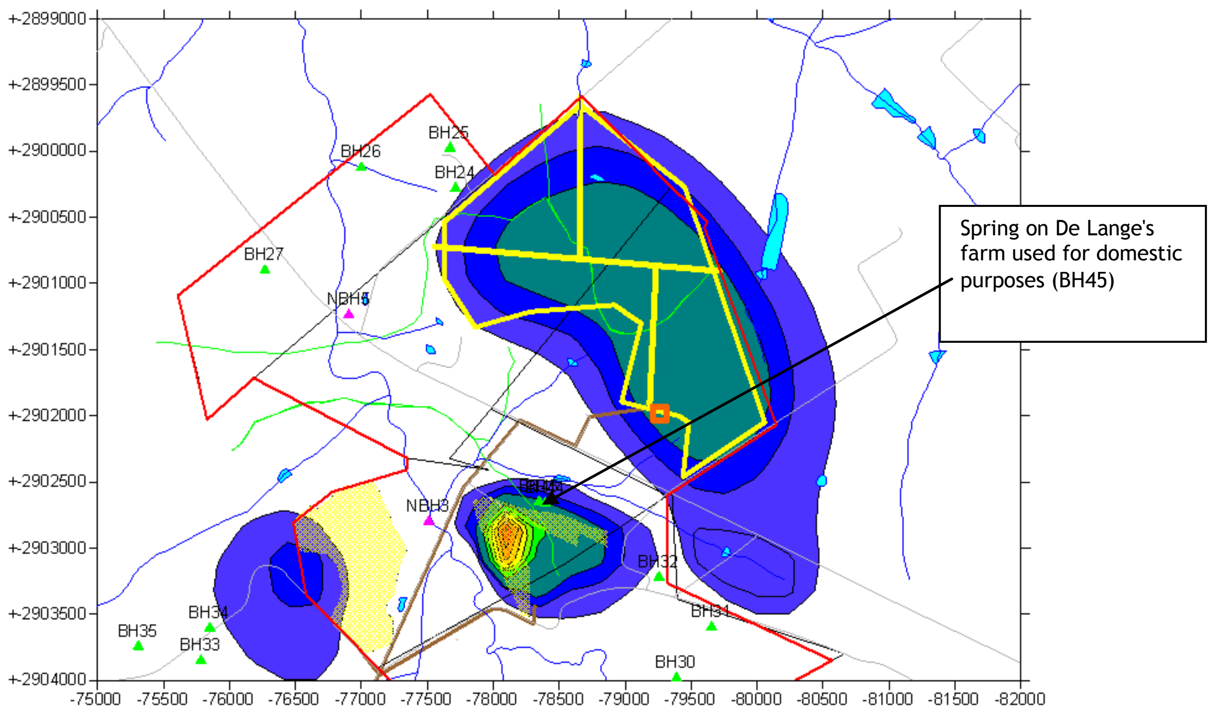


Figure 3-6: Map showing farm boreholes within the De Wittekrans North Area and zone of de-watering

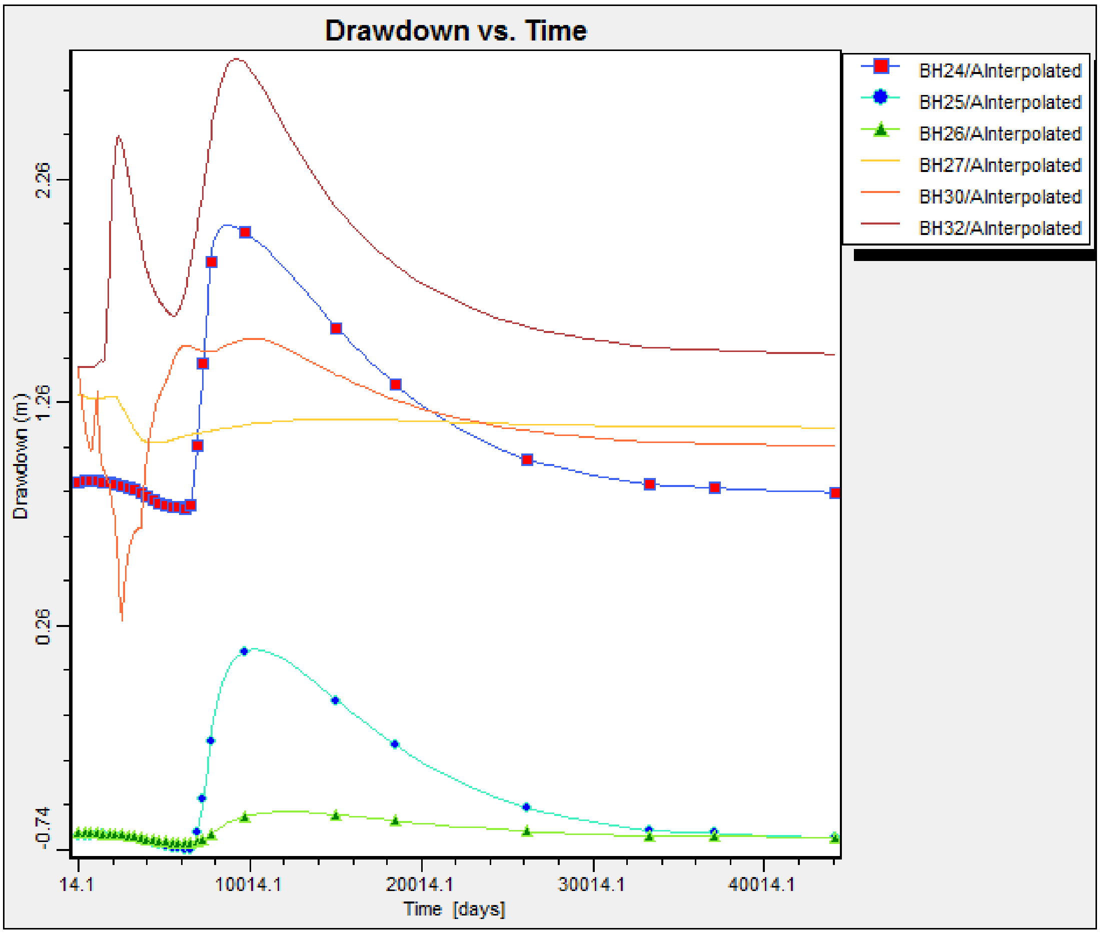


Figure 3-7: Borehole drawdown prediction for the De Wittekrans North Area

Southern Mine Section:

Figure 3-8 showing a map of the southern farm boreholes; it can be seen that 13 sites were visited during the 2009 hydro-census which represent 13 boreholes and no springs. Figure 3-9 shows a time series plot of predicted drawdown in the boreholes; it can be seen that the drawdown in the boreholes range between 6 and 0.5 m from the static regional groundwater level. The degree of drawdown depends on the distance away from the proposed mining activities. The regional drawdown cone will be recovered 50% approximately 5 years after mining has stopped and 100% approximately 20 years after mining has stopped.

Model simulations indicate that the two boreholes of Mr. Van Vuren in the south will experience no or limited drawdown; the boreholes will not "dry up" during the operational life of the mine.

Borehole BH43 on the farm Isreal of Mr. CJ de Vos, will be situated within the demarcated plant and discard area.

Boreholes BH41 and BH42 of Mr. De Vos could experience drawdown of almost 7.5 m; the mine must compensate by drilling an additional borehole for Mr. De Vos further to the west if required.

Boreholes BH20 to BH23 belongs to Mr. Gilbert (082 651 2845) on farm Trendal 002; these boreholes seems to also get impacted on; again the mine must compensate by drilling an additional borehole for Mr. Gilbert further to the west if required.

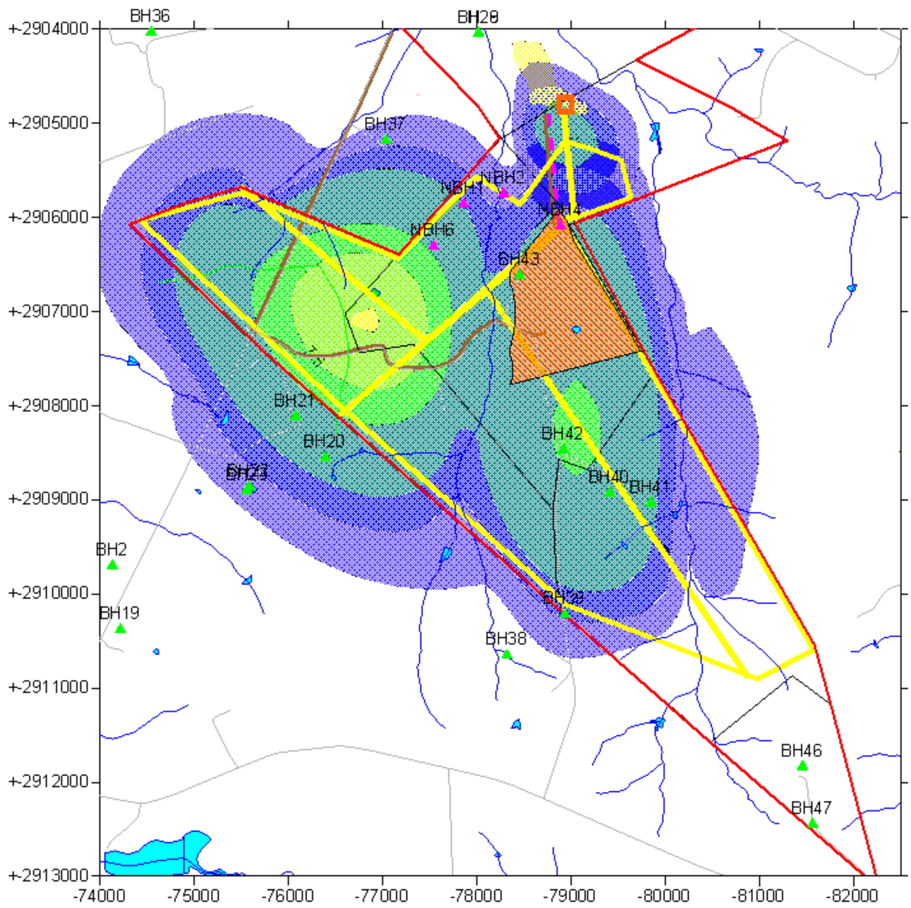


Figure 3-8: Map showing farm boreholes within the De Wittekrans South Area

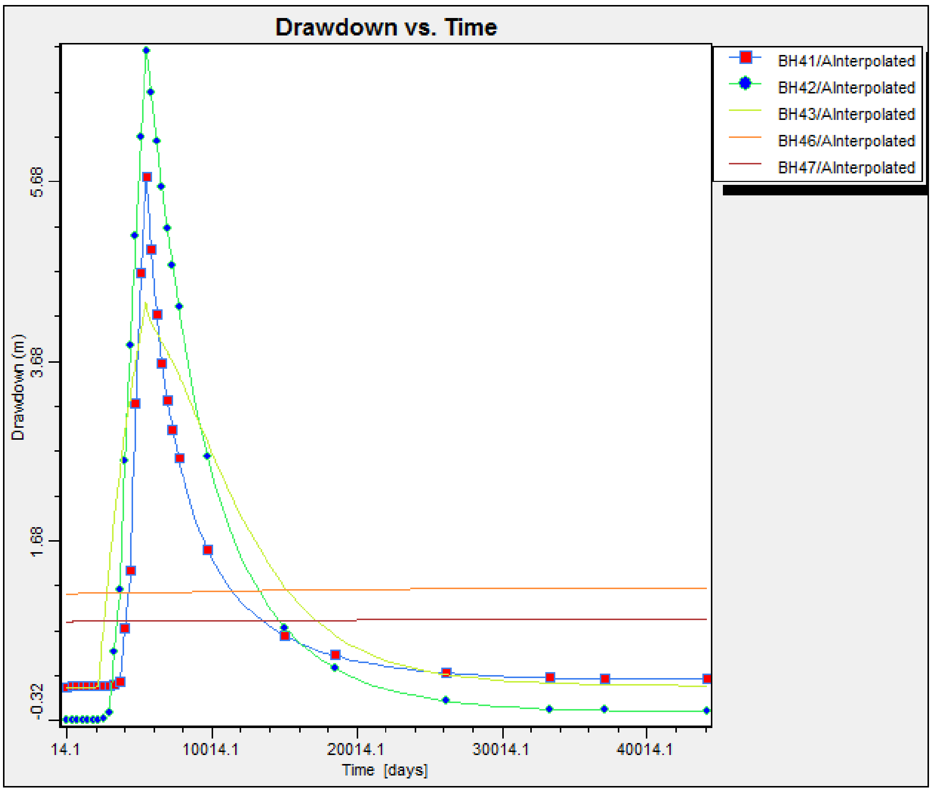


Figure 3-9: Borehole drawdown prediction for the De Wittekrans South Area

Base-flow in the shallow perched aquifer usually occurs above impermeable dolerite sills, ferricrete, clay and sandstone layers. Where the **streams** cut through or onto these formations, water tends to seep from the rock contact zones into the streams. Although rainfall and run-off dominate regional stream flow, seepage from groundwater also contributes. It can be seen from Figure 3-3 to Figure 3-5 that the maximum drawdown area does not intersects the Klein Olifants River within the northern section and only some of the non-perennial streams in the south.

