Groundwater Complete

Belfast Project: Baseline Report on Geohydrological Investigation as part of the EIA and IWULA for the proposed mining operation.

November 2009

Contact Details:
Phone: 0844091429
Fax: 0866950191
PO Box 448
Riversdale
6670
Groundwatercomplete@vodamail.co.za

Gerhard Steenekamp, M.Sc. Geohydrology Pr.Sci.Nat.(400385/04)

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Executive summary

A groundwater study was performed at the proposed Belfast Project of Exxaro Coal as specialist input to the Environmental Impact Assessment (EIA) and Integrated Water Use License Application (IWULA). The EIA is conducted to investigate potential impacts and compile a management plan for the activities of the proposed mining operation on the receiving environment.

The proposed Belfast project is situated south-west of the town of Belfast in Mpumalanga Province. The project will consist of two blocks, namely the West and East blocks. The mine blocks are divided by a tributary of the Klein-Komati River. The blocks will be mined by the roll over opencast method.

The baseline study and user surveys for the proposed Belfast project area and surroundings were conducted and the results will be discussed in this document. The environmental impact assessment in terms of groundwater and also the management plans for the proposed operation at the Belfast project will be discussed in terms of the mine type, depth, schedule and recharge/discharge properties.

All the main aspects required to assess geohydrological conditions in an area have been addressed, including physical properties of the groundwater domain, geohydrological features, groundwater users and uses around the mining area, the geology and acid generating potential of the host rocks, the hydraulic properties of the saturated zone, groundwater quality characteristics, groundwater flow velocities will be calculated from first principles, recharge impacts will be addressed and all data will be combined to construct conceptual and numerical models to aid in impact assessment.

The proposed Belfast project area is underlain by rocks of the Karoo Supergroup. The 2, 3 and 4 seams will be mined. Based on the geological profile descriptions the unsaturated zone is composed of soils and colluvium underlain by clay, siltstone, coal and sandstone.

The geohydrological regime in the study area is made up of two aquifer systems. The first, the upper, semi-confined aquifer sometimes occurs in the weathered zone but is often not a reliably and widely used aquifer. The second, deeper aquifer is associated with fractures, fissures and joints and other discontinuities within the consolidated Karoo bedrock and associated intrusives. Yields usually vary between 0 and 2 l/s.

Natural static groundwater levels generally vary between 0 and approximately 16 meters below surface (mbs) in the mining area but groundwater abstraction for domestic use and other purposes have caused water levels to decrease to 30 mbs in isolated instances.

The overall ambient groundwater quality is good but variance is rather high due to different co-existing aquifers, impact types and recharge conditions.

The numerical groundwater model was used to estimate groundwater seepage rates and contamination during the operational phase as well as water level recovery and plume movement after mine closure. The calculated annual seepage rates of groundwater to the mine blocks indicate a range of between 100 m^3/d and 950 m^3/d when the mining occurs at the deepest levels and flow gradients are the highest.

A decant rate for the **West Block** is estimated at approximately **2000 m^3/day** to the north-west and south-east while decant is estimated from the **East Block** at **3600 m^3/day** on its south-western boundary. The time to decant in both of the mine blocks is less than 1 year. It was concluded from acid-base accounting result on coal and overburden material that acid formation in the proposed Belfast project area is very likely to occur. This tendency of the coal and overburden to turn acidic, combined with the fact that the majority of the backfill material will remain under oxidizing conditions, will result in a poor quality water – most probably acidic – decanting from the Belfast project mine blocks.

Unfortunately, there is nothing to be done on the geometry of the coal reserve or the acid neutralizing capacity of the backfill material and it is imperative for the Belfast Project to take proper and timeous action to manage the poor quality decant that will start to occur nearly directly after mine closure.

Mitigation measures will be implemented to prevent decant from entering the receiving surface water environment and a monitoring program will be in place from the operational phase throughout the life-of-mine until after closure to monitor the occurrence of any adverse groundwater impacts.

Monitoring data will be used to update the current numerical model simulation for more accurate predictions of groundwater flow and quality and action plans will be formulated and implemented if adverse such impacts are identified.

The monitoring results will be reported regularly and records of monitoring and audit reports will be available for inspection by the regional director if necessary.

1 GENERAL DESCRIPTION OF GEOHYDROLOGY

Groundwater Complete have been contracted by Exxaro Coal Mpumalanga to conduct a specialist geohydrological study and report on findings as input to the EIA and IWULA for the proposed Belfast Project.

The project will be referred to in this document as the proposed **Belfast project.** This report provides methodology, findings and recommendations of the geohydrological specialist study as input to the total environmental impact evaluation and management plan.

1.1 DESK TOP STUDY

Data from new monitoring boreholes drilled for the proposed Belfast project as well as boreholes of surrounding users was used for the study and results are presented in this document.

Groundwater information for the survey was obtained mainly from two different sources:

- Groundwater information gathered during two hydrocensus studies in the area and interpretation of the data in support of the EIA and IWULA for the proposed Belfast project,

- The second source comprises dedicated information gathering through groundwater quality analysis, water level measurements, aquifer testing and interpretation thereof and other groundwater information gathered in the new monitoring boreholes drilled at the Belfast project.

For the purpose of this study the hydrocensus and new monitoring boreholes information were combined and interpreted in a holistic manner. For the purpose of compiling this specialist report the physical and chemical properties of the groundwater regime were evaluated using the following methodology:

- Topographical and geological maps and orthographic photographs were used to describe the **physical properties** of the groundwater domain,

- Aquifer test data from new monitoring boreholes at the proposed Belfast project were evaluated to describe the **geohydrological features** and **calculate aquifer parameters such as transmissivity**,

- A hydrocensus was conducted during which **groundwater users** around the mining area were identified, boreholes were surveyed in terms of positions, flow and **water quality** and water **uses** were determined,

- A number of monitoring boreholes were drilled and logged in the proposed mining area to determine the **geology** and **acid generating potential** of the host rocks.

- Information from new monitoring boreholes drilled at the proposed Belfast project were used to determine the **hydraulic properties** of the saturated zone,

- Groundwater **flow velocities** were calculated from first principles to use as guidelines in numerical model construction,

- All the above data types were interpreted with appropriate techniques in each case and were used to construct a **conceptual and numerical model** of the groundwater regime, and

- The numerical model was calibrated using groundwater levels, aquifer test information, and information from surrounding mining activities.

The locality of the proposed Belfast project relative to existing mining operations is presented in **Figure 1.1-1**.

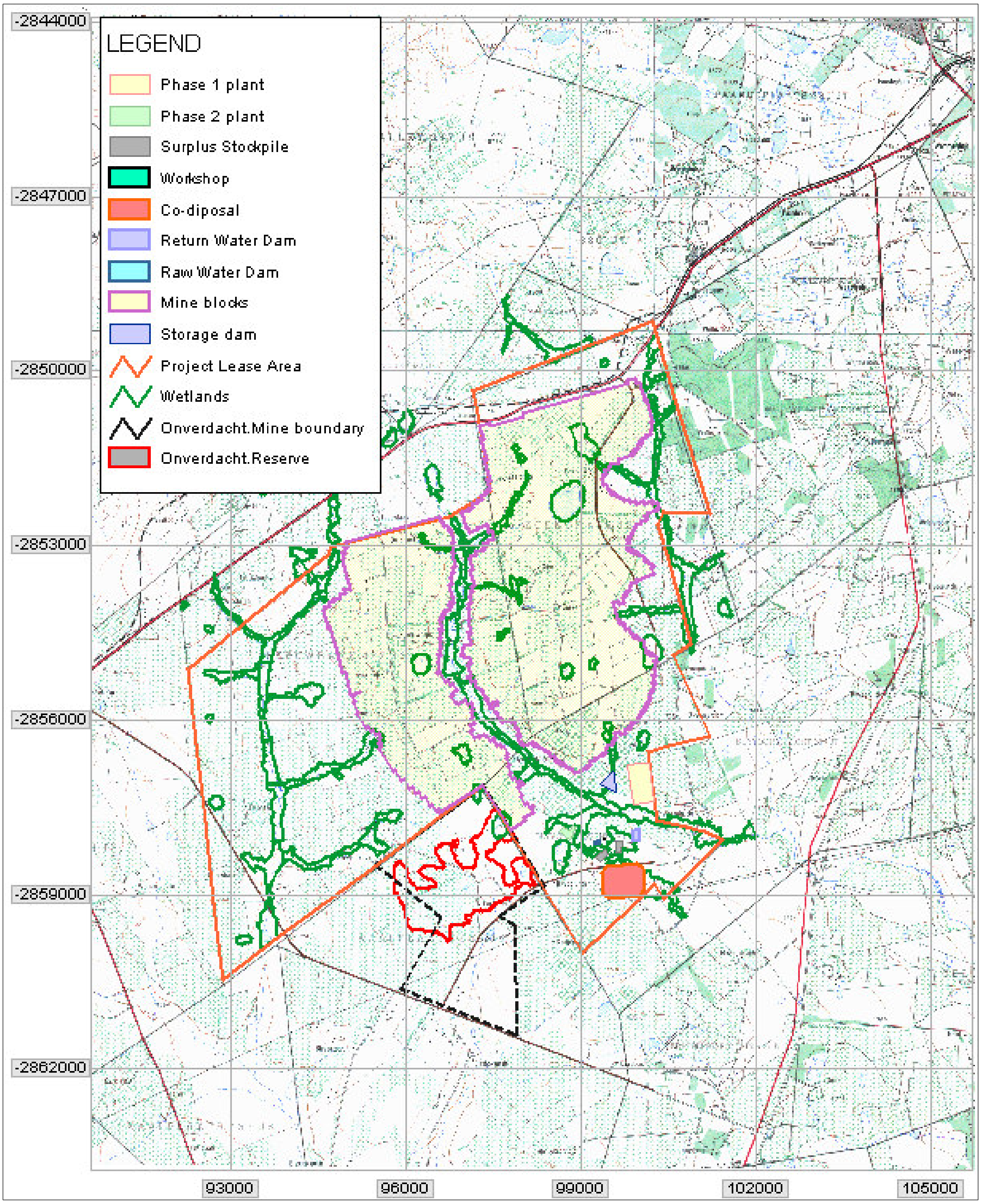


Figure 1.1-1: Locality map of the proposed new Belfast project

1.2 AMBIENT GEOHYDROLOGICAL CONDITIONS

1.2.1 Groundwater use (user survey/hydrocensus results)

From the hydrocensus and water user survey it followed that groundwater from boreholes is used mainly for domestic supply, livestock watering and watering of gardens at farmsteads. Yields in the Karoo type aquifers are too low to sustain any mentionable irrigation schemes. In general, borehole yields reported during the user survey for the local aquifers in the proposed Belfast project area correspond well with literature and more regional Karoo type aquifers with most yields being between 0.01 and 2 l/s. The overall yields therefore indicate that the aquifers in the area generally do not represent major aquifers.

Widespread pollution or depletion of the groundwater resource will impact negatively not only on the resource, but also on the users depending on the source as **sole source** of domestic water as well as for livestock and gardening. Apart from the groundwater use, the aquifers in the area provide a widespread base flow component to an abundance of surface water courses that will be affected should adverse impacts occur on the quality or availability of the resource. The positions of the hydrocensus localities are presented in **Figure 1.2.1-1**. The blue dots are boreholes while the blue squares are springs located during the hydrocensus.

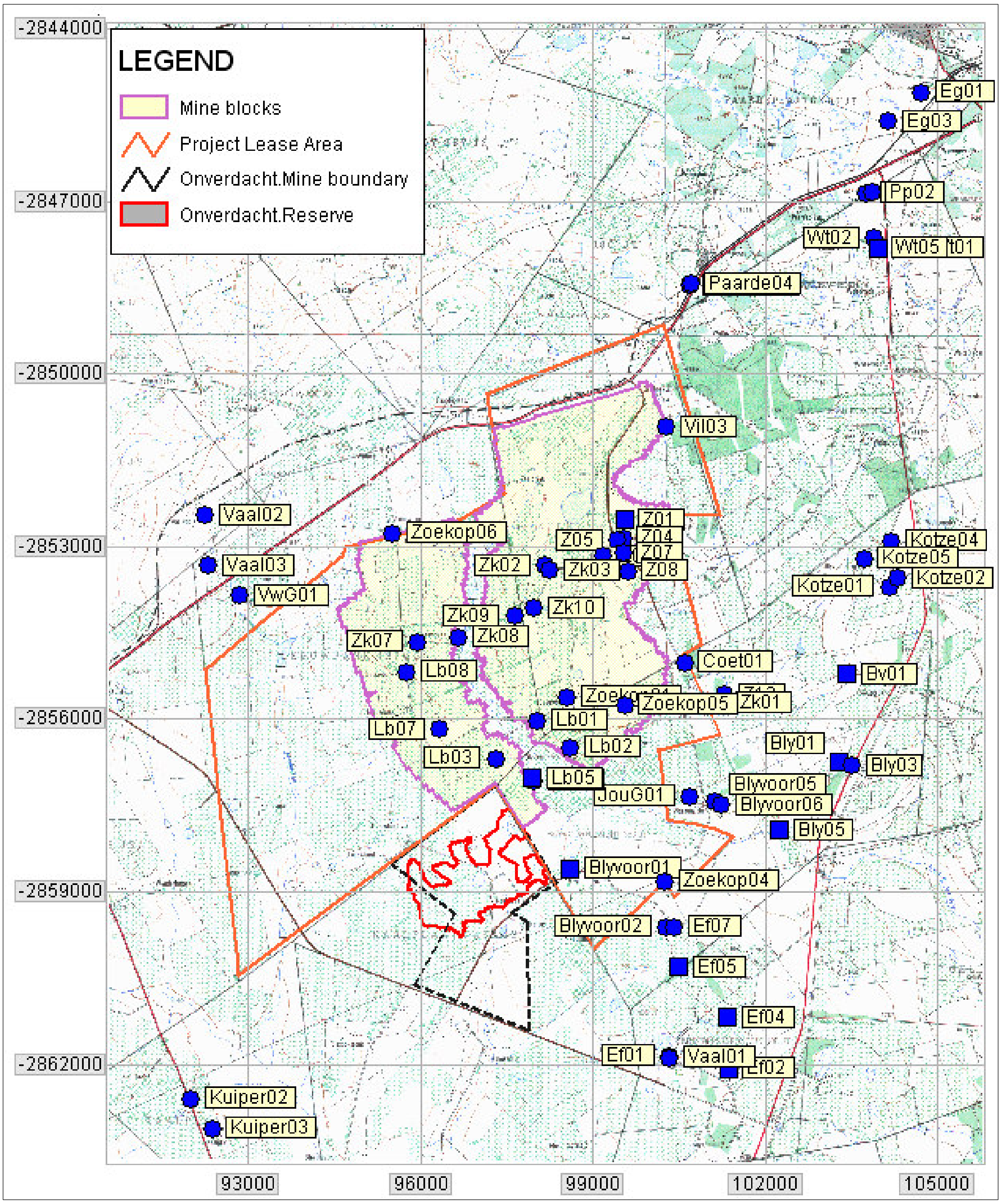


Figure 1.2.1-1: Boreholes and springs recorded during the 2009 hydrocensus survey of the area

1.2.2 Groundwater zone

The following aspects would delineate the applicable "Groundwater zone":

- The thickness, soil characteristics, infiltration rate and water bearing properties of the unsaturated zone.

- The geological properties and dimensions of each unit in the geological column that could potentially be impacted upon by groundwater contamination. This includes rock type, thickness of aquifer(s) and confining units, aerial distribution, structural configuration, storativity, water levels, infiltration or leakage rate, if appropriate.
- Aquifer recharge and discharge rates.
- The direction and rate of groundwater movement in potentially impacted units.
- Groundwater and surface water relationships.
- Background water quality of potentially impacted units.
- Potential sources and types of contamination.

1.2.2.1 Unsaturated zone

Based on the geological profile descriptions, the unsaturated zone is composed of sandy soils (reddish-yellowish brown) underlain by sandstone, siltstone, shale and coal, followed by diamictite and basement rocks of the older Transvaal Supergroup. The unsaturated zone impacts on the aquifer in terms of both groundwater quality and quantity.

The permeability and thickness of the unsaturated zone are some of the main factors determining the infiltration rate, the amount of runoff and consequently the effective recharge percentage of rainfall to the aquifer.

The type of material forming the unsaturated zone as well as the permeability and texture will significantly influence the mass transport of surface contamination to the underlying aquifer(s). Factors like ion exchange, retardation, bio-degradation and dispersion all play a role in the unsaturated zone.

The thickness of the unsaturated zone was determined by subtracting the pre-mining static water levels in the study area from the topography. Water level measurements in boreholes of users in the area showed that the depth to water level, and thus the unsaturated zone, generally varies between ± 0.5 and ± 16 meters below surface **(Figure 1.3.1-1)**. Although deeper static water levels were measured during the hydrocensus, some water levels had to be excluded because they represent boreholes where impacts from pumping for domestic water supply occurred at the time of measurement. Only the static water levels in boreholes where no pumping was known to occur were considered.

1.2.2.2 Geology of the study area

The Belfast project area is underlain by rocks of the Karoo Supergroup on a basement of the older Mokolian intrusives and extrusives.

The Karoo Supergroup comprises mainly a sedimentary succession of sandstones, shales and coal measures. The coal measures are contained within the Vryheid Formation that forms part of the Middle Ecca Group. The sedimentary succession overlies the Dwyka formation, comprising of diamictites and tillites at the base of the Karoo sequence. Igneous intrusives (dolerite dykes) of late Karoo age invariably characterize the Mpumalanga coal fields as was found at the proposed Belfast project.

The number 2, 3 and 4 seams will be mined. The number 3 coal seam, however, is described in the area and used mainly as a marker layer since it is not an economically mineable seam. Portions of the number 4 seam have been eroded away and vary significantly in thickness. A generalized vertical section of the sub-surface geology in the Belfast project area is presented in Figure 1.2.2.2-1.

A simplified geological surface map/plan of the area is presented as **Figure 1.2.2.2-2**, representing surface geology as reproduced from the 1:250 000 scale geological map of the area.

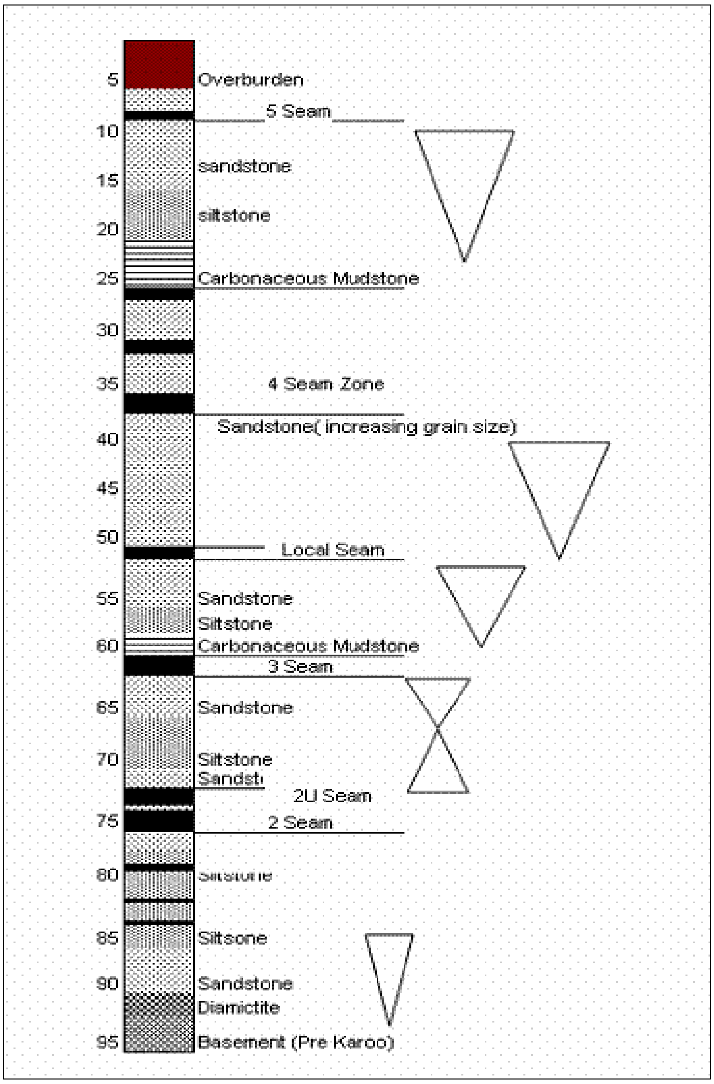


Figure 1.2.2.2-1: Stratigraphic Column of Belfast Project (Mining works programme for the proposed Belfast Coal mine, July 2009)

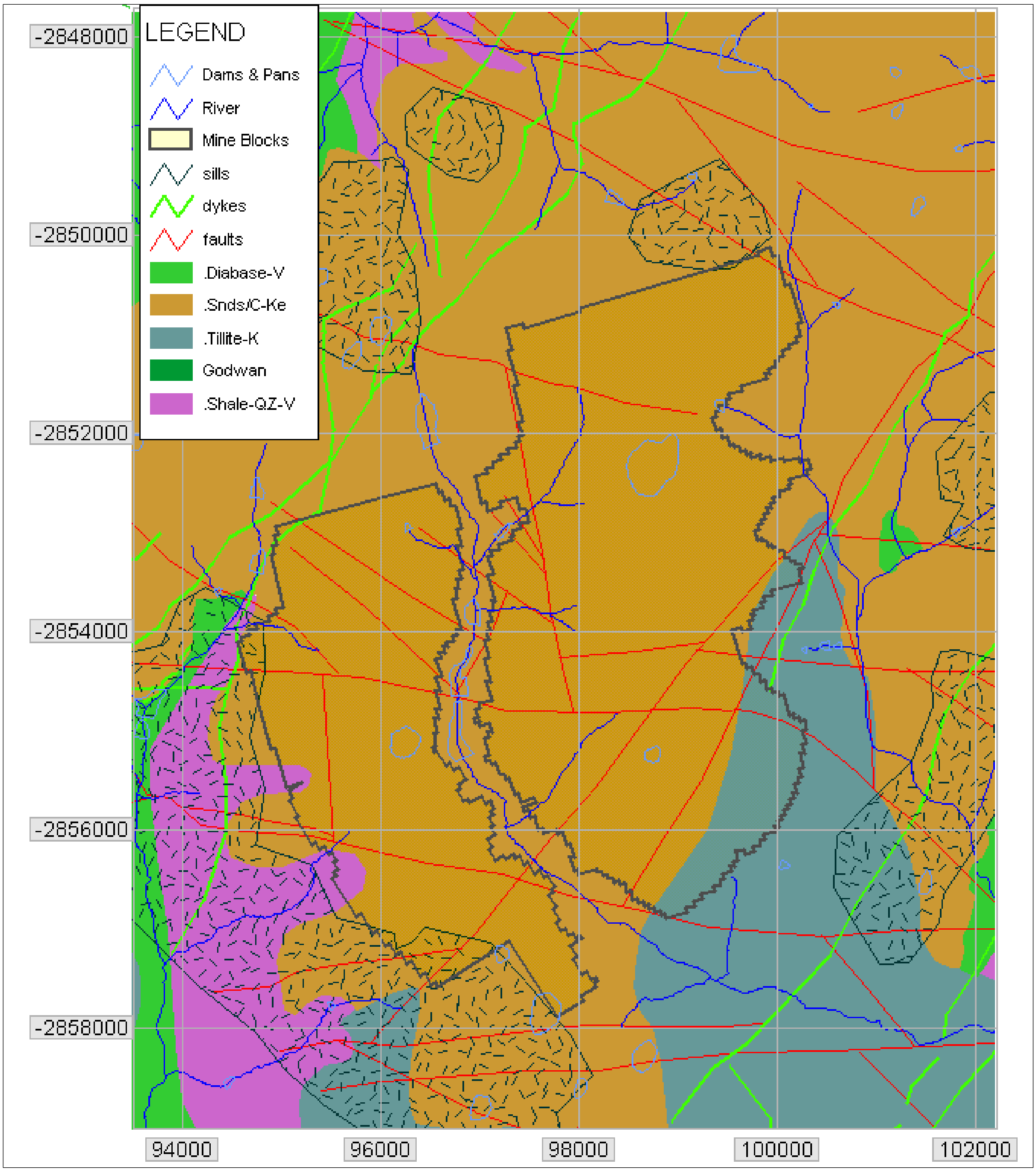


Figure 1.2.2.2-2: Simplified geological map (1:250 000 scale) of the proposed Belfast project area

The faults, dykes and sills indicated in the figure were mostly delineated during interpretation of the aeromagnetic survey conducted during the exploration phase. The intrusive dykes mostly trend NE-SW while the faults strike in random directions. The interpreted structures were used as basis for placement of monitoring boreholes, namely to plan geophysical line traverses for the magnetic and electro-magnetic field survey to site the boreholes. The presence of some of the structures was confirmed during the field survey but others were not located.

In a hard rock aquifer environment such as the Belfast project, understanding of the structural geology is of utmost importance since geological structures largely govern the flow and mass transport in the area. Fault zones may contain highly transmissive fracture zones that will act as preferred pathways for groundwater flow and mass transport. Intrusive dykes can play different roles, namely

- as barriers for horizontal groundwater flow and pollution movement so that the aquifer is compartmentalized, and
- the outer contact zones between the dyke and the sedimentary rocks is usually fractured and acts the same as a fault zone, namely as a preferred pathway for flow and mass transport along the sub-vertical fracture zone.

The dolerite sill can act in the same manner as a dyke, but the orientation is generally horizontal, resulting in a barrier for vertical groundwater movement and a horizontal seepage plane.

All this information was considered during the study, especially during formulation of the conceptual model and construction of the numerical model.

1.2.2.3 Geophysical investigations

Geophysical investigations were conducted at the proposed Belfast project during the exploration phase in the form of an aeromagnetic survey and during the groundwater study to delineate dolerite intrusions or fault zones where boreholes were to be placed for geohydrological characterization and later monitoring purposes.

All of the monitoring boreholes drilled during this investigation were sited through ground geophysical traverses using a combination of magnetic and electro-magnetic methods

The field results of the geophysical study are represented in **Appendix C**

1.2.2.4 Aquifer delineation

Aquifer delineation is conducted to show which part of the aquifer was used or considered during simulation exercises (numerical modeling) and/or for recharge and environmental water balance calculations. Because the main aquifer is a fractured rock type and fractures could assume any geometry and orientation, the physical boundary or 'end' of the aquifer is very difficult to specify or quantify.

No-flow boundaries are groundwater divides (topographically high or low areas / lines) across which no groundwater flow is possible. Constant head boundaries are positions or areas where the groundwater level is fixed at a certain elevation and cannot change. In nature, these will be formed by perennial rivers, dams, lakes or the ocean.

With the proposed Belfast project area mostly situated astride a surface and groundwater divide area, numerous aquifer boundaries can be specified without adding value to the study. More appropriately for the purpose of the study, the boundary conditions that have been considered during numerical model simulations can be described. Aquifer boundaries in a model mostly include no-flow boundaries (groundwater divides), constant head boundaries, or general head boundaries.

No-flow boundaries in a model, as in nature, are groundwater divides (topographically high or low areas / lines) across which no groundwater flow is possible. Constant head boundaries are positions or areas where the groundwater level is fixed numerically/mathematically at a certain elevation and cannot change. General head (or flux) boundaries are boundaries through which groundwater movement is possible. The rate at which the groundwater will move through the flux boundary depends on the groundwater gradient as well as the hydraulic conductivity specified for the boundary.

In the regional model constructed to include the proposed Belfast project area and surrounds, general head boundaries as well as constant head boundaries were used as model boundaries. The constant head boundaries were not inserted as constant head nodes in the model but **river nodes** were rather employed on the same elevations and positions where the larger streams occur near the mining area. The 'rivers' act very much the same as constant head boundaries. Water levels in the aquifer are largely fixed at these points and the river nodes will add water to (act as a losing stream) or remove water from (as a gaining stream) the aquifer if the surrounding model water levels respectively decrease below or rise above the assigned elevation of the river.

A no-flow boundary in a numerical model is usually represented by the end or edge of the active cells of the model grid. The regional Belfast project model area showing general head boundaries and river nodes is presented in **Figure 1.2.2.4-1**.

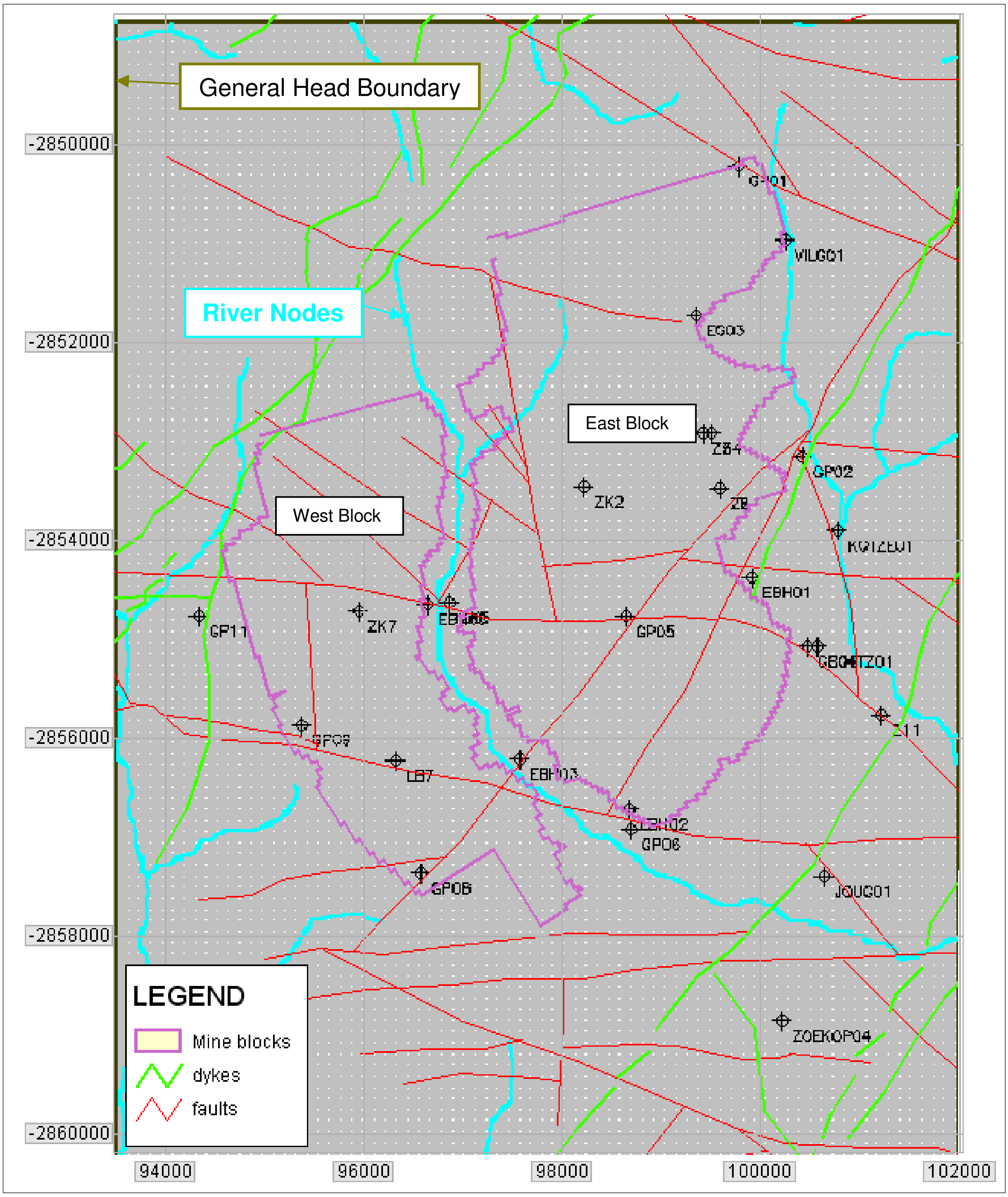


Figure 1.2.2.4-1: Regional Belfast project model area with river nodes and no-flow boundaries

1.2.2.5 Aquifer thickness

The aquifer thickness in the coal mining environment is often taken as the difference between the estimated static water level of the aquifer and the base of the lowest mined coal seam. In the vicinity of the Belfast project mineral boundary area, such an assumption cannot be made because of mainly two reasons:

- Very few significant groundwater strikes are usually recorded in or near the coal seams – this was true for all of the boreholes drilled for monitoring purposes.
- The main water strikes in the highest yielding boreholes occurred in faults or bedding plane fractures or between rock types of differing consistence and spatial distribution.

Additional to these facts, the nature of the fractured rock aquifers combined with the undulating topography of the Karoo sediments will result in very thick 'aquifers' in places where the coal is deep and in no 'aquifer' whatsoever where the coal reserve sub-outcrops or has been eroded away.

Considering the fact that the actual 'aquifer' consists of transmissive fractures, fissures or cracks of **any orientation, extent of aperture in any of the rock types** underlying the site, an **assumption can at best be made** on the thickness of the aquifer.

In the boreholes drilled in the vicinity of the proposed new Belfast project area, few water-yielding fractures were intersected. Those that were intersected occurred from ± 11 m to a maximum depth of 25 m. It is thus considered more accurate or appropriate to calculate the aquifer thickness from the piezometric water level to the deepest water yielding fractures in the study area.

On the basis of the drilling results during this investigation, the aquifer thickness in the region generally varies between approximately 3 and 22 meters. This ''thickness'' can definitely increase in some areas where much deeper water strikes occur in older basement rock types.

1.2.2.6 Generalised conceptual model

In an attempt to predict the movement of water in the subsurface, a conceptual geohydrological model of the area was postulated. The basis of such a model is the structural geological make-up, water strikes, yields and water levels depths and all other related information such as climate and soil of the study area.

As discussed previously, it is likely that the geohydrological regime in the study area is made up of two aquifer systems. The first, the upper, semi-confined aquifer would occur in the weathered zone and on pedological discontinuities (e.g. hardpan ferricrete formations). This aquifer is, however, poorly developed in the study area and only seepage moisture was intersected during drilling. It is concluded that this aquifer only develops during times of high rainfall (e.g. summer months) and is not used as a reliable source of groundwater supply.

The second aquifer is associated with fractures, fissures and joints and other discontinuities within the consolidated Karoo bedrock and associated intrusives where those are present. The aquifer occurs at depths of between 5 and 30 meters below surface in the study area.

Proposed mining at the Belfast project will penetrate both these aquifers and the physical structure of the aquifers will be destroyed.
Under natural conditions, water entering the groundwater system will migrate vertically downwards until a more impervious layer that forms a perched aquifer is encountered. As the perched aquifer did not feature during drilling at the proposed Belfast project it is likely that the majority of recharge water will migrate downwards into the saturated zone. From there it will migrate in the direction of the hydraulic gradient until it eventually enters surface water bodies (i.e. rivers or springs) from where it will discharge as surface water.

The lateral rate of migration usually exceeds the vertical rate, especially in a sedimentary rock environment where the layers are more or less horizontal. Vertical leakage through especially the Dwyka diamictites will be slow with higher recharge rates where sandstone and basement rocks outcrop. Two simplified sectional sketches to illustrate the vertical relationship between the topography and coal seam based on actual elevations are presented in **Figure 1.2.2.6-2**. The positions/traces of the vertical section lines have been indicated in **Figure 1.2.2.6-1**. The coal seams generally dip from north to south. A general dip of between 0.5% and 1% exists.

The sedimentary strata can therefore be described as sub-horizontal and the dip as such will have a very limited effect on groundwater seepage rate. The fact that the groundwater gradient is also generally southwards in the area, combined with the southward dip of the strata, will cause a stronger tendency for groundwater seepage and pollution migration in the southward direction. The effect of geological structures such as dykes and faults on groundwater flow and mass transport have been discussed briefly in Section 1.2.2.2. The relative transmissivities and other hydraulic properties of these structures were calculated through drilling and pump testing and were supplemented by literature values of research and testing in similar geological environments.

Opencast mining will cause major changes in the properties of the aquifers in the positions of the opencast pits. In the open pit position, the entire structure of the aquifer will be ripped out and hydraulic properties will change significantly. The major changes can be summarized as follows:

- The active void will have an infinitely high transmissivity and a storage coefficient of 1 and will act as a groundwater sink where it is developed below the depth of the static water level.
- The rehabilitated (backfilled) pit will have a transmissivity and storativity at least one to two orders of magnitude higher than the undisturbed aquifer host rock.
- Where semi-confined or confined aquifer conditions prevailed before mining, the ‘aquifer’ in the pit areas will change to unconfined.
- Effective recharge to the pit areas will also increase by an order of magnitude.
- The water quality in the pit area will also change dramatically, from very high quality water to saline water. The salinity will be caused by release of saline (especially chloride and sodium) connate water as well as acid-base reactions as a result of exposure of pyrite-containing carbonaceous material in and around the coal horizon to oxygen and water. These reactions will cause significant

deterioration of the water quality in the pit areas and will be discussed in more detail later in this report.

- The higher recharge rate to the pit areas will cause filling up of the rehabilitated and backfilled voids. The undisturbed surrounding aquifer will not be able to handle the higher recharge rate and the water will build up and flow out at the lowest surface elevation of the pit – it will decant.

All of these factors are included and play a role in the numerical simulation by calibration of the model and concepts will be illustrated in the model simulation.

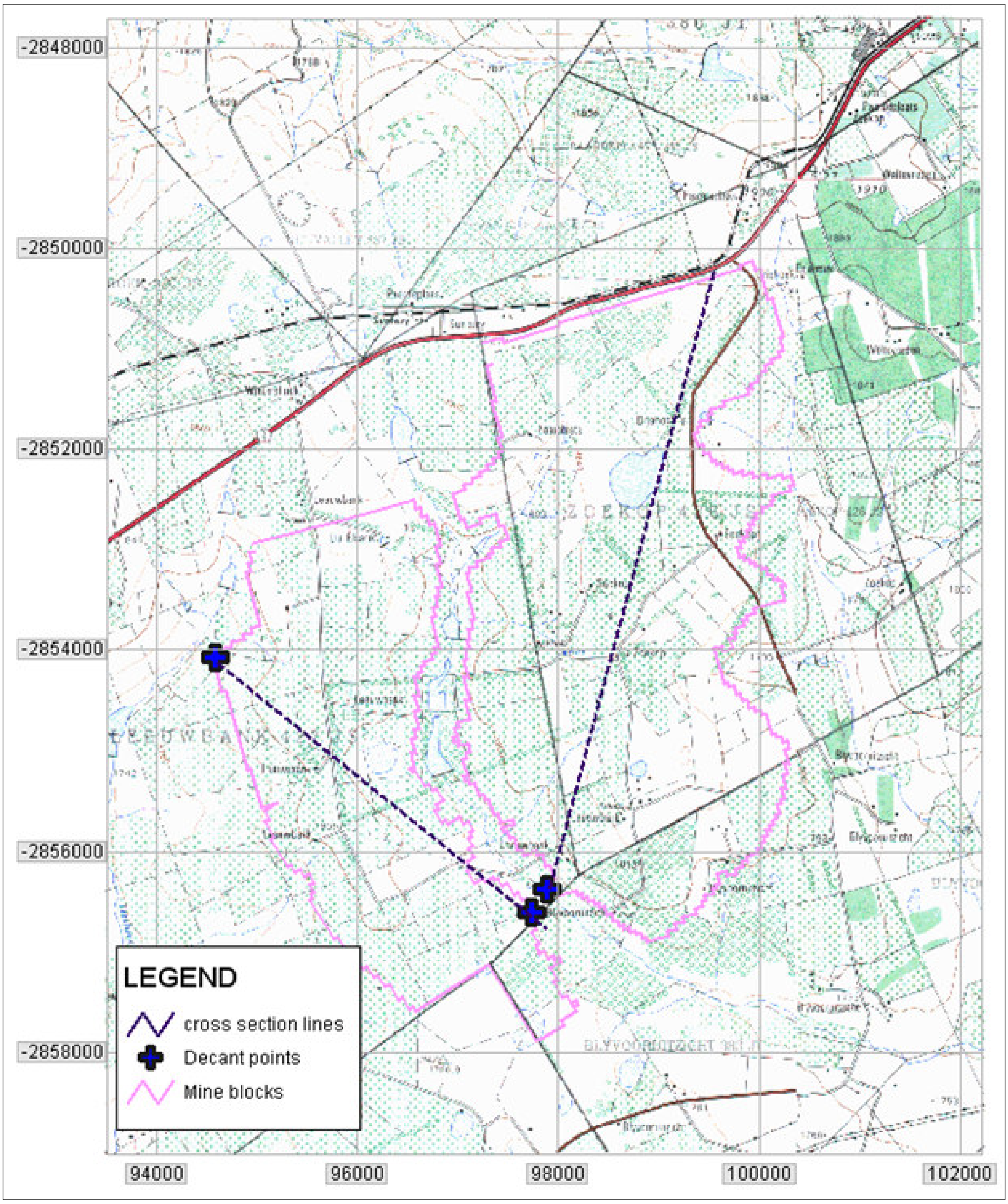


Figure 1.2.2.6-1: Vertical section position in relation with the study area

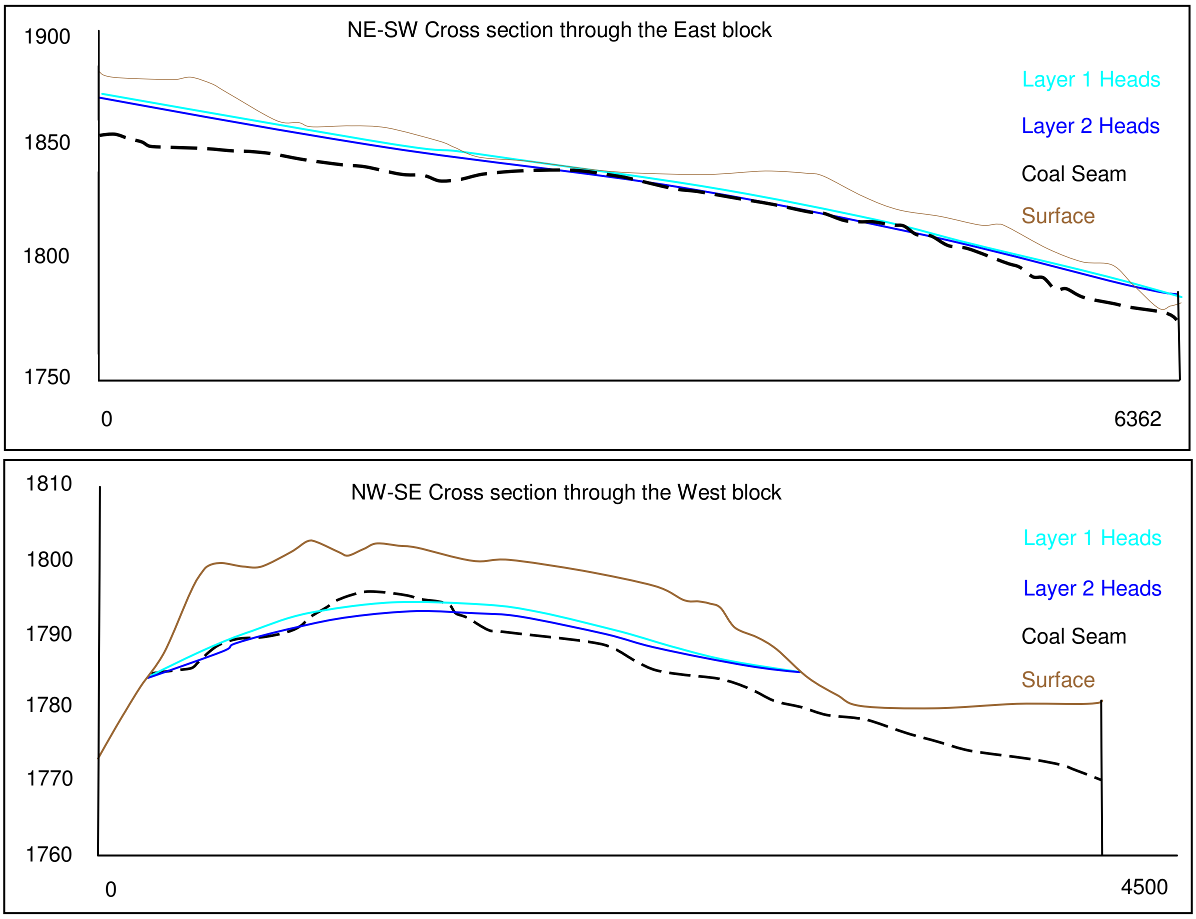


Figure 1.2.2.6-2: Vertical sections illustrating the relation between the basement coal seams, steady state heads in layer 1 and layer 2 of the model and the topography

1.2.3 Presence of boreholes and springs

As mentioned previously, a hydrocensus was conducted as part of this study around the proposed Belfast project area. As part of the hydrocensus, boreholes and springs were mapped within a 1 km radius of the proposed mining areas. The potential radius of influence on the groundwater regime around a coal mine in Karoo sediments is usually accepted as 1 km. A larger area was included in the survey because the radius of influence depends strongly on geological structures such as faults and dykes (preferred groundwater flow paths), groundwater gradients, nearby mining operations and the presence of other groundwater production boreholes or dewatering from mining in the area.

Experience from other coal mines in similar Karoo-type aquifer conditions has, however, indicated that the influences of open pit and underground coal mining activities on the regional groundwater level are usually not very extensive and usually limited to less than 0.5 km. Because of the heterogeneous nature of the aquifer(s), the presence of basement rocks on the fringes of the coal reserve and the proximity to farming, the area covered by the hydrocensus was extended to 2 km around the planned mining areas.

Different types of groundwater information were obtained for a total of approximately 45 points during the groundwater user survey and hydrocensus undertaken in August 2009.

The water supply source of each nearby user was sampled and analyzed for macro element inorganic chemistry. The yields of the hydrocensus boreholes varied between 0.1 l/s and 2 l/s, a range typical for the Karoo type aquifers. The yields of the monitoring boreholes drilled and pump tested in the mining area also compared very well with boreholes in similar Karoo aquifer environments.

Several springs were recorded in the areas under investigation. Springs in a semi-confined or confined fractured rock aquifer usually occur where structural discontinuities in the aquifer bisect the confining layer / material and a fracture or fracture system reaches the surface. For a spring to occur, the water level or piezometric head at that point in the aquifer must be higher than the land surface.

Although the natural trend for the groundwater level or piezometric head is to follow the surface topography, the water level is the closest to surface in the topographically low-lying areas. For this reason, springs will mostly occur in these areas, or at least on the slopes of hills. In perched and confined aquifers however, groundwater or piezometric levels may also be high in topographical higher lying areas with subsequent spring formation.

The geohydrological logs of all the groundwater monitoring boreholes are not discussed in detail because it would become somewhat exhaustive. The most important lithological intersections, water levels, and coordinates for all the drilled monitoring boreholes are indicated in **Table 1.2.3-3**. Logs of the monitoring boreholes are supplied in Appendix B of this document.

Table 1.2.3-3: Summary of monitoring borehole data

BH	Depth	Lithology*	X-Coord	Y-Coord	WL	Casing
GP01	31	Samples lost before logging	99802	-2850160	7.6	11
GP02	31	SOIL, SNDS	100452	-2853109	6.7	5
GP04	31	SOIL, SNDS	100494	-2855021	6.9	11
GP05	31	SOIL, SNDS, SHLE, COAL, SDSL	98656	-2854725	3.1	13
GP06	31	SOIL, SNDS	98721	-2856886	7.4	11
GP08	31	SOIL, SHLE	96591	-2857316	8.2	7
GP09	31	SOIL, SNDS, SHLE, COAL, SDSL	95380	-2855815	1.2	12
GP11	31	SOIL, SHLE, SNDS	94338	-2854716	4.6	11

* SHLE - Shale
SNDS - Sandstone
SDSL - Sandstone and Shale – interlaminated
WL – Water Level (meters below surface)
Casing – casing depth (m)
Co-ordinate system – Cape LO29

This geohydrological data, together with water level information, is crucial for better understanding of the geohydrological regime and processes that will determine groundwater types, flow and transport velocities and aquifer parameter distribution. All information gathered from these boreholes was used, where available, in the compilation of applicable parts such as the conceptual and numerical modeling, impact and risk assessments. The positions of the monitoring boreholes are indicated in **Figure 1.4-2**.

The groundwater monitoring boreholes in the proposed Belfast project area have been sited mainly on geological structures such as dykes or faults around the planned opencast mining operation. Groundwater seepage will be away from the mine blocks in a southern, south-western and south eastern direction.

As such, only one upgradient monitoring borehole occurs. All the boreholes have been drilled specifically for monitoring purposes at the new mining areas and were constructed accordingly.

Drilling results indicate that most of the **intersected aquifers** (coal/shale, and sandstone) have relative **low groundwater yields**. Yields vary from zero to less than 2 liter per second in the proposed new mining area with the most common groundwater intersections occurring in contact zones between Karoo Supergroup rocks such as coal and sandstone.

1.3 GROUNDWATER FLOW EVALUATION

1.3.1 Depth to water level

Groundwater levels in the Belfast project area are available from both the new monitoring and hydrocensus boreholes.

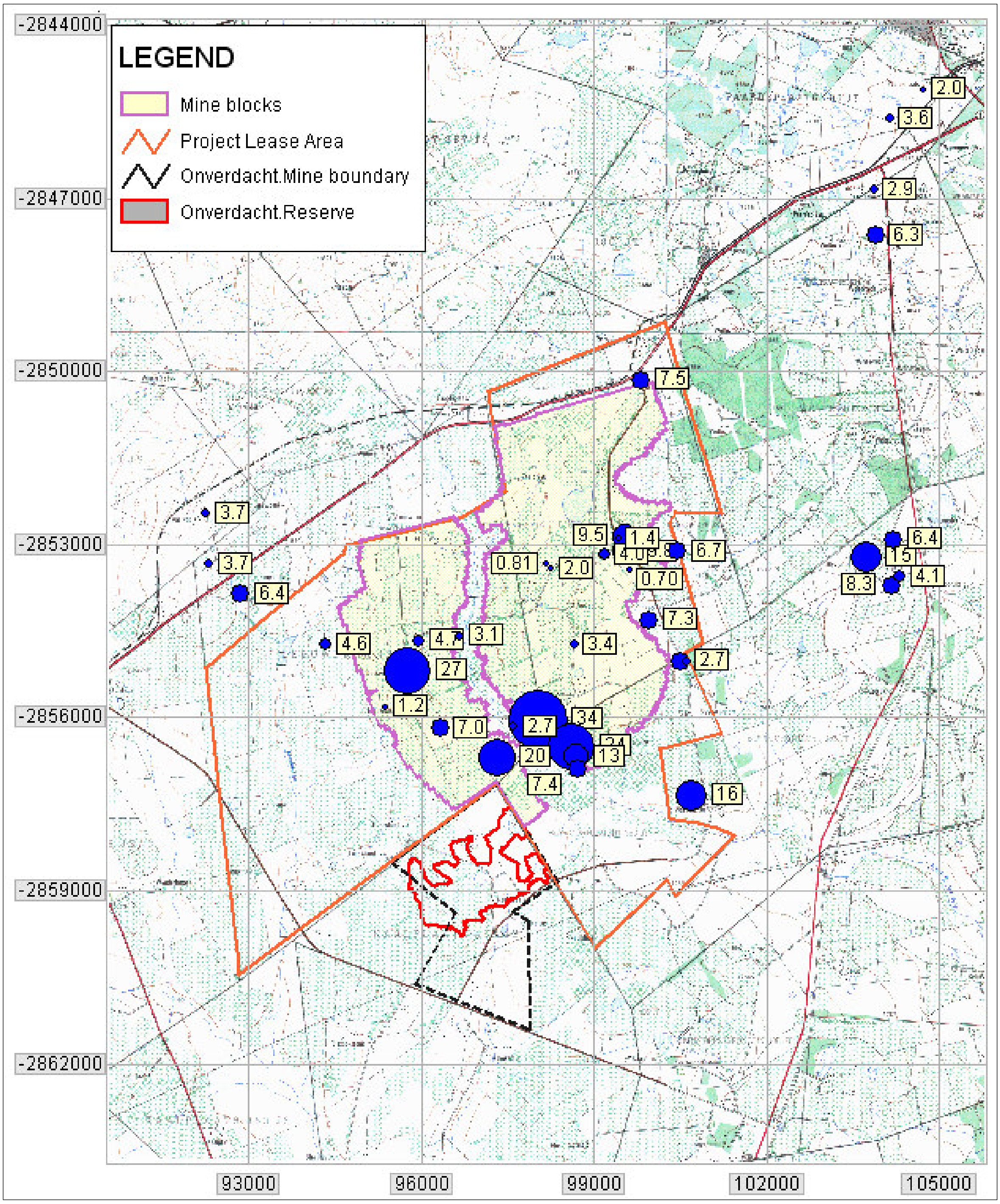


Figure 1.3.1-1: Thematic water level map of both hydrocensus and monitoring boreholes

In the proposed Belfast project area two interacting aquifer systems were identified, although they are mostly of the same aquifer type. In fractured bedrock (secondary) aquifers like those that dominate at the Belfast project, groundwater flow and mass transport are nearly fully restricted to open fissures, cracks or fractures in the relatively impermeable host rock matrix. Aquifer thickness, yield and other parameters thus fully depend on the characteristics of these fractures. Such characteristics include fracture aperture, extent, orientation, frequency and texture of the fracture-matrix interface.

The groundwater levels available from the hydrocensus and monitoring boreholes in and around the proposed opencast mining areas are presented in **Figure 1.3.1-1**. With all the available groundwater level data, the water level distribution was used to construct a groundwater level iso-surface (contour) map with the use of steady state flow model calibration **(Figure 1.3.1-2)**.

Regional static groundwater levels around the proposed Belfast project areas vary between 1 mbs and approximately 16 mbs. Some groundwater levels measured during the hydrocensus were significantly deeper than the general trend as a result of groundwater abstraction from the boreholes. Due to the generally low aquifer transmissivities the pumping causes deep drawdown of the groundwater levels/piezometric heads and depression cones form that are deep, but very limited in lateral extent.

Due to impacts from these groundwater abstraction areas as well as other potential impacts, the groundwater level does not always follow the trend of the surface topography. The highest static water level elevations are approximately 1 890 mamsl and occur in the topographically higher region north-east of the East mining block **(Figure 1.3.1-2)**. The lowest static water level elevations **where no impact from abstraction occurs** are at approximately 1 700 mamsl south-west of the West block.

Groundwater flow will be from the higher hydraulic head areas towards the lower hydraulic head areas perpendicular to the groundwater contours. Flow will therefore be from north to south, south-west and south-east.

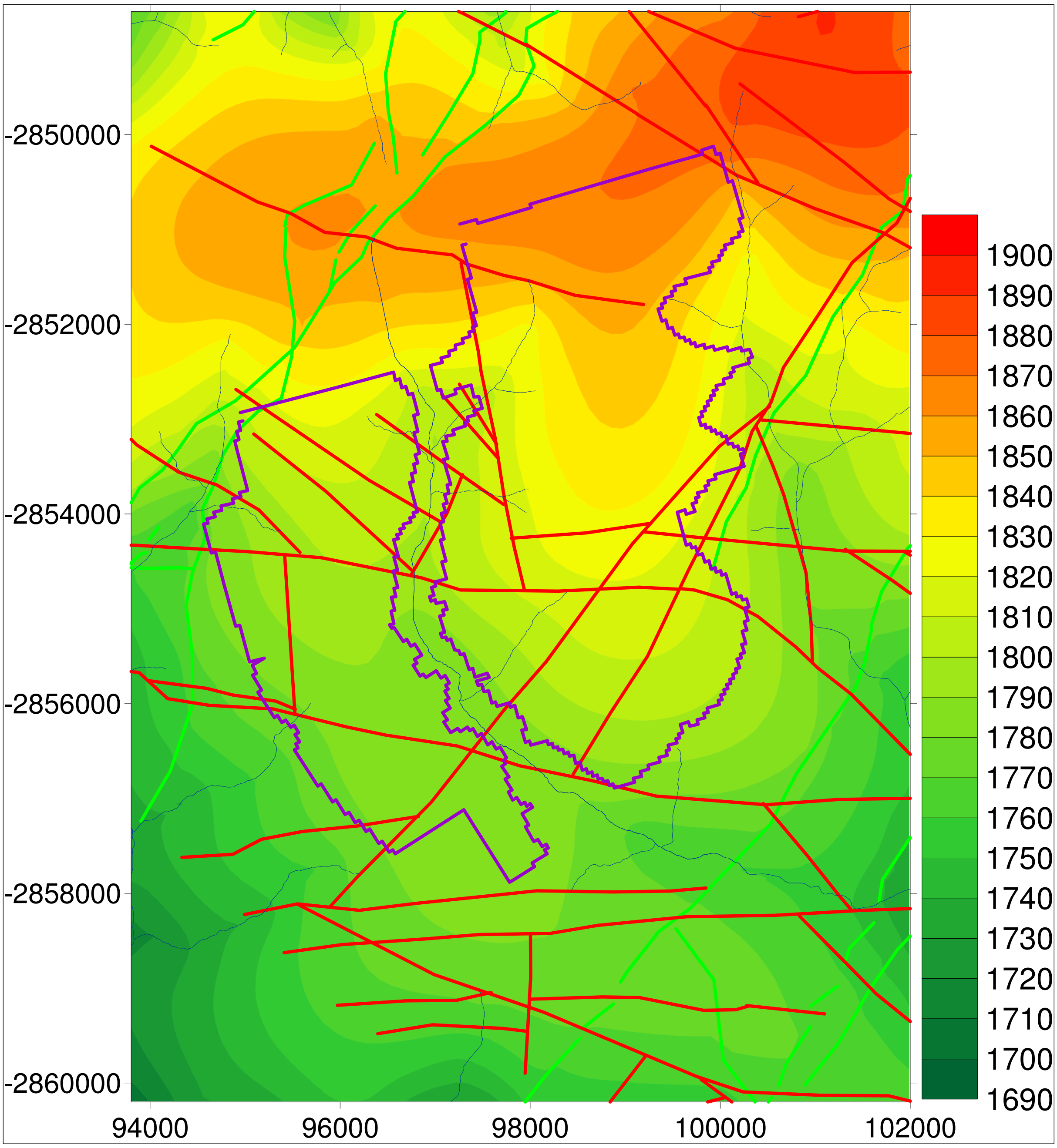


Figure 1.3.1-2: Steady state calibrated groundwater level contour map of the larger Belfast project area, indicating groundwater divides and preferred pathways.

Future water level impacts from opencast coal mining are expected to remain localized and should only be evident in boreholes within very close proximity (± 500 m) thereof. The reasons for expecting limited radius of influence from opencast mining are the:

- limited depth of the coal reserves – the mine voids will thus create limited groundwater gradients, and
- relatively low aquifer transmissivities that allow for limited depression cone formation.

The groundwater levels in the proposed mining area together with levels measured during the hydrocensus survey will be used as calibration points for the numerical groundwater model to verify the conceptual model and construction thereof. Seen in the light of water level differences because of mining, pumping and recharge effects, filtering and processing of water levels is required to remove water levels considered anomalous high or low. **The final interpolated potentiometric surface of the water levels is thus bound to contain local over- or under estimations of the actual water levels but it will be representative of the general regional trend of the static groundwater level.**

The natural interpolated groundwater level contours (without impacts from mining / other) were estimated through steady state model calibration and are presented in **Figure 1.3.1-2** as a contour map. The **natural** flow direction for groundwater differs locally and occurs away from the site in all directions except directly to the North. The directions of groundwater flow will always be perpendicular to the groundwater level contours.

In Karoo-type sediments like those underlying the proposed mining areas, it is generally accepted that the majority of groundwater flow occurs through the bedding plane fractures between the different sedimentary units. A digital iso-surface model of the base of the number 2 Seam coal horizon that will be mined is presented in **Figure 1.3.1-3**. It follows from the contour map that the coal floor in the Belfast project area has a general south-wards dip of approximately 1 to 1.2%.

The natural groundwater gradient and other influences such as groundwater abstraction or nearby mine voids/ quarries would have significant impacts on the natural drainage rate and direction.

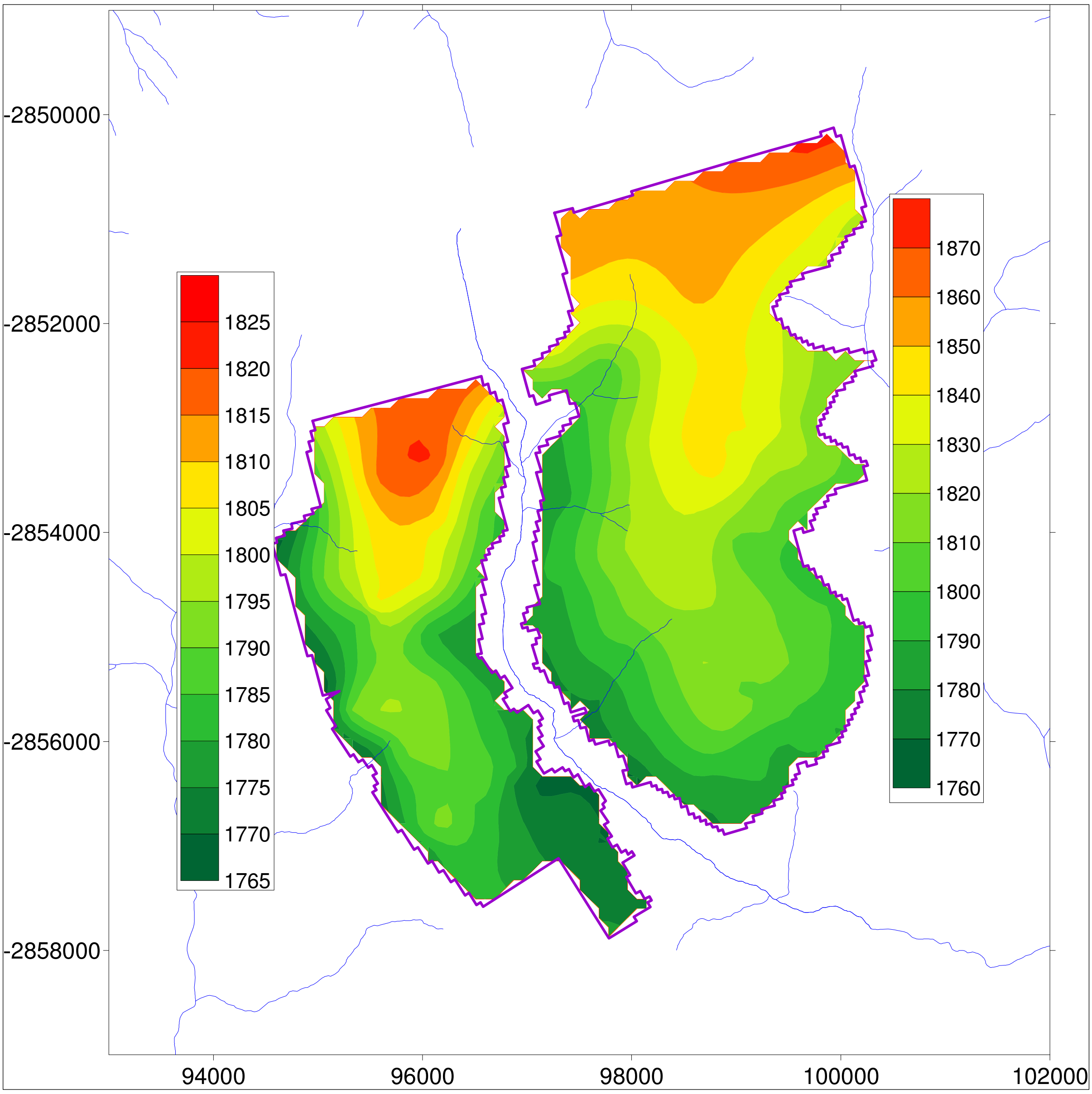


Figure 1.3.1-3: Coal floor contours of the 2Seam in the Belfast project coal reserve area

For the purpose of numerical modeling, some representative average groundwater level has to be specified as a starting point. There are also not enough groundwater level measurements available in each of the co-existing aquifer systems to produce a separate water level contour map for each system. It is thus likely that over-estimation in some areas and under-estimation of the water level in other areas will arise in the model. With the heterogeneous characteristics of fractured rock aquifers, interpolation of the water level with recognized techniques is preferable. The resulting groundwater level contours represent **average water levels** expected among an unknown number of co-existing aquifers.