De-watering of the **opencast sections** will impact on the base flow towards the Klein Olifants River for the 1st 3 to 5 years of the mining project only. As mentioned earlier opencast mining will be much smaller as per the new proposed mine plans; it can be seen from Table 3-3 that a total of 120 ha will be opencast mined with the biggest block at 63 ha. These will be mined according to the role-over method and concurrent rehabilitation will be applied; opencast blocks will therefore not remain open for more than 2 years at a time which limit de-watering significantly. The opencast areas will be recharged fairly rapidly initially (during and directly after closure, refer to Table 3-3) due to the nature of the backfilled material. This will increase the recovery rate of the regional groundwater levels significantly and will reduce the impact of mining on the Klein Olifants River accordingly.

Table 3-3: Proposed opencast blocks for the De Wittekrans Coal Mine and probable recharge within the 1st year after rehabilitation

Mining Block	Approx Depth (m)	Area (m2)	% Recharge	Rainfall (m)	Annual Inflow (m3)	Daily (m3)	l/sec
OC 1	30 - 40	631239	10.0%	0.71	44 817.97	122.79	1.4
OC 2	30 - 50	280268	10.0%	0.71	19 899.03	54.52	0.6
OC 3	40	268940	10.0%	0.71	19 094.74	52.31	0.6
Total Area (Ha)		**118.0447**					

Only two (2) underground **mine portals** will be developed; one for the North, and one for the South Section. These will impact on the top weathered aquifer for a longer period but groundwater inflows into the Adits will be sealed off and managed accordingly. The zone budget function was applied and zones were allocated to the Klein-Olifants system to obtain an indication of the impact on the system due to de-watering activities. The zones were applied to the entire 1st model layer and include the aquifer as well as the stream basins and can be viewed from Figure 3-11. The graphs for each zone are presented in **Appendix B** and a summary of the baseflow and aquifer flow can be seen from Figure 3-10 per zone. The reduction in aquifer flow and **the recovery** thereof afterwards can also be seen from the graphs in **Appendix B**.

This assessment on aquifer flow only supplies an indication of possible aquifer and base flow reduction and it suggest a maximum decrease of almost 25% for a maximum period of 5 years from where it will decrease again (refer to Figure 3-10 and Table 3-4).

Table 3-4: Aquifer and Base-flow assessment figures for the Klein Olifants system

	Aquifer Flow in m3/day		
Zone	Pre Mine	Operational	Difference
Zone 21	48	34	14
Zone 22	189	97	92
Zone 23	62	49	13
Zone 24	66	55	11
Total	**365**	**235**	**130**

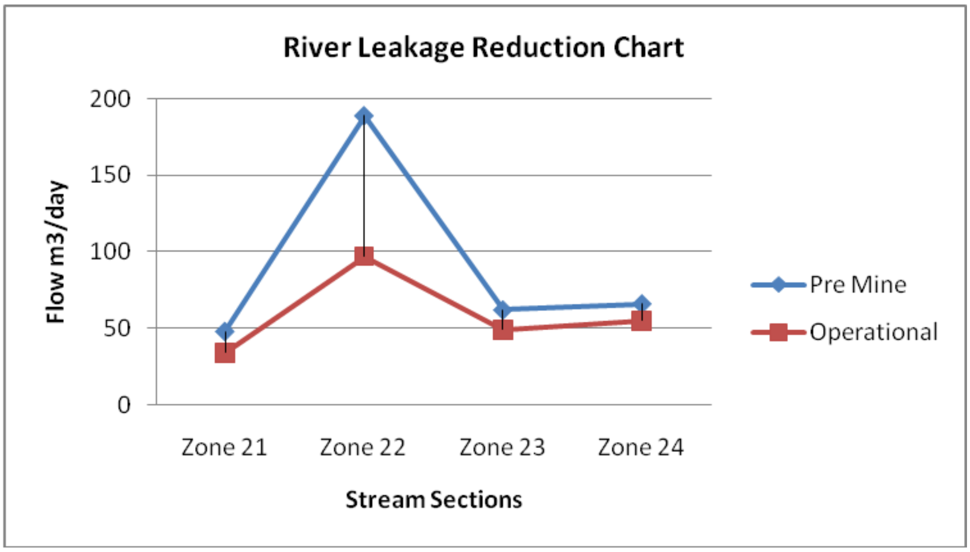


Figure 3-10: Indication of base flow and weathered aquifer flow reduction before and during mining

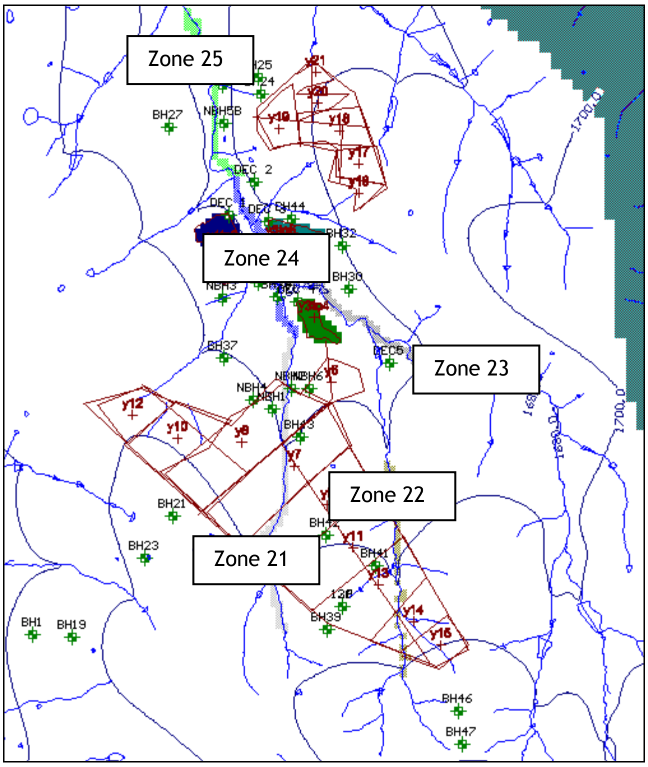


Figure 3-11: Zones Applied for aquifer flow assessment

- Loss of groundwater due to abstraction

Potential total loss in groundwater due to water abstraction amounts to ±2.96 x 106 m^3 over the planned 21-year opencast and underground mining life. This volume is far less than the groundwater catchment recharge, 4.6 x 107 m^3, over the same period; the local mini-sub catchment was considered (refer to Figure 3-12) and an average annual recharge of 2%.

The impact will therefore be small and temporary of nature. Steady state recovery is within 20 years for the directly affected areas.

Comments from the I&APs indicates farm groundwater usage around 20 to 30 m^3/day; the mine will de-water and use between 100 and 500 m^3/day; daily recharge (on average) will be around 6000 m^3/day for the mini-sub catchment area if 2% recharge is considered.

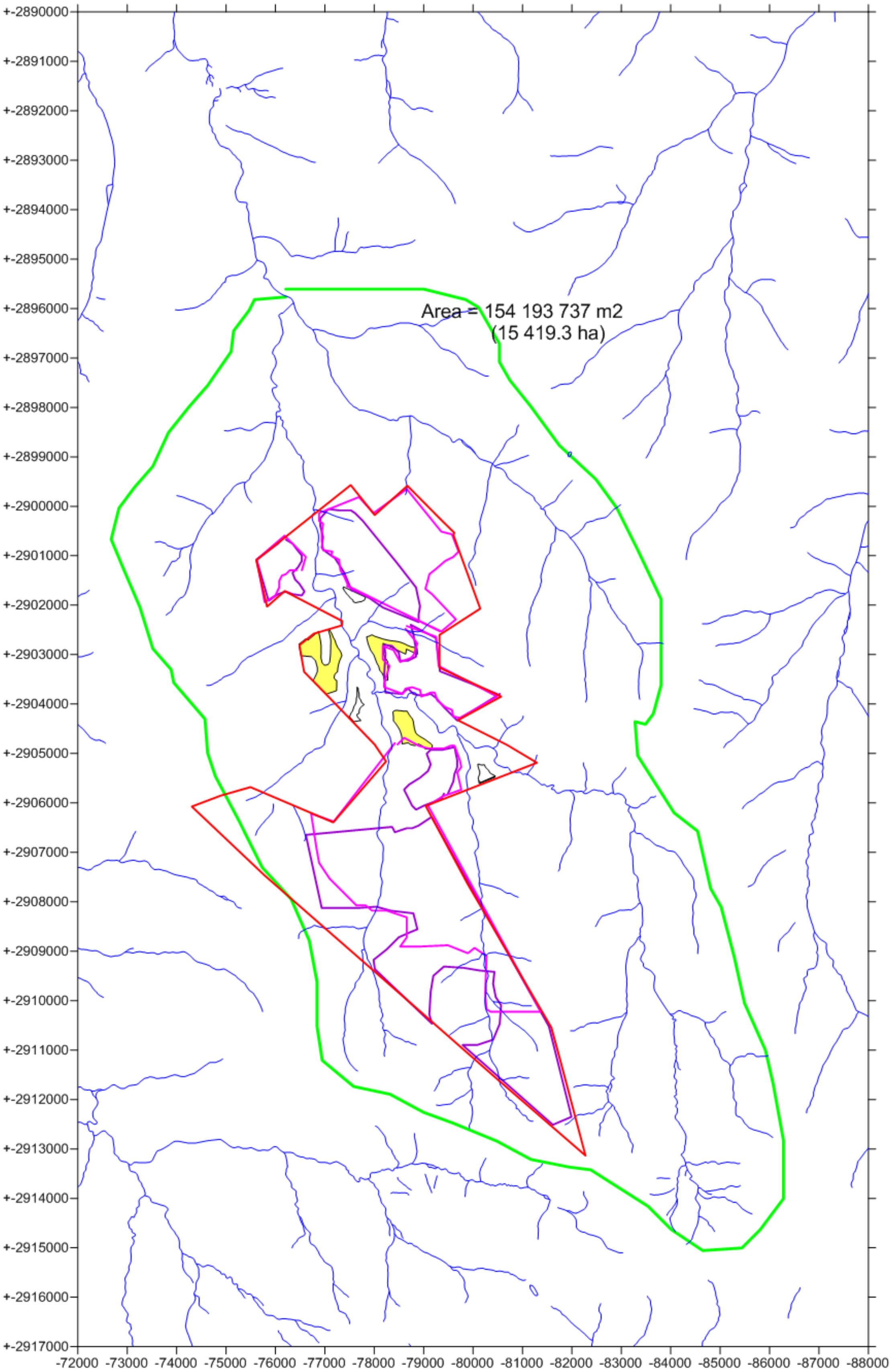


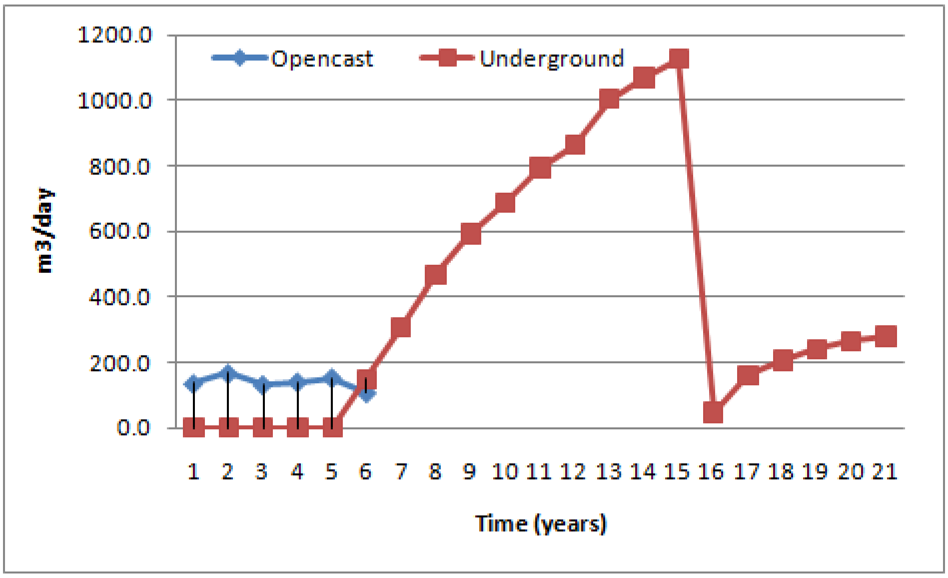
Figure 3-12: Local mini-sub-catchment area for the De Wittekrans project area

3.4 Predicted Inflow Rates

Predicted inflow rates were obtained from the modelling simulations. The conceptual mining area was sub-divided into sub-sections. The 20 sub-sections represent mine development over time; e.g. section 1 is developed and mined during the first year, section 2 over the next year, section 3 over the next 1 year, etc. Different zones were allocated to each section within the groundwater model. Zone budgets for the drain nodes are then exported and the inflow rates can be captured accordingly.

Figure 3-13 shows the combined predicted inflow rates; the flow model simulation indicates an average opencast inflow rate of about 150 m^3/day over the 6 year period.

As mining continues underground from years 6 to 21 and a bigger area is developed with increasing depth below the regional groundwater level, the inflow rate will increase as mining progresses and groundwater is released from storage. The inflow rate will decrease when the bigger South Mine is mined -out after approximately 16 years, the prediction indicates mine water generation to be in the order of 1100 m^3/day. Mining will then communes in the Northern Block and due to a much smaller mine inflows will decrease to around 300 m^3/day.