1.3.2 Flow gradients

Contours of the static water level or piezometric heads in and around the Belfast project mineral rights area have been shown in **Figure 1.3.1-2**. Path lines or flow lines of groundwater particles are lines perpendicular to the contours. Flow occurs faster where contours are closer together and gradients are thus steeper.

On the relatively steeper sloping hillocks where groundwater gradients are higher, groundwater seepage rates are correspondingly higher. Seepage rates on the other hand are much lower in the flat plateaus and valley bottoms.

Average groundwater gradients were calculated from the water level elevation data. Groundwater generally flows from north to south at the East block and north-east to south-west at the West block. The average groundwater gradient at both blocks is estimated at between 1 and 1.2%.

1.3.3 Aquifer types and yield

From drilling results of 8 new monitoring boreholes as well as numerous other monitoring boreholes and geological exploration boreholes or for domestic and livestock water supply, two possible aquifer types have been found present in the study area. For the purpose of this study an aquifer is defined as a geological formation or group of formations that can yield groundwater in economically useable quantities. According to this definition of an aquifer, only the weathered-fresh interface or fractures in the hard rocks below the weathered zone could be defined as aquifers.

The first system is a shallow aquifer that occurs in the transitional soil and weathered bedrock zone or sub-outcrop horizon. This aquifer generally has a low yield with phreatic water levels sometimes occurring on un-weathered bedrock or clayey layers. Yields in this aquifer are low (generally less than 0.3 l/s) and the aquifer is not usable as a groundwater supply source on a continuous basis. Where consideration of the shallow aquifer system becomes important is during seepage estimations into open pit voids and mass transport simulations from mine-induced contamination sources because a lateral seepage component in the shallow water table zone in the weathered zone often occurs. According to the Parsons Classification system, the aquifer is usually regarded as a minor or even a non-aquifer system. By definition, an aquifer is a geological formation or group of formations that can yield groundwater in economical exploitable quantities.

Although groundwater seepage does occur in the weathered zone, the yields are very low and this zone cannot really be defined as an ‘aquifer’ according to the true meaning of the term. The main value and function of the shallow weathered zone ‘aquifer’ lies in the storage and transfer of moisture from rainfall to soil (laterally), vegetation (upwards) and the deeper aquifer (downwards).

The second aquifer system is the fractured Karoo rock-type aquifer where groundwater yields, although more heterogeneous, can be higher than the weathered zone aquifer. This aquifer system usually displays semi-confined or confined characteristics with piezometric heads often significantly higher than the water-bearing fracture position. The aquifer forms in transmissive fractures in the consolidated and mostly impervious bedrock. The fractures may occur in any of the co-existing host rocks due to different tectonic, structural and depositional processes. Aquifer yields in this system vary from zero to approximately 2 l/s in the Karoo rock types that occur in the Belfast project area.

Yields from this aquifer could be sufficient to supply drinking and sanitation water to mining operations but are too low to use as a source of process water supply. In the boreholes tested as well as surveyed during the hydrocensus, sustainable yields of between 0.1 and 2 l/s were determined. According to the Parsons Classification system, the aquifer could be regarded as a minor, but often a sole aquifer system.

The drilling and testing of the monitoring boreholes in the area indicated that the shallow weathered zone aquifer is poorly developed and will mainly manifest during the wetter summer months when significant seepage in the shallow weathered zone occurs. Because of its shallow position and direct interaction with the surface, this aquifer has most characteristics of a primary type aquifer.

In spite of relatively low expected blow-out yields or being dry altogether, pump tests were performed on the majority of the new monitoring boreholes, even if they did not show any significant water strike during drilling. These pump tests were performed using a low yield pump with the main aim of determining the transmissivity and storage characteristics of the solid geological formation – the so-called aquifer matrix. These low rate pump tests are performed instead of the more commonly used slug tests because of the much improved accuracy obtained with the pump tests, resulting in much more reliable aquifer parameters calculated from the tests.

The transmissivity values for boreholes in the proposed open pit mining areas were calculated and averaged **(Table 1.3.3.1)** to use as model input and calibration parameters.

1.3.3.1 Aquifer transmissivity and storativity

Aquifer transmissivity is defined as a measure of the amount of water that could be transmitted horizontally through a unit width of aquifer by the full-saturated thickness of the aquifer under a hydraulic gradient of 1. Transmissivity is the product of the aquifer thickness and the hydraulic conductivity of the aquifer, usually expressed as m^2/day (Length^2/Time).

Storativity (or the storage coefficient) is the volume of water that a permeable unit will absorb or expel from storage per unit surface area per unit change in piezometric head. Storativity (a dimensionless quantity) cannot be measured with a high degree of accuracy in slug tests or even in conventional pumping tests. It has been calculated by numerous different methods with the results published widely and a value of 0.002 to 0.01 is taken as representative for the Karoo Supergroup sediments.

Table 1.3.3.1: Aquifer parameters of monitoring boreholes

Borehole	Tf	Tm	Sf	Sm
Unit	m^2/d	m^2/d		
EBH01	1.7	0.2	0.005	NA
EBH02	1.9	0.2	0.004	NA
EBH03	59	14	0.005	0.1
EBH08	1.7	0.5	0.004	0.007
GP01	1.1	0.2	0.002	NA
GP02	29	7.7	NA	0.005
GP04	29	8.8	NA	0.007
GP05	13.6	5.5	0.006	0.04
GP08	1.6	0.2	0.004	0.005
GP09	1.5	0.4	0.003	0.01
GP11	10.3	4.8	0.001	0.007
Harmonic Mean	2.6	0.4	0.003	0.01
Geometric Mean	5.3	1.2	0.004	0.015
Har + Geo Mean Average	**4.0**	**0.8**	**0.003**	**0.012**

***Note**:*
Tf – Transmissivity at the start of the test, usually fracture dominated flow.
Tm – Transmissivity at the end of the test, usually matrix dominated flow.
Sf – Storativity at the start of the test, usually fracture dominated flow.
Sm – Storativity at the end of the test, usually matrix dominated flow.
NA – not accurately determinable by the specific method or test or unrealistic result.

The GP boreholes targeted anomalies indicated by geophysical surveys. The transmissivities in the numerical model for the general aquifer matrix are thus slightly lower than those indicated in Table 1.3.3.1.

1.3.3.2 Aquifer recharge and discharge rates

Recharge in the Belfast project area is estimated as between 1 and 3 % of MAP. Where sandstone outcrop occurs, the effective recharge percentage can be slightly higher while in low-lying topographies where discharge generally occurs and thicker sediment deposition, the effective recharge will be lower. Based on this estimate, the average recharge to the pre-mined East mine block area referred to in **Figure 1.2.2.4-1** is approximately 920 m^3/d (337 000 m^3/y) and to the West block approximately 510 m^3/d (188 000 m^3/y).

1.3.3.3 Direction and rate of groundwater movement in potentially impacted areas

The pre-mining static groundwater contours are presented in **Figure 1.3.1-2** and were constructed with the use of steady state model calibration. These contours represent steady state conditions without impacts from sources or actions other than natural conditions like rivers, natural spring discharges, pans or wetland recharge areas.

A large number of manmade actions could impact on the groundwater regime; including the aquifer structure, flow paths and directions, storage, discharges and recharge. Possible impacts relevant to the proposed project will be discussed briefly:

Aquifer structure, flow paths and directions

During active mining and thereafter, the voids created by mining will impact on the natural groundwater movement. Mine voids destroy the in situ aquifer structures and could be compared to areas of very high (even infinitely high) transmissivity and also high storativity. Because groundwater will follow the route of least resistance, groundwater will prefer to move through the mined-out areas.

The final mined area and inter-mine flow relationships will directly determine the final groundwater flow paths, directions and decants.

Even after the mine has been closed and the mine voids have been backfilled, the transmissivity and storativity remain higher than the pre-mining natural aquifer(s). Because the Karoo rocks where mining will take place have relatively low transmissivity values, impacts on the natural flow pattern in the Belfast project region are expected to be noticeable to a limited extent and in the immediate vicinity of the operations. The extent of the impact depends mostly on the transmissivity of the *in situ* aquifer material. Karoo type formations in the coal mining environment generally do not have very high *in situ* transmissivities, as could be seen from the pumping test analyses.

Aquifer discharge

A mining and processing operation may impact significantly on the discharge of an aquifer in different ways. If mining occurs and mine dewatering is required, the natural aquifer discharge will decrease by the volume of groundwater removed by dewatering. Aquifer discharge may also increase with the use of return water dams, slurry and other dams through leakage of water to the subsurface, especially if water is imported to the project from other sources. Other factors that may decrease the aquifer discharge are compacted surfaces, haul roads and concrete surfaces that prevent infiltration to the aquifer and decrease groundwater discharge, although increasing surface runoff.

The relative surface area of these features is however usually a very small percentage of the total surface area of the operation.

After mine closure, however, recharge is usually significantly higher to the backfilled mine void compared to the pre-mining aquifer and after filling up, the discharge is usually higher than before the disruption by mining. The effective recharge is especially higher for opencast mining and can be as much as 5 to 15 times the natural recharge without the effect of mining. With all proposed mining in the Belfast project area being opencast operations, the recharge pattern will thus be changed dramatically.

Aquifer recharge

All the aspects mentioned under aquifer discharge apply to aquifer recharge. Opencast mining usually causes a significant increase in aquifer recharge percentage. Surface water features like dams (tailings, slurry, process water, storm water, return water etc.) will also usually increase the recharge to the aquifer but compacted or concrete surfaces and roads will decrease the recharge.

1.4 *GROUNDWATER QUALITY EVALUATION*

Groundwater qualities in and around the proposed Belfast Project areas were measured where possible in boreholes of nearby users during the hydrocensus and the new monitoring boreholes. The groundwater quality data were evaluated with the aid of diagnostic chemical diagrams and by comparing the inorganic concentrations with the South African Drinking Water Guidelines for Domestic Use **(Table 1.4-1)**. The groundwater quality data were collected from two sources namely: the analysis of groundwater samples taken from **hydrocensus boreholes** and purpose drilled **monitoring boreholes**.

Table 1.4-1: South African Drinking Water Standards

Chemical Parameter	Ideal	Recommended	Absolute Maximum
	mg/l		
Calcium	0 - 150	150 - 300	300
Chloride	0 - 200	200 - 600	600
Chromium	0 - 0.1	0.1 - 0.5	0.5
Copper	0 - 1	1 - 2	2
EC	0 - 150	150 - 370	370
Fluoride	0 - 1	1 - 1.5	1.5
Iron	0 - 0.2	0.2 - 2	2
Lead	0 - 0.02	0.02 - 0.05	0.05
Magnesium	0 - 70	70 - 100	100
Manganese	0 - 0.1	0.1 - 1	1
Potassium	0 - 50	50 - 100	100
Sodium	0 - 200	200 - 400	400
Sulphate	0 - 400	400 - 600	600
TDS	0 - 1000	1000 - 2400	2400

Because only once-off monitoring data exists for many of the boreholes, time-series data, statistical analysis and trend analysis are not possible. The first step in the water quality interpretation was to classify the groundwater quality

The classification was based on the following:

- the spatial distribution of the monitoring points, and
- the proximity of the monitoring points to certain known pollution sources that are expected to impact on the groundwater and / or surface water in the downstream flow direction area.

The four main factors usually influencing groundwater quality are:

- **annual recharge** to the groundwater system,
- **type of bedrock** where ion exchange may impact on the hydrogeochemistry,

- **flow dynamics** within the aquifer(s), determining the water age, and
- **source(s) of pollution** with their associated leachates or contaminant streams.

Where no specific **source of groundwater pollution** is present upstream of the borehole, only the other three factors play a role.

One of the most appropriate ways to interpret the type of water at a sampling point is to assess the plot position of the water quality on different analytical diagrams like a Piper, expanded Durov and Stiff diagrams. Of these three types, the expanded Durov Diagram probably gives the most holistic water quality signature.

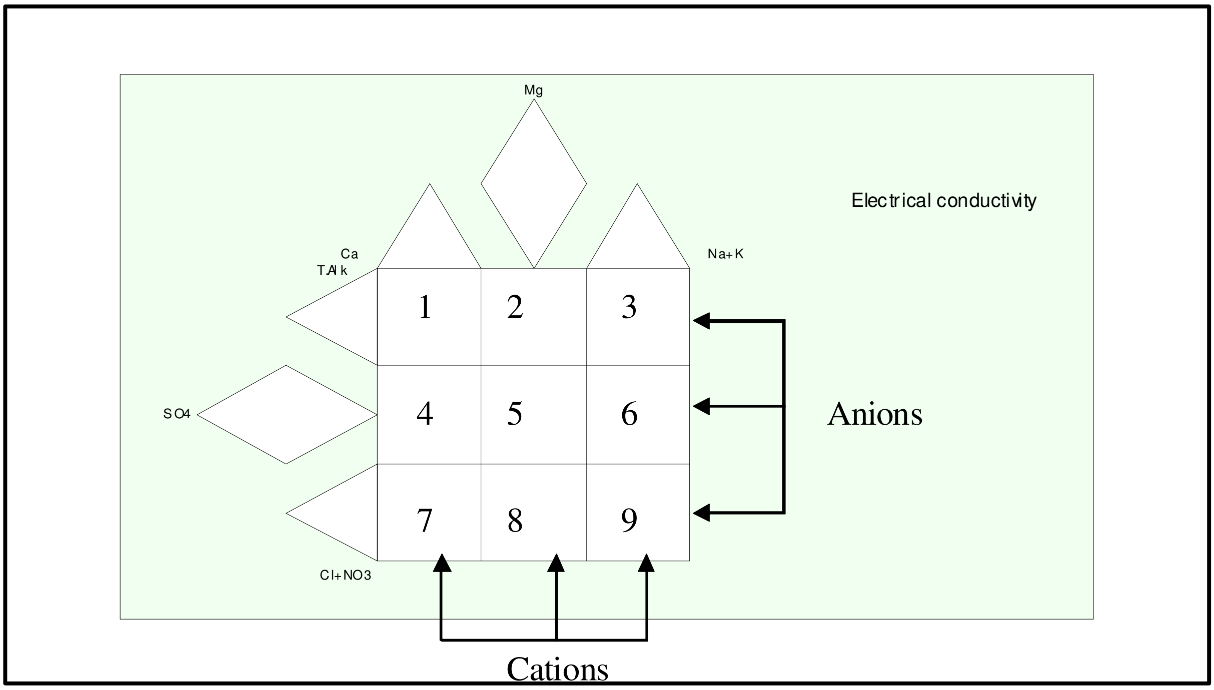


Figure 1.4-1: Layout of fields of the expanded Durov diagram

Although never clear-cut like a fail-safe recipe, the general characteristics of the different fields of the diagram could be summarized as follows:

Field 1:
Fresh, very clean recently recharged groundwater with HCO_3 and CO_3 dominated ions.
Field 2:
Field 2 represents fresh, clean, relatively young groundwater that has started to undergo mineralization with especially Mg ion exchange.
Field 3:
This field indicates fresh, clean, relatively young groundwater that has undergone Na ion exchange (sometimes in Na - enriched granites or felsic rocks) or because of contamination effects from a source rich in Na.
Field 4:
Fresh, recently recharged groundwater with HCO_3 and CO_3 dominated ions that has been in contact with a source of SO_4 contamination or that has moved through SO_4 enriched bedrock.

<u>Field 5:</u>
Groundwater that is usually a mix of different types – either clean water from fields 1 and 2 that has undergone SO_4 and NaCl mixing / contamination or old stagnant NaCl dominated water that has mixed with clean water.
<u>Field 6:</u>
Groundwater from field 5 that has been in contact with a source rich in Na or old stagnant NaCl dominated water that resides in Na rich host rock / material.
<u>Field 7:</u>
Water rarely plots in this field that indicates NO_3 or Cl enrichment or dissolution.
<u>Field 8:</u>
Groundwater that is usually a mix of different types – either clean water from fields 1 and 2 that has undergone SO_4, but especially Cl mixing / contamination or old stagnant NaCl dominated water that has mixed with water richer in Mg.
<u>Field 9:</u>
Old or stagnant water that has reached the end of the geohydrological cycle (deserts, salty pans etc) or water that has moved a long time and / or distance through the aquifer or on surface and has undergone significant ion exchange because of the long distance or residence time in the aquifer.

The layout of the fields of the Expanded Durov diagram (EDD) is shown in **Figure 1.4-1**.

Another way of presenting the signature or water type distribution in an area is by means of Stiff diagrams. These diagrams plot the equivalent concentrations of the major cations and anions on a horizontal scale on opposite sides of a vertical axis. The plot point on each parameter is linked to the adjacent one resulting in a polygon around the cation and anion axes. The result is a small figure / diagram of which the geometry typifies the groundwater composition at the point. Groundwater with similar major ion ratios will show the same geometry. Ambient groundwater qualities in the same aquifer type and water polluted by the same source will for example display similar geometries.

In terms of suitability of the groundwater for agricultural use (irrigation) the SAR diagram (Sodium Adsorption Ratio) is a handy tool to assess the suitability of the water. Sodium enrichment with respect to Ca and Mg in groundwater will present a risk of sodium accumulation in soils (especially when clayey) and cause deterioration in soil structure and increase erodability because of dispersion reactions in the soil. Soils will form surface crusts, compaction rates will increase which will in turn cause poorer infiltration, higher runoff and more erosion.

The typical impacts on groundwater quality caused by coal mining operations include different chemical reactions such as ion exchanges, mobilization and precipitation of ions and / or groups of ions. Sulphate (SO_4) related chemical reaction is one of the most important reactions in this regard and is a fair representation of pollution in coal mines. SO_4 related reactions take place when it enters the groundwater system through oxidation of pyrite through chemical weathering, mining, washing or percolation through stockpiles of the host material, coal.

An example of a reaction is:

$2FeS_2$ + $7O_2$ = $2FeSO_4$ + $2H_2SO_4$

pyrite + oxygen = iron sulphate + sulphuric acid

Iron sulphate forms, as well as sulphuric acid (H_2SO_4), causing decreases in the pH and mobilization of metal ions (that are usually more soluble at a low pH). The reactions are collectively referred to as **Acid Mine Drainage** (AMD). Composite samples were taken from the coal and carbonaceous overburden. **Acid Base Accounting** (ABA) was done on the samples in order to determine the acid generating potential of the material. The results of the ABA are discussed in **Section 3.2.1** of the document.

As seen from the reaction equation, oxygen is required for the oxidation and consequent acidification to take place. At the pre-mining environment of the proposed Belfast project, coal reserves and associated pyrite mostly occur below the static groundwater level and under anaerobic conditions, causing a reducing chemical environment and none of the acid mine drainage reactions to occur.

1.4.1 Regional groundwater quality evaluation

During the site investigation and hydrocensus conducted by Clean Stream Scientific Services, groundwater qualities around the proposed Belfast project areas were measured at 39 boreholes and springs.

A map showing the distribution of the borehole positions where groundwater quality information is available is presented in **Figure 1.4.1-1**.

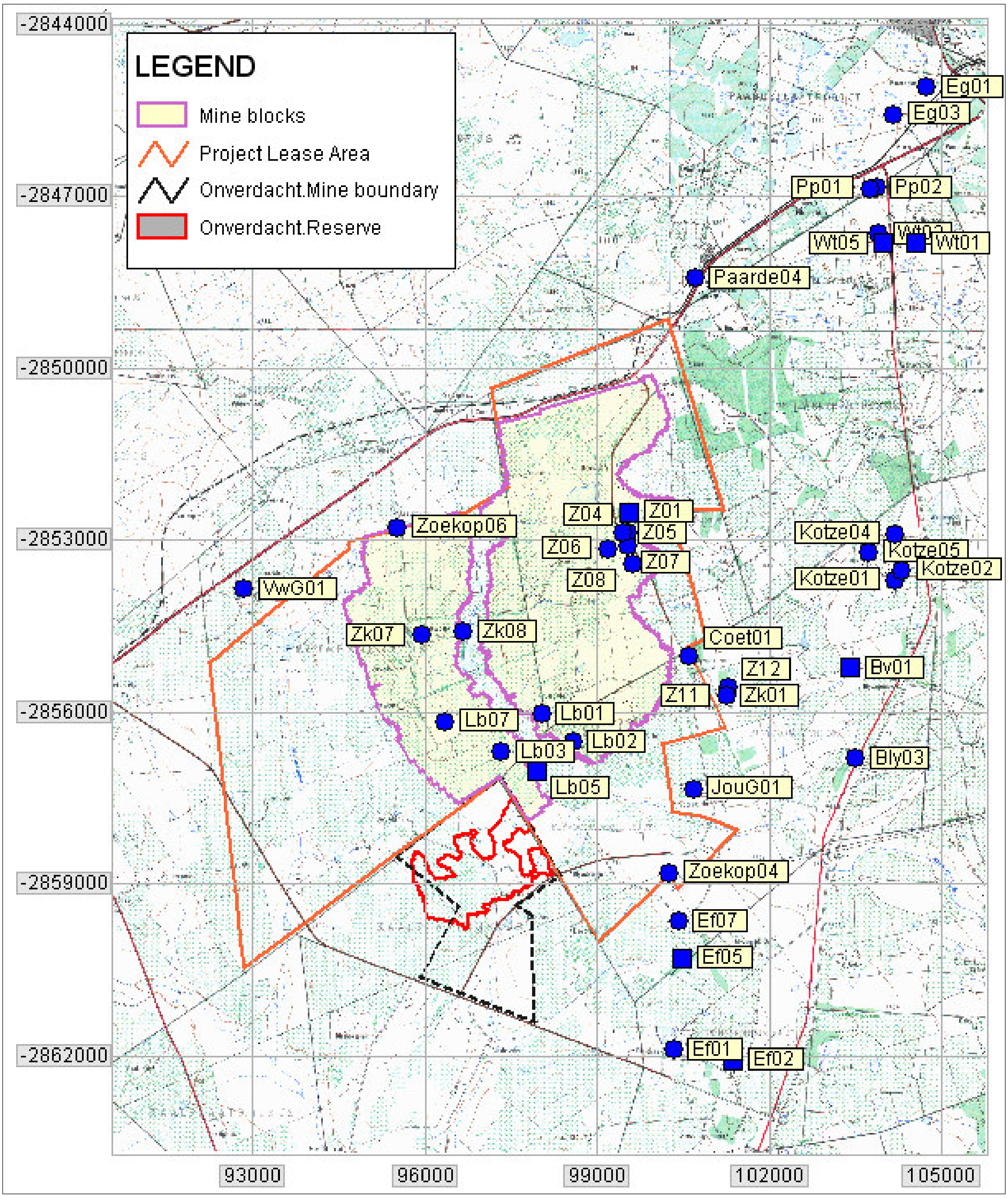


Figure 1.4.1-1: Distribution of hydrocensus sampling points

In the wider Belfast project area most of the boreholes of surrounding users display very good groundwater quality. The direct analyzed groundwater qualities are presented in the hydrocensus report in table format and measured concentrations are compared with guideline concentrations and standards. The hydrocensus report is attached in **Appendix A** of this document.

The reason for the good ambient quality is the fact that no groundwater quality impacts from mining or similar operations occur in the area and the aquifer host rocks are mostly inert. The highest measured electrical conductivity is 210 mS/m at Ef5, which exceeds the ideal limits for domestic use. Electrical conductivity exceeds the ideal limits only in Ef5. Ef5 is impacted on by some source, with sulphate concentrations in Ef5 exceeding the maximum permissible limits for drinking water. Elevated fluoride concentrations are visible in Zk1 (1.3 mg/l) and Lb3 (1.9 mg/l). The fluoride concentrations in Lb3 exceed the maximum permissible limits for drinking water.

If the spatial distribution of qualities over the area is considered, no definite trend of better or poorer quality is discernible.

The ambient groundwater levels are usually relatively shallow with rest water levels generally less than 16 m below surface. The average rainfall is in the order of 700 mm per year and even with a low effective **recharge percentage,** a good natural groundwater quality is to be expected since active recharge occurs and stagnation of groundwater in aquifers is very uncommon.

The hydraulic conductivities of the bedrock in the vicinity of the boreholes are usually in the order of 10^{-3} m/d. Such conductivities should facilitate a sufficient flow rate to prevent stagnant groundwater conditions, especially where groundwater gradients are higher such as along the sloping topography. As with similar aquifers in the Karoo Supergroup a significant proportion of groundwater seepage does not go down vertically to the solid bedrock zone but drains horizontally in the weathered zone between 1 and 15 m below surface. Evapotranspiration along the riparian zones also play a major role in the groundwater balance.

Aquifer flow dynamics, in spite of the relatively low matrix transmissivities, do appear to be sufficient to facilitate the existence of fresh groundwater in the proposed Belfast project areas.

Differences in inorganic ion content can be ascribed to ion exchange reactions occurring from the moment that recharge enters the land surface and continues all the way down the geohydrological cycle. The groundwater infiltrates the subsurface and aquifer, thereby coming into contact with different rock types where different degrees of ion exchange occur. The seepage rate (caused by groundwater gradient, storativity and transmissivity), the type of aquifer host rock and the prevailing redox conditions determine the degree of ion exchange that will take place.

In none of the boreholes does the **type of bedrock** in which the aquifer occurs seem to significantly impact on the chemical composition of the groundwater. If groundwater salinities or indicator parameters are plotted against the backdrop of the regional geology, no clear correlation between groundwater quality and geology is discernible.

As could be expected from the large area under investigation with different aquifer types, different aquifer residence times and recharge/discharge zones, the groundwater qualities measured during the hydrocensus survey are not confined to a single field of the expanded Durov diagram included in **Figure 1.4.1-2**.

The qualities are distributed all over the diagram with the majority of the points occurring in fields 2 and 3 of the diagram, indicating relatively fresh, recently recharged groundwater that has started to be mineralized through ion exchange of calcium being replaced by magnesium.

The groundwater qualities are dominated by magnesium or sodium on the cation side. Bicarbonate alkalinity, sulphate or chloride/nitrate dominates the anion side.

Stiff diagrams of the regional groundwater qualities around the proposed new mining areas of 20 of the sampled boreholes are presented in **Figure 1.4.1-3**. The geometries of the Stiff diagrams with very low ion concentrations show that the groundwater is of excellent quality.

From the SAR diagram in **Figure 1.4.1-4** it follows that most of the groundwater in the area present low sodium hazard and a low salinity hazard towards soil and vegetation if used for irrigation. Ef5 is the only spring indicating a high to very high salinity hazard. Further discussion on this aspect is not considered applicable since the groundwater of the area is not used for irrigation on any meaningful scale.

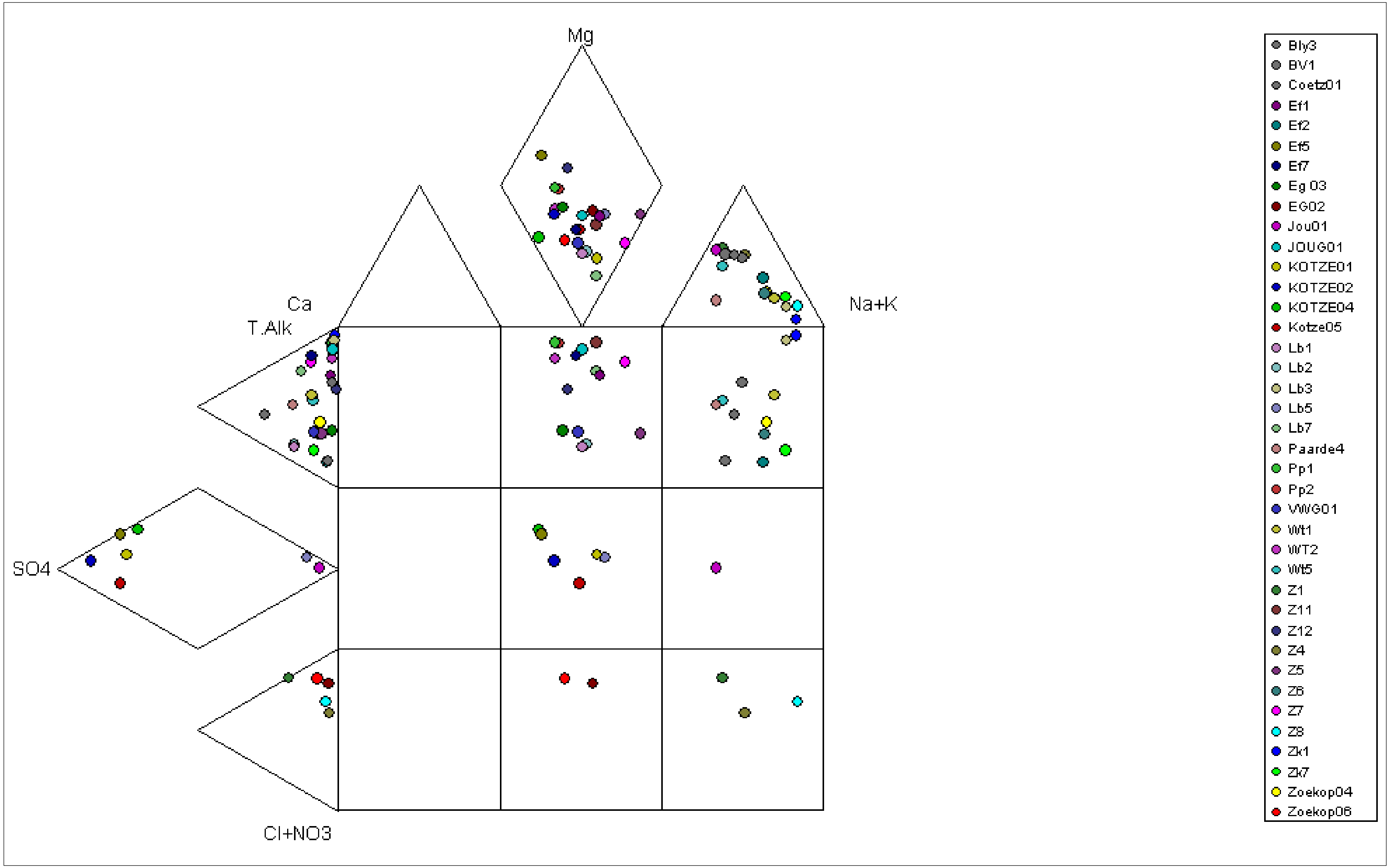


Figure 1.4.1-2: Expanded Durov diagram of ambient groundwater qualities

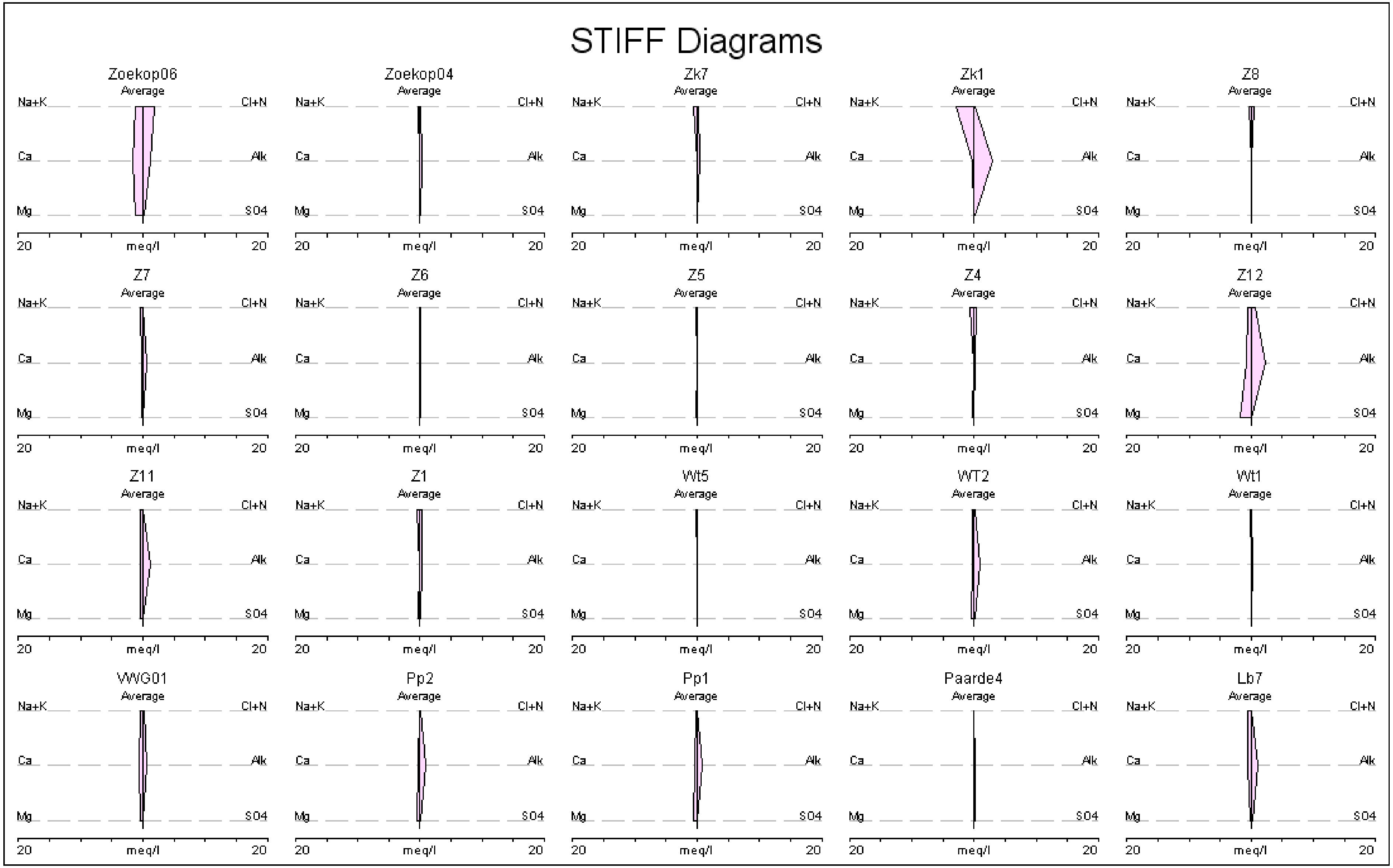


Figure 1.4.1-3: Stiff diagrams of ambient groundwater qualities

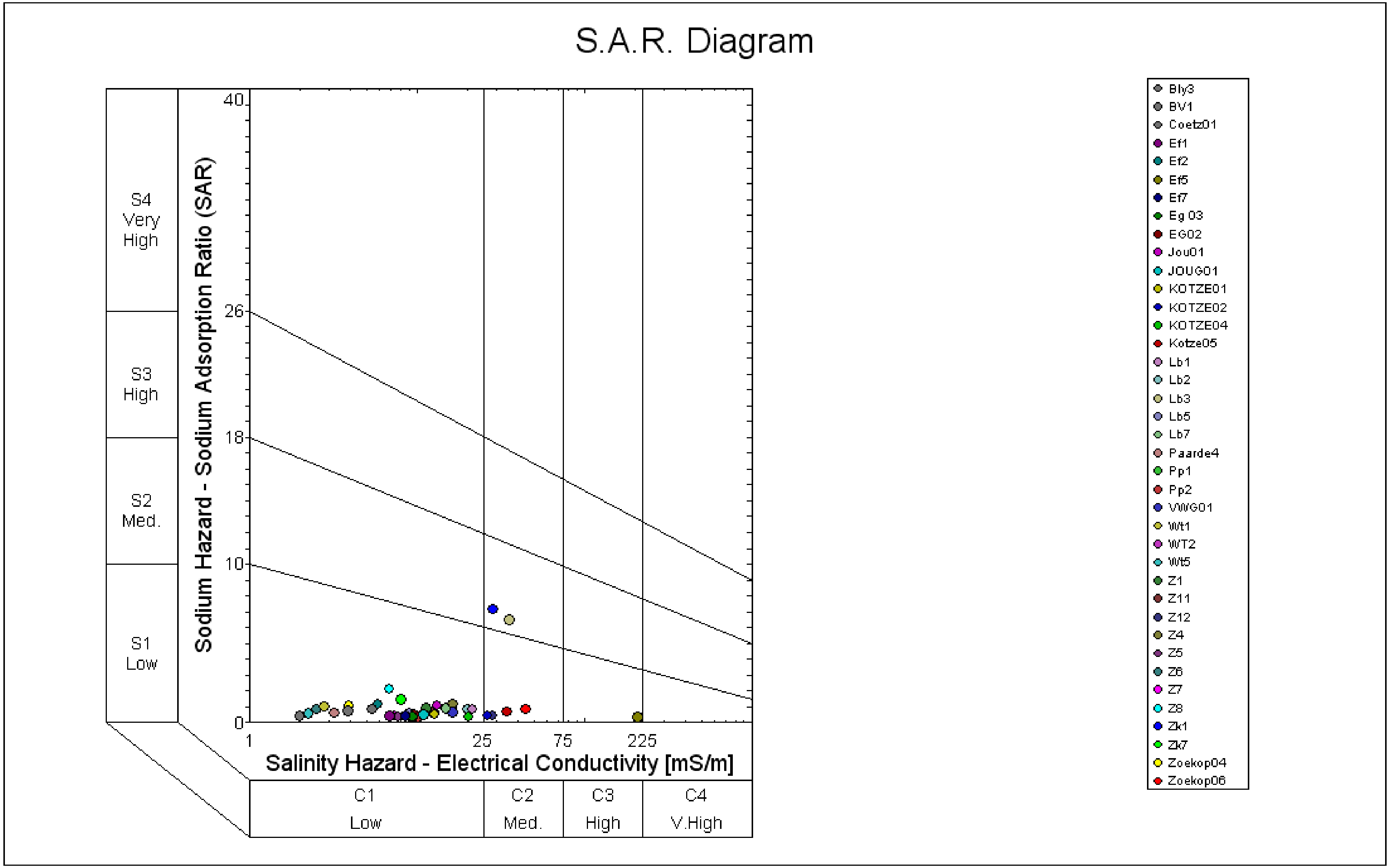


Figure 1.4.1-4: SAR diagram of ambient groundwater qualities

1.4.2 Site specific groundwater quality evaluation

As mentioned previously, a total of 8 new boreholes were drilled strategically in order to sufficiently cover the area with monitoring boreholes **(Figure 1.4.2-1)**. Eleven initial monitoring boreholes were sited. Already existing monitoring boreholes were found at 3 of the points. Seven of the new monitoring boreholes and four already existing monitoring boreholes were sampled for site specific quality characteristics. All macro inorganic chemical elements were analysed for, but only those that are expected to occur within a coal mining environment will be discussed such as total dissolved solids (TDS), sulphate, nitrate, iron, pH, and sodium.

As opencast mining has only recently begun within the wider Belfast project area in the form of Onverdacht Colliery to the south-west, the very good ambient groundwater conditions are expected to be reflected in the site specific groundwater conditions.

Because of the fact that only one set of samples have been taken and analyzed for the newly drilled monitoring boreholes, trends cannot be distinguished. It would therefore not be accurate to attempt to interpret each different type and find explanations for all the different quality characteristics of every analyzed sample.

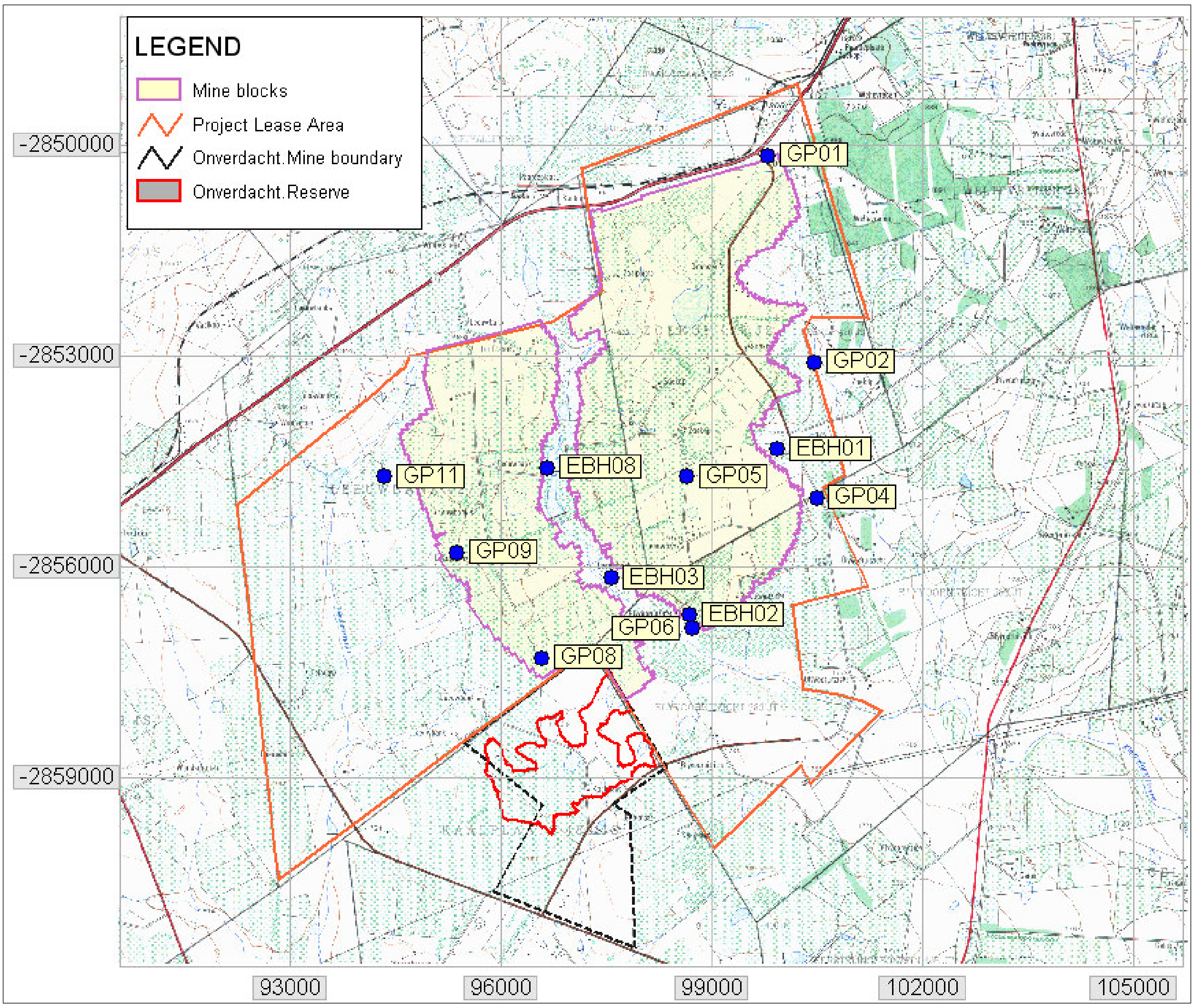


Figure 1.4.2-1: Distribution of monitoring borehole sampling points

All of the above mentioned chemical parameters are well within the ideal limits for domestic use except iron concentrations that exceeds the maximum permissible limits in 3 boreholes (GP09, EBH08 and GP11) and exceeds the ideal limits in four of the boreholes (GP02, GP04, GP05 and EBH03). Aluminium concentrations also exceed the maximum permissible limits for drinking water in five of the boreholes (GP02, GP04, GP09, GP11 and EBH08). The reason for the high metal concentrations is not clear since the pH of the groundwater varies between 6.5 and 8.6. Elevated metal concentrations are normally expected in an acidic environment since the ions are mobilized under these conditions.

The majority of the site specific groundwater chemistries plot within field 2 and 3 of the Expanded Durov diagram **(Figure 1.4.2-2)**, which represents fresh, clean, relatively young groundwater that has started to undergo mineralization with especially magnesium and sodium ion exchange.

The dominant cations and anions are magnesium and sodium and bicarbonate alkalinity respectively. The groundwater chemistries of boreholes GP02 differ from the majority, as its quality plot within field 8 of the EDD.
From the SAR diagram **(Figure 1.4.2-4)** it follows that most of the groundwater in the area present a very low sodium hazard and a low to medium salinity hazard towards soil and

vegetation if used for irrigation. Further discussion on this aspect is not considered applicable since the groundwater of the area is not used for irrigation on any meaningful scale.

Summary:

- The site specific groundwater is of excellent quality and is suitable for human consumption.
- Elevated iron and aluminium concentrations are observed in some of the monitoring boreholes. The reason for the high concentrations is unclear since the pH of the groundwater varies between 6.5 and 8.6, which represent close to neutral groundwater.

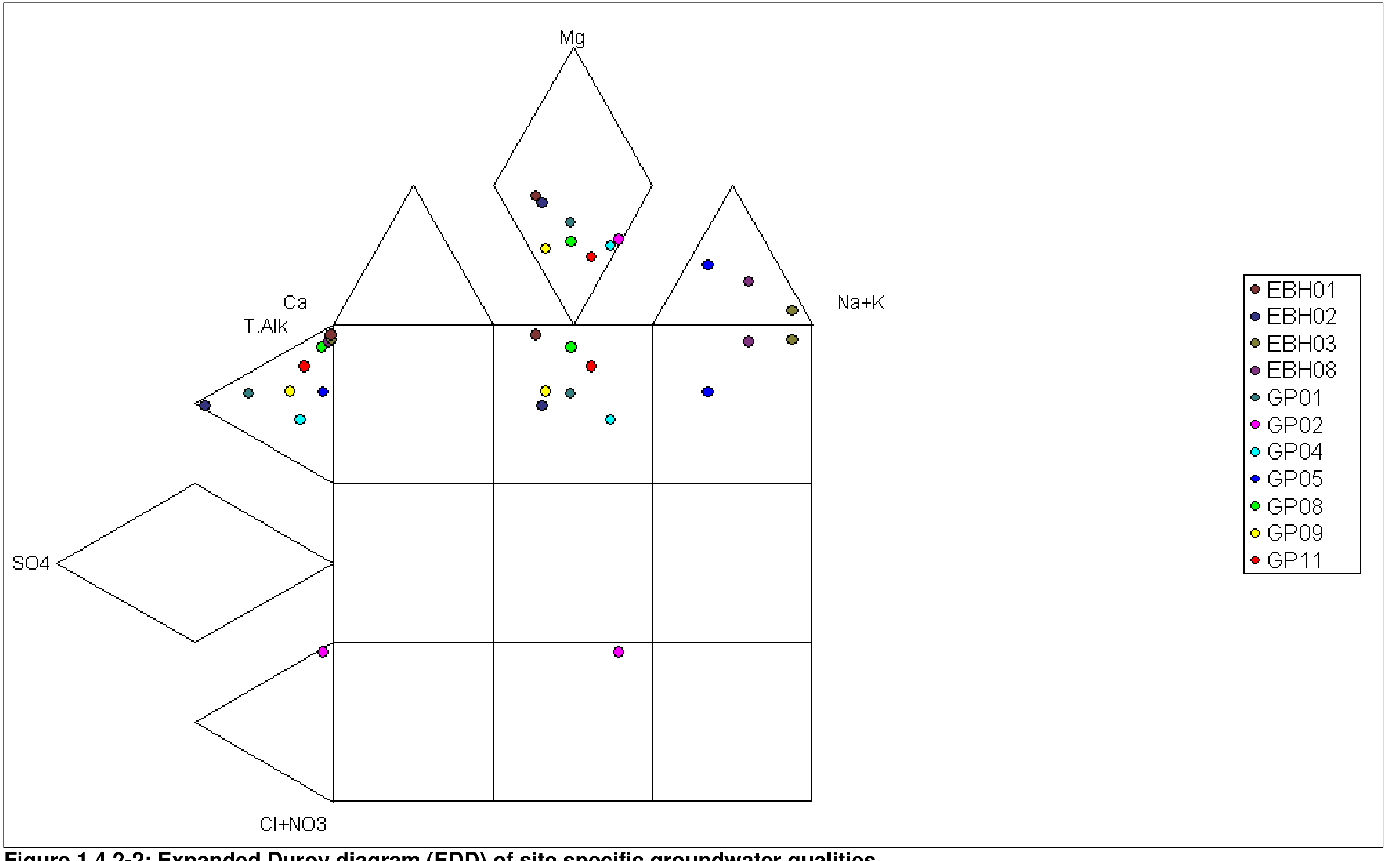


Figure 1.4.2-2: Expanded Durov diagram (EDD) of site specific groundwater qualities

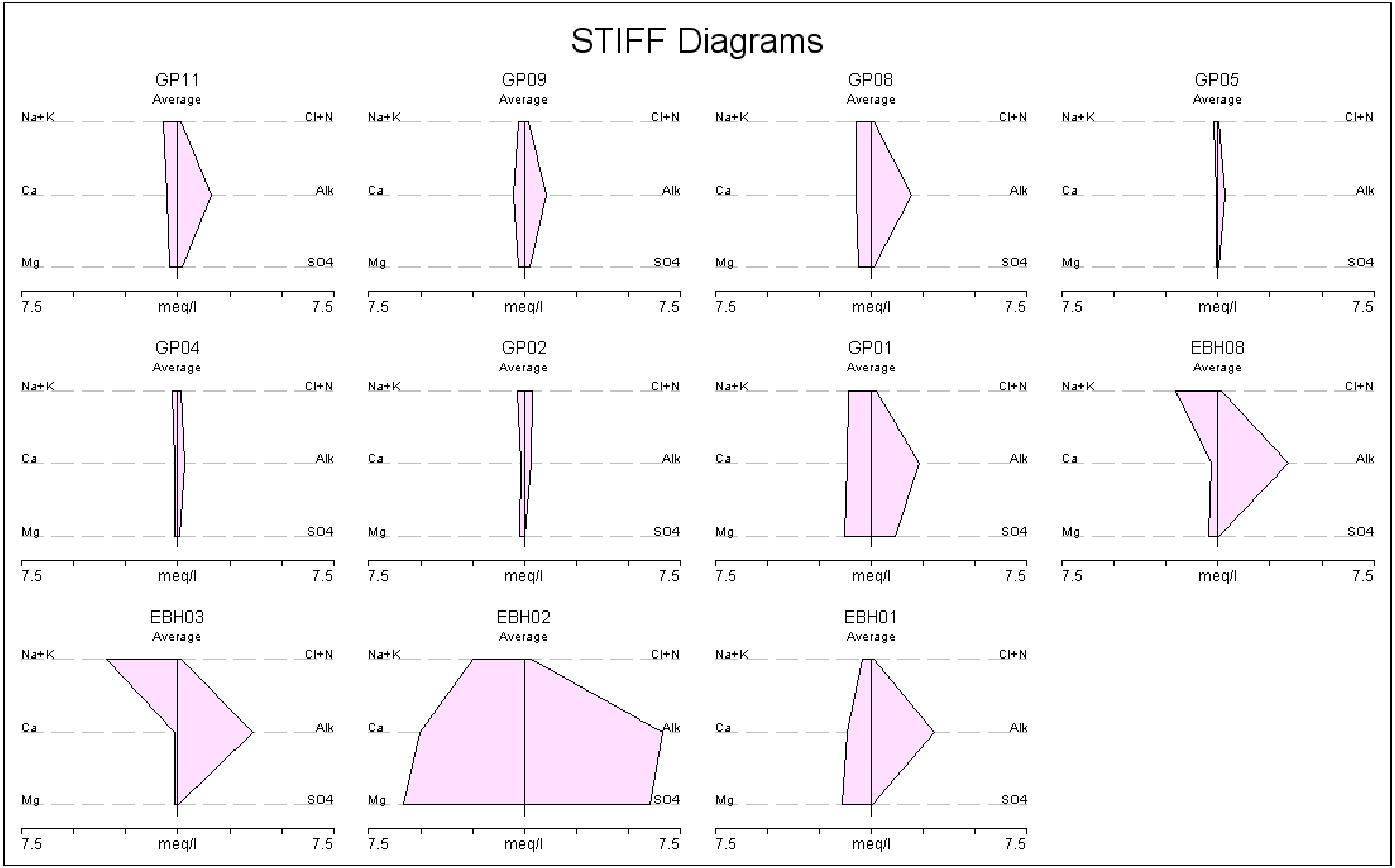


Figure 1.4.2-3: Stiff diagrams of site specific groundwater qualities

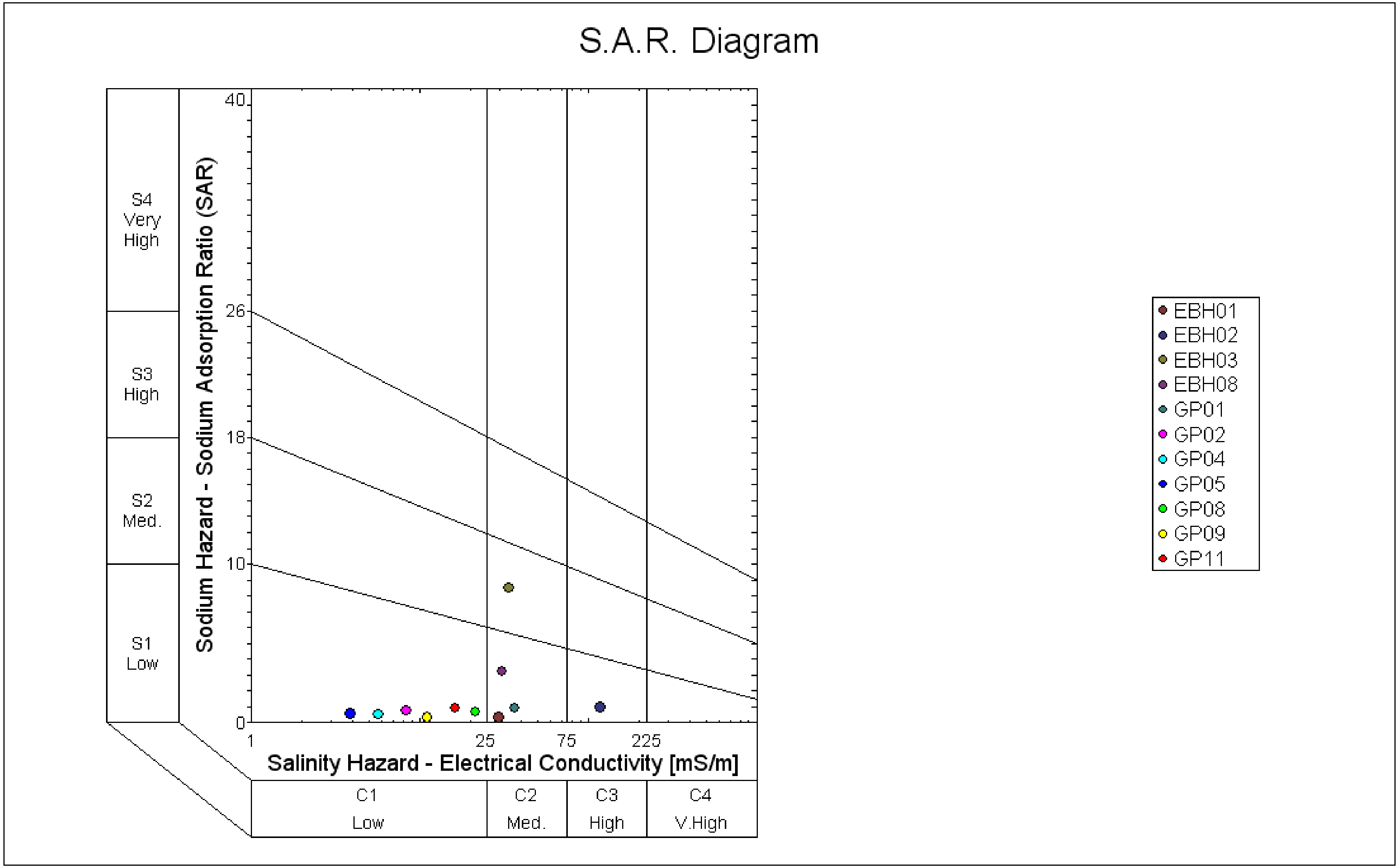


Figure 1.4.2-4: SAR diagram of site specific groundwater qualities

2 ENVIRONMENTAL IMPACT ASSESSMENT AND MITIGATION MEASURES FOR THE PROPOSED BELFAST PROJECT

This part of the geohydrological input to the EIA and IWULA report describes and evaluates the potential impact of the proposed Belfast project on the environment. The management program proposed for the proposed new mining areas from a geohydrological perspective will also be discussed in this section. Generic aspects will be discussed together but aspects pertaining to one project specifically will be discussed as such with the specific areas.

Exxaro Resources, through the proposed Belfast project, accept all implications in terms of the legally binding nature of all commitments made and management measures described in this specialist study for the EIA and IWULA document.

Exxaro Resources are further also committed to rehabilitating the proposed new mining areas (West and East mining blocks and infrastructure) at the proposed Belfast Project in a responsible manner, with a balanced approach by adequately managing negative environmental impacts to within acceptable limits. Remediation of negative impacts will, as far as possible, be based on the principle of Best Environmental Option (BEO), with the implementation of technically proven and acceptable rehabilitation measures. New techniques will be evaluated when they become available and will be implemented should they prove effective within financial constraints. The evaluation of impacts is conducted in terms of the following criteria:

Extent	
Site	Effect limited to the site and its immediate surroundings.
Local	Effect limited to within 3 – 5 km of the site.
Regional	Effect will have an impact on a regional scale.
Duration of impact	
Short	Effect lasts for a period 0 to 5 years.
Medium	Effect continues for a period between 5 and 10 years.
Long	Effect will cease after the operational life of the activity either because of natural process or by human intervention.
Permanent	Where mitigation either by natural process or by human intervention will not occur in such a way or in such a time span that the impact can be considered transient.
Probability	
Improbable	Less than 33 % chance of occurrence.
Probable	Between 33 and 66 % chance of occurrence.
Highly Probable	Greater than 66 % chance of occurrence.
Definite	Will occur regardless of any prevention measures.

Significance of impact	
Low	Where the impact will have a relatively small effect on the environment and will not have an influence on the decision.
Medium	Where the impact can have an influence on the environment and the decision and should be mitigated.
High	Where the impact definitely has an impact on the environment and the decision regardless of any possible mitigation.
Status	
Positive	Impact will be beneficial to the environment.
Negative	Impact will not be beneficial to the environment.
Neutral	Positive and negative impact.

It must be noted that many of the potential negative consequences can be mitigated successfully. It is however, necessary to make a thorough assessment of all possible impacts in order to ensure that environmental considerations are taken into account, in a balanced way, as far as possible, supporting the aim of creating a healthy and pleasant environment.

2.1 LAND CLEARANCE

The following land clearance activities will take place during the construction and operational phases:

- Vegetation clearance,
- Topsoil and sub-soil stripping and stockpiling.

2.1.1 Construction Phase

2.1.1.1 Potential impacts

The **stripping and stockpiling** of topsoil and subsoil from the pit and infrastructure surface areas is considered negligible since no chemical interaction is envisaged that could have an adverse impact on groundwater quality.

2.1.2 Operational Phase

2.1.2.1 Potential impacts

The **stripping and stockpiling** of topsoil and subsoil from the pit and infrastructure surface areas is considered negligible since no chemical interaction is envisaged that could have an adverse impact on groundwater quality.

Groundwater Impact Rating: Land Clearance
Extent of groundwater impact
Duration of operation impact on groundwater
Probability of impact on groundwater
Significance of impact on groundwater
Status of impact on groundwater

2.2 CONSTRUCTION OF INFRASTRUCTURE

The following infrastructure will be constructed during the construction phase:

- Construction of workshops, administration buildings & power infrastructure
- Construction of roads (haul, access and service), haul bridge between East and West mine blocks
- Construction of railway siding and overland conveyor belt

2.2.1 Construction Phase

2.2.1.1 Potential impacts

The construction of **access and haul roads, workshops and administration buildings** will cause a very small reduction in recharge due to the compaction of the surface of the roads and the foundation layer of the hard rock stockpile area. This impact is countered by the fact that the runoff water will contribute to the catchment yield. No adverse impact is foreseen on groundwater quality since no carbonaceous or otherwise reactive material will be used for construction.

Groundwater Impact Rating: Construction of Infrastructure
Extent of groundwater impact
Duration of operation impact on groundwater
Probability of impact on groundwater
Significance of impact on groundwater
Status of impact on groundwater

2.3 CONSTRUCTION AND UTILISATION OF SURFACE WATER MANAGEMENT MEASURES

The following activities will take place during the construction, operational, and decommissioning phases:

- Construction of water management and reticulation infrastructure,
- Utilisation of water and waste management measures and pollution control facilities,
- Containment and re-use of contaminated water within isolated dirty water management areas,
- Storage and or removal of liquid and solid hazardous and non-hazardous waste.

2.3.1 Construction Phase

2.3.1.1 Potential impacts

Seepage from carbonaceous material will be of high salinity and may be slightly acidic, which will increase salinity, mobilise metals and degrade the quality of groundwater when entering the groundwater system. Therefore, any construction undertaken with carbonaceous material can be viewed as a potential source of groundwater pollution and will be avoided.

2.3.1.2 Management objectives and principles

- To minimize seepage, prevent contact between clean and dirty areas, and to recycle contaminated water.
- All contaminated water will be contained for re-use and evaporation.
- To minimize the extent of disturbance of the aquifer.
- To prevent degeneration of groundwater quality, and
- To manage the anticipated impacts associated with the inflow of groundwater to the opencast pits.

2.3.1.3 Management activities or mitigation measures

- No construction of any water management measures, such as the storm water management berms or the haul roads will be undertaken with carbonaceous material.
- All dams will be lined in an effort to minimize the seepage of poor quality leachate.
- Clean surface water will not come into contact with dirty water or coal bearing material.

2.3.2 Operational Phase

2.3.2.1 Potential impacts

The utilisation of water and waste management measures and pollution control facilities must inadvertently have some form of impact on groundwater, although the primary purpose of the facilities is to prevent or contain water contamination. Detailed designs of the facilities have not been available at the time of this report but even when constructed with clay or synthetic liner material, some leakage or spilling is not out of the question.

For the wet management facilities – settling dams, pollution control dams, return water dams etc – seepage has a direct impact and is only governed by the hydraulic properties of the liner of the facility and the rest of the unsaturated zone. The added seepage rate from the wet facilities – especially where no lining material occurs – causes artificial recharge to the aquifer and often result in mounding of the aquifer water level below the facility. The mounding changes a local increase in the groundwater gradient, which causes increased flow rate of contaminated seepage.

For dry facilities – i.e. waste disposal sites, stockpile areas, discard dumps and the plant dirty footprint area – impact on the groundwater only occurs through leachate formation from surface. Impact thus only occurs as a result of rainfall recharge or when water is introduced in some form where leachate can form that seeps to the groundwater regime. The artificial recharge and mounding concept does not come into play with dry sources and therefore the intensity and rate of transport of contamination is far less significant than at wet sources.

In terms of storage and or removal of liquid and solid hazardous and non-hazardous waste, specific applications and studies will be conducted depending on the waste types, volumes and regulatory requirements.

2.3.2.2 Management objectives and principles

- To minimize seepage, prevent contact between clean and dirty areas, and to recycle contaminated water.
- All contaminated water will be contained for re-use and evaporation.
- To minimize the extent of disturbance of the aquifer.
- To prevent degeneration of groundwater quality, and
- To manage the anticipated impacts associated with the inflow of groundwater to the opencast pits.

2.3.2.3 Management activities or mitigation measures

- Clean surface water will not come into contact with dirty water or coal bearing material.

2.3.3 Decommissioning Phase

2.3.3.1 Potential impacts

Removal or decommissioning of water management and containment infrastructure should have a slight positive effect on the groundwater regime since it entails elimination of sources with pollution risk.