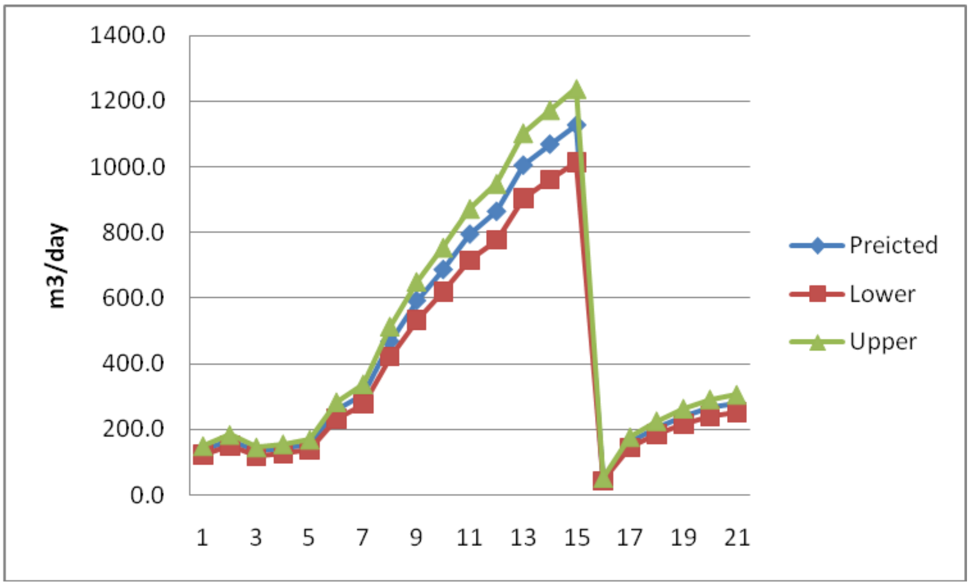


Figure 3-13: Predicted Inflow rates for the proposed De Wittekrans mining sections with 10% range

Note: This inflow prediction assessment must only be seen as a probable indication of mine water inflows; it is suggested that the groundwater model be calibrated 2 years after mining has started and when a better feel for field conditions are obtained.

3.5 Groundwater level recovery:

Groundwater levels will recover during the decommissioning and post closure phase, due to mine dewatering being stopped.

The simulated rebound and change in groundwater level in the area is shown in Figure 3-7 and Figure 3-9 above. The figures show that the groundwater levels will initially recover at a faster rate, due to higher flow gradients. Over time, as the groundwater level rises and the flow gradient decreases, the recovery rate will decrease. The groundwater levels in close proximity to the underground workings will stabilise after approximately 20 years (also refer to Figure 3-14 below). It must be noted that the underground voids will keep on de-water the surrounding aquifer as it is recharged with groundwater and gradually fill up to reach a level of approximately 1670 to 1680 mamasl. However, if the mine is backfilled with slurry material this process can be changed significantly (it is suggested that this aspects needs to be clarified and confirmed).

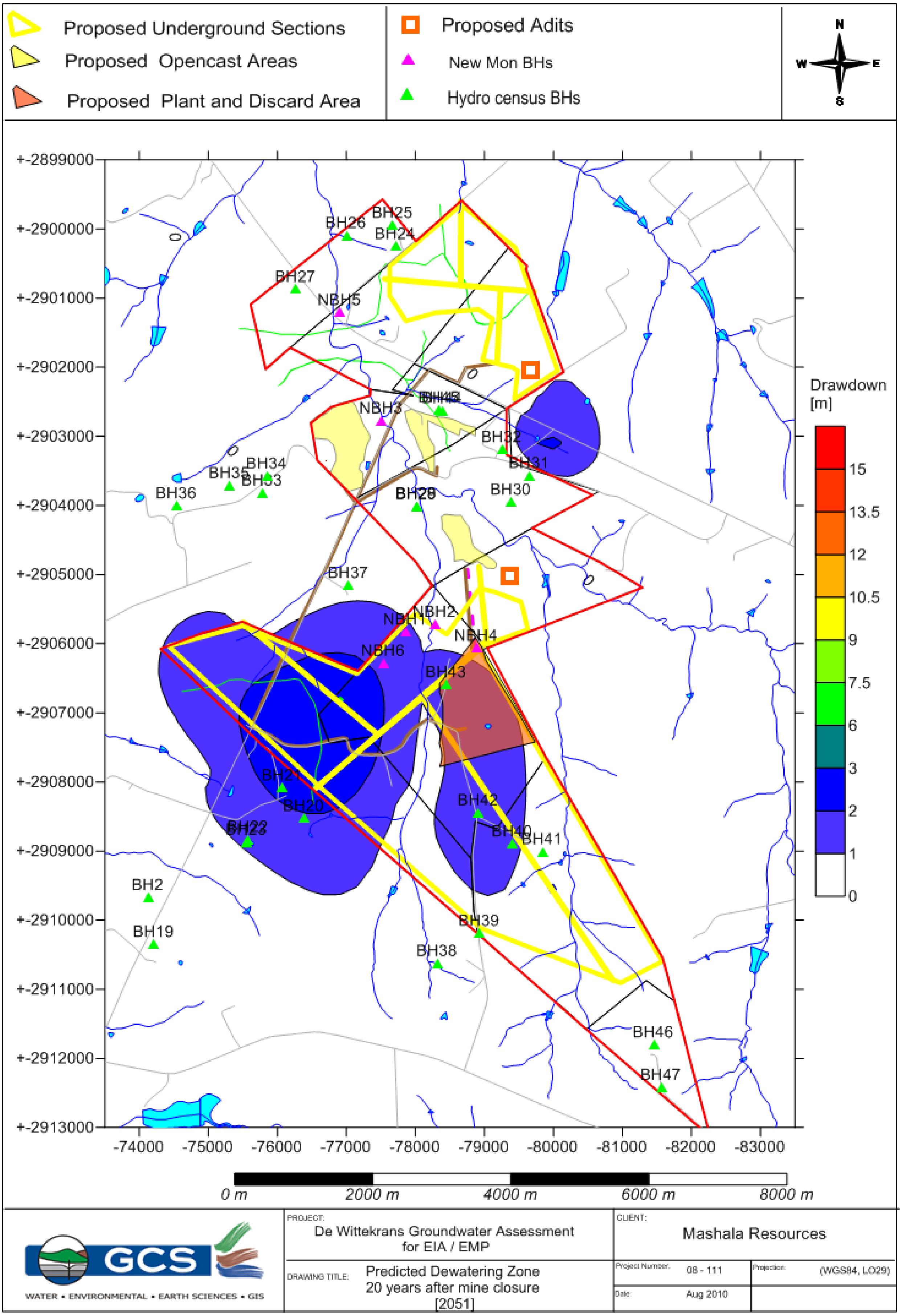


Figure 3-14: Zone of dewatering 20 years after closure

3.5.1 Concluding Remarks

The low vertical permeability of the Karoo strata will limit the dewatering of the weathered and fractured aquifers overlying the C and B Coal Seams, except in the vicinity of the box cut. Increased dewatering may also be required in the vicinity of the dyke intersections, due to the higher vertical permeability of the dyke-Karoo contact. The observations at other mines in the area indicates that deep underground de-watering have limited dewatering impact of the overlying strata. However, surface boreholes intersect the underground workings will result in recharge back into the mine workings from the above aquifer systems.

4 *Possible Decant/Diffuse Seepage*

When the mining activities stop, the groundwater levels will start to recover to the same level, or almost to the natural pre-mining groundwater level[1] and the natural groundwater gradients and flow patterns will be restored.

The following discussion supplies more information in terms of possible decant behaviour for the underground and opencast mine section at the proposed De Wittekrans Mine. Again, it is important to note that the opencast mine plan changed significantly and the assessment conducted in 2009 will be updated accordingly:

Underground:

The vertical hydraulic conductivity of the over- and underlying sediments is usually too low to convey water of any significance into the mines. The odd vertical fracture that may be present sometimes yields water for a limited period.

Water in mined-out areas will flow along the coal floor and accumulate in low-lying areas. This is a simplistic view of the situation. In reality, water would accumulate in many isolated areas, where it would dam against barriers of coal or dolerite dykes left in place.

After complete filling of the underground workings, which seems to be in the order of 20 to 25 years after closure, the upper and shallow groundwater levels will rebound towards its original level.

In principle, the possibility of decant is dependent on the dip of the coal floor, the topography, the presence of any geological feature that acts as a conduit /barrier and the rate of recharge to the mining area. It is therefore critical that recharge be managed as far as possible.

Furthermore, the existence of exploration boreholes, ventilation shafts and other man-made connections to underground workings can also add to the probability of post-closure decant.

The following summarises the main findings:

- Figure 1-3 indicates the C Lower floor elevations and projected water flow directions within the underground mine voids. It can be seen that the coal floor dips away from the proposed mine adits. This will prevent water flowing out of the adit systems and make direct **decant highly unlikely**.
- Naturally base-flow contributes to most of the stream and river flow in the area. This flow is not connected to the deeper flow where mining occurs. However, through the connection of the Adit system, which connects deeper flow with shallow flow, poor quality water can filter through the weathered zone and add saline underground workings water to the existing shallow

[1] Post mining groundwater levels can differ from pre-mining levels if aquifer permeability is changed significantly. Usually opencast pits are backfilled with broken overburden rock and spoil material, which results in much higher permeability and recharge rates (at least initially until a certain degree of compaction is reached). Normal recharge is around 3-5% and can increase to 12% for old backfilled opencast pit.

base-flow component. It is recommended that the Adits be sealed off along the weathered zone after closure to overcome mixing;

Recommendations:

- Furthermore, it is generally recommended that no mining occur <20-30 mbgl along topographical low areas; available borehole logs suggest a shallow weathering aquifer and a deeper fractured rock aquifer – the aim is not to connect the two aquifers with mining but rather stay in the deeper fractured zones. This will also prevent higher aquifer recharge that will result in more elevated groundwater levels and seepage; and
- Refer to Figure 4-2 which indicates areas where shallow seepage can occur, areas where increased recharge can occur and flow direction in the underground workings – it is evident that none of the underground working falls within the <30m zones which can be regarded as the higher recharge zones.
- It is also suggested that no stooping or any other pillar mining along dyke/sill contact zones and / or along areas where mining is shallower than 30 to 40 m. Again, it is important to ensure that natural recharge remains and that no additional recharge occurs.
- The risk of subsidence also becomes greater where underground mining occurs along shallow zones. Subsidence will subsequently results in additional recharge. Sound geotechnical and/or rock mechanic principles must be applied during mining to prevent subsidence, especially in areas where the underground workings are shallower than 30m.

Opencast:

Figure 4-1 shows the areas where decant is most likely to occur; these must be regarded as an indication only at this stage. **It is recommended that the numerical groundwater model be updated within the 2nd year of mining operations, once sufficient groundwater monitoring information is available. The following aspects need to be updated:**

- More accurate elevation/topographical data for the mining area and mine blocks,
- All observation boreholes need to be surveyed for accurate collar and water level elevation, this must be done before any mining started,
- At least three sets of water level data from the monitoring boreholes, and
- A final mine progression plan.
- A final rehabilitation plan.

Table 4-1 shows the predicted decant elevations. Again, these are preliminary and need to be confirmed at a later stage. The decant quantities will be very small IF occur and will be less than approximately 10% of the annual rainfall over the rehabilitated opencast mining areas (60 to 25 m3/day on average – more in summer and less in winter). ***This aspect can only be confirmed when more information is obtained; it is very important to note that decant can totally be overcome by the implementation of sound mining and rehabilitation practices***. The following summarises the main aspects that needs to be implemented:

- Rehabilitation of open pits must be as soon as possible after mining,
- Prevent inflow form surface run-off and minimise rainfall recharge into the back-filled areas by sloping and compaction of the areas.
- Prevent breaking topographical lines lower than the proposed decant elevations.

Table 4-1: Decant elevations for the different pits

Pit	Decant Elevation (mamsl)
Pit 1	1660.25
Pit 2	1660
Pit 5	1674.5

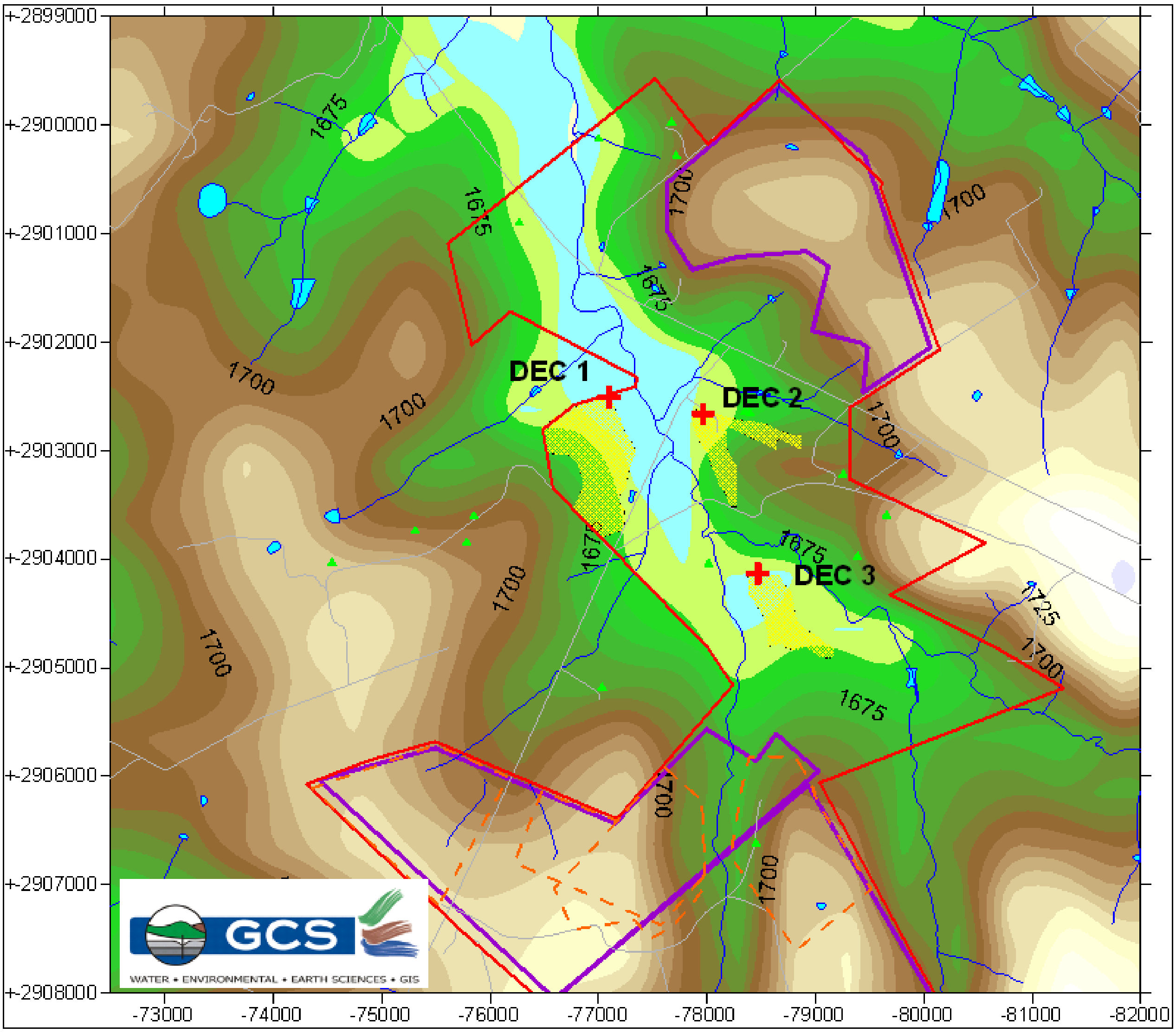


Figure 4-1: Predicted decant/seepage areas for the De Wittekrans open cast mining area

5 *Water Quality aspects*

5.1 Contaminant Transport Modelling

Following the calibration of the flow model, a contaminant transport model was constructed for the mining area. In order to determine the long-term effect of the mining on groundwater quality, the post-operational migration of contamination was simulated. Sulphate ($S0_4$) was chosen as the parameter to be modelled, as sulphate is one of the typical end-products of acid mine drainage from the coal mining environment (which the ABA testing shows as a probable possibility). It typically comprises about 50% of the Total Dissolved Solids (TDS) in groundwater contaminated by coal mining. To determine the specific input parameters for mass transport modelling a series of parameters must be considered:

- Laboratory testing conducted to determine the possible composition of leachate from the material under recharge conditions.
- Recharge rate and filling up of underground workings.
- Leach ability of overburden spoils backfilled in the open cast pits and also rebound rate of groundwater levels.
- Overall geochemical behaviour over time that can only be predicted with long-term humidity/kinetic leach tests and geochemical modelling. These laboratory tests must be run over a period of 3 to 6 months.

For the application of this preliminary mass transport prediction exercise only static leach test were conducted to supply a 1st order idea of leachate quality of the coal seam pillars and overburden material (refer to Section 2). The test results indicate SO4 ranging between 500 and 1200 mg/kg during normal water extraction and a maximum 45 000 mg/kg and minimum of 7 500 mg/kg during full oxidation.

For this preliminary mass transport model the following sulphate concentrations were applied as recharge concentrations for the backfilled open cast pits and discard area and constant concentration for the underground workings:

- Recharge Concentrations = 1500 to 2000 mg/l SO4
- Constant Concentrations = 1000 to 1800 mg/l SO4

The following map figures represents predicted contamination transport for the De Wittekrans Mine Area:

- Figure 5-1: Predicted sulphate plume for the discard and plant area at the life of mine and closure phase. Lower aquifer also included.
- Figure 5-2: 50 years after closure,
- Figure 5-3: 100 years after closure.

Figure 5-4 predicted breakthrough curve for the opencast and discard/plant observation boreholes.

It is evident from the mass transport predictions that limited impact will occur on the Klein Olifants River System. A proper surface water monitoring system will be implemented up and down stream of the mining activities.

River flow data needs to be obtained to determine possible in-stream qualities over time, this aspect will receive more attention during routine monitoring phases.

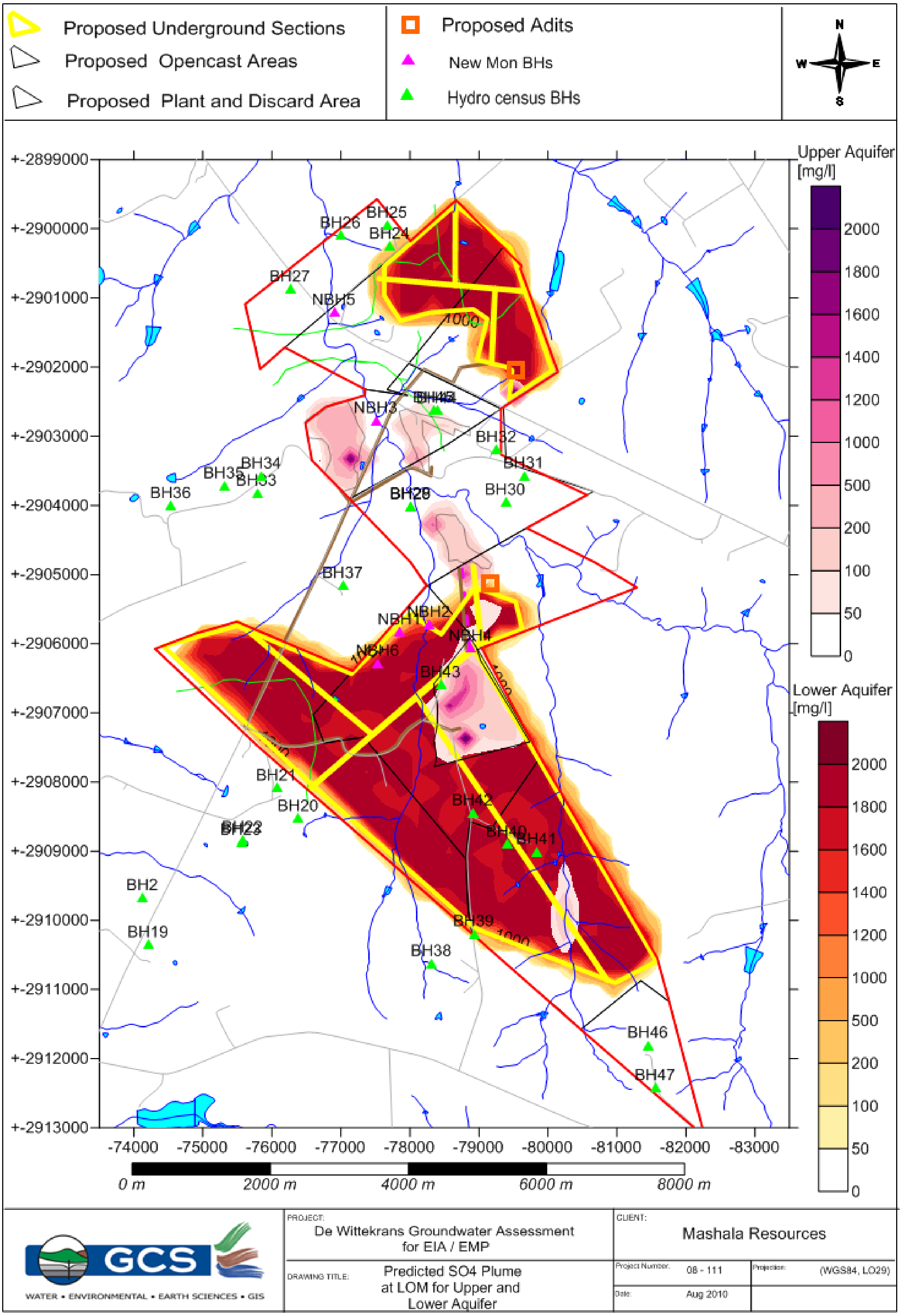


Figure 5-1: Predicted sulphate plume for the upper weathered and lower aquifer during LOM

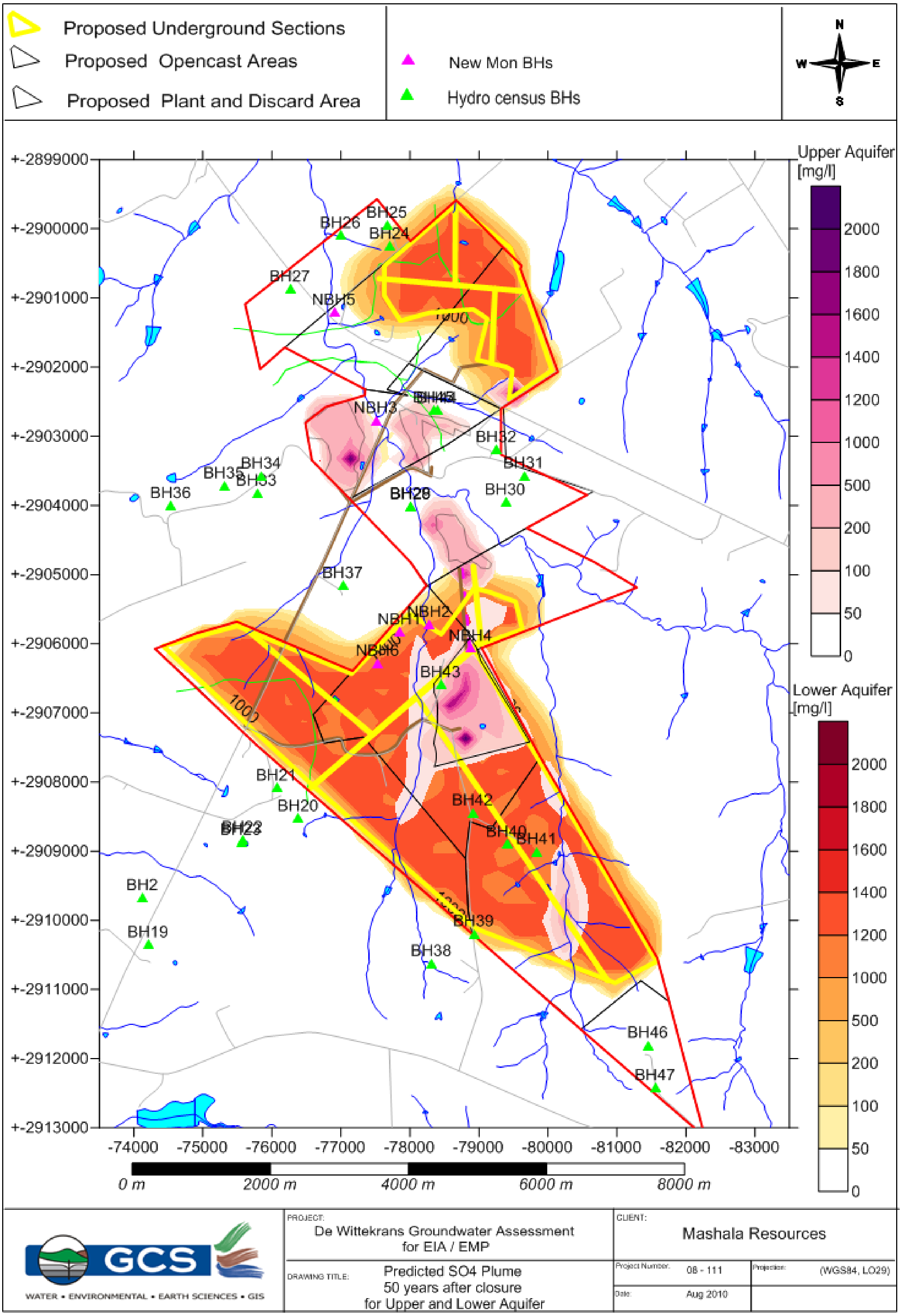


Figure 5-2: Predicted sulphate plume for the upper weathered and lower aquifer 50 years after closure