2.3.3.2 Management objectives and principles

- To minimize seepage, prevent contact between clean and dirty areas, and to recycle contaminated water.
- All contaminated water will be contained for re-use and evaporation.
- To minimize the extent of disturbance of the aquifer.
- To prevent degeneration of groundwater quality, and
- To manage the anticipated impacts associated with the inflow of groundwater to the opencast pits.

2.3.3.3 Management activities or mitigation measures

Clean surface water will not come into contact with dirty water or coal bearing material.

Groundwater Impact Rating: Construction and utilization of surface water management measures
Extent of groundwater impact
Duration of operation impact on groundwater
Probability of impact on groundwater
Significance of impact on groundwater
Status of impact on groundwater

2.4 DEVELOPMENT OF BOX-CUT AND THE PROGRESSION OF MINING CUTS

The following activities will take place during the construction and operational phases:

- Development of the initial box-cut, including blasting, the removal and separate storage of overburden from the initial box-cut opencast area(s) to expose coal layer to be mined,
- Progressive development of mining cuts, including blasting, the removal of overburden, the extraction of coal, and relocation of some of the water management measures, if required, as the box-cut advances.

2.4.1 Construction Phase

2.4.1.1 Potential impacts

With the construction of the **initial box-cut**, dewatering of the aquifer will begin to occur, but only within the immediate vicinity of the box-cut.

2.4.1.2 Management objectives and principles

Not applicable.

2.4.1.3 Management activities or mitigation measures

The dewatering of the aquifer within the immediate vicinity of the pits cannot be prevented, unless the groundwater level elevation is below the base of the mine.

2.4.2 Operational Phase

2.4.2.1 Potential impacts

The degree of aquifer dewatering depends on the extent and depth of the opencast pits.

During the operational phase the open pit mining will be active which will cause the dewatering of the surrounding aquifer(s). The cone of depression should not exceed a distance of 1000 m (generalized conditions typical to Karoo aquifers where opencast coal operations occur and also confirmed by the numerical groundwater model) from the mining area, thus the impact will be limited. The effect of dewatering at nearby open pits is usually less than 1000 m due to the generally low transmissivity of the aquifer(s).

Lowering of the groundwater levels will affect availability of groundwater for domestic and stock watering use to all groundwater users within 1 km radius. No large scale irrigation occurs in the vicinity of the proposed Belfast project pits and no significant impact on any such user is expected.

Acid-base accounting showed that there exist a strong potential for AMD in the proposed Belfast project areas. The impact on salinity levels of the aquifer is expected to be intermediate during the operational phase, since some plume movement can be expected during this phase. Because of the upgradient mining, the water level downgradient can somewhat start to recover during the operational phase. Groundwater contamination of surrounding users can therefore take place while the pit is still operational.

Affected storm water runoff will be contained in the purpose-built containment facilities. Some quality impacts may still be registered on the weathered zone aquifer. In general, pollution migration will be slow because of low transmissivities.

It is expected that the sulphate concentration of the water in the evaporation pond could be between 500 and 1000 mg/l during the operational phase due to relatively short contact time with carbonaceous material.

2.4.2.2 Management objectives and principles

No management action is available to prevent dewatering.

Drains and cut-off trenches (storm water management system) around the proposed opencast pits will be implemented before commencing with pit development to prevent clean run-off water from entering the pit.

2.4.2.3 Management activities or mitigation measures

The dewatering of the aquifer system cannot be prevented. If the monitoring program indicates that nearby groundwater users are affected by the dewatering, the users need to be compensated for the loss.

2.4.3 Decommissioning Phase

2.4.3.1 Potential impacts

During the rehabilitation period, the backfilled pits will start filling with groundwater seepage to reinstate the equilibrium with surrounding aquifers.

2.4.3.2 Management objectives and principles

Carbonaceous material should be placed at the bottom of the pit so that it can be covered by water and the oxygen removed as soon as possible.

The rehabilitation should however aim at minimizing infiltration to the rehabilitated pits since this will cause higher decant rates of contaminated water that will need to be managed. The final surface needs to be free-draining to minimize recharge.

2.4.3.3 Management activities or mitigation measures

It is anticipated that the groundwater quality will improve away from the proposed Belfast project opencast pits as the dilution effect of the entire aquifer increases further away from the open pit areas.

The results from the groundwater investigation will be verified through monitoring during the operational phase of the mine and suitable mitigation measures implemented should the results not confirm the initial conclusion regarding decommissioning phase groundwater related impacts.

Groundwater Impact Rating: Development of the box-cut and progression of mining cuts
Extent of groundwater impact
Duration of operation impact on groundwater
Probability of impact on groundwater
Significance of impact on groundwater
Status of impact on groundwater

2.5 HANDLING AND PROCESSING OF COAL

2.5.1 Construction Phase

The following activities will take place during the operational phase:

- Construction of crushing and screening plant
- Construction of Washing plant
- Construction of co-disposal site

2.5.2 Operational Phase

The following activities will take place during the operational phase:

- Utilisation of the Crushing- and Screening Plant,
- Utilisation of Washing plant,
- Utilisation of co-disposal facilities,
- Utilisation of overland conveyor.

2.5.2.1 Potential impacts

Plant areas where coal is handled and processed are definite sources of groundwater pollution. Poor quality leachate emanates from these areas, which may degrade the quality of groundwater to below the acceptable levels.

2.5.2.2 Management objectives and principles

- To prevent contact of clean runoff water with coal-bearing material,
- To prevent further degeneration of groundwater quality,
- To contain all dirty water in the return water dam and in-pit sump area,
- To minimize the impact of the proposed new mining activities on groundwater quality or availability.

2.5.2.3 Management activities or mitigation measures

- Clean water will be prevented to come into contact with dirty water or coal bearing material,
- Clean runoff water will be diverted away from dirty areas.
- Opencast areas will be rehabilitated as soon as available to reduce the availability of oxygen and volume of infiltration thereby reducing the generation of AMD.
- Refilling of the voids will be according to sequential layering of carbonaceous material with highest pollution potential at the bottom of the pit.

Groundwater Impact Rating: Handling and processing of coal
Extent of groundwater impact
Duration of operation impact on groundwater
Probability of impact on groundwater
Significance of impact on groundwater
Status of impact on groundwater

2.6 UTILISATION OF INFRASTRUCTURE

The following activities will take place during the operational phase:

- Utilisation of surface infrastructure (i.e. offices, workshops, ablution facilities),
- Utilisation of haul, access and service roads,
- Maintenance of machinery and vehicles.

2.6.1 Operational Phase

2.6.1.1 Potential impacts

Very little impact is expected since no water seepage or abstraction is involved that would affect water levels and no leachate or contaminated seepage is involved that could affect groundwater quality.

2.6.1.2 Management objectives and principles

Wastage of coal-bearing material outside the allocated dirty water management area during the construction phase will be prevented. Haul roads and other compacted surfaces will be kept free of carbonaceous material by cleaning spillages, thereby reducing infiltration of contaminated water.

Dirty water will be contained in fit-for-purpose designed facilities, which will limit infiltration of contaminated water to the groundwater.

Water accumulating in the in-pit sump areas will be pumped to the return water dam to limit the quality related impacts.

Preparation, including compaction of the foundation layer for the low grade- and hard rock stockpile area and coal transfer area at the Belfast project will be undertaken with the purpose of limiting infiltration of contaminated water to the groundwater.

The size of compacted areas must be minimized to as small as practically possible.

Should it be found that the yield and quality of surrounding users are affected due to the proposed construction phase activities, suitable alternatives should be investigated. A number of groundwater users in the vicinity of the proposed Belfast project area were identified during the user survey.

A very limited impact on groundwater quantity and quality is expected overall due to the construction phase activities mostly because of the small surface area involved during this project life phase and the short duration thereof. The reduction in groundwater recharge is balanced by the increase in runoff. Groundwater quality impacts during construction phase are expected to be insignificant if the proposed management measures are implemented. Dewatering of the groundwater regime will commence due to the development of the initial box-cut.

2.6.1.3 Management activities or mitigation measures

No potential groundwater impacts are expected.

2.6.2 Decommissioning Phase

2.6.2.1 Potential impacts

Decommissioning phase activities such as the removal of carbonaceous material from disturbed surface areas and rehabilitation of the return water dam area will have a positive impact on groundwater due to the improvement of the quality of surface water infiltration and reduction of poor quality seepage to groundwater.

2.6.2.2 Management objectives and principles

The main aim is to remove all dirty material with a potential for leachate formation.

2.6.2.3 Management activities or mitigation measures

Ripping of access and haul roads and other compacted surface will cause a positive affect by reinstating original recharge to the aquifer.

Groundwater Impact Rating: Utilization of Infrastructure
Extent of groundwater impact
Duration of operation impact on groundwater
Probability of impact on groundwater
Significance of impact on groundwater
Status of impact on groundwater

2.7 TRANSPORTATION

The following activities will take place during the operational phase:

- Hauling of coal via road and overland conveyor to the domestic market.

2.7.1 Operational Phase

2.7.1.1 Potential impacts

A very small reduction in recharge will result due to the compaction of the surface of the roads relating to the hauling of coal. This impact is countered by the fact that the runoff water will contribute to the catchment yield. Since all contaminated surface water runoff from haul road areas will be collected in the dirty water management system, infiltration of contaminated water will be minimized.

2.7.1.2 Management objectives and principles

To ensure that contaminated surface water runoff from haul roads do not come into contact with clean surface water runoff, or infiltrate into the groundwater system.

2.7.1.3 Management activities or mitigation measures

All contaminated surface water runoff from haul road areas will be collected in the dirty water management system, which means that the infiltration of contaminated water will be minimized.

Groundwater Impact Rating: Transportation
Extent of groundwater impact
Duration of operation impact on groundwater
Probability of impact on groundwater
Significance of impact on groundwater
Status of impact on groundwater

2.8 REHABILITATION

The following activities will take place during the operational and decommissioning phases:

- Concurrent backfilling (including in-pit disposal of mine waste) and rehabilitation of mined-out opencast areas and any other redundant disturbed surface land use areas,
- Backfilling of the final void, depending on the outcome of the long-term groundwater management strategy,
- Levelling of remaining in-pit spoils, shaping and landscaping of rehabilitated areas (the shaping and landscaping of the rehabilitated areas will be specific to conform with the Closure objectives set for the rehabilitated mining surface in terms of both water management aspects and the re-establishment of catchment areas for the pans),
- Removing carbonaceous material from disturbed land use areas for disposal into the final void (below the pre-mining coal level), depending on the long-term groundwater management strategy,
- Demolishing and rehabilitation of redundant surface infrastructure, such as pollution control facilities, depending on the long-term groundwater management strategy and agreed end land use,
- Exotic and invasive plants will be removed, and the re-establishment of such species within the rehabilitated areas will be prevented,
- Final rehabilitation, including the placement of topsoil and establishment of vegetation on rehabilitated areas,
- Aim to establishment of a sustainable and agreed end land use through final rehabilitation,

2.8.1 Operational Phase

2.8.1.1 Potential impacts

The rehabilitation of the mine voids will have a positive effect on the groundwater system.

2.8.1.2 Management objectives and principles

- To limit the availability of oxygen in the mine voids, in an effort to minimise the occurrence of acid mine drainage.
- To minimise groundwater recharge that will eventually lead to decant of poor quality mine water.

2.8.1.3 Management activities or mitigation measures

The mine voids are continuously backfilled as the opencast pits progress with time.

2.8.2 Decommissioning Phase

2.8.2.1 Potential impacts

The rehabilitation of the final mine voids and disturbed surface areas will have a positive effect on the groundwater system.

2.8.2.2 Management objectives and principles

To return the post-mining groundwater system to an agreed post-mining condition.

2.8.2.3 Management activities or mitigation measures

Groundwater Impact Rating: Rehabilitation
Extent of groundwater impact
Duration of operation impact on groundwater
Probability of impact on groundwater
Significance of impact on groundwater
Status of impact on groundwater

3 RESIDUAL IMPACTS AFTER CLOSURE

This section is included in the groundwater impact study since the most significant negative impact of the coal mining operation on the groundwater environment occurs after the mine has closed and after it has been rehabilitated. Some of the impacts are described from the operational phase through to after closure to illustrate changes in the water balance and flow conditions.

The following possible impacts are generally associated with closure of coal mining projects:

- Deterioration of groundwater quality within the back-filled opencast mine workings due to acid mine drainage reactions.
- Downstream movement of a deeper groundwater pollution plume.
- Opencast pits will decant into the shallow aquifer and on surface at the lowest surface elevations intersected by the pits if not managed.

3.1 GROUNDWATER LEVEL AND RECHARGE RATE

During decommissioning, and for a certain time after closure, the geohydrological environment will dynamically attain a new equilibrium after the dewatering effects of the open pits. The time it will take both the pits to decant were calculated with the use of a numerical modeling exercise and volume/recharge calculations and are given in Table 3.1-1.

Due to the irregular sizes and shapes of the backfilling material the effective porosity of the rehabilitated opencast pit may vary between 20 and 30%. The total volume of voids were therefore calculated for both the East and West blocks with varying degrees of porosity – as indicated in Table 3.1-1. An effective recharge of 10, 12.5 and 20% of the mean annual rainfall (in the order of 700 mm/y) were used in the decant calculations.

In the rehabilitated opencast pits the groundwater level is thus expected to attain a new equilibrium after closure. Although the transmissivity and storativity are higher after rehabilitation, the effective recharge percentage is also expected to be higher in spite of compaction practices and creation of a free runoff surface profile.

The potential decant from the pit areas will be managed to prevent adverse impact on the watercourse.

The Belfast project will investigate different options of managing any post-closure decant and implement the best option towards closure. Monitoring data during the operational and closure phases will be used to update, calibrate and refine current model simulations to base decisions on verified data.

Decant calculations are provided in Table 3.1-1, including estimate recharge rates, void volumes and time for the different mining areas to start decanting after closure. A decant rate for the **West Block** is estimated at approximately **2100 m^3/day** to the west and east while the **East Block** is estimated to be decanting at **3800 m^3/day** on its western boundary.

Table 3.1-1: Decant calculations

	West Block	East Block
Annual Rainfall (m)	0.7	0.7
Decant Elevation (mamsl)	1772	1779
Mined Area (m2)	8930000	16000000
Total void Volume Below Decant Elevation (m3)	869000	656000
Decant from opencast areas (m3/d)		
Low (10% rech)	1710	3070
Most Probable (12.5% rech)	**2 140**	**3 835**
High (20% rech)	3 420	6 140
Voids (m3):		
20%	173820	131260
25%	**217275**	**164075**
30%	65183	49223
Average Time to Decant (Years):	**<1**	**<1**

It follows from the volume and recharge calculations in Table 3.1-1 that the **time to decant** for the most probable effective recharge scenario in both of the mine blocks is **less than 1 year**. The reason for this very short time to decant is simply the geometry and dip direction of the coal seams. **Given the short estimated time to decant it is very important that planning for post-closure management of mine water decant starts early in the operational life of the mine.** Construction and commissioning of a water treatment plant takes a number of years and planning for the plant such as pilot testing, and what to do with the treated water and the brine needs to start in time.

Figure 3.1-1 indicates that the coal floor in the West Block forms a ridge separating the mine block into two parts. This ridge is at a higher elevation than the decant elevation on both the western and south-eastern boundaries. This coal floor geometry will result in the pit filling up on either side of the ridge after closure and lead to decanting on surface in two areas as indicated in Figure 3.1-1. If areas are considered on either sides of the ridge, approximately 37% of the decant will occur on the western boundary while the other 63% will occur on the south-eastern boundary of the mine block.

The only way to have only one decant point to manage is to implement some form of engineering intervention. This can be achieved by

- pumping the water from the west to the southern decant and managing all decant from there,
- by mining deeper into the coal floor in the southern end of the West Block to create a link between the two sides of the ridge that is lower than the decant elevations, or

- by managing the water level at the one decant area at as low elevation as possible, thus making it possible to create a siphon effect from the one decant area to the other lower water level and eliminating active pumping.

The bottom line is that Exxaro needs to develop a clear management plan in the operational phase already to manage the expected decant since development of management infrastructure may be required while the pit is still operational.

A further implication of the pit geometry is the small percentage of pit area that will be filled with water before decant will start to occur. **Figure 3.1-1** is included to show which part of each of the mine blocks will be filled with water before decant. It is accepted best practice in the coal mining environment that carbonaceous material be backfilled at the bottom of the pit. The aim with this practice is to have the carbonaceous material covered with water as soon as possible when the water level in the pit starts to recover. When covered with water, acid-base reactions in the carbonaceous material are minimized since the majority of these reactions require oxygen, i.e. oxidation reactions. When water covers the carbonaceous matter and causes a reducing environment, the acid-mine-drainage group of reactions diminishes and results in a much improved water quality compared to the oxidation environment.

At the Belfast project, a very small portion of the carbonaceous matter will be covered with water by the time when decant will start to occur. The result will be a much poorer water quality since water infiltrating the rehabilitated spoils over the entire pit area will undergo acid-mine-drainage reactions for nearly the entire surface area and the time it takes to migrate through the spoils to the lowest point where decant will occur. Unfortunately, there is nothing to be done on the geometry of the coal reserve but the fact is stressed that **proper and timeous management actions need to be taken to manage the poor quality decant** that will start to occur nearly directly after mining ends.

In section **1.3.1** and **1.3.2** of the document the pre-mining groundwater flow directions and gradients have been calculated and discussed. The mining activities, and especially the opencast pits, will without any doubt influence the natural flow directions and gradients of the groundwater. As already mentioned in the document, the opencast pits will act as groundwater sinks throughout the operational phase until a new groundwater equilibrium has been reached after active mining has ceased.

During the backfilling process material is placed back into the opencast pits in such a manner as to return the pit areas to their original pre-mining hydraulic state. Despite all the measures taken, the backfilled opencast pits will have higher transmissivities than the surrounding environment due to the irregular sizes and shapes of the backfill material. The backfilled pit areas will therefore act as preferred flow paths for groundwater.

During, and after active mining has ceased groundwater will tend to move through the backfilled opencast pit areas. The water collected in the pit is expected to be of poor quality due to the high potential of the carbonaceous material to generate acid.

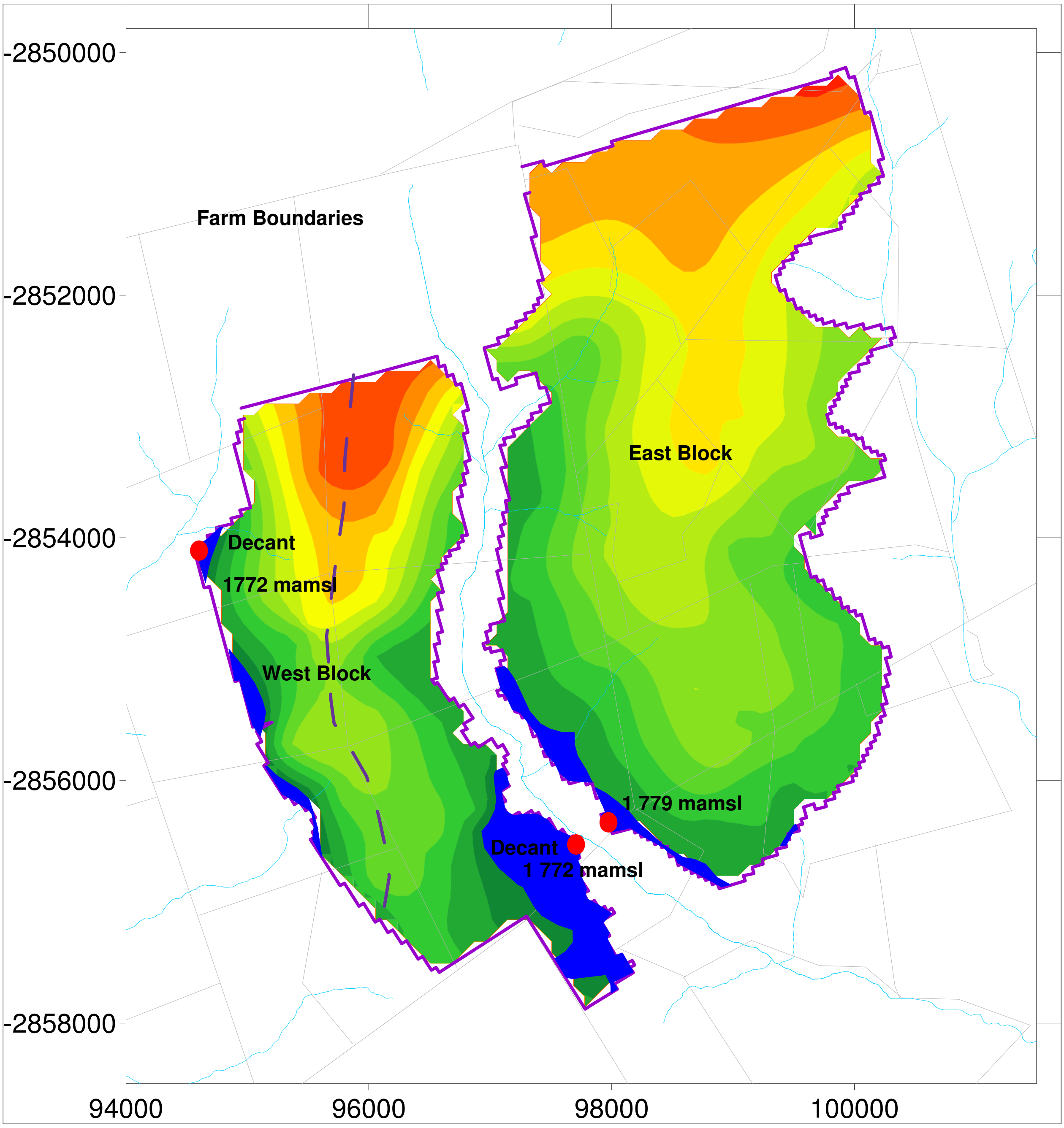


Figure 3.1-1: Groundwater level in mine blocks at decant

3.2 GROUNDWATER QUALITY

The two most common processes by which groundwater are contaminated include **interstitial release** and **ion exchange release**. Argillaceous sediments such as shale and mudstone are known to contain pore water with high saline content. Significant amounts of contaminants may therefore be released as these sediment structures disintegrate because of weathering or when exposed and crushed though the mining process. The most commonly released ions during this weathering process are sodium and chloride. The process by which ions in solution will exchange for those minerals absorbed onto solid particles is known as **ion exchange**.

Clay minerals are usually negatively charged, which is mostly attributable to broken bonds at the edges of structural clay units. As a result, cations are absorbed onto the clay particles to neutralize the negative charges. The exchangeable cations are held in an aqueous film near the clay particle surface, which is commonly referred to as a diffuse layer. Clays exhibit a selective preference for some ions over others according to the ion size, charge etc. The order of preference for the more common ions is:

$Ca^{2+} > Mg^{2+} > K^{+} > Na^{+}$

As groundwater moves through the spoil in rehabilitated areas or through underground workings where it is exposed to coal in abundance, calcium and magnesium in the groundwater will be absorbed onto clay particles in exchange for sodium and potassium. Both interstitial and ion exchange release therefore result in groundwater with high sodium content.

Operational and post-mining geohydrological impacts are described below based on collating information from the previous groundwater sections and adding geohydrological experience from previous coal mine projects in similar geological environments.

The secondary, water-bearing characteristics of the geological formations (Karoo Supergroup) or aquifers where mining will take place in the Belfast project area are relatively low. The secondary porosity of this material can vary between 10 and 30 percent with most probable range between 25 and 30%.

The hydraulic conductivities of spoils used to backfill the open pit void are significantly higher than the *in situ* material and can be as high as 10 to 100 m/d with boreholes in spoils yielding up to 15 l/s (Hodgson et al., 1985). Weathering and fracturing of sedimentary formations will enhance their water bearing capacity. Blasting operations and excavation of subsoil will increase the fracturing of the rock material within only few meters (< 20 m) from the pits or coal seam.

During the operational phase and for a time after closure the open pits act as a groundwater sink. Groundwater will thus flow radially inwards towards the open pit areas and the natural groundwater flow direction will be increased, decreased, altered or reversed, depending on the position in the depression cone.

Preferential pathways or zones of high seepage velocity such as major faults or fractured contact zones of intrusive dykes have been mapped in the opencast areas that are to be disturbed. After filling up of the mine voids the groundwater flow directions will tend to return to the normal flow directions that existed before mining commenced. Because of the higher conductivity of the backfill areas, flow on a regional scale will be through the voids as preferred flow regions due to high transmissivity.

Long-term pollution effects depend on the amount and type of pyrite in the coal and other sediments, as well as the amount of air (specifically oxygen) available for chemical reaction.

Rehabilitation of the opencast pit areas should aim at duplicating the pre-existing *in situ* soil profile and entails tipping of coal spoils and other carbonaceous material in the bottom of mined-out cuts. This will be followed by placement of clayey overburden in a dry state, compacted by frequent traversing of the surface after flattening by graders, and a final cover of topsoil.

The low permeability clay layer encapsulates the carbonaceous material placed at the bottom of the mined out cuts. These materials should be placed below the regional groundwater level in order to create a reducing redox environment and eliminate contact with oxygen, thus reducing acid mine drainage to a minimum. Although the carbonaceous materials will be submerged, horizontal groundwater seepage of clean water as well as limited infiltration of surface water will occur and some contamination will occur over the medium and long-term.

The effective recharge percentage to the aquifer is a function of the amount of rainfall, the permeability of the strata and evapo-transpiration from surface. Depending on the shaping and compaction of the capping layers (especially the clay), the effective recharge to the groundwater system at the opencast pits will vary between 3 and 20 % of the mean annual precipitation (MAP).

Long-term groundwater pollution on coal mines and associated processing and disposal operations is synonymous with acid-mine-drainage (AMD) reactions. The root of the problem lies in **chemical and bacteriological oxidation of pyrite** occurring in the coal and other carbonaceous material. The pyrite oxidation model of Stumm and Morgan (1981) is one of the ways to present the reaction group:

$$FeS_2(s) + 3.5O_2 + H_2O \rightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+ \quad (1)$$

$$Fe + 0.25O_2 + H^+ \rightarrow Fe^{3+} + 0.5H_2O \quad (2)$$

$$3FeS_2 + 14Fe^{3+} + 8H_2O \rightarrow 15Fe^{2+} + 2SO_4^{2-} + 16H^+ \quad (3)$$

$$Fe^{3+} + 3H_2O \rightarrow Fe(OH)_3\,(s) + 3H^+ \quad (4)$$

Of importance is the fact that reactions 1 and 2 are chemical reactions whereas the reaction 3 is also the result of bacteriological action. This bacteriological reaction flourishes in a pH environment of between 2 and 6, which is often reached by water leaching through coal mine operations.

Another distinction is that reactions 1 and 2 are oxidation reactions while reaction 3 is anaerobic. Exclusion of oxygen or elimination of the bacteria will thus greatly limit acid formation. Exclusion of oxygen will occur automatically when water levels in the mined pit start to recover after closure through seepage and aquifer recharge.

Decant after filling up is often a problem because large volumes of contaminated water could be generated that cannot be released into the environment. A relatively small portion of the opencast pit will be flooded with water when decant starts to occur and poor quality leachate will continue to form since a large portion of the carbonaceous material in the pit remains under aerobic conditions.

Acid-base accounting (ABA) of coal and overburden samples was also conducted to determine the acid generating potential of the different aquifer host rock types. ABA data in basic terms measure the potential of host rock to buffer acidity in water or to cause acid-mine-drainage reactions in water with which it comes in contact with. Samples for ABA tests were taken and varying acid generating potential values were obtained.

Most ABA samples indicated a potential for acid generation. All carbonaceous and coal reserve material will therefore be treated as acid forming to ensure that all reasonable measures are taken to minimize pollution and prevent pollution spread. For the purpose of constructing an environmental management and mine closure plan, all such material is thus treated as if it will have an adverse impact if in contact with water with the potential for acid mine drainage reactions to occur.

In the operational phase the overall inorganic salinity of the water will increase over time as will be evident in the total dissolved solids (TDS) content of the water. Indicator parameters like sulphate and magnesium can also be expected to increase significantly from the ambient concentrations.

With AMD reactions becoming active the pH and bicarbonate alkalinity values of the water can be expected to decrease. The majority of metals have very low solubility in water at the normal (pH 6 to 8) pH range but will go into solution as a result of the lower pH environment (see reactions 2 and 3 above).

As the water leaves the coal-containing areas, it will mix with better quality water and the pH and bicarbonate values will be buffered back to more acceptable levels. Metals should also precipitate and the sulphate and TDS concentrations should decrease through dilution.

Over the long-term, the groundwater quality will improve because of dilution effects with high quality recharging water. Such recharge will result in a stratified water quality distribution in the backfilled opencast pit with the best quality water on top and the more saline (and with slightly higher specific gravity) water in the bottom of the pit.

3.2.1 The potential for acid mine drainage (AMD) or poor quality leachates

Acid-base accounting is done to determine the acid generating and neutralizing potential of a mine by completely oxidizing the coal and overburden samples after which their initial and final pH values are compared. Acid-base accounting (ABA) was done on nine samples taken from monitoring and exploration boreholes drilled in and around the study area.

The results of the ABA tests are presented in **Table 3.2.1-1**. The net neutralizing potential (NNP) is of importance, as it is the difference between the **base potential** and **acid potential**. Therefore, whenever the NNP is a negative value the acid potential exceeds the base potential, implicating that water leaching through this material will tend to turn acidic.

The results of the ABA are presented in **Table 3.2.1-1**. The net neutralizing potential (NNP) is of importance, as it is the difference between the **base potential** and **acid potential**. Therefore, whenever the NNP is a negative value the acid potential exceeds the base potential.

The Certificate of Analysis for the Acid Base Accounting is presented in Appendix D.

Table 3.2.1-1: Results of acid-base tests on coal and overburden at Belfast project

Acid – Base Accounting	Sample Identification								
	LK427 JS/66	LK427 JS/65	ZP426 JS/58	ZP426 JS/59	ZP426 JS/53	LK427 JS/39	GP05	GP08	GP09
Paste pH	6.3	6.6	7.1	6.7	7.4	7.3	7.7	7.6	7.7
Total Sulphur (%) (LECO)	0.59	0.5	0.2	0.64	0.17	0.29	0.12	1.54	1.34
Acid Potential (AP) (kg/t)	18.44	15.63	6.25	20	5.31	9.06	3.75	48.13	41.88
Neutralization Potential (NP)	9	10	0.75	3.75	12.75	0	0	6	4.25
Nett Neutralization Potential (NNP)	-9.44	-5.63	-5.5	-16.3	7.44	-9.06	-3.75	-42.1	-37.6
Neutralising Potential Ratio (NPR) (NP : AP)	0.49	0.64	0.12	0.19	2.4	0.14	0.53	0.12	0.1
Rock Type	I	I	II	I	III	I	II	I	I

Table 3.2.1-2: Rock type classification

Type I	Potentially acid forming	Total Sulphur > 0,25 % and AGP:GNP ratio 1:1 or less
Type II	Intermediate	Total Sulphur > 0,25 % and AGP:GNP ratio 1:3 or less
Type III	Non acid forming	Total Sulphur > 0,25 % and AGP:GNP ratio 1:3 or greater

Note:

AGP = Acid generation potential GNP = Acid neutralisation potential

Six of the nine samples analysed during acid-base accounting indicate a definite potential to generate acid (JS/66, JS/65, JS59, JS/39, GP08 and GP09). Only one sample (JS/53) has a nett acid neutralizing potential. It can therefore be concluded that acid formation in the proposed Belfast project area is very likely to occur. This tendency of the coal and overburden to turn acidic, combined with the fact that the majority of the backfill material will remain under oxidizing conditions, will result in a poor quality water – most probably acidic – decanting from the Belfast project mine blocks.

3.3 NUMERICAL GROUNDWATER MODEL

3.3.1 Flow model

Numerical flow and mass transport groundwater models were constructed to simulate current aquifer conditions and impacts and to provide a tool for evaluation of different management options for the future. A risk analysis could also be performed where affects of different flow and concentration parameters as well as the impacts of nearby existing operations and management options could be evaluated.