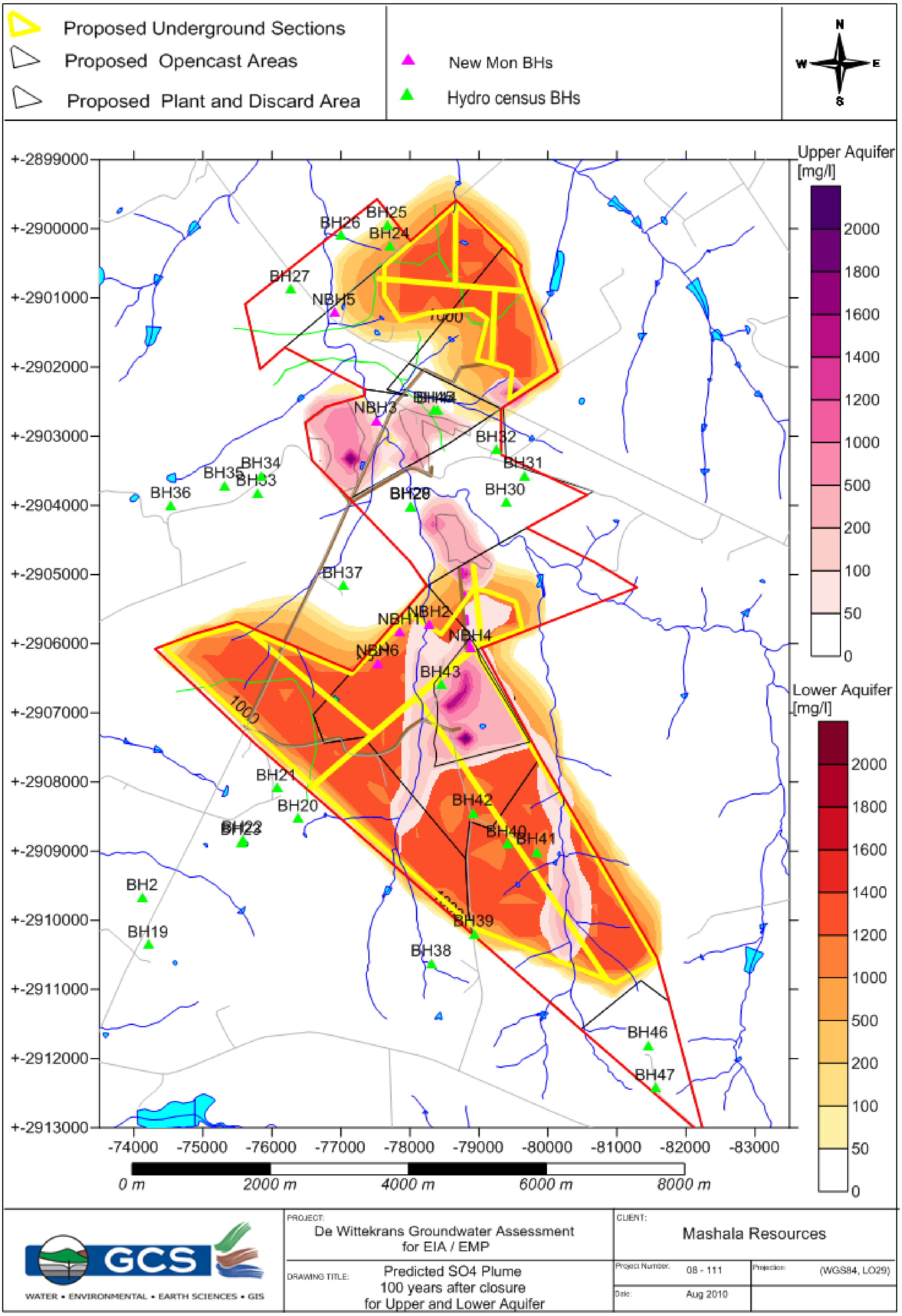


Figure 5-3: Predicted sulphate plume for the upper weathered and lower aquifer 100 years after closure

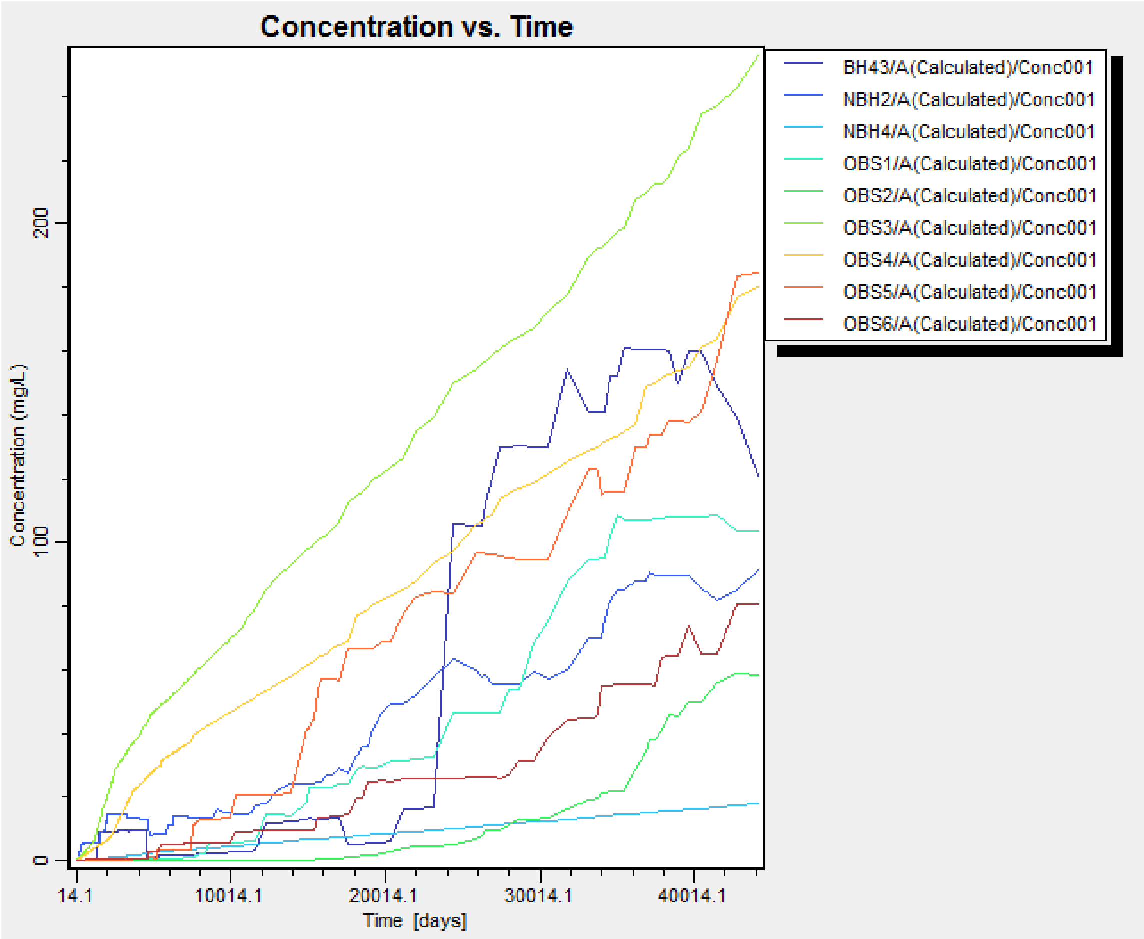


Figure 5-4: Predicted sulphate trend graph for the plant and open cast areas - upper aquifer

6 *Hydrogeological Impact Assessment*

The impact assessment is performed based on guidelines provided by the GCS Environmental Unit. The impact assessment will focus on groundwater **quantity and quality issues** over the life-cycle of the proposed mining activities which will be construction, operational, closure and post closure. It is important to understand the previous sections which dealt with gathering of basic information and impact prediction while study the next section on impact assessment. A comprehensive groundwater management plan is also provide in the following section (Section 7) and serve as supplement documentation; it must also be studied in conjunction with this section.

6.1 Open Cast Mining

6.1.1 Construction phase

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION						RECOMMENDED MITIGATION MEASURES/ REMARKS	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION					
		M	D	S	P	TOTAL	SP		M	D	S	P	TOTAL	SP
Construction Phase - Opencast Mining														
Groundwater Quantity: Limited open cast mining will occur during the construction phase during development of the opencast areas - topsoil stockpiling, etc	Mining	2	1	1	1	4	L	N/A	2	1	1	1	4	L
Groundwater Quality: N/A	Mining	2	1	1	1	4	L	N/A	2	1	1	1	4	L

6.1.2 Operational Phase

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION						RECOMMENDED MITIGATION MEASURES/ REMARKS	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION					
		M	D	S	P	TOTAL	SP		M	D	S	P	TOTAL	SP
Operational Phase - Opencast Mining														
Groundwater Quantity: Opencast blocks will be small and mining will therefore take shorter times to be completed. Impact will occur on the local weathered aquifer and stream flow reduction will occur. Refer to Section 3.1 for the detailed assessment.	Mining	6	4	2	4	48	M	The opencast sections can be kept small and rehabilitation is undertaken concurrent with mining through the roll-over method of mining . Under these circumstances no opencast section to be de-watered for more than 18 months or the time period of de-watering be kept as small as possible per opencast block.	4	3	2	3	27	L
Groundwater Quality: The ABA results indicate that the floor and roof material could leach contaminants - limited impacts will occur on the lower aquifer system during the operational phase. The impact on groundwater quality will further be limited during the operational phase due to the developed cone of depression around the open cast pits, contaminants will rather flow towards mining during this time.	Mining	6	4	2	3	36	M	The extent to which acid mine drainage will be generated from the pits will be controlled by careful handling of the spoils, and specifically any pyritic material, like the shale, during the operational phase; and by flooding the exposed coal seam at the bottom section of the pits as quickly as possible. The shale/sandstone that will be stripped above the coal seam will be backfilled to the lowest possible elevation during the roll-over method of mining. This will ensure that the potential poor quality material is flooded as quickly as possible after mining is completed and so reduce the risk of oxidation and acidification.	4	5	2	3	33	M

6.1.3 Post Closure

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION						RECOMMENDED MITIGATION MEASURES/ REMARKS	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION					
		M	D	S	P	TOTAL	SP		M	D	S	P	TOTAL	SP
After Closure Phase - Opencast Mining														
Groundwater Quantity: Refer to Section 3.1	Mining	6	3	2	3	33	M	It is not expected that any of the groundwater boreholes be used for domestic/farming activities within the direct vicinity of the opencast mine areas. The mine must compensate for any losses of groundwater during the recovery period if identified to be necessary. Effective pit rehabilitation will ensure that de-watering occur over short periods during the operational phase and recovery can occur in shorter time periods.	4	3	2	3	27	L
Groundwater Quality: Poor quality leachate will occur from the backfilled open cast pits, leachate will be enhanced by increased recharge into the pits. Recharge will decrease over time as the material get naturally compacted. The impact on the surrounding aquifer system will be medium Refer to Section 5. Decant of poor quality water into the stream/river system will be highly unlikely and flow in the underground workings will rather "push" back to the Forzando South Area.	Mining	6	5	2	4	52	M	Little can be done to mitigate oxidation of poor quality leachate forming minerals and the formation of poor quality leachate. The mined-out areas should be allowed to be submerged as soon as practically possible, this will displace oxygen and stop oxidation of the minerals. After initial flooding recharge will be minimised and improve natural run-off from the area to ensure that poor quality leachate can decrease over time.	6	5	2	3	39	M

6.2 Impact Assessment for the Mining Activities - Underground

6.2.1 Construction phase

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION						RECOMMENDED MITIGATION MEASURES/ REMARKS	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION					
		M	D	S	P	TOTAL	SP		M	D	S	P	TOTAL	SP
Construction Phase - Underground Mining														
Groundwater Quantity: No underground mining will occur during the construction phase while development of the mine portal will be in progress	Mining	2	1	1	1	4	L	N/A	2	1	1	1	4	L
Groundwater Quality: N/A	Mining	2	1	1	1	4	L	N/A	2	1	1	1	4	L

6.2.2 Operational Phase

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION						RECOMMENDED MITIGATION MEASURES/ REMARKS	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION					
		M	D	S	P	TOTAL	SP		M	D	S	P	TOTAL	SP
Operational Phase - Underground Mining														
Groundwater Quantity: Refer to Section 3.1. The extent of dewatering of the upper aquifer system is expected to be minimal and will be confined to the proposed De Wittekrans mining area and to a higher degree in the vicinity of the proposed mine adits, where the depth to the seam is less than 30m below surface.	Mining	6	4	2	4	48	M	It is evident that some farm boreholes will be impacted on during the operational phase. No management measures can be implemented since de-watering is necessary to mine BUT the farm boreholes can be monitored on a yearly basis and IF problems occur the mine must compensate the farmers for additional water sources. The impact on regional stream flow will be minimal and will return to pre-mining conditions approximately 20 years after closure.	6	4	2	4	48	M
Groundwater Quality: The ABA results (Refer to Section 2) indicate that the floor and roof material could leach contaminants - limited impacts will occur on the lower aquifer system during the operational phase. The impact on groundwater quality will further be limited during the operational phase due to the developed cone of depression around the Adit system, contaminants will rather flow back to the Adit's direction during this time.	Mining	6	4	2	3	36	M	Limited management measures can be applied to the underground workings and possible leachate of sulphate and AMD development during the operational phase. As mentioned earlier, migration of contaminant will be controlled by the cone of depression.	2	4	2	3	24	L

6.2.3 Post Closure

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION						RECOMMENDED MITIGATION MEASURES/ REMARKS	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION					
		M	D	S	P	TOTAL	SP		M	D	S	P	TOTAL	SP
After Closure Phase - Underground Mining														
Groundwater Quantity: The groundwater levels in the mining area will start to recover when the mine dewatering stops. This will lead to the re-establishment of groundwater levels, flow directions and flow gradients to near pre-mining levels. This will re-establish the base flow rates within the zone of influence. However, on the negative side it will enable contamination to migrate away from the mining area, and could possibly lead to decant/seepage. The recovery of water levels will, however, take a long time - 20 to 25 years.	Mining	6	4	2	4	48	M	It is evident that some farm boreholes will be impacted on during the operational phase and this will continue for at least another 10 years until groundwater levels recovered to pre-mining conditions. The impact on regional stream flow will be minimal and will return to pre-mining conditions approximately 20 years after closure.	6	4	2	3	36	M
Groundwater Quality: The underground mining activities occur on fairly deep elevations, especially towards the south west and seepage from the underground workings will be limited by low permeability of the sandstone layers. The impact on the surrounding aquifer system will be small. Decant of poor quality water into the stream/river system will be highly unlikely.	Mining	6	5	2	4	52	M	Little can be done to mitigate oxidation of poor quality leachate forming minerals and the formation of poor quality leachate. The mined-out areas should be allowed to be submerged as soon as practically possible, this will displace oxygen and stop oxidation of the minerals. This impact is difficult to effectively mitigate and is dependent on the natural rock characteristics. Ideally a sufficient barrier should be left along the outside ridge of the ore body to stop seepage along the coal / sediment contact to daylight. Please refer to the Section on "Decant" for management options in terms of recharge, open boreholes, seepage, etc.	6	5	2	3	39	M