It is important to note a few aspects of the numerical modeling exercise:

- The numerical model is a very simplified representation or simulation of the actual situation.
- Measured aquifer parameters are used to calibrate the numerical model and the level of confidence of model calculations is only as good as the information (accuracy, distribution, frequency etc) on which it is based and the conceptual understanding of the groundwater regime.
- Where time-series monitoring data is not available for model calibration (as is the case at the Belfast Project) the level of confidence of predictions cannot be very high, especially where predictions are made far into the future.
- With the lack of time-series monitoring information, the predictions of flow and mass transport from the numerical model for the Belfast Project should be **considered only qualitatively and not much value can be attached to the quantitative results**.
- Quantitative predictions should only be used towards the end of the life of mine when a long time-series monitoring record has been developed that can be used for model calibration and refinement.

The modeling package PMWIN Pro (Processing Modlfow Professional for Windows) was used for the simulation. The regional Belfast project model that includes both the West and East proposed new mining blocks covers an area of ± 98 km^2 (8.5 by 11.5 km). The model was run in steady state conditions until representative transmissivity and recharge distributions were obtained with a simulated hydraulic head distribution closely mimicking the average measured conditions. Two model layers were constructed in the model. Layer 1 simulates the upper weathered zone aquifer conditions, which has both the characteristics of a primary and secondary aquifer. Layer 2 represents the fractured rock, or secondary aquifer. The aquifer parameters that were assigned to the model are given in **Table 3.3.1-1**.

After the model was run and the steady state solution was used to calibrate simulated water levels with the available measured water level information, a groundwater mass transport model was constructed. Calibration of the flow model was aided largely by existing flow and water level information gathered from various hydrocensus and monitoring boreholes, which are situated within the same geological environment. The calibration results are indicated in **Figure 3.3.1-1**. A correlation of 94% between calculated and observed water level elevations was achieved with the steady state calibration of the flow model.

Table 3.3.1-1: Numerical flow model parameters

	Layer 1	Layer 2
Properties	Confined/Unconfined	Confined
Thickness (m)	20	100
Recharge (m/d): High topographical areas	6.5E-05 (3.6%)	None
Recharge (m/d): Valley bottom discharge areas	4.2E-05 (2.3%)	None
Transmissivity of general rock matrix (m^2/d)	1.2	0.5
Dykes transmissivity (m^2/d)	0.05	0.05
Faults transmissivity (m^2/d)	10	10
Storage Coefficient	0.08	0.005

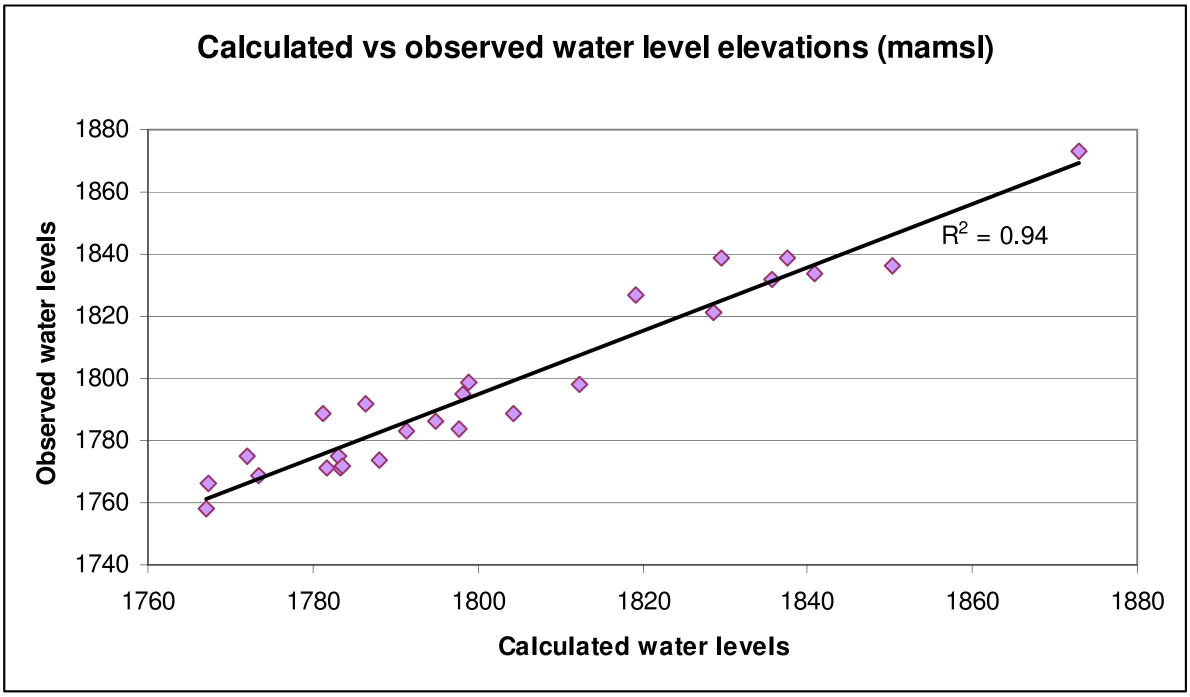


Figure 3.3.1-1: Calculated vs. observed hydraulic heads

The model simulation was subdivided into 39 different stress periods. A stress period in the model is a period where groundwater flow and mass transport conditions are constant. All time dependent parameters in the model, like drains, rivers, aquifer recharge, contaminant sources, sinks and contaminant concentrations remain constant during the course of a stress period. For the proposed new mining areas at the Belfast project, the following conditions were used to divide the simulation into stress periods in the transient state model run after steady state was simulated:

Table 3.3.1-2: Stress periods in the numerical model

Stress Period	Conditions and impacts
1 – 5	Active mining at the East block begins.
6 – 27	Mining of the West block begins at the beginning of stress period 6. Active mining of the East mining block continuous. Mining in the West Block ceases at the end of stress period 27.
28-39	Active mining at the East block ceases at the end of stress period 39 according to the mine schedule.

Simulated impacts on groundwater level at 5 and 10 years after mining has started

Water level impacts have been simulated with the numerical model at three stages, namely 5 years into the operation, 10 years into the operation and at the end of the operation when maximum impacts occur.

The simulated drawdown from steady state water levels are indicated in the figures below.

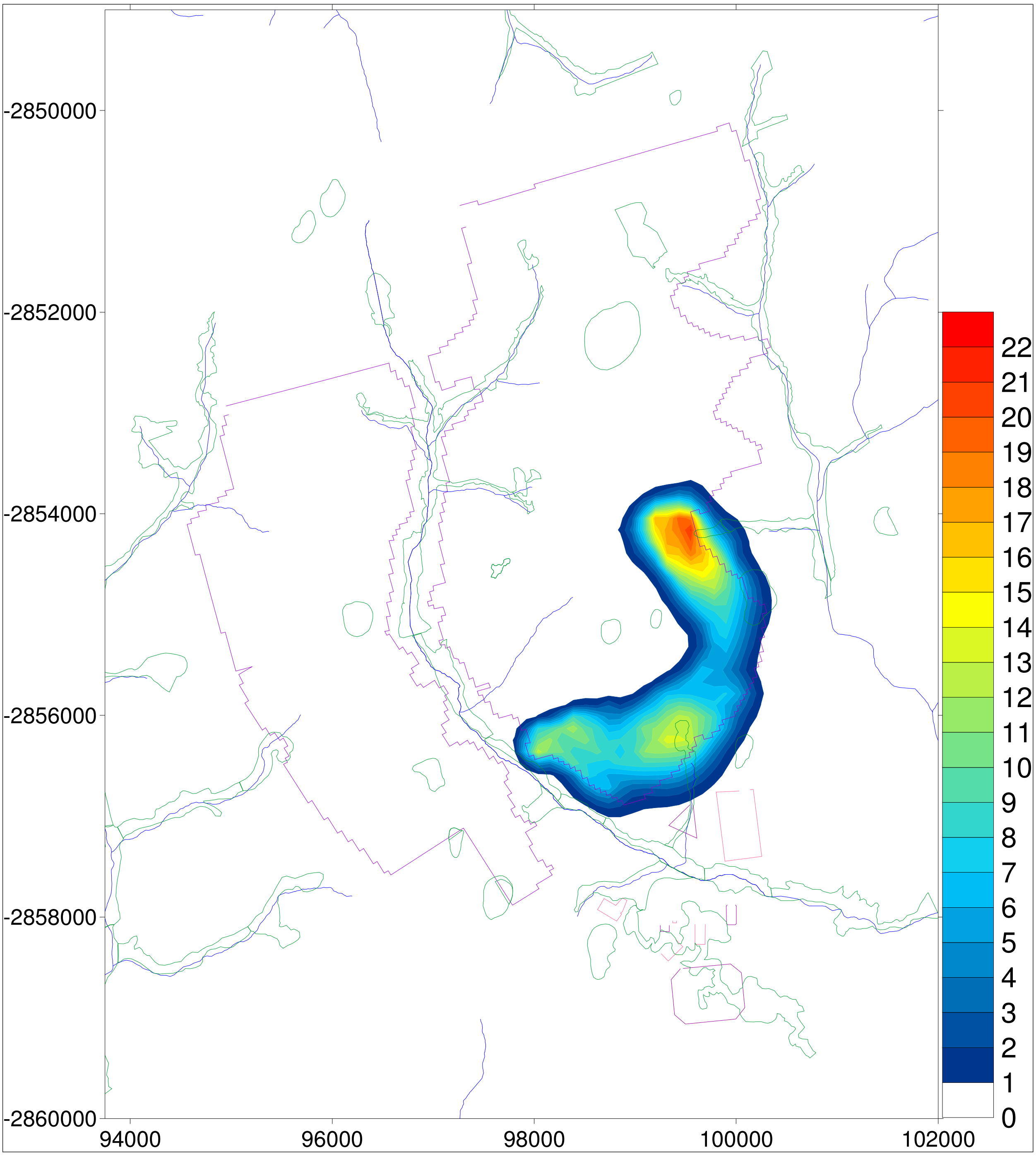


Figure 3.3.1-2: Simulated drawdown 5 years after mining has started

A maximum simulated water level drawdown of 22 meters is visible towards the eastern boundary of the East block. The tributaries and wetlands in the extent of the cone of depression will be affected in terms of discharge volume. No water level drawdown is simulated for the West Block since the mine schedule does not include any mining in the West Block for the first 5 years. The cone of depression is estimated to be limited to around 300 meters from the pit.

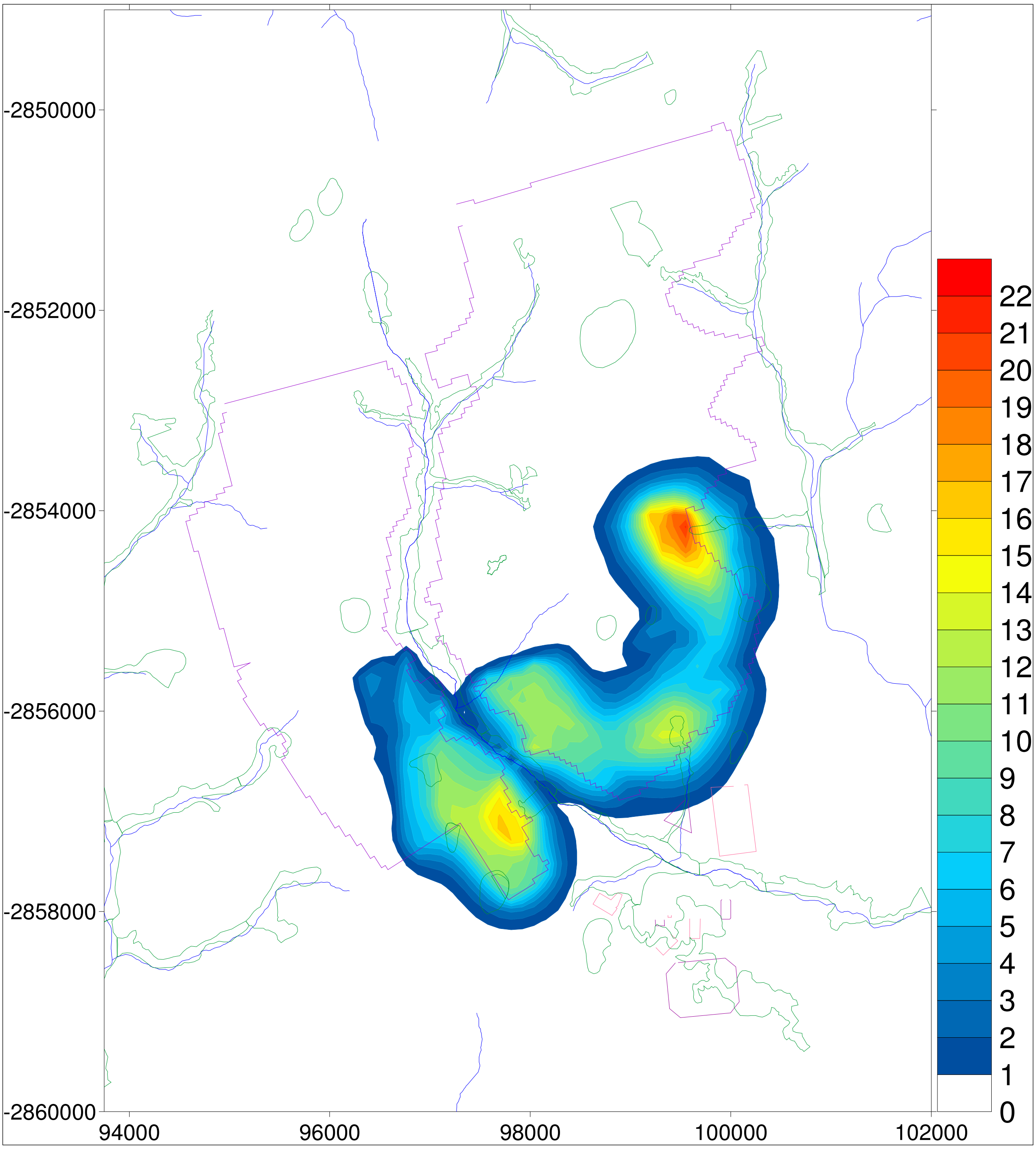


Figure 3.3.1-3: Simulated drawdown 10 years after mining has started

Ten years after mining has commenced, the cone of depression will have increased in size. The maximum drawdown is still 22 meters in the East Block. Mining has started at the West Block and the maximum simulated drawdown in the West Block is approximately 17 meters. It is indicated that the depression cone will be measurable at a maximum distance of approximately 500 meters from the pit.

Maximum Possible Groundwater Level Impacts at the end of mining

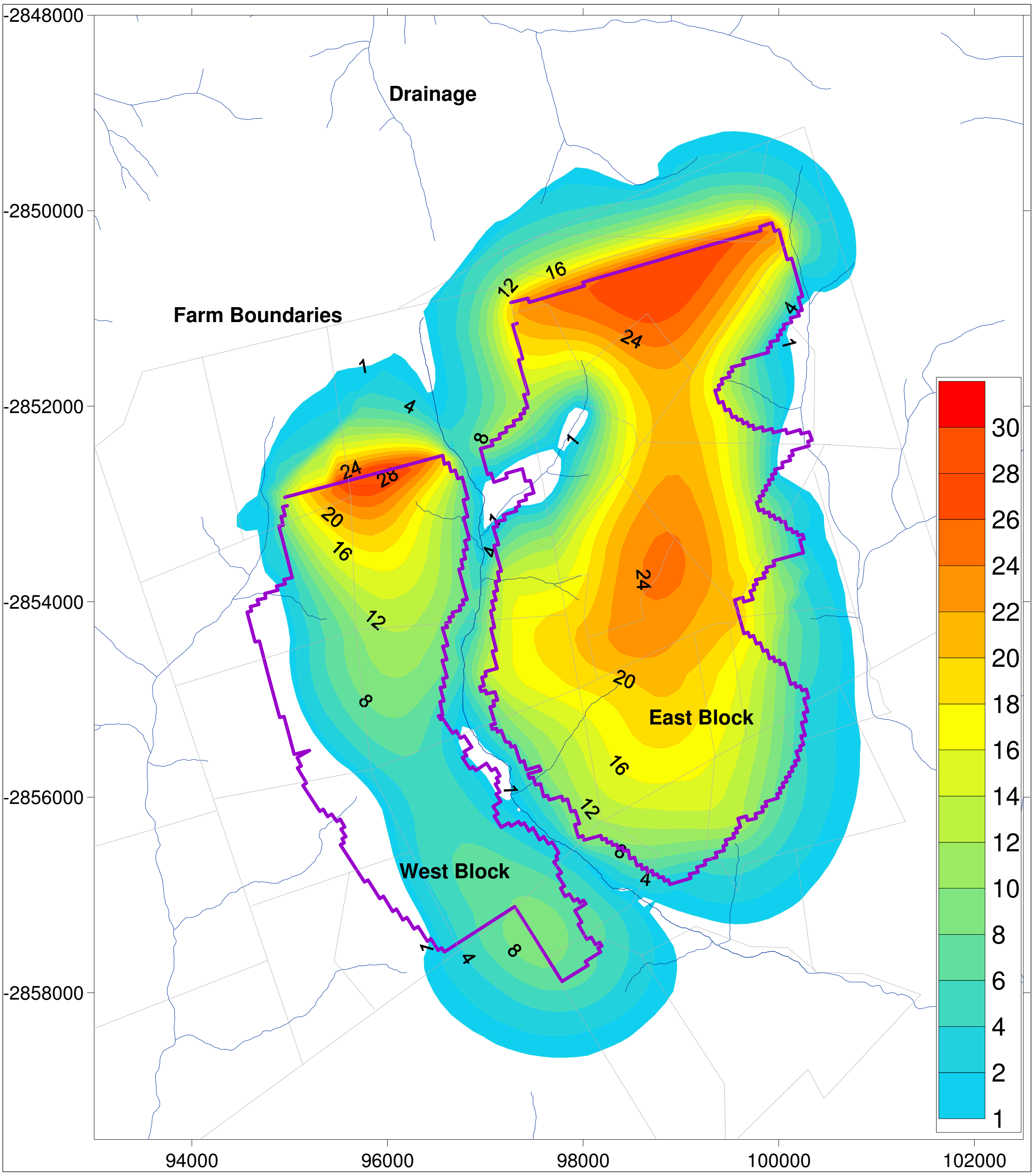


Figure 3.3.1-4: Simulated maximum possible cone of depression at the end of mining

The simulated cone of depression, or drawdown, caused by mine dewatering is given in **Figure 3.3.1-4.**

To obtain the maximum possible drawdown of groundwater, the transmissivity of the mine blocks was increased to 30 m^2/day during the operational phase.

According to the model simulations a maximum possible drawdown (worst case) of more than 26 meters can be expected in the East block, while a maximum possible drawdown of more than 28 meters was simulated for the West block. The simulated drawdown in the East block is less than in the West block simply because the pit will be shallower or the water levels deeper resulting in a smaller difference in depth between the groundwater level and base of the coal seam.

The maximum estimated drawdown was simulated to be in the northern part of the proposed pits, as this is where the maximum difference between the water level and coal seam exists.

In some areas in the mine blocks a rise in water level is visible during the operation phase. In these areas the coal seam is higher than the static water levels. Mining will therefore not cause drawdown in these areas. The recharge in the mining areas increases during the operational phase of mining to approximately 12% of the mean annual precipitation, which is in the order of 700 mm/a. The increase in recharge will cause a rise in water levels in the areas where the coal seam is higher than the static water levels.

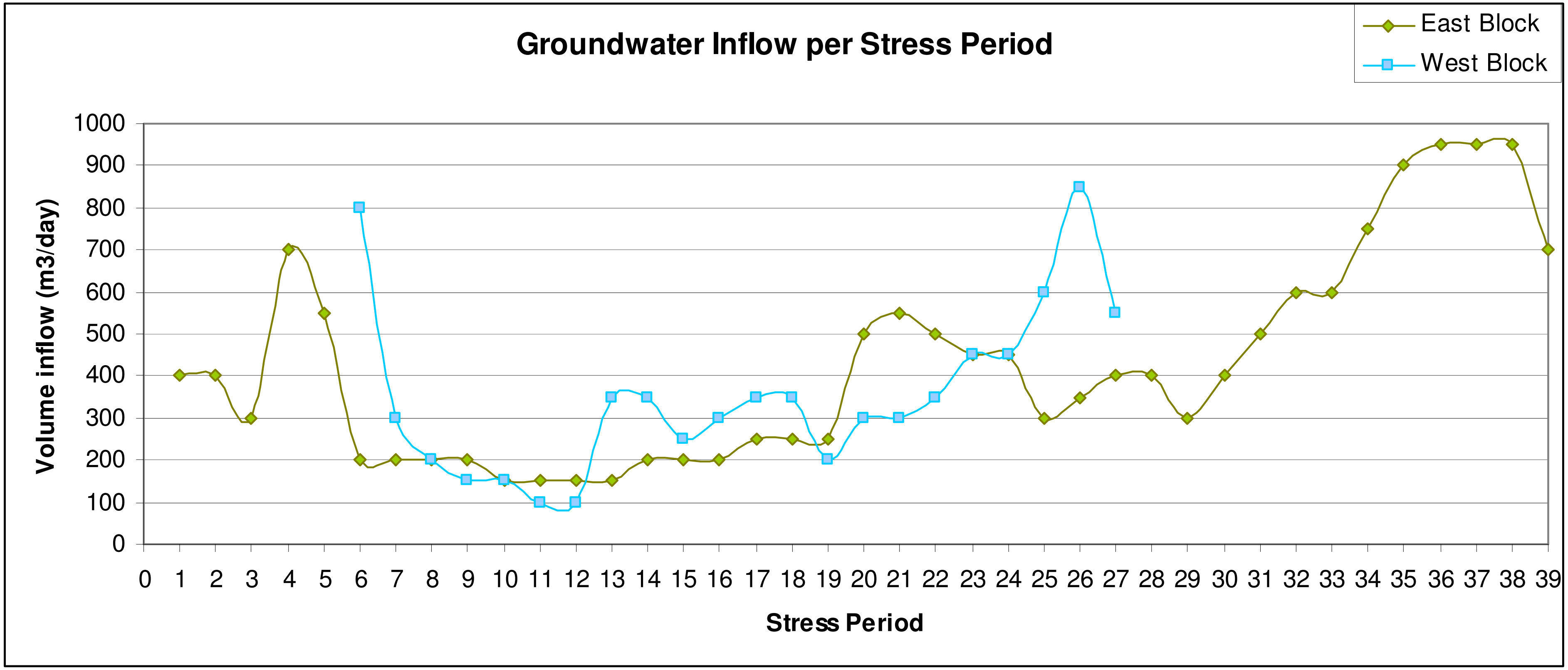


Figure 3.3.1-5: Simulated maximum possible groundwater inflow to mining areas

Groundwater status 50 years after mine closure

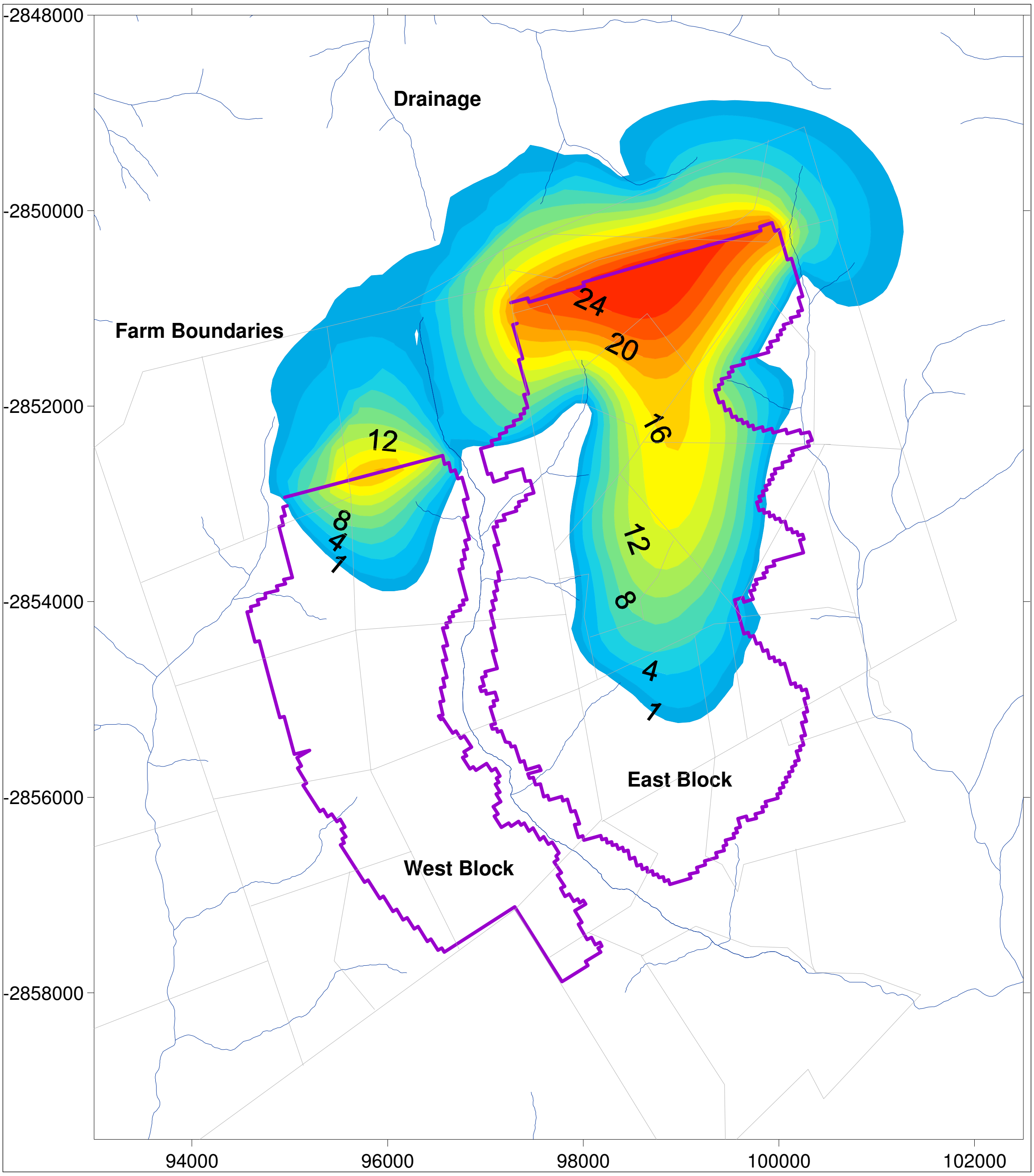


Figure 3.3.1-6: The extent of the cone of depression 50 years after mine closure

The transmissivity and storativity increases in the mined areas. A transmissivity of 30 m^2/day and storage coefficient of 0.35 was used in the post closure numerical model. The drains which were used to simulate the mine blocks have been removed in the post closure model. The model was then run for a period of 50 years.

The groundwater level has not recovered 50 years after mine closure as indicated in Figure 3.3.1-6. The main reason for the lack of full recovery of the pit water level is the higher transmissivity of the backfill material in the rehabilitated pits that will result in southwards flow of water through the spoils and the fact that decant will occur in the south of the mined-out blocks. The decant onto surface in the south will occur at lower elevations than the pit floor elevation in the northern portion of the mine. The water level in the northern part of the mine blocks will thus **never recover fully after mining**.

The maximum difference between the steady state water levels and the 50 years post closure water levels is just over 26 meters in the East block. These higher differences are observed in the northern regions of the mining blocks where maximum drawdown was caused during the operational phase. The larger extent of the depression cone is caused by the higher transmissivity and storage coefficient applied to the post-closure model.

Although it becomes a very long shot in terms of model prediction, the applicant requested an export of the impact on the water level at 150 years after closure. It has been indicated at the beginning of the section that the level of confidence in the accuracy of predictions far into the future becomes very low and it is reiterated that the results should be considered qualitatively alone.

It follows from the simulated drawdown contours that the geometry of the depression cone at 150 years after mine closure is similar to the cone 50 years after closure. The reason is that the water level will never recover in the northern portions of the two backfilled pits. The much higher transmissivity of the backfill material will result in a flat water level in the pits and the water level will recover only to the decant elevation.

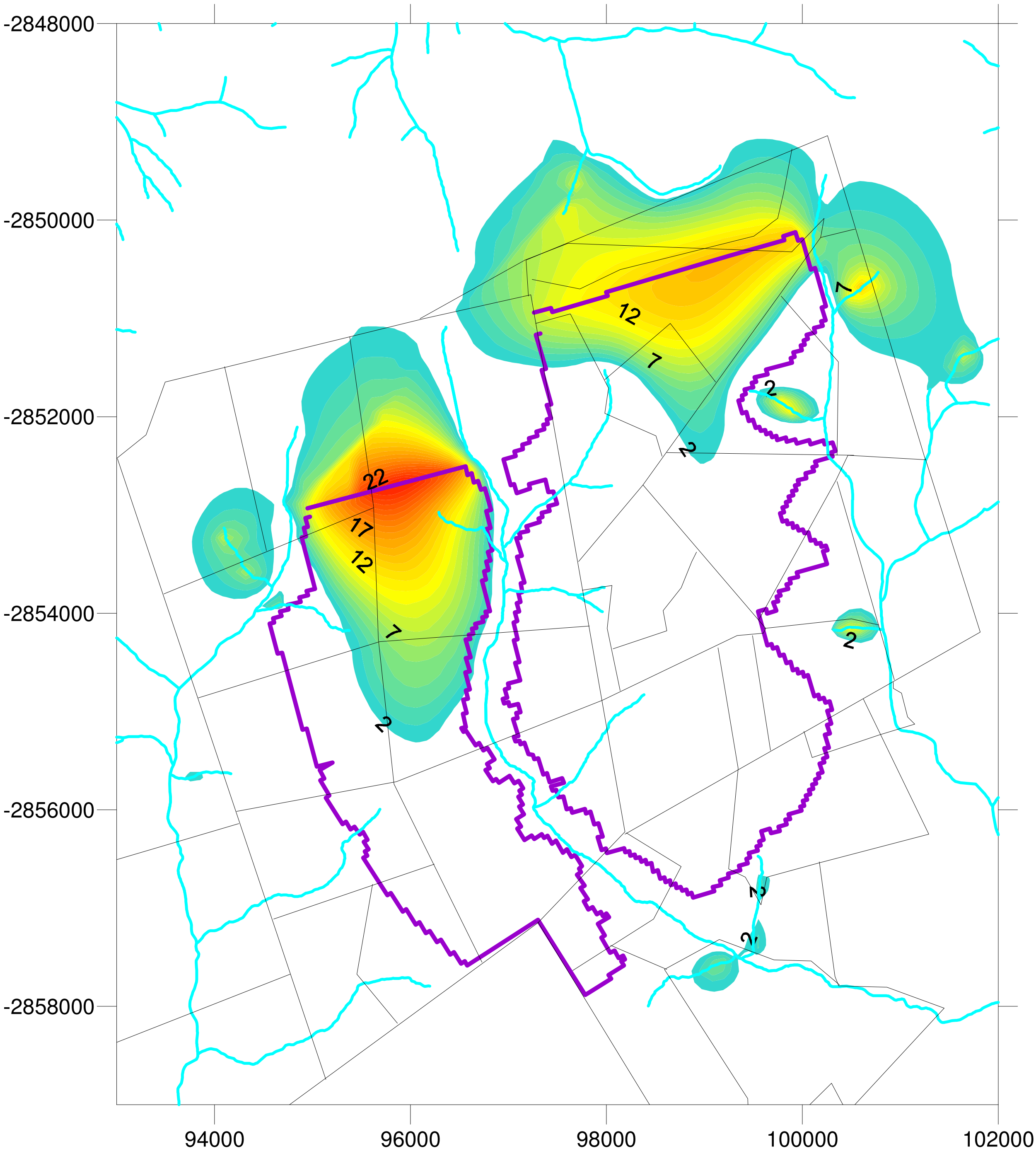


Figure 3.3.1-7: The simulated extent of the cone of depression 150 years after mine closure

3.3.2 Mass transport model – Simulated pollution plumes and movement

In the case of a perched water table or an unconfined / semi-confined aquifer, the hydraulic gradient is equal to the slope of the water table, measured at different points in the aquifer. The hydraulic gradients in the Belfast project area were calculated from the difference in elevation of groundwater levels in each area. The averaged hydraulic conductivities of the saturated zone, as calculated from the low rate pumping tests, were used as approximations of the saturated hydraulic conductivity of the Belfast project area. The average groundwater flow velocities, more accurately termed the Darcy velocity or Darcy flux, in the Belfast project area were calculated, using the following equation (after Fetter, 1994):

$$v = \frac{KI}{\phi}$$

where: *v = flow velocity (m/day)*

K = hydraulic conductivity (m/day) = 0.06

I = average hydraulic gradient = 0.01

ϕ = probable average porosity = 0.1

The hydraulic conductivity and average porosity were chosen so as to provide a very liberal estimation of seepage velocity. The actual seepage through the aquifer matrix should be lower than the products calculated below but highly transmissive fracture zones or areas of steeper gradient might cause higher transport rates.

The hydraulic conductivity and the average hydraulic gradient are known parameters. By making use of these values, the average steady state Darcy velocity in the proposed mining areas is estimated 0.006 m/day (2.2 m/a)

These estimates do however not take into account all known or suspected zones in the aquifer like preferential flow paths formed by igneous contact zones like the intrusive dykes that have higher than average flow velocities. In fractured aquifer media, the transport velocity is usually significantly higher than the average velocities calculated with this formula and may increase several meters or even tens of meters per year under steady state conditions. Under stressed conditions such as at groundwater abstraction areas the seepage velocities could increase another order of magnitude.

During active opencast mining and until a new groundwater equilibrium has been reached, the opencast pits act as groundwater sinks and groundwater will move radially inwards towards the pits. This means that during this period poor quality leachate generated by acid mine drainage will move towards the mine voids and cannot drain towards the immediate surroundings. Mining at the proposed Belfast project occurs from south to north, which is upgradient. Where progressive backfilling has occurred at lower elevations the water level can somewhat recover and cause leachate to move away from the backfilled areas. For this reason the migration of pollution will be simulated at mine closure and 50 years post-closure.

The mass transport model was constructed by assigning high transmissivity, storativity, and recharge values to the backfilled opencast pits. Six potential sources of groundwater pollution exist within the model boundary namely: the backfilled opencast pits, the crushing, screening and washing plants, co-disposal site, surplus stockpiles, dams (return water, raw water and storage dams) and workshops. The backfilled opencast pits, crushing, screening and washing plants, workshop and surplus stockpiles were simulated with the use of contaminated recharge. The co-disposal facility and return water dam were simulated as contaminated river nodes since they are wet sources.

The significance of pollution plume migration and the coinciding affect on the groundwater quality of downstream regions is more significant because groundwater users occur downgradient. **Poor quality leachates are likely to affect surface water quality in the tributaries of the Leeubank stream to the west of the West block and the Klein Komati River to the east of the West block as well as tributaries west, east and south of the East block.**

The long-term impacts on quality have been estimated through numerical modeling but have to be confirmed through groundwater monitoring during the operational and closure phases should the mining project go ahead. Two figures were exported from the numerical model to illustrate simulated impacts on the groundwater quality during and after mine closure. The two figures contain TDS concentrations contours at different times in the life-of-mine, namely at mine closure when plume movement has started in some areas and at 50 years after closure when plumes have moved a distance from the sources.

Groundwater contamination starts moving away from the mine during the operational and decommissioning phases because the mining progresses upgradient. In the downgradient areas, where mining has finished and the areas were backfilled (roll over mining method), the groundwater level can start to recover. The contamination can therefore start to move downgradient during the operational phase. At active mining areas the mine acts as a groundwater sink area and flow with associated mass transport is radially inwards towards the mined area. Therefore, no pollution movement is possible away from the active mining until the water level has recovered to near pre-mining levels.

Due to the fact that the decanting point is lower than the majority of the pit area, little carbonaceous material will be covered before decanting starts. A large portion of the pits will therefore be exposed to oxygen. Contamination in the form of acid mine drainage will thus occur.

Figure 3.3.2-1 indicates that contamination at mine closure will start to spread away from the mine since the water levels can start to recover downgradient. A Total Dissolved Solids (TDS) concentration of 5 000 mg/l was applied to the mine voids and all other potential source areas. The exact TDS concentration at the end of mining is unknown but 5 000 mg/l is considered to be a conservative estimated of what the final concentration of the groundwater will be. The TDS will be the highest at the source and will decrease away from the source as the contamination plume moves.

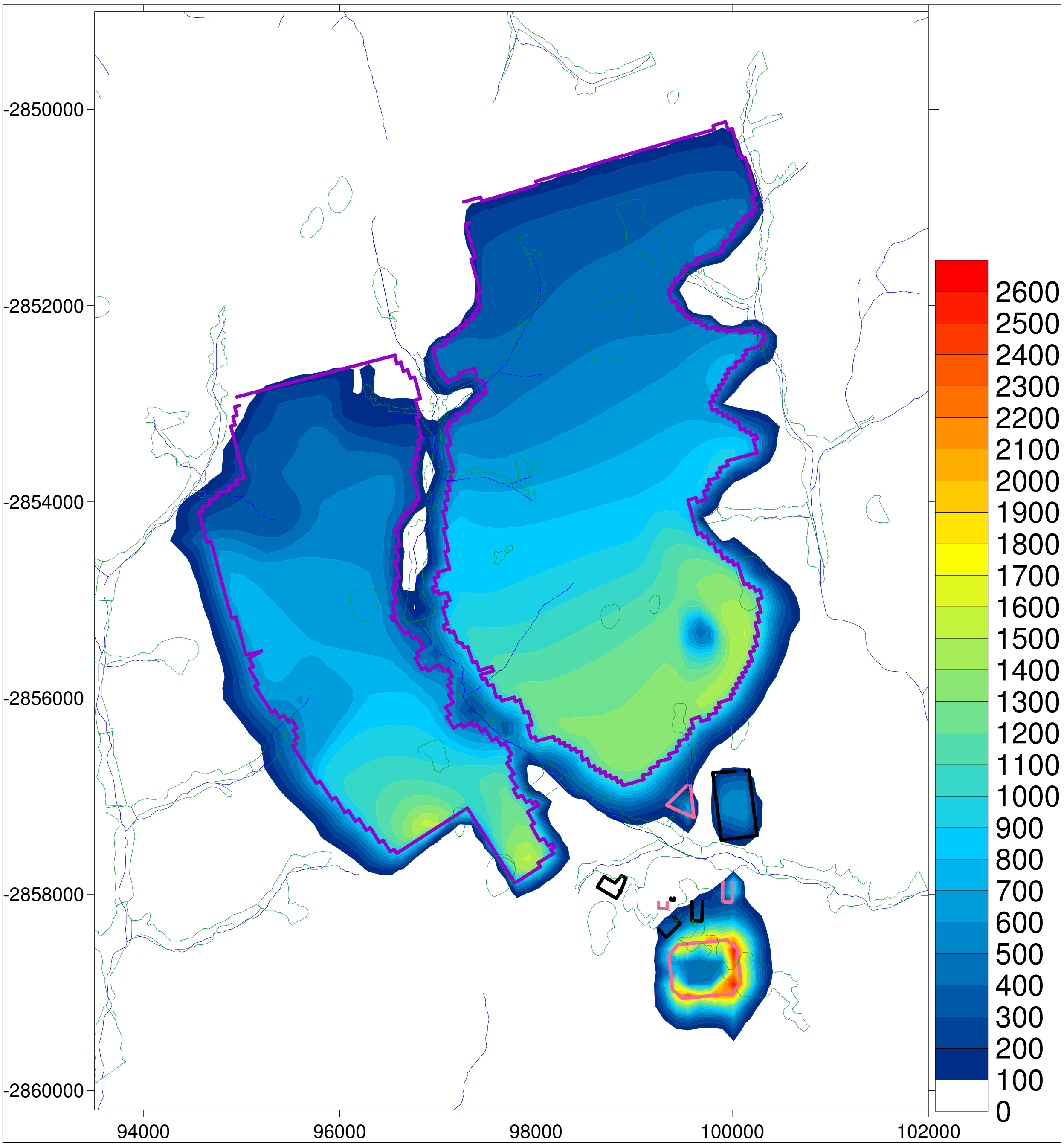


Figure 3.3.2-1: Simulated TDS source concentration contours at mine closure

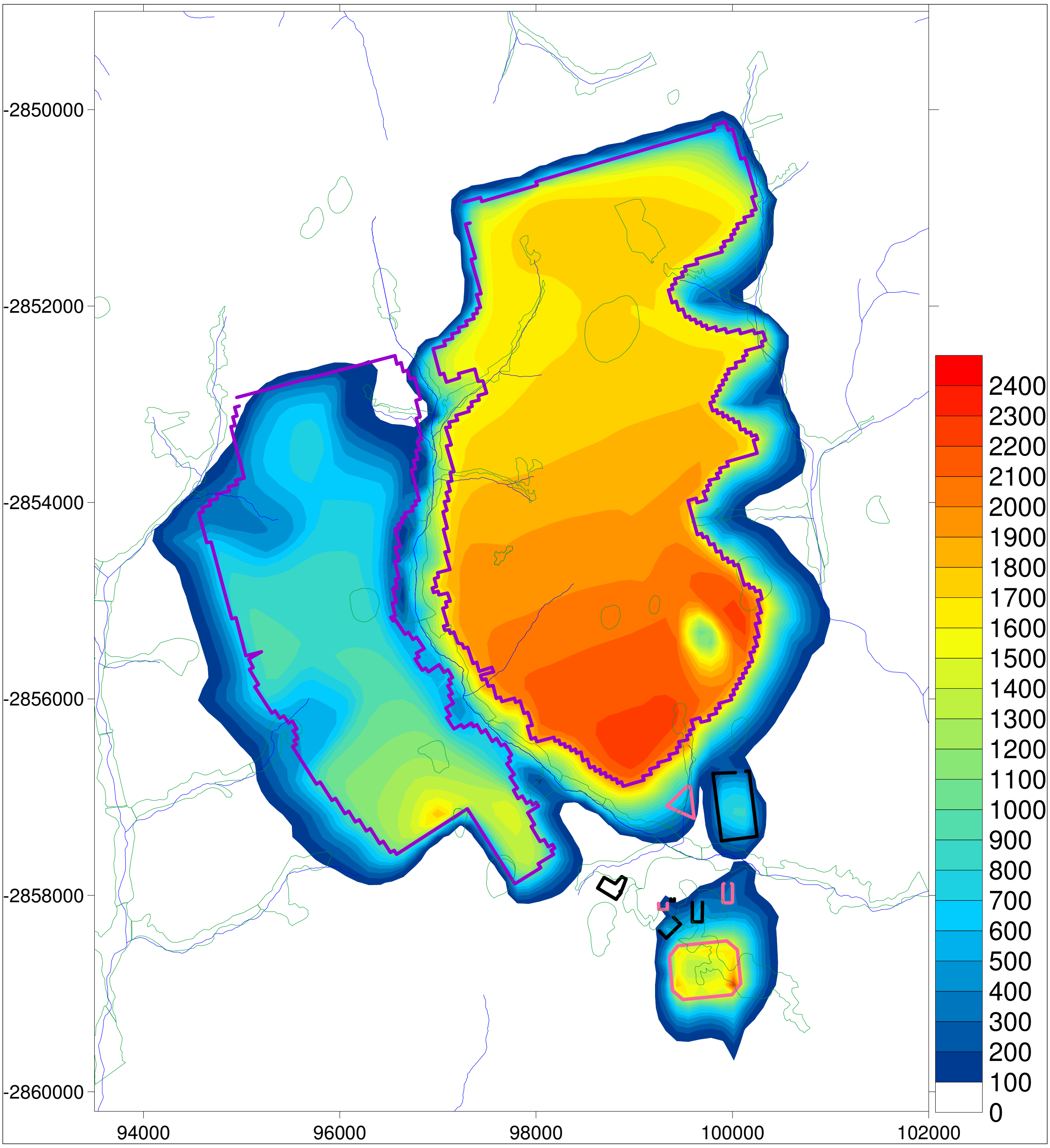


Figure 3.3.2-2: Simulated TDS concentration contours 50 years after mine closure

It follows from the figures that the pollution concentrations continue to increase in the rehabilitated pit areas as a result of continued leachate formation but concentrations decrease in the decommissioned processing areas because the sources of contamination have been removed.

The surface water tributaries surrounding the two opencast areas and the mine related infrastructure areas (plants, co-disposal site, workshop and RWD) will be affected by plume movement. The plume will move towards the west, east and south from the pit areas. The plumes will extend a maximum distance of approximately 500 m from the pits and sources.

It should be noted that plume movement from the rehabilitated opencast areas can be contained or reduced to a large extent by lowering the decant elevation. This can be achieved by leaving a deeper void (at least 5-10 meters below surface) at the decant point and pumping at a rate that keeps the water level down below the surface. The same can be achieved by a dewatering borehole drilled or built into the backfill material at the decant point.

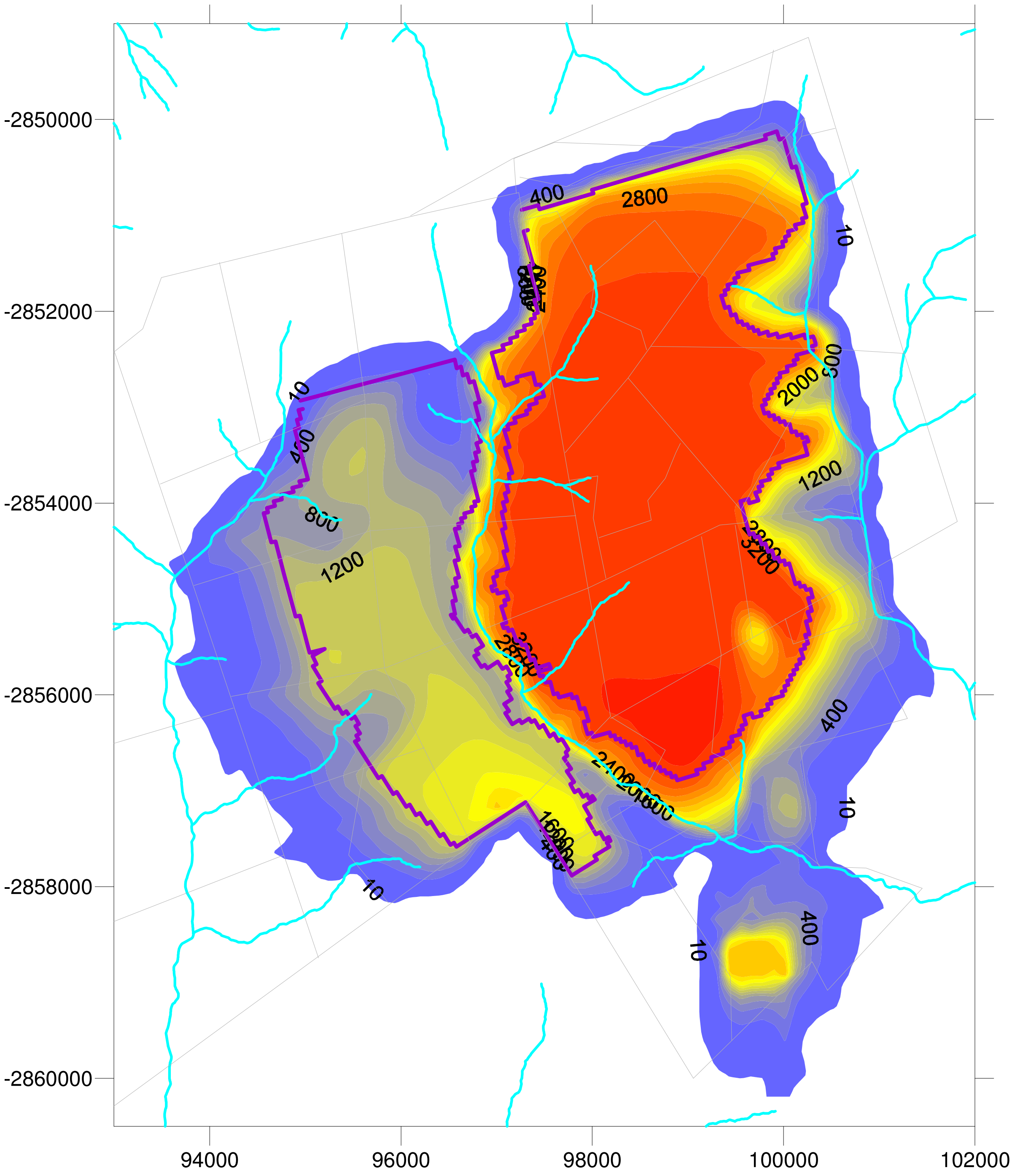


Figure 3.3.2-3: Simulated TDS concentration contours 150 years after mine closure

3.3.3 Estimated quality and quantity impacts on wetlands and pans

If the environmental water balance is considered, it is estimated that only approximately 3% of the mean annual precipitation (MAP) ends up as effective recharge to the aquifer(s). If the direct surface run-off is considered to be in the order of 20% of MAP, it means that the remainder of the MAP exists as water retained in and migrating horizontally through the soil profile, as well as water being lost to evapo-transpiration. It is also this soil moisture/water that is considered to have by far the most significant contribution to the water in the wetlands (channel flow, hill-slope etc.) and pans in the Belfast Project surface area.

The water that ‘feed’ the pans in the Belfast project area is therefore considered as soil water rather than groundwater. This water remains within the soil layer due to a less permeable layer underlying the soil horizon. The water level drawdown due to mining will thus have a direct effect on the groundwater level but is not considered to having a significant adverse impact on the soil water and will therefore not cause severe decreases in water flow to the streams and pans. The pans within the two mine block boundaries will be mined away completely.

The drawdown in water level will however cause a decrease in the base-flow discharge to the tributaries / hill-slope wetlands. The biggest impacts in terms of base-flow discharge are the tributary (of the Klein-Komati River) and hill-slope wetlands that flows through from north to south between the two mine blocks. At maximum impact at the end of the life of mine a decrease in discharge of more than 70% is expected for the portion of the stream between the mine blocks. Discharge to the smaller tributaries surrounding the mining blocks will decrease between 10 and 40% towards mine closure.

The mining is also expected to have an impact on the surrounding tributaries and hill-slope wetlands in terms of quality. At mine closure a maximum total salt load that can be released into the surrounding tributaries can vary between 22 and 80 kg/day. Fifty years post closure this figure can increase up to a maximum of 1800 kg/day.

Please note that no tests were done to determine surface water and groundwater interaction. The values provided above are only estimates and will have to be confirmed by an updated model using time-series monitoring information.

4 MONITORING PLAN/PROTOCOL – WHERE, WHAT, HOW

Water samples will be taken around the mining areas as well as in the dams constructed for the purpose of dirty water management on a quarterly basis. Samples will also be taken in the monitoring boreholes on a quarterly basis. Water levels of these boreholes will also be determined on a quarterly basis when the sampling is done. Samples will be analyzed for chemical and physical constituents normally associated with coal mining. These constituents are listed in **Table 4.1-1**.

It must be mentioned that this monitoring schedule will be re-assessed by a qualified geohydrologist at a later stage in terms of stability of water levels and quality. Should the sampling program be changed, it would be done in consultation with the DWA&F.

Table 4.1-1: Groundwater constituents for routine analysis

Monitoring	Variable
Quarterly*	EC, pH, TDS, total hardness, total alkalinity, calcium, magnesium, sodium, potassium, chloride, sulphate, fluoride, nitrate, iron, manganese, aluminium and turbidity

Note:
** = Once trends are established, some of these constituents may be sampled less frequent, while others found to be problematic may be added as determined on consultation with the relevant role players, such as the DWAF: Regional Office.*

Reporting on groundwater quality conditions will be included in the annual report.

The quarterly report will be an update of the database with time-series graphs, statistical analysis (average, maximum, minimum, 5 -, 50 – and 95 percentile values as well as linear performance). Data will also be presented in a map format to present a clear picture of the water quality situation. Laboratory results will be analyzed against the target water quality guidelines for domestic use, the aquatic environment, livestock watering and irrigation (according to the South African Water Quality Guidelines, 1996: DWAF). The strictest value between the target water quality objectives or objectives through a reserve determination will be used.

In terms of flow, all water uses and discharges will be measured on an ongoing basis. The flows include:

- Make-up water.
- Volumes of groundwater seepage into the pit and pumped from the in-pit sump.
- Volumes of contaminated water used for dust suppression.
- An annual detailed evaluation report on the surface and groundwater quality will be prepared that will analyze the water quality situation in detail to investigate trends and non-compliance.

Data Management

Monitoring results will be entered into an electronic database as soon as results are available, and at no less than one quarterly interval, allowing:

- Data presentation in tabular format,
- Time-series graphs with comparison abilities,
- Statistical analysis (minimum, maximum, average, percentile values) in tabular format,
- Graphical presentation of statistics,
- Linear trend determination,
- Performance analysis in tabular format,
- Presentation of data, statistics and performance on diagrams and maps, and
- Comparison and compliance to South African Water Quality Guidelines and any other given objectives.

As far as possible, the same monitoring points will be used from the construction phase through the operational and decommissioning phases to after mine closure to develop a long data record and enable trend analysis and recognition of progressive impacts with time.

4.1 SURFACE REHABILITATION INSOFAR IT AFFECTS GROUNDWATER

It was indicated that it is the purpose of the surface rehabilitation to re-establish surface drainage to the pre-mining conditions as far as practical.

The rehabilitation will aim to:

a. Restore normal infiltration rates to areas where recharge were reduced due to surface compaction such as the access roads, and
b. Restore normal infiltration rates where recharge was increased such as the exposed surfaces prior to rehabilitation of the opencast mining area.

The rehabilitation, including the placement of soils and re-vegetating of the opencast mining areas will form part of the roll-over mining method used. These previously disturbed areas will thus be rehabilitated to be free draining thereby maximizing the clean surface water runoff and minimizing the percentage infiltration of water, which may become polluted.

The dams constructed for the purpose of dirty water management will also be rehabilitated and the disturbed area sloped to be free draining and vegetated with the purpose of maximizing clean runoff.

4.2 LEGITIMATE REQUIREMENTS OF GROUNDWATER USERS

The proposed new project is in short expected to have the following impacts on the legitimate requirements of the surface or surrounding groundwater users in terms of quantity or quality:

a. No adverse impact is expected on the nearby groundwater users in terms of groundwater availability since the cone-of-depression is not expected to extend more than 1000 m from the pit.
b. Simulated pollution movement is also not further than 600 m from the pit at 50 years post closure.
c. The receiving surface water environment will however be affected adversely through base flow reduction and base flow of polluted water.

All of the above predictions and estimated will however be verified during monitoring through the production, closure and post-closure phases according to the proposed monitoring program.

Management actions will be evaluated to deal with any potential decant predicted by this investigation at the proposed Belfast project opencast areas.

Should it be indicated through monitoring and investigation by a suitably qualified person that any legitimate groundwater users are impacted upon in terms of quantity or quality of borehole water, suitable alternatives should be investigated.

The Belfast Project will comply with the target objectives set for the surface- and groundwater resources in terms of a reserve determination under the National Water Act, 1998.

4.3 PERFORMANCE ASSESSMENT AND MONITORING OF THE ENVIRONMENTAL MANAGEMENT PROGRAM

In order to ensure compliance with the environmental management program and to assess the continued appropriateness and adequacy of the environmental management program, Belfast Project commits to:

- Conduct the monitoring of the environmental management program on an ongoing basis.
- Conduct the performance assessments of the environmental management program.
- Compile and submit to the Director: Mineral Development a report on the performance assessment of the environmental management program.
- The performance assessments of the environmental management program and the compilation and submission of the reports will occur every year from the date of approval of the environmental management program.
- The first performance assessment of the environmental management program will be scheduled to take place within 1 year of the approval of this EIA and IWULA report.
- The Belfast project will appoint a responsible person(s), in writing, who will monitor all environmental aspects of the site on a regular basis. A copy of this letter of appointment

including the relevant emergency numbers will be supplied to the Director: Mineral Development of the DME.

- The appointed person will communicate, on a regular basis, with the local interested and affected parties identified with regards to the project and will report on the progress made with regards to implementation of the mitigation measures. Any complaint, with regards to the mining activity, will be reported to the appointed person and be recorded in the complaint register.

A report with regards to the following issues will be submitted to the DME on a yearly basis:

a. Quantities processed to be recorded on a monthly basis.
b. Percentage of disturbed area rehabilitated (rehabilitation figures) – recorded on a three monthly basis. A six monthly report to be compiled.
c. Water quality results;
d. Water levels of identified boreholes, and
e. A copy of the complaints register.

A quarterly water quality (surface and groundwater) report will be compiled and submitted to the Regional Director: Department of Water Affairs and Forestry; Mpumalanga. The contents of the report will include the monthly water monitoring results at surface points and quarterly results at groundwater monitoring positions.

A register of environmental monitoring and auditing results will be available for inspection. This will also include compliance with environmental legislation, e.g. Environment Conservation Act, 1989 (Act 73 of 1989), National Environmental Management Act, 1998 (Act 107 of 1998), National Water Act, 1998 (Act 36 of 1998), etc.

4.4 SUBMISSION OF INFORMATION

The following environmental aspects will be monitored during the closure phase:

Groundwater quality and levels on a quarterly basis of all monitoring boreholes for the specified variables (refer to Part 4.1). The schedule will be based on the variance of the groundwater quality database during LOM. Accessibility of boreholes for monitoring purposes will also be assessed to determine maintenance requirements.

Surface water quality on a quarterly basis based on variance of surface water quality database (refer to Part 4.1 for localities and analyses).

4.5 *ANNUAL MONITORING OF REHABILITATION SUCCESS*

An annual monitoring report will be submitted to the Director: Mineral Development until official closure has been obtained. Once the database shows stability of the various environmental aspects, application for official closure will be made. This will be accompanied by a geohydrologist report with an updated and calibrated model to indicate long-term groundwater conditions and management measures, if required.

Boreholes

The following maintenance activities will be adhered to:

- Monitoring boreholes will be capped and locked at all times,
- Borehole depths will be measured quarterly and the boreholes will be blown out with compressed air, if required and
- Vegetation around the boreholes will be removed on a regular basis and the borehole casings painted, when necessary, to prevent excessive rust and degradation.

5 APPENDIX A: BELFAST PROJECT HYDROCENSUS REPORT

EXXARO RESOURCES
Belfast NBC Project

Hydrocensus

October 2009

1. INTRODUCTION

Exxaro operates a coal mining complex in the province of Mpumalanga which is situated between the towns of Carolina and Belfast. This complex is referred to as the North Block Complex (NBC) and consists of the Glisa and Strathae coal mines as well as the Eerstelingsfontein and Belfast coal projects.

As part of the NBC, Exxaro is in the process of assessing the feasibility of the Belfast project, situated some 10 km southwest of Belfast in Mpumalanga, on the farms Leeuwbank, Zoekop, and Blyvooruitzicht. The Belfast project entails the development of an opencast mine to produce 2.0 Mtpa of coal for Eskom and 1.5 Mtpa of A-grade thermal coal for export markets.

A mining right application for the Belfast Project has been submitted to the Department of Minerals (DM), Mpumalanga Province, which was accepted on 10 July 2009. As required by the Mineral Petroleum Resources Development Act, 2002 [MPRDA] (Act No. 28 of 2002), Exxaro must submit a Scoping Report, Environmental Impact Assessment (EIA) and Environmental Management Programme (EMP) to the DM as part of the mining right application process.

Exxarro also intends to submit an Integrated Water Use License Application (IWULA) that will address all the water use requirements of the mine during the construction and operational phases. This will be done in accordance with the National Water Act [NWA] (Act No. 36 of 1998).

The proposed mining area as well as the required one kilometre buffer zone was surveyed. The potential surface and groundwater users in the area were identified. Although more than one borehole often exists for a user like a farmstead, all boreholes will be surveyed and water level, use and related info recorded but only the main used borehole will be sampled and analysed for groundwater quality. Water quality will only be analysed for other boreholes if used for a specialized and/or sensitive purpose other than general uses like livestock water supply.

Clean Stream Scientific Services was commissioned by Groundwater Complete to conduct the hydrocensus for the proposed expansion. Field work for the hydrocensus was conducted in late August and early September 2009.

2. SCOPE OF WORK

The goal of a hydrocensus field survey is as follows:

- Locating and informing all I&AP of the proposed development
- Gathering of personal information from the I&AP (Name, Telephone number, Address, etc.)
- Accurately logging representative boreholes on the I&AP properties
- Gathering of information of the logged boreholes (Water level, pump type, use, etc.)
- Analysing a representative groundwater sample from the I&AP property
- Presenting all the surveyed localities on a GIS based map

3. INTERESTED AND AFFECTED PARTIES

Contact was made with 25 interested and affected parties, as shown in Table 3-1 and Table 3-2 below. Table 3-2 indicates the I&AP which were contacted, but refused access to their properties, until Exxaro Resources has set up a personal meeting with the owners. Issues which were raised during the telephone conversation with these land owners can be summarised as follow:

- No communication is currently taking place between Exxaro and the landowner,
- No information regarding the proposed project has been communicated through to the landowner,
- Requests for information regarding the proposed expansion have not been fulfilled,
- Access to the properties is denied until such time that Exxaro has contacted and met with the landowners.

From Table 3-1 (properties to which access was allowed), various water use localities were logged (118 localities were surveyed), and water levels (if possible) were taken. Water samples were taken from representative boreholes (42 water samples), on each farm, preferable the boreholes used for domestic purposes. Table 3-1 is only a summarised version of the I&AP information gathered during the hydrocensus, for complete information, the hydrocensus form in Appendix A can be viewed.

Figure 3-1 illustrates the localities surveyed during the hydrocensus. The proposed mine boundary is indicated in orange. Appendix C further illustrates the hydrocensus localities on a satellite image map.

Table 3-1: A summarised I&AP information table gathered for the boreholes on the Belfast NBC Hydrocensus.

I&Aps	Farm	Localities Surveyed	Tel no	Fax No	Cell	Postal Address
Mr P Badenhorst	Blyvooruitzicht 383JT Ptn03	6	-	-	082 443 3086	PO Box 421, Belfast, 1100
Mr WP Pretorius	Blyvooruitzicht 383JT Ptn09/10, Weltevreden, Zoekop Ptn01/07/12	8	013 253 1200	013 253 1200	083 388 4371	PO Box 64, Belfast, 1100
Mr A Mahlango	Blyvooruitzicht Ptn12	2	-	-	-	-
Mrs M Msibi	Blyvooruitzicht Ptn11	2	-	-	082 668 2562	-
Mr De Villiers	Blyvooruitzicht Ptn01	2	-	-	082 770 6141	PO Box 111, Belfast, 1100
Mr Erasmus	Paardeplaats 380J Ptn27	3	-	-	082 326 9446	-
Mr PJ Doyer	Blyvooruitzicht 383JT Ptn12, Eerstelingsfontein 406JT Ptn01	10	-	-	083 756 7427	PO Box 673, Belfast, 1100
Mr R Joubert	Blyvooruitzicht 383JT Ptn11	2	-	-	083 951 0343	-
Mr W Coetzer	Blyvooruitzicht 383JT	1	-	-	083 245 5968	PO Box 671, Belfast, 1100
Mr Kotze	Blyvooruitzicht 383JT Ptn04	6	-	-	082 561 6934	-
Mr G Kuiper	Kaalplaats, Wonderfontein	3	013 297 1643	-	-	-
Mr J Burger (Jan)	Leeuwbank 427 JS Ptn07/08/10	9	013 253 0642	-	082 828 0064	PO Box 396, Belfast, 1100
Mr Walraven	Paardeplaats 380JT Ptn15	2	-	-	083 952 9752	-
Mr P Roets	Paardeplaats 380JT Ptn01	3	013 253 1841	013 253 1841	082 928 2809	PO Box 2903, Witrivier, 1214
Mr J Burger (Johan)	Vaalbank 423JS Ptn14/17/18	3	013 246 7303	013 246 7303	083 457 8727	-
Mr A Viljoen	Zoekop 426JS Ptn04	3	013 253 1057	013 253 1057	083 625 5157	PO Box 403. Belfast, 1100
Mr PC van Wyk	Leeuwbank 427 JS Ptn02	4	013 246 7206	-	082 377 8990	-
Mr A Wannenburg	Weltevreden 381JT Ptn04	1	013 253 1852	-	-	-
Mr L van Rooyen	Weltevreden 381JT Ptn11/12	5	-	-	082 772 9003	Postnet 533, Private Bag X10, Elarduspark
Mr JA Gerrits	Zoekop 426JS Ptn08	12	013 253 1434	013 253 1434	083 7711 820	PO Box 138, Belfast, 1100
Mr C Botha / Mrs E Botha	Zoekop 426JS Ptn05	10	-	-	082 489 9977	PO Box 109, Belfast, 1100
No contact person	Localities for which no contact was established (streams, rivers, pans, etc)	21	-	-	-	-
Total	**All localities surveyed**	**118**				

Table 3-2: A summarised I&AP information table gathered for the Belfast NBC Hydrocensus to which access was denied.