6.3 Impact Assessment for Plant and Discard Operations

6.3.1 Construction phase

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION						RECOMMENDED MITIGATION MEASURES/ REMARKS	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION					
		M	D	S	P	TOTAL	SP		M	D	S	P	TOTAL	SP
Construction Phase - Plant and Discard														
Groundwater Quantity: No impacts are foreseen	Plant and Discard	2	1	1	1	4	L	N/A	2	1	1	1	4	L
Groundwater Quality: During the construction of the plant and discard dump no quality issues are foreseen. Construction will include proper	Plant and Discard	2	1	1	1	4	L	A groundwater quality monitoring network will be up and running at this stage and any groundwater quality issues addressed accordingly.	2	1	1	1	4	L

6.3.2 Operational Phase

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION						RECOMMENDED MITIGATION MEASURES/ REMARKS	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION					
		M	D	S	P	TOTAL	SP		M	D	S	P	TOTAL	SP
Operational Phase - Plant and Discard														
Groundwater Quantity:	Plant and Discard	2	1	1	1	4	L	N/A	2	1	1	1	4	L
Groundwater Quality: Poor quality seepage will occur from coal storage areas and discard dump due to rainfall infiltration and subsequent seepage into the underlying strata.	Plant and Discard	6	4	2	4	48	M	Coal discard will be compacted to reduce rainfall infiltration. Ponding of water will be reduced to limit infiltration. Lining of the pollution control and return water dams to prevent poor quality seepage from the water storage system.	6	4	1	3	33	M

6.3.3 Post Closure

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION						RECOMMENDED MITIGATION MEASURES/ REMARKS	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION					
		M	D	S	P	TOTAL	SP		M	D	S	P	TOTAL	SP
After Closure Phase - Plant and Discard														
Groundwater Quantity:	Plant and Discard	2	1	1	1	4	L	N/A	2	1	1	1	4	L
Groundwater Quality: All ROM stockpile areas will now be limited and closure will be implemented.	Plant and Discard	6	4	2	4	48	M	The discard facility will be rehabilitated to reduce rainfall infiltration. Plant area will be cleaned and rehabilitated. The return water dams will be rehabilitated only after clean runoff from the dump is established and no seepage occurring.	4	4	2	3	30	L

6.4 Office, Workshop, Diesel Storage and Power Supply

6.4.1 Construction Phase

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION						RECOMMENDED MITIGATION MEASURES/ REMARKS	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION					
		M	D	S	P	TOTAL	SP		M	D	S	P	TOTAL	SP
Construction Phase - Office, Workshop and Power Supply														
Groundwater Quantity: Limited impacts are foreseen	Surface Infrastructure	2	1	1	1	4	L	N/A	2	1	1	1	4	L
Groundwater Quality: Limited impacts are foreseen	Surface Infrastructure	2	1	1	1	4	L	N/A	2	1	1	1	4	L

6.4.2 Operational phases

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION						RECOMMENDED MITIGATION MEASURES/ REMARKS	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION					
		M	D	S	P	TOTAL	SP		M	D	S	P	TOTAL	SP
Operational Phase - Office, Workshop and Power Supply														
Groundwater Quantity: Limited impacts are foreseen	Surface Infrastructure	2	1	1	1	4	L	N/A	2	1	1	1	4	L
Groundwater Quality: Seepage from the workshop wash bay and seepage from the on site sewage management facility can occur if not managed correctly.	Surface Infrastructure	4	3	1	3	24	L	Storage and maintenance features should be designed properly and good house keeping should be in place to prevent accidental spillage.	2	3	1	2	12	L

6.4.3 Decommissioning and Post-mining phases

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION						RECOMMENDED MITIGATION MEASURES/ REMARKS	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION					
		M	D	S	P	TOTAL	SP		M	D	S	P	TOTAL	SP
After Closure Phase - Office, Workshop and Power Supply														
Groundwater Quantity: N/A	Surface Infrastructure	2	1	1	1	4	L	N/A	2	1	1	1	4	L
Groundwater Quality: N/A	Surface Infrastructure	2	1	1	1	4	L	N/A	2	1	1	1	4	L

6.5 ROM Stockpiles

6.5.1 Construction Phase

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION						RECOMMENDED MITIGATION MEASURES/ REMARKS	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION					
		M	D	S	P	TOTAL	SP		M	D	S	P	TOTAL	SP
Construction Phase - Rom Stockpiles														
Groundwater Quantity: No impacts are foreseen	Coal Stockpile	2	1	1	1	4	L	N/A	2	1	1	1	4	L
Groundwater Quality: During the construction of the stockpile areas no quality issues are foreseen. Construction will include proper compaction,	Coal Stockpile	2	1	1	1	4	L	A groundwater quality monitoring network will be up and running at this stage and any groundwater quality issues addressed accordingly.	2	1	1	1	4	L

6.5.2 Operational phases

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION						RECOMMENDED MITIGATION MEASURES/ REMARKS	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION					
		M	D	S	P	TOTAL	SP		M	D	S	P	TOTAL	SP
Operational Phase - Rom Stockpiles														
Groundwater Quantity:	Coal Stockpile	2	1	1	1	4	L	N/A	2	1	1	1	4	L
Groundwater Quality: Poor quality seepage will occur from coal storage areas due to rainfall infiltration and subsequent seepage into the underlying strata.	Coal Stockpile	6	4	2	3	36	M	Compaction of area before storage activities occur to reduce seepage. Effective surface water drainage methods to ensure the containment of dirty runoff and subsequent seepage into the underlying strata. The coal stockpiles should be kept as small as possible. This will reduce the volume of potentially poor quality leachate infiltrating the aquifers. The base of the coal stock pile should be compacted to reduce the permeability and therefore the infiltration. Monitoring of the monitoring boreholes will indicate possible anomalies	4	3	1	2	16	L

6.5.3 Decommissioning and Post-mining phases

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION						RECOMMENDED MITIGATION MEASURES/ REMARKS	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION					
		M	D	S	P	TOTAL	SP		M	D	S	P	TOTAL	SP
After Closure Phase - Rom Stockpiles														
Groundwater Quantity:	Coal Stockpile	2	1	1	1	4	L	N/A	2	1	1	1	4	L
Groundwater Quality: All ROM stockpile areas will now be limited and closure will be implemented.	Coal Stockpile	4	3	2	4	36	M	After mine closure the coal stockpile should be rehabilitated, thereby eliminating a long-term source of contamination to the underlying aquifers. Monitoring of groundwater from boreholes will continue for the next 2 years.	4	2	2	2	16	L

6.6 Pollution control dam and return water dams

6.6.1 Construction Phase

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION						RECOMMENDED MITIGATION MEASURES/ REMARKS	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION					
		M	D	S	P	TOTAL	SP		M	D	S	P	TOTAL	SP
Construction Phase - PCD and RWD														
Groundwater Quantity: No impacts are foreseen	Water Storage	2	1	1	1	4	L	N/A	2	1	1	1	4	L
Groundwater Quality: During the construction of the dams no quality issues are foreseen. Construction will include proper compaction/lining,	Water Storage	2	1	1	1	4	L	A groundwater quality monitoring network will be up and running at this stage and any groundwater quality issues addressed accordingly.	2	1	1	1	4	L

6.6.2 Operational phases

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION						RECOMMENDED MITIGATION MEASURES/ REMARKS	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION					
		M	D	S	P	TOTAL	SP		M	D	S	P	TOTAL	SP
Operational Phase - PCD and RWD														
Groundwater Quantity: Leakage of the dams can result in seepage and elevated groundwater levels but this will be highly unlikely.	Water Storage	4	3	1	2	16	L	Ensure proper management of lining and groundwater monitoring down-gradient.	2	1	1	1	4	L
Groundwater Quality: Poor quality seepage will occur into the underlying strata if the dams are situated on permeable soil formation or on a groundwater flow path like dykes and/or fault systems. Overflow of dams can also result in down-stream contamination of surface water bodies and seepage into groundwater.	Water Storage	6	4	2	3	36	M	Compaction /lining of dams before storage activities occur to reduce seepage. Dam levels should be kept at the required levels (refer to GN704)	4	3	1	2	16	L

6.6.3 Decommissioning and Post-mining phases

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION						RECOMMENDED MITIGATION MEASURES/ REMARKS	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION					
		M	D	S	P	TOTAL	SP		M	D	S	P	TOTAL	SP
After Closure Phase - PCD and RWD														
Groundwater Quantity:	Water Storage	2	1	1	1	4	L	N/A	2	1	1	1	4	L
Groundwater Quality: The pollution control dams will remain on site if seepage from the area occur otherwise all dams will be closed and rehabilitated.	Water Storage	4	3	1	2	16	L	After mine closure the containment facilities will be rehabilitated, thereby eliminating a long-term source of contamination to the underlying aquifers. Monitoring of groundwater from boreholes will continue for the next 2 years.	2	2	2	2	12	L

7 GROUNDWATER MANAGEMENT PLAN

7.1 Groundwater Management Objectives

7.1.1 Construction Phase

To prevent contamination of surface water runoff from the box cut and infrastructure development.

Actions: Construction Phase

- Separate clean and dirty runoff and contain dirty water in adequately sized pollution control dams. Ensure that pollution control dams are adequately sized according to the specifications in DWAF's GN704 or other applicable regulations;
- Prevent dirty water runoff from leaving the box cut and adits in the general mining area;
- Keep dirty areas as small as possible; and
- Compact the base of dirty areas, like the ROM coal stockpile, workshops and oil and diesel storage areas to minimise infiltration of poor quality water to the underlying aquifers.

7.1.2 Operational Phase

To restrict the impact of polluted groundwater to the mining area and mitigate the loss of groundwater from the catchment.

Actions: Operational Phase

- Eliminate the development of subsidence to surface through sound underground mine planning and leaving sufficient pillars and barrier zone along shallow sub-outcrop zones underground;
- Re-use groundwater seepage collected in the Adit to adequately sized pollution control facilities in the mining process;
- Keep dirty areas like the pollution control dam and coal stockpiles, workshops and oil and diesel storage areas as small as possible; and
- Contain poor quality runoff from dirty areas and divert this water to pollution control dam for re-use.
- Reduce the recharge potential through spoils by ongoing rehabilitation through implementing and maintenance of the roll-over method of mining.
- Re-use groundwater seepage collected in the pits to adequately sized pollution control facilities in the mining process.

7.1.3 Groundwater Closure Objectives

- To negotiate and get the groundwater closure objectives approved by Government during the Decommissioning Phase of the project, based on the results of the monitoring information obtained during the Construction and Operational Phases of the project, and through verification of the numerical model constructed for the project;
- To continue the groundwater quality and groundwater level monitoring for a period of two to four years after mining ceases in order to establish post-closure groundwater level and quality trends. The monitoring information must be used to update, verify and recalibrate the

predictive tools used during the study to increase the confidence in the closure objectives and management plans;

- To present the results of the monitoring programme to Government on an annual basis. The post-closure monitoring programme will be re-evaluated on an annual basis in consultation with Government;
- To negotiate mine closure with Government based on the results of the groundwater monitoring undertaken, after the two-four year post-closure monitoring periods.

Actions: Closure

- To close all old vent shafts and adits;
- Multiple-level monitoring wells must be constructed to monitor base-flow quality within the identified sensitive zones and to monitor groundwater level behaviour in the underground workings. The deep underground boreholes will only be required towards mine closure.Use the results of the monitoring programme to confirm/validate the predicted impacts on groundwater availability and quality after closure;
- Update existing predictive tools to verify long-term impacts on groundwater, if required; and
- Present the results to Government on an annual basis to determine compliance with the closure objectives set during the Decommissioning Phase.

7.2 Groundwater Management Implementation plan

7.2.1 Management of groundwater availability (quantity)

- Groundwater seeping into the underground workings must be collected in dedicated underground sumps and re-used as part of the mining operations.
- Sufficient pillars must be left underground, as part of sound mine planning, to avoid subsidence of the roof to surface along the more shallower areas (where underground mining is less than 25m from surface). This will ensure that the rate of recharge to the underground workings remain at natural rates and will minimise decant from the workings post-closure.
- Groundwater monitoring will be undertaken in the monitoring boreholes to generate a database. The information will be used to evaluate and confirm trends.
- Finalisation of the rehabilitation programme will be undertaken during the decommissioning phase. Groundwater monitoring boreholes will be drilled into the underground workings to track rebound and recharge of the underground workings and also to monitor groundwater quality aspects.
- The groundwater that flows into the pits during the operational phase of mining will be used continually as part of the mine water balance. This will create a localised cone of depression around the mining area and will reverse groundwater flow towards the pit. This cone of depression is not anticipated to extend more than 1km from the pit, but cumulative impacts could be more extensive.
- Further management measures implemented during the roll-over method of mining will relate to continuous rehabilitation as mining progresses. The recharge potential for un-levelled spoils is higher than that for levelled spoils or re-vegetated areas. Optimisation of continuous rehabilitation will effectively minimise recharge to the areas disturbed by mining and thus

reduce the impact of mining on the availability of groundwater, as well as on the amount of leachate that could be generated inside the pits.