Land Owners within/adjacent Mining Rights area - No Access Allowed

I&APs	Farm	Tel no	Fax No	Cell	Postal Address	Remarks / Comments
Mr PN Kane-Berman	Leeuwbank 427JS Ptn16	013 246 7116	013 246 7116	082 388 3503	Private Bag X251836, Middelburg, 1050	Contact was made with a Mr Roets. Said Exxaro must contact him personally.
Mr C Botha (Christo)	Leeuwbank 427JS Ptn09/15	013 246 1432	013 2461371	083 251 3087	Postnet Suite 87, P/Bag X1866, Middelburg, 1050	Contact was made with Mr Botha. Said Exxaro must contact him personally.
Mr G Roos	Leeuwbank 427JS Ptn04/05/06, Zoekop 426JS Ptn06/09	013 253 1078	013 253 1078	083 228 4653	PO Boc 60, Wonderfontein, 1101	Contact was made with Mr Roos and with his wife. Said after repeated attempts to set up meeting with Exxaro, no feedback was received. Said Exxaro must set up meeting with him.
Mr JP Pretorius	Zoekop 426JS Prt10	013 253 0051	086 514 6085	083 986 4400	PO Box 201, Belfast, 1100	Contact was made with Mr Pretorius (EEPOG). Access denied.

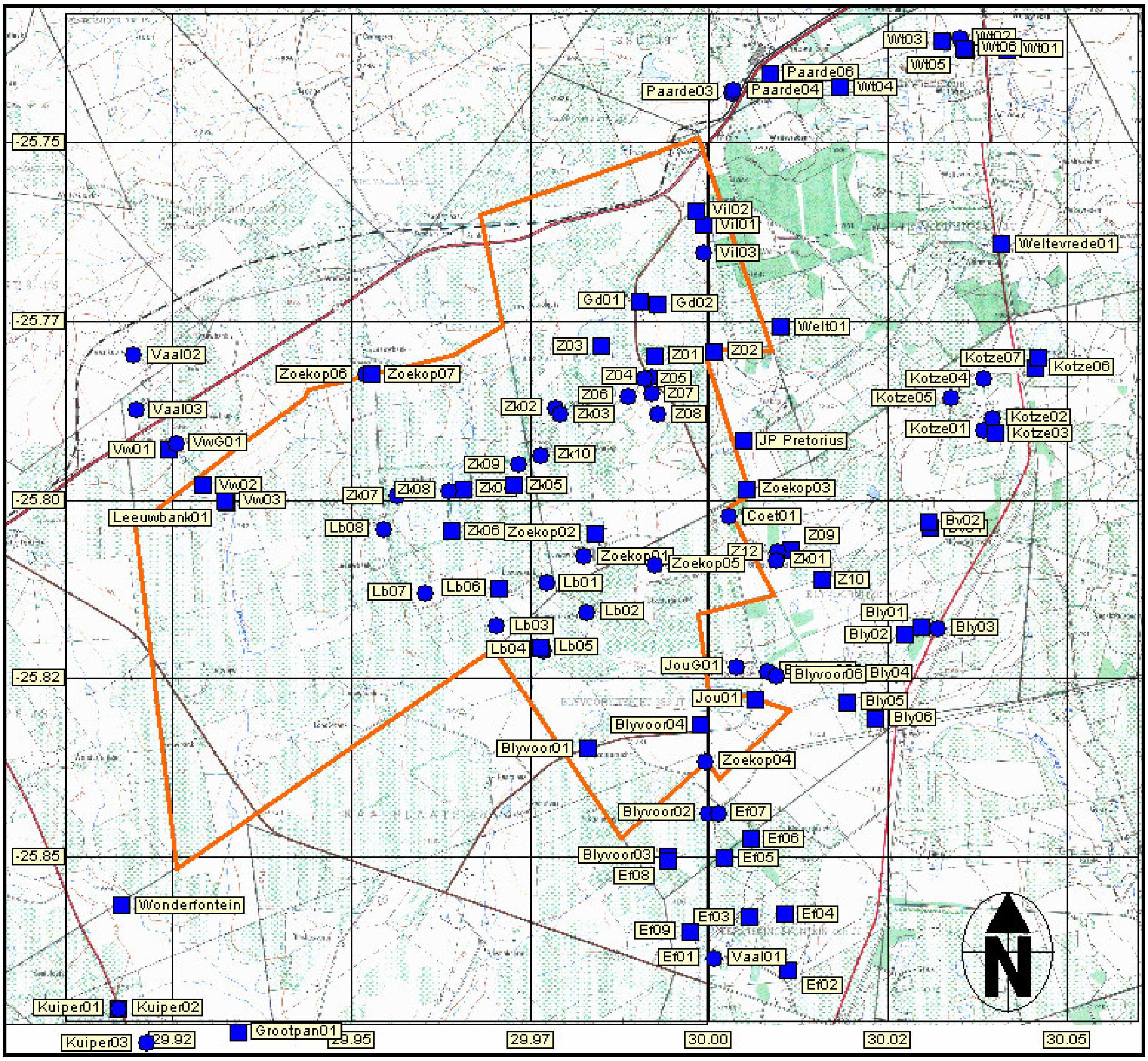


Figure 3-1: Localities surveyed during the Belfast NBC hydrocensus, October 2009.

4. FIELD RESULTS & FINDINGS

Table 4-1 indicates the summarised geohydrological information gathered for the boreholes surveyed on the various farms. The complete hydrocensus form with the data surveyed at each farmer can be viewed in Appendix A.

Table 4-1: Summarised geohydrological information gathered for the boreholes on the Belfast NBC survey (Coordinates in Geodetic, WGS84).

Site Name	Ycoord	Xcoord	Zcoord	Site Type	Description	Water level	Water Use	Owner
Bel01	-25.70105	30.03840	1887	D	Dam		Livestock	Natural watercourse
Bly01	-25.81791	30.02980	1771	F	Fountain		Livestock	Petri Badenhorst
Bly02	-25.81898	30.02751	1763	D	Dam		Livestock	
Bly03	-25.81816	30.03195	1784	B	Borehole		Domestic, Livestock	
Bly04	-25.82439	30.02002	1743	R	River		Livestock	
Bly05	-25.82852	30.01940	1740	F	Fountain		Livestock	
Bly06	-25.83075	30.02327	1744	D	Dam		Livestock	
Blyvoor01	-25.83483	29.98314	1784	F	Fountain		Livestock	W.P. Pretorius
Blyvoor02	-25.84396	29.99989	1790	B	Borehole		Livestock	A Mahlango
Blyvoor03	-25.84991	29.99435	1767	D	Dam		Livestock	
Blyvoor04	-25.83155	29.99887	1774	D	Dam		Livestock	Natural watercourse
Blyvoor05	-25.82410	30.00826	1772	B	Borehole		Domestic	Mr Msibi
Blyvoor06	-25.82473	30.00940	1770	B	Borehole		Domestic	
Bv01	-25.80399	30.03095	1797	F	Fountain		Livestock	Mr de Villiers
Bv02	-25.80316	30.03085	1801	R	River		Livestock	
Coet01	-25.80243	30.00287	1801	B	Borehole	2.71	Domestic, Livestock	W Coetzer
E01	-25.71658	30.03545	1907	D	Dam		Livestock	P. J. Doyer
Ef01	-25.86420	30.00070	1759	B	Borehole		Not in use	
Ef02	-25.86604	30.01105	1782	F	Fountain		Livestock	
Ef03	-25.85852	30.00566	1767	D	Dam		Livestock	
Ef04	-25.85808	30.01066	1774	F	Fountain		Livestock	
Ef05	-25.85015	30.00221	1777	F	Fountain		Livestock	
Ef06	-25.84751	30.00587	1786	D	Dam		Livestock	
Ef07	-25.84401	30.00131	1788	B	Borehole		Domestick	
Ef08	-25.85059	29.99437	1764	D	Dam		Livestock	
Ef09	-25.86046	29.99752	1754	D	Dam		Livestock	
Eg01	-25.71260	30.04312	1916	B	Borehole	1.98	Domestick	Mr. Erasmus
Eg02	-25.71705	30.03743	1912	B	Borehole	3.65	Not in use	
Eg03	-25.71705	30.03741	1914	B	Borehole	3.40	Not in use	
Gd01	-25.77230	29.99032	1847	R	River		Livestock	Natural watercourse
Gd02	-25.77277	29.99284	1835	R	River		Livestock	Natural watercourse
Grootpan01	-25.87461	29.93425	1695	D	Dam		Livestock	Natural watercourse
Jou01	-25.82803	30.00658	1752	R	River		Livestock	Mr R. Joubert
JouG01	-25.82348	30.00378	1778	B	Borehole	15.99	Domestic, Livestock	
JP Pretorius	-25.79173	30.00482	1788	R	River		Livestock	JP Pretorius
Kotze01	-25.79028	30.03842	1842	B	Borehole	8.25	Domestic, Livestock	Mr Kotze
Kotze02	-25.78876	30.03961	1849	B	Borehole	4.06	Not in use	
Kotze03	-25.79076	30.04016	1841	D	Dam		Livestock	
Kotze04	-25.78303	30.03855	1864	B	Borehole	6.44	Not in use	
Kotze05	-25.78580	30.03396	1839	B	Borehole	14.90	Domestic	
Kotze06	-25.78171	30.04575	1854	D	Dam		Livestock	
Kotze07	-25.78009	30.04613	1855	D	Dam		Old Quarry	
Kuiper01	-25.87140	29.91759	1705	R	River		Livestock	Mr Gerhard Kuiper
Kuiper02	-25.87140	29.91760	1705	B	Borehole		Domestic	
Kuiper03	-25.87610	29.92145	1712	B	Borehole		Domestic	

Site Name	Ycoord	Xcoord	Zcoord	Site Type	Description	Water level	Water Use	Owner
Lb01	-25.81169	29.97737	1795	B	Borehole	34.35	Domestic	Mnr Jan Burger
Lb02	-25.81592	29.98302	1801	B	Borehole	23.85	Domestic	
Lb03	-25.81775	29.97033	1798	B	Borehole	20.17	Domestic	
Lb04	-25.82115	29.97685	1785	B	Borehole		Not in use	
Lb05	-25.82073	29.97654	1780	F	Fountain		Livestock	
Lb06	-25.81242	29.97079	1780	D	Dam		Livestock	
Lb07	-25.81311	29.96045	1801	B	Borehole	6.99	Not in use	
Lb08	-25.80416	29.95466	1809	B	Borehole	27.32	Livestock	
Leeuwbank01	-25.80051	29.93258	1762	D	Dam		Livestock	Natural watercourse
Paarde01	-25.72711	30.01083	1915	D	Dam		Domestic	Mrs B Tshoma
Paarde03	-25.74315	30.00325	1911	B	Borehole		Domestic	Mr Welroven
Paarde04	-25.74276	30.00354	1912	B	Borehole		Domestic	
Paarde06	-25.74041	30.00870	1910	D	Dam		Livestock	
Pp01	-25.72860	30.03370	1920	B	Borehole		Not in use	Mnr Pieter Roets
Pp02	-25.72836	30.03468	1920	B	Borehole	2.90	Domestic, Livestock	
Pp03	-25.72805	30.03370	1915	D	Dam		Livestock	
Vaal01	-25.86434	30.00084	1801	B	Borehole		Domestic, Livestock	Mnr Johan Burger
Vaal02	-25.77976	29.91956	1840	B	Borehole	3.70	Livestock	
Vaal03	-25.78752	29.91999	1834	B	Borehole	3.70	Livestock	
Vil01	-25.76163	29.99931	1853	D	Dam		Livestock	Mr A. Viljoen
Vil02	-25.75967	29.99821	1880	D	Dam		Livestock	
Vil03	-25.76543	29.99928	1836	B	Borehole		Livestock	
Vw01	-25.79306	29.92460	1821	D	Dam		Livestock	Mr PC v Wyk
Vw02	-25.79798	29.92935	1771	D	Dam		Livestock	
Vw03	-25.80028	29.93235	1765	D	Dam		Livestock	
VwG01	-25.79223	29.92558	1823	B	Borehole	6.37	Domestic	
Welt01	-25.77590	30.01015	1840	D	Dam		Livestock	W. P. Pretorius
Weltevrede01	-25.76427	30.04104	1834	R	River		Livestock	Natural watercourse
Wonderfontein	-25.85677	29.91799	1699	R	River		Livestock	Natural watercourse
Wt01	-25.73706	30.04186	1893	F	Fountain		Livestock	Mr Wannenburg
Wt02	-25.73549	30.03513	1913	B	Borehole	6.25	Domestic, Livestock	Mr L van Rooyen
Wt03	-25.73590	30.03264	1909	D	Dam		Livestock	
Wt04	-25.74227	30.01841	1897	D	Dam		Livestock	
Wt05	-25.73709	30.03597	1906	F	Fountain		Livestock	
Wt06	-25.73699	30.03571	1906	D	Dam		Livestock	
Z01	-25.77999	29.99238	1836	F	Fountain		Domestic, Livestock	Mnr Kowie Gerrits
Z02	-25.77927	30.00071	1808	D	Dam		Livestock	
Z03	-25.77858	29.98504	1850	D	Dam		Livestock	
Z04	-25.78298	29.99199	1844	B	Borehole	9.50	Domestic	
Z05	-25.78311	29.99111	1849	B	Borehole	1.40	Domestic	
Z06	-25.78567	29.98871	1854	B	Borehole	3.95	Livestock	
Z07	-25.78510	29.99202	1843	B	Borehole	9.75	Not in use	
Z08	-25.78809	29.99288	1834	B	Borehole	0.70	Not in use	
Z09	-25.80722	30.01147	1772	D	Dam		Livestock	
Z10	-25.81122	30.01588	1768	D	Dam		Livestock	
Z11	-25.80863	30.00937	1784	B	Borehole	9.90	Domestic, Livestock	
Z12	-25.80726	30.00965	1782	B	Borehole		Not in use	
Zk01	-25.80857	30.00937	1807	B	Borehole		Livestock	Ester Botha

Site Name	Ycoord	Xcoord	Zcoord	Site Type	Description	Water level	Water Use	Owner
Zk02	-25.78732	29.97854	1839	B	Borehole	0.81	Domestic	
Zk03	-25.78800	29.97922	1846	B	Borehole	2.04	Not in use	
Zk04	-25.79861	29.96571	1794	D	Dam		Livestock	
Zk05	-25.79809	29.97288	1817	D	Dam		Livestock	
Zk06	-25.80439	29.96403	1791	D	Dam		Livestock	
Zk07	-25.79946	29.95647	1814	B	Borehole	4.65	Not in use	
Zk08	-25.79882	29.96362	1791	B	Borehole		Monitorng Borehole	
Zk09	-25.79513	29.97345	1829	B	Borehole		Monitorng Borehole	
Zk10	-25.79393	29.97660	1840	B	Borehole		Not in use	
Zoekop01	-25.80796	29.98259	1830	B	Borehole		Domestic	
Zoekop02	-25.80478	29.98418	1830	D	Dam		Livestock	
Zoekop03	-25.79872	30.00542	1788	D	Dam		Livestock	
Zoekop04	-25.83668	29.99958	1735	B	Borehole	3.43	Not in use	W.P. Pretorius
Zoekop05	-25.80927	29.99250	1817	B	Borehole		Domestic	
Zoekop06	-25.78257	29.95203	1838	B	Borehole		Livestock	
Zoekop07	-25.78256	29.95292	1842	D	Dam		Livestock	

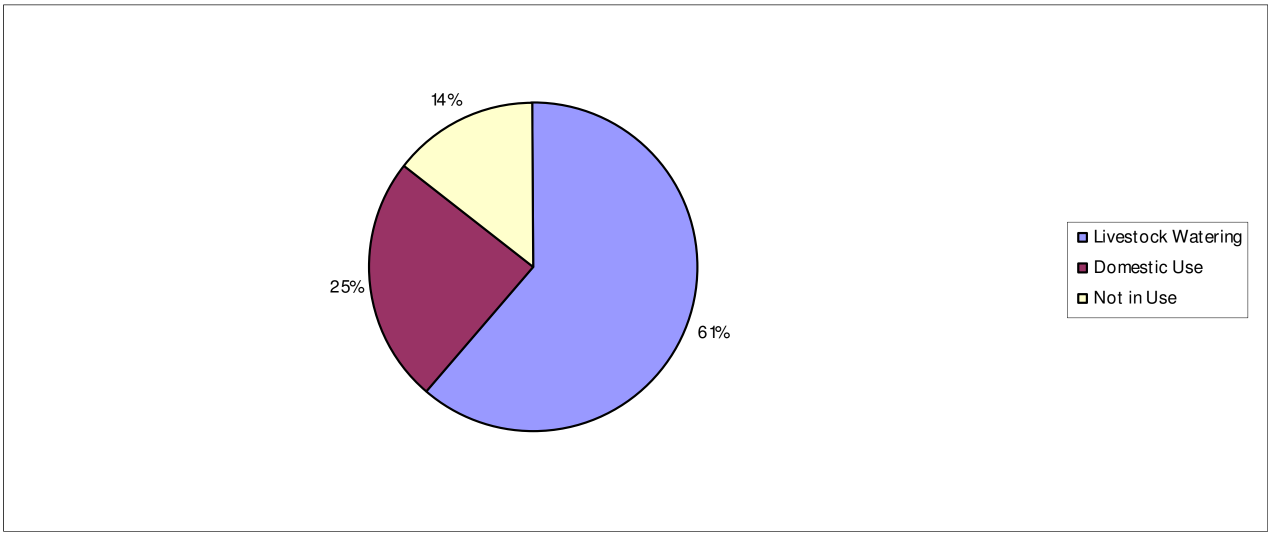


Chart 4-1: Pie Chart indicating the water use recorded for the surveyed localities.

As is clear from Chart 4-1, no groundwater in the area is used for irrigation purposes, although there was some mention for future use. The majority of the use is divided between livestock watering (61%) and domestic use (25%). 14% of the boreholes are currently not in use.

5. WATER QUALITY RESULTS

Water quality analysis was done for 42 strategically identified localities. Clean Stream Scientific Services were responsible for the hydrochemical analysis and the Analytical Certificates are presented in Appendix B. Water qualities are discussed and compared against the proposed DWAF Targeted Water Quality Guideline for Domestic use (Ideal) and Livestock Watering. Water quality results are presented in Table 5-1 to Table 5-4.

Table 5-1: Water quality results for selected hydrocensus localities – Belfast NBC Project, October 2009.

Belfast NBC Project : Selected date - 2009/09/11													
Variable	Domestic Use	Live-stock	Monitoring localities										
			Bly3	BV1	Coetz01	Ef1	Ef2	Ef5	Ef7	EG02	EG03	JOU01	JOUG01
pH ()	6.0 - 9.0	-	8.44	6.90	7.11	7.16	7.22	7.10	6.96	7.18	7.82	7.65	6.92
EC (mS/m)	70	500	2.01	5.44	3.90	6.91	5.85	**209.60**	8.55	9.66	9.47	13.26	11.05
TDS (mg/l)	450	1000	-65	-65	-65	-65	-65	**1436**	-65	-65	-65	-65	-65
T hardness	200	-	3.0	10.0	6.0	18.0	6.0	**1225.0**	30.0	26.0	34.0	29.0	41.0
Ca (mg/l)	80	1000	-0.5	1.6	0.9	2.8	1.0	**169**	6.0	4.1	6.2	4.9	7.1
Mg (mg/l)	70	500	0.5	1.4	1.0	2.7	1.0	**195**	3.6	3.9	4.6	4.0	5.6
Na (mg/l)	100	2000	1.7	5.8	4.0	3.8	6.6	26	4.7	6.0	4.7	13.5	7.1
K (mg/l)	25	-	1.2	-1.0	1.4	1.7	1.9	**32**	2.5	-1.0	-1.0	2.8	2.0
M alk (mg/l)	-	-	-8.3	13.3	15.5	12.5	14.8	249	40.4	13.1	29.3	27.1	50.1
Cl (mg/l)	100	1500	-1.4	6.7	2.2	1.5	7.6	5	1.5	14.6	9.8	19.1	2.5
SO_4 (mg/l)	200	1000	3.5	0.8	0.4	0.4	1.1	**860**	4.3	1.2	1.0	3.8	1.1
NO_3_N	6	100	0.10	-0.06	0.19	3.89	-0.06	-0.06	-0.06	1.38	-0.06	-0.06	0.17
F (mg/l)	0.7	2	-0.183	-0.183	-0.183	-0.183	-0.183	-0.183	-0.183	-0.183	-0.183	-0.183	-0.183
Al (mg/l)	0.15	5	-0.037	0.070	-0.037	-0.037	0.090	-0.037	-0.037	-0.037	-0.037	-0.037	-0.037
Fe (mg/l)	0.5	10	-0.001	0.020	-0.001	-0.001	0.280	-0.001	-0.001	-0.001	0.010	-0.001	-0.001
Mn (mg/l)	0.1	10	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
NH_4 (mg/l)	1	-	-0.01	-0.01	-0.01	-0.01	0.05	0.02	0.02	-0.01	0.06	0.04	0.01
PO_4 (mg/l)	2	-	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	0.43
SAR (ratio)	-	-	0.42	0.81	0.70	0.38	1.14	0.32	0.37	0.51	0.35	1.09	0.48

Table 5-2: Water quality results for selected hydrocensus localities – Belfast NBC Project, October 2009.

Belfast NBC Project : Selected date - 2009/09/11												
Variable	Domestic Use	Livestock	Monitoring localities									
			Kotze01	Kotze02	Kotze04	Kotze05	Kotze08	Lb1	Lb2	Lb3	Lb5	Lb7
pH ()	6.0 - 9.0	-	7.70	7.44	7.84	6.22	**4.53**	7.60	**4.56**	7.74	7.86	7.95
EC (mS/m)	70	500	12.74	26.36	20.46	34.53	10.66	21.53	20.30	35.93	9.03	14.96
TDS (mg/l)	450	1000	66	129	111	154	-65	106	103	220	-65	76
T hardness	200	-	30.0	85.0	77.0	71.0	20.0	65.0	61.0	33.0	21.0	40.0
Ca (mg/l)	80	1000	6.9	16.8	18.6	14.1	3.7	15.2	14.0	7.3	3.1	10.7
Mg (mg/l)	70	500	3.0	10.5	7.5	8.7	2.7	6.4	6.4	3.6	3.3	3.2
Na (mg/l)	100	2000	6.3	9.0	7.4	12.8	4.5	15.3	15.2	85.0	5.8	12.4
K (mg/l)	25	-	6.6	3.2	3.5	4.7	5.9	4.1	4.2	1.5	-1.0	5.1
M alk (mg/l)	-	-	-8.3	-8.3	22.6	-8.3	22.0	51.6	51.3	187.8	11.5	53.6
Cl (mg/l)	100	1500	2.9	2.6	-1.4	14.2	-1.4	19.9	18.9	5.2	7.0	3.6
SO_4 (mg/l)	200	1000	36.7	85.6	59.4	95.1	13.4	14.3	13.9	3.0	2.6	8.6
NO_3_N	6	100	0.18	-0.06	-0.06	4.19	-0.06	-0.06	-0.06	-0.06	2.69	-0.06
F (mg/l)	0.7	2	-0.183	-0.183	-0.183	-0.183	-0.183	0.236	-0.183	1.910	-0.183	-0.183
Al (mg/l)	0.15	5	-0.037	-0.037	-0.037	7.180	-0.037	-0.037	-0.037	-0.037	0.380	-0.037
Fe (mg/l)	0.5	10	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	0.010	-0.001
Mn (mg/l)	0.1	10	-0.001	0.320	-0.001	0.370	0.030	-0.001	-0.001	-0.001	-0.001	-0.001
NH_4 (mg/l)	1	-	-0.01	0.08	0.03	0.07	-0.01	0.04	0.02	0.02	0.04	-0.01
PO_4 (mg/l)	2	-	-0.03	0.32	0.33	0.12	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
SAR (ratio)	-	-	0.51	0.42	0.37	0.66	0.43	0.83	0.84	6.44	0.55	0.86

Table 5-3: Water quality results for selected hydrocensus localities – Belfast NBC Project, October 2009.

Belfast NBC Project : Selected date - 2009/09/11												
Variable	Domestic Use	Livestock	Monitoring localities									
			Paarde4	Pp1	Pp2	Vil03	VWG01	Wt1	Wt2	Wt5	Z1	Z11
pH ()	6.0 - 9.0	-	8.30	7.66	7.02	7.23	6.96	7.75	7.54	7.65	7.03	7.95
EC (mS/m)	70	500	3.23	9.42	10.10	25.98	16.42	2.80	9.97	2.24	11.42	12.65
TDS (mg/l)	450	1000	-65	-65	-65	130	-65	-65	-65	-65	-65	-65
T hardness (mg/l)	200	-	5.0	45.0	44.0	76.0	48.0	2.0	41.0	4.0	21.0	41.0
Ca (mg/l)	80	1000	1.6	7.3	7.1	20.3	10.5	-0.5	7.7	0.8	3.2	7.0
Mg (mg/l)	70	500	-0.3	6.5	6.5	6.1	5.2	0.3	5.2	0.5	3.1	5.6
Na (mg/l)	100	2000	3.1	4.3	4.6	17.6	9.9	3.6	5.0	2.5	8.9	9.1
K (mg/l)	25	-	1.4	-1.0	-1.0	8.2	2.8	1.7	-1.0	-1.0	4.4	2.9
M alk (mg/l)	-	-	-8.3	45.9	46.4	76.9	29.6	9.3	44.0	-8.3	10.4	55.6
Cl (mg/l)	100	1500	-1.4	-1.4	-1.4	19.1	9.5	1.5	3.2	1.5	11.5	1.8
SO_4 (mg/l)	200	1000	1.9	1.0	1.3	12.0	4.0	1.1	1.1	1.0	5.6	1.1
NO_3_N (mg/l)	6	100	0.56	-0.06	-0.06	-0.06	5.26	-0.06	-0.06	0.20	2.30	-0.06
F (mg/l)	0.7	2	-0.183	-0.183	-0.183	0.398	-0.183	-0.183	-0.183	-0.183	-0.183	-0.183
Al (mg/l)	0.15	5	-0.037	-0.037	-0.037	-0.037	-0.037	-0.037	-0.037	0.040	-0.037	-0.037
Fe (mg/l)	0.5	10	-0.001	-0.001	-0.001	0.010	-0.001	0.090	-0.001	-0.001	-0.001	-0.001
Mn (mg/l)	0.1	10	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
NH_4 (mg/l)	1	-	0.02	-0.01	-0.01	0.71	0.04	0.02	0.02	-0.01	0.02	0.03
PO_4 (mg/l)	2	-	-0.03	0.04	0.06	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
SAR (ratio)	-	-	0.62	0.28	0.30	0.88	0.62	1.05	0.34	0.55	0.85	0.62

Table 5-4: Water quality results for selected hydrocensus localities – Belfast NBC Project, October 2009.

Belfast NBC Project : Selected date - 2009/09/11												
Variable	Domestic Use	Livestock	Monitoring localities									
			Z12	Z4	Z5	Z6	Z7	Z8	Zk1	Zk7	Zoekop04	Zoekop06
pH ()	6.0 - 9.0	-	6.87	7.33	8.03	8.37	7.18	6.27	6.87	7.76	7.21	7.60
EC (mS/m)	70	500	28.42	16.46	7.76	2.53	7.34	6.88	28.69	8.07	3.92	45.00
TDS (mg/l)	450	1000	138	-65	-65	-65	-65	-65	169	-65	-65	194
T hardness (mg/l)	200	-	126.0	19.0	11.0	0.0	17.0	2.0	16.0	5.0	4.0	139.0
Ca (mg/l)	80	1000	16.1	2.5	1.0	-0.5	2.9	-0.5	4.7	0.8	0.7	31.5
Mg (mg/l)	70	500	20.9	3.2	2.0	-0.3	2.4	0.5	0.9	0.8	0.4	14.6
Na (mg/l)	100	2000	11.0	11.5	2.6	3.0	4.1	8.7	64.9	7.5	4.4	22.7
K (mg/l)	25	-	2.4	6.2	3.6	1.2	5.7	4.0	2.3	7.3	1.3	7.2
M alk (mg/l)	-	-	111.8	-8.3	-8.3	-8.3	26.1	-8.3	150.5	16.0	11.0	61.9
Cl (mg/l)	100	1500	19.2	14.0	2.8	2.8	-1.4	11.9	2.8	6.8	3.1	65.2
SO_4 (mg/l)	200	1000	1.2	0.9	0.8	0.9	3.0	1.1	1.8	2.3	1.0	11.8
NO_3_N (mg/l)	6	100	-0.06	6.77	4.17	0.08	-0.06	-0.06	-0.06	0.85	0.22	3.72
F (mg/l)	0.7	2	-0.183	-0.183	-0.183	-0.183	0.230	-0.183	1.312	-0.183	-0.183	-0.183
Al (mg/l)	0.15	5	-0.037	-0.037	-0.037	-0.037	-0.037	-0.037	-0.037	-0.037	-0.037	-0.037
Fe (mg/l)	0.5	10	-0.001	-0.001	-0.001	-0.001	0.010	-0.001	-0.001	**0.520**	-0.001	-0.001
Mn (mg/l)	0.1	10	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
NH_4 (mg/l)	1	-	0.02	0.03	0.02	0.03	0.04	0.04	0.03	0.04	0.02	0.05
PO_4 (mg/l)	2	-	0.08	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	0.03
SAR (ratio)	-	-	0.43	1.14	0.34	1.59	0.43	2.60	7.16	1.42	1.03	0.84

Although all chemical parameters analysed are indicated in the abovementioned Tables, only four chemical parameters will be discussed. The selected chemical parameters (pH, TDS, SO_4, Fe) are known indicators of contamination commonly occurring at coal mining operations.

For coal mining operations, the typical impacts on groundwater quality are caused by various chemical interactions such as ion exchanges, mobilisation and precipitation of ions and / or groups of ions. Sulphate (SO_4) related chemical reactions are one of the most important in this regard and a fair representation of pollution at coal mines. Sulphate (SO4) related reactions take place when it enters the groundwater system through the oxidation of pyrite (FeS_2) through chemical weathering, mining, washing or percolation through stockpiles of the host material, coal. Typically, with the addition of oxygen (O_2) pyrite is oxidised to an iron sulphate ($FeSO_4$) and sulphuric acid (H_2SO_4). With the formation of iron sulphate and sulphuric acid, the pH decreases and causes the mobilisation of metal ions, collectively referred to as acid mine drainage.

Subsequently, the selected chemical parameters (pH, TDS, SO_4, Fe) will be the first indicators of pollution should the Belfast NBC project continue, and any pollution from the project occur.

5.1 pH

pH is the logarithmic expression of the hydrogen ion concentration in water which reflects the degree of acidity (pH < 7.0) or alkalinity (pH > 7) of the water. The pH levels of most unpolluted waters are between 6.5 – 8.5. pH levels below 6.5 may be found in areas were acidification processes have occurred, the most dramatic being that of acid mine drainage where pH levels may drop to 3.5.

Health effects associated with pH can be direct or indirect. Direct causes include the irritation or burning of the mucous membranes with extreme acidic waters, and indirect causes are