7.2.2 Management of groundwater quality

- The spread of contaminated leachate from the underground workings will be managed through containing seepage in dedicated underground holding facilities and re-using this water as part of the mining operations. A buffer zone will be left around the underground workings to contain potential contaminated leachate and limit its spread into the surrounding aquifers.
- The shale and pyritic rocks present in the overburden material will be backfilled at the bottom of the pits to ensure that it is flooded as quickly as possible and so minimise acid mine drainage.
- In order to limit the generation of acid mine drainage inside the pits, it is recommended that the pits are flooded as quickly as possible. The rate of groundwater level rise in the pits will be monitored with the aid of the spoils boreholes to ensure that water levels in the pits do not exceed the decant elevation. The water level in the pits must be kept below the depth of weathering to ensure that contamination does not enter the perched aquifer and migrate towards streams. This level is approximately 3 - 5m below surface. Once the pits are flooded according to the description above, it will be shaped and re-vegetated according to acceptable standards. This will ensure a free draining area and limit the risk of decant from the pit. Surface runoff will be diverted from the rehabilitated area by constructing berms and cut off trenches around the mining areas and to divert clean runoff back into the catchment. This will also minimise erosion over the rehabilitated area.
- The extent to which acid mine drainage will be generated from the pits will be controlled by careful handling of the spoils, and specifically the shale and other pyritic overburden, during the operational phase; and by flooding the bottom section of the pits as quickly as possible, as discussed above.

7.3 Monitoring: Groundwater

Groundwater monitoring will be undertaken to establish the following:

- <u>The impact of mine dewatering on the surrounding aquifers.</u> This will be achieved through monitoring of groundwater levels in the monitoring boreholes. If private boreholes are identified within the zone of impact on groundwater levels, these will be included in the monitoring programme.
- <u>Groundwater inflow into the mine workings.</u> This will be achieved through monitoring of groundwater levels in the monitoring boreholes.
- <u>Groundwater quality trends</u>. This will be achieved through sampling of the groundwater in the monitoring boreholes.
- <u>The rate of groundwater recovery and the potential for decant</u> after mining ceases and full rehabilitation. This will be achieved through drilling of additional boreholes into the underground workings and rehabilitated spoils for monitoring purposes. These boreholes must be drilled in the deepest sections of the mine.
- Groundwater monitoring will be undertaken according to SABS and DWAF requirements according to the schedule presented in Table 7-1 below.

Table 7-1: Groundwater monitoring programme

Monitoring position	Sampling interval	Analysis	Water Quality Standards
Construction, Operational and Decommissioning Phases			
All monitoring boreholes	Monthly: measuring the depth of groundwater levels	No analysis required	
All monitoring boreholes	Quarterly: sampling for water quality analysis (April, July, Oct, Jan)	Full SABS analysis Groundwater level	South African Water Quality Guidelines: Domestic Use
All hydrocensus boreholes	Annually (Oct)	Full SABS analysis Groundwater level	South African Water Quality Guidelines: Domestic Use
Rainfall	Daily at the mine	No analysis required	
Post-closure phase for 2 to 4 years after mining ceases			
All monitoring boreholes	Quarterly (April, July, Oct, Jan)	Full SABS analysis Groundwater level	South African Water Quality Guidelines: Domestic Use
All hydrocensus boreholes	Annually (Oct)	Full SABS analysis Groundwater level	South African Water Quality Guidelines: Domestic Use
Rainfall	Daily at the mine	No analysis required	Not Applicable

It must be noted that NO dedicated groundwater monitoring sites exist for the proposed mining areas. It is recommended that additional monitoring boreholes be constructed to cater for these areas. The following guideline can be used:

- One up-gradient and two down-gradient of the Coal Discard Dump,
- One borehole down-gradient of each mine Adit and coal stockpile area,

Laboratory analysis techniques will comply with SABS guidelines. The groundwater monitoring database will be updated on a monthly basis as information becomes available. The database will be used to analyse the information and evaluate trends noted. An annual compliance report will be compiled and submitted to the authorities for evaluation and comment. This report will be submitted by 15 December annually for the construction, operational and decommissioning phases as well as for two years after mining ceases. The mine will develop a monitoring response protocol after the completion of the Construction Phase of the project. This protocol will describe procedures in the event that groundwater monitoring information indicates that action is required.

7.4 Financial provision: Groundwater

The financial provision that must be provided to comply with the commitments made with respect to groundwater includes:

- Groundwater monitoring during mining operations, according to the schedule presented in Table 7-1 above.

- Drilling of monitoring boreholes according to the following guideline (three boreholes were drilled to obtain an idea of the pre-mining conditions in 2009; this network will be expanded where find necessary to cater for full operational/closure monitoring purposes):
    - Drilling of one borehole in each underground working according to scientific base selection practices to measure rebound – this action will only be planned 1 year before closure or if otherwise required,
    - Other areas where poor quality seepage are expected from mining activities. These will be identified as mining progresses, based on the implemented monitoring programme and observations on site.
- Groundwater monitoring after mining ceases, for an initial period of two to 4 years. The length of this monitoring period must be negotiated with Government during the Decommissioning Phase of the project.

Table 7-2: Groundwater Management Plan Approximate Costs

Action Plan	**Time Frame**	**Responsible Person**	**Capital Required (capex)**	**Operational Cost (opex)**
Groundwater Monitoring				
Quarterly monitoring of 3 monitoring boreholes	Every quarter	Environmental Manager	Boreholes already drilled	Approximately R60 000 per annum for monitoring an analyses
Drilling of a possible 5 additional boreholes during operation	Within the 1st 5 years	Environmental Manager	Approx R160 000	Approximately R40 000 per annum for monitoring an analyses
Drilling of a possible two boreholes to monitor rebound and decant potential	1 year before closure and 4 years after closure	Environmental Manager	Approx R80 000	Approximately R50 000 per annum for monitoring an analyses
Water Containment:				
Containment of groundwater seepage	Operational	Mine Manager	Part of mining construction plan	Operational cost from mining
Minimization of recharge into underground workings:				
Proper pillar ratio in areas where mining is shallower than 25 m	Operational	Mine Manager	Part of mining construction plan	Operational cost from mining
Buffer zone in areas where mining is shallower than 25 m	Operational	Mine Manager	Part of mining construction plan	Operational cost from mining

7.5 Environmental Awareness Plan: Groundwater

- Mine employees must be made aware, through the required training programmes, of the significance of the groundwater monitoring programme to ensure that the boreholes are maintained and the monitoring schedule adhered to; and

Mining sub-contractors and mine personnel must be instructed, through the required training programmes, to implement and maintain the roll-over method of mining to ensure that potential impacts on mining are minimised.

8 References

- BREDENKAMP, D.B., BOTHA, L.J., VAN TONDER, G.J., AND VAN RENSBURG, H.J. 1995. Manual on the quantitative estimation of groundwater recharge and aquifer storativity. Water Research Commission, TT 73/95, Pretoria.
- DEPARTMENT OF WATER AFFAIRS AND FORESTRY 1996. South African Water Quality Guidelines, Volume 1, Domestic Use. DWAF, Pretoria.
- Institute of Groundwater Studies for the Water Research Commission. Groundwater Quality Deterioration in the Olifants River Catchment above the Loskop Dam wit Specialised Investigations in the Witbank Dam sub-catchment. WRC Report No 291/1/98, 1998.
- Department of Water Affairs and Forestry. (1998). Waste Management Series Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste.
- Parsons, R. (1995). A South African Aquifer System Management Classification. Water Research Commission Report No. KV 77/95.
- SABS (2001). South African Standard Specification Drinking Water. SABS 241 Edition 5.
- The national groundwater database. Department of Water Affaires and Forestry, Pretoria, South Africa.
- Weaver, J.M.C. (1992). Groundwater sampling a comprehensive guide for sampling methods. Water Research Commission Report No. TT54/92

Appendix A – 2009 Hydrocensus Data

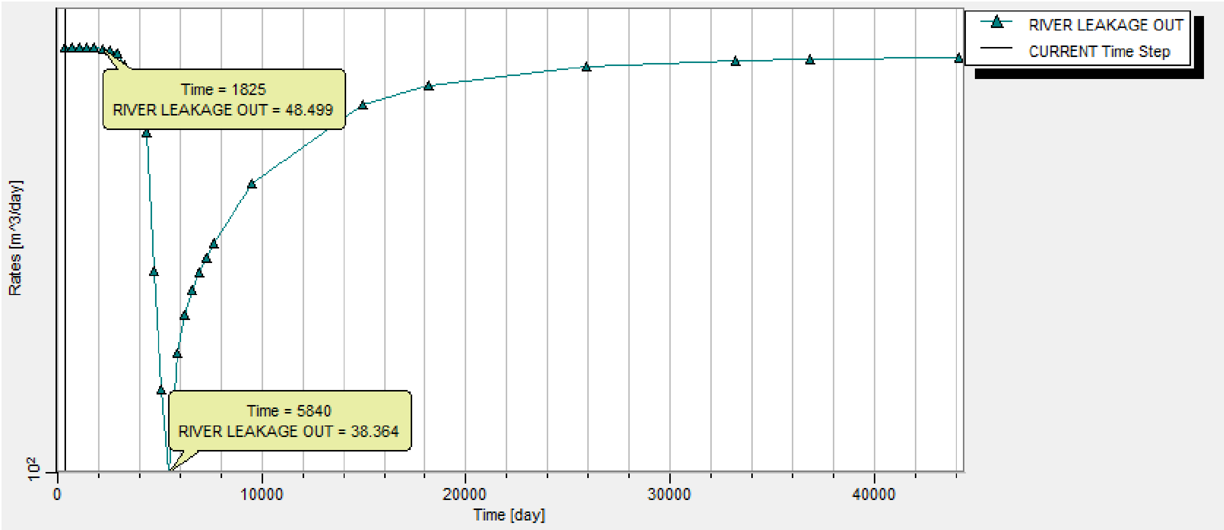
BH ID	Farm Name	Farm Owner	Contact Details	Y (m in LO 29, WGS84)	X (m in LO 29, WGS84)	Alt (mam sl)	WL (mbgl)	Collar Height	Equipment	pH	EC (mS/m)	TDS	Use	Comments
BH1	Witbank 12	Gilbert	082 651 2845	-73480.46	2910329.48	1694	15.11	0.25	Windpump	7.08	0.81	0.40	Domestic and stock watering	Wind-pump that pumps into a concrete tank for farm dwellers and cattle.
BH2	Witbank 12	Gilbert	082 651 2845	-74128.23	2909700.5	1693			Windpump				Stock farming	Wind-pump that pumps into a concrete tank for cattle.
BH3	Graspan 6	Jaco de Klerk	083 268 0814	-65880.12	2906862.53	1674			Windpump	7.21	0.33	0.16	Domestic	Water used by farm dwellers.
BH4	Graspan 6	Jaco de Klerk	083 268 0814	-66525.02	2906556.71	1669			Windpump				Unused	Located in the cattle farm. Pump seems to be broken.
BH5	Graspan 6	Jaco de Klerk	083 268 0814	-66496.6	2907809.7	1676	6.81	0	Windpump				Unused	Located in the recently cultivated farm. Pump seems to be broken.
BH6	Graspan 3	Gilbert	082 651 2845	-67084.27	2908323.53	1685	3.98	0.27	None	6.92	0.14	0.07	Unused	Open borehole was drilled by the previous farm owner and left it un-equipped.
BH7	Graspan 11	Gilbert	082 651 2845	-66361.55	2908821.72	1672	3.21	0	Windpump				Unused	Pump broken. Empty concrete tanks next to the borehole.
BH8	Witbank 7	M. Kadish	082 469 4108	-69150.38	2911771.46	1716	20.16	0	Mono pump	7.37	0.62	0.31	Domestic	Pump connected to a tank. Water is used in the farm house, workshop and compound.
BH9	Witbank 7	M. Kadish	082 469 4108	-68944.45	2911814.67	1715			Windpump				Stock farming	Water is pumped into a concrete tank for cattle farming.
BH10	Witbank 7	M. Kadish	082 469 4108	-70538.6	2911736.86	1681			Windpump	8	0.18	0.18	Domestic and stock watering	Water is pumped into a concrete tank for cattle farming.
BH11	Witbank 7	M. Kadish	082 469 4108	-70076.15	2912308.3	1704	5.89	0.23	None				Unused	An open borehole, wind-pump was removed.
BH12	Graspan 4	Gilbert	082 651 2845	-68103.42	2909396.97	1694	14.25	0.44	Submersible pump	8.23	0.37	0.18	Domestic	Located about 100m from a dam in the farm. Water used only by farm dwellers.
BH13	Graspan 4	Gilbert	082 651 2845	-69216.07	2910694.82	1689	11.85	0.5	Windpump				Stock farming	Water is pumped into a concrete tank for cattle farming.
BH14	Graspan 4	Gilbert	082 651 2845	-69765.27	2911446.79	1702			Broken Mono Pump				Unused	Borehole was used to supply water to the compound before the pump was stolen.

BH ID	Farm Name	Farm Owner	Contact Details	Y (m in LO 29, WGS84)	X (m in LO 29, WGS84)	Alt (mam sl)	WL (mbgl)	Collar Height	Equipment	pH	EC (mS/m)	TDS	Use	Comments
BH15	Graspan 4	Gilbert	082 651 2845	-67832.82	2909384.47	1707	6.63	0	None				Unused	Pump was removed. It was used for domestic purpose and cattle farming before the removal of the pump.
BH16	Graspan 3	Gilbert	082 651 2845	-67649.85	2910565.75	1685	4.93	0	Submersible pump				Domestic	Borehole located next to the farm house and used for domestic purpose.
BH17	Graspan 3	Gilbert	082 651 2845	-67179.64	2910918.96	1667			Windpump	7.43	0.37	0.19	Domestic and stock watering	Borehole located on a wetland, pumping into 2 concrete tanks.
BH18	Graspan 3	Gilbert	082 651 2845	-66303.49	2909819.73	1668			Broken Windpump					Broken windpump with a concrete tank next to it. Located on a grassy wetland area.
BH19	Witbank 12	Gilbert	082 651 2845	-74213.21	2910380.2	1724	2.9	0	None					Open borehole. Blocked at about 3m. Located in an what used to be a cattle farm.
BH20	Trenedal 0002	Gilbert	082 651 2845	-76386.18	2908555.77	1730			Windpump	8.67	0.34	0.17	Domestic and stock watering	Water is pumped into a concrete tank for domestic use in the compound and cattle farming. Water level could not be measured.
BH21	Trenedal 0002	Gilbert	082 651 2845	-76074.16	2908112.94	1743	5.65	0	Broken Windpump				Unused	Located next to old, vandalized farm houses. Connected to 2 concrete tanks.
BH22	Trenedal 0002	Gilbert	082 651 2845	-75578.34	2908860.16	1722			Windpump	8.45	0.23	0.11	Cattle farming	Water is pumped into a concrete tank for drinking by cattle. Located on an open area just upgradient to a wetland.
BH23	Trenedal 0002	Gilbert	082 651 2845	-75557.14	2908898.81	1719	8.45	0	None				Unused	Open borehole located about 30m from a windpump. Pump was removed.
BH24	Tweefontein	John Schinkerling	084 581 3049	-77713.38	2900280.12	1689	8.17	0.36	Submersible pump	6.35	0.25	0.12	Domestic and stock watering	Borehole located next to a farm house.
BH25	Tweefontein	John Schinkerling	084 581 3049	-77672.22	2899976.28	1694	2.75	0.19	None				Unused	Old, open borehole next to a farm house. A wind-pump was removed from the borehole.

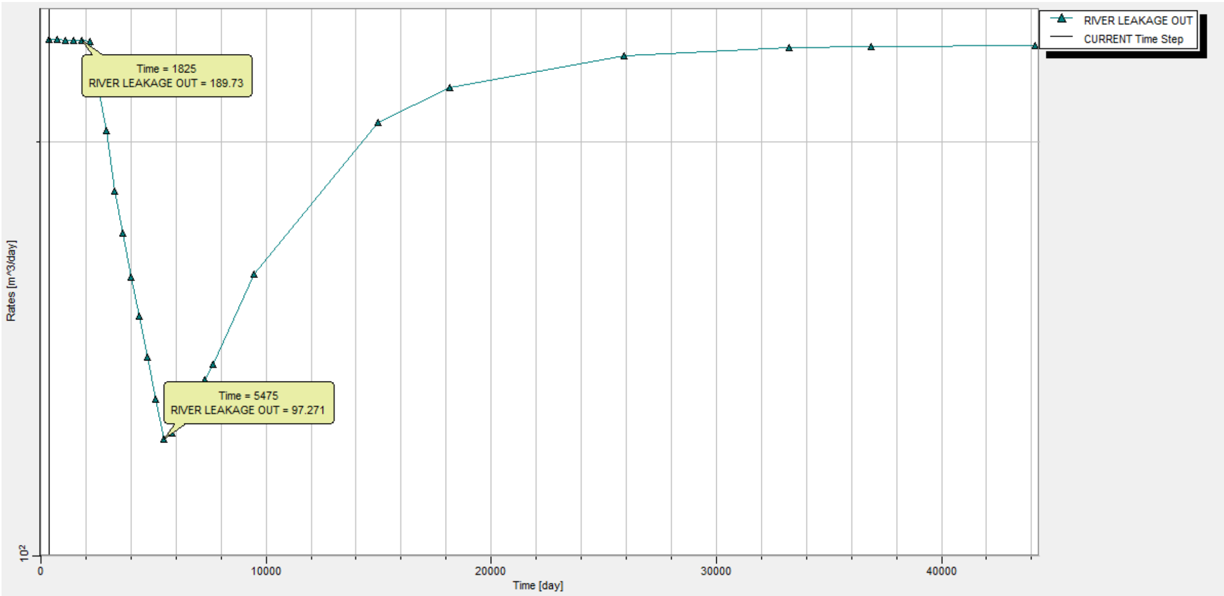
BH ID	Farm Name	Farm Owner	Contact Details	Y (m in LO 29, WGS84)	X (m in LO 29, WGS84)	Alt (mam sl)	WL (mbgl)	Collar Height	Equipment	pH	EC (mS/m)	TDS	Use	Comments
BH26	Tweefontein	John Schinkerling	084 581 3049	-76999.68	2900124.07	1652	4.75	0	Submersible pump				Used occasionally	Borehole located on a wetland, at the bottom of the mountain. Connected to the two tanks in the farm house.
BH27	Tweefontein	John Schinkerling	084 581 3049	-76268.47	2900900.89	1667			Hand pump	6.24	0.23	0.11	Domestic	Located about 150m from the Ermelo-Hendrina road, on a grassy land used for grazing. Water is used by farm dwellers.
BH28	De Wittekrans	Anel Shulze	083 628 8212	-78015.57	2904040.34	1653			Submersible pump				Stock farming	Two boreholes located on a valley, about 300m from the river. Used to pump water concrete tanks for cattle. Water has a strong smell of sulphur.
BH29	De Wittekrans	Anel Shulze	083 628 8212	-78016.54	2904044.77	1654	6.29	0.2	Submersible pump	7.32	0.42	0.21	Stock farming	
BH30	De Wittekrans	Anel Shulze	083 628 8212	-79387.83	2903981.09	1681			Windpump				Unused	Borehole not currently in use, located on the mountain side on a grazing land.
BH31	De Wittekrans	Anel Shulze	083 628 8212	-79653.98	2903597.13	1707			None				Unused	Unused borehole closed with concrete on top, had a windpump which was removed by the previous farm owner.
BH32	De Wittekrans	Anel Shulze	083 628 8212	-79255.61	2903219.07	1694			Windpump				Unused	Borehole with a broken windpump located at a farm used as grazing land.
BH33	De Wittekrans	Anel Shulze	083 628 8212	-75783.49	2903848.69	1704			Windpump	7.57	0.21	0.1	Domestic	Borehole located next to a village in the farm. Water is pumped into a concrete tank and used by farm workers.
BH34	De Wittekrans	Anel Shulze	083 628 8212	-75850.88	2903603.1	1688			Broken Windpump				Unused	Two boreholes located on a grazing land in the farm. Both windpumps are broken. They were connected to concrete tanks for ctock watering.
BH35	De Wittekrans	Anel Shulze	083 628 8212	-75309.49	2903741.77	1698			Broken Windpump				Unused	
BH36	De Wittekrans	Anel Shulze	083 628 8212	-74540.42	2904033.15	1707			Windpump	7.41	0.41	0.2	Stock farming	Borehole equiped with a windpump and pumps into a concrete tank for stock

BH ID	Farm Name	Farm Owner	Contact Details	Y (m in LO 29, WGS84)	X (m in LO 29, WGS84)	Alt (mam sl)	WL (mbgl)	Collar Height	Equipment	pH	EC (mS/m)	TDS	Use	Comments
														watering.
BH37	De Wittekrans	Anel Shulze	083 628 8212	-77032.54	2905184.57	1684	8.09	0	Windpump	5.86	0.46	0.23	Domestic and stock watering	Borehole equipped with a windpump and pumps into a concrete tank for domestic use and stock watering.
BH38	Israel	C. J. De Vos	082 388 3008	-78316.23	2910652.63	1717			Submersible pump				Domestic	Borehole located on a wetland next to a dam. Connected to 3 tanks that supply to a farm house, workshop and to the farm worker's village.
BH39	Israel	C. J. De Vos	082 388 3008	-78930.06	2910220.92	1741	13.59	0.21	Submersible pump				Used occasionally	Water contains oil.
BH40	Israel	C. J. De Vos	082 388 3008	-79408.41	2908927.45	1733			Submersible pump	7.86	0.36	0.18	Domestic and stock watering	Borehole located next to the farm worker's village, used to supply water to the farm house, village and cattle.
BH41	Israel	C. J. De Vos	082 388 3008	-79842.24	2909035.39	1751	23.62	0	Submersible pump				Used occasionally	Located among the mielie fields, upgradient to a dam.
BH42	Israel	C. J. De Vos	082 388 3008	-78915.77	2908473.46	1726	2.37	0	Broken Windpump				Unused	Borehole was used for irrigation before the pump broke, located on the boundary between the mielie and the potato fields.
BH43	Israel	C. J. De Vos	082 388 3008	-78450.55	2906621.34	1691			Windpump	7.95	0.13	0.06	Unused	Borehole located next to an old, unoccupied village, on a grazing land.
BH44	De Wittekrans	B. De Lange	082 862 7515	-78394.65	2902656.49	1674	44.53	0	Submersible pump				Domestic	The only borehole in the farm used for domestic purpose in the farm house. No agricultural use of groundwater. Located on a grazing land.
BH45	De Wittekrans	B. De Lange	082 862 7515	-78347.74	2902647.34	1669			Spring	5.02	0.09	0.04	Domestic	Spring located about 40m from a borehole. Used by farm workers for domestic purpose.

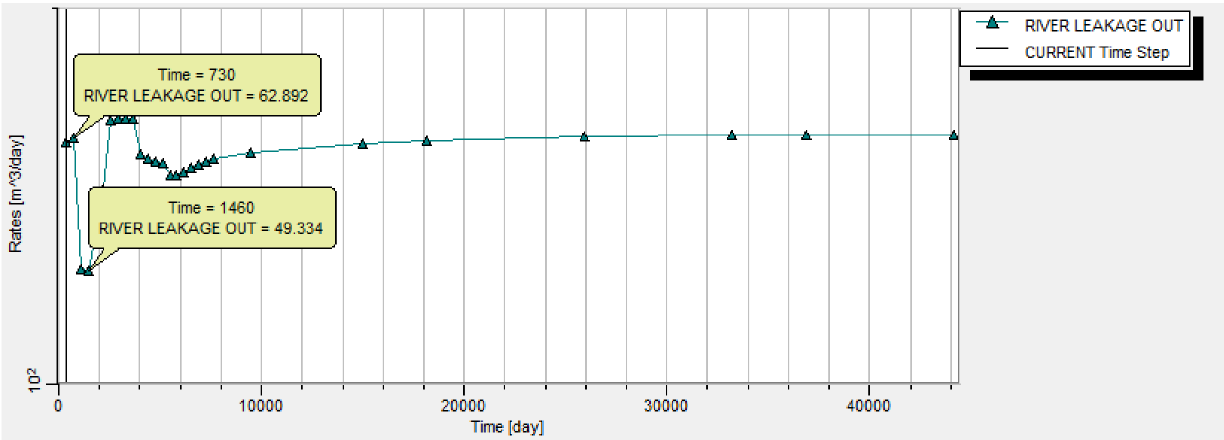
Appendix B - Stream Flow Zone Budget Calculation Graphs



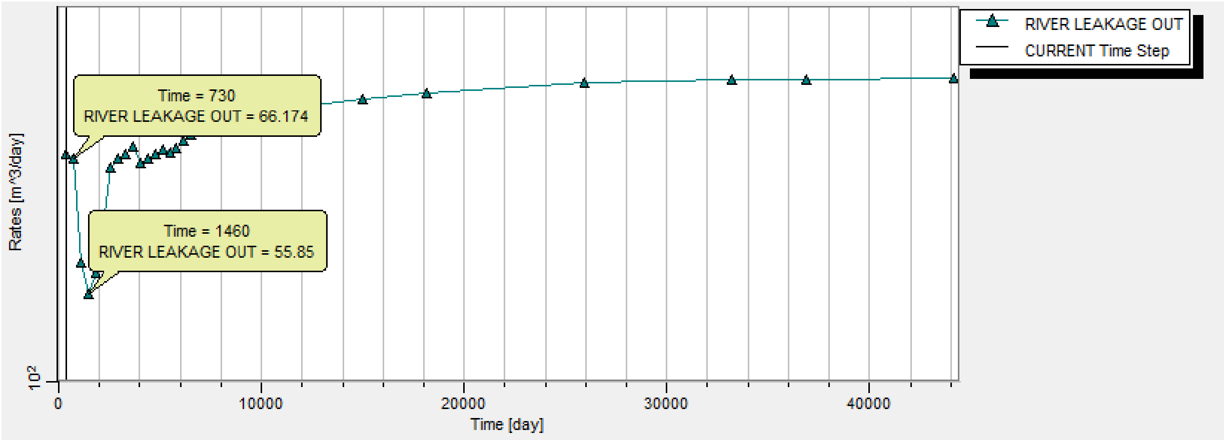
Zone 21



Zone 22



Zone 23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CURRENT Time Step
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RIVER LEAKAGE OUT = 66.174
Time = 1460
RIVER LEAKAGE OUT = 55.85
Rates [m^3/day]
10^2
0
10000
20000
30000
40000
Time [day]

Zone 24

Appendix C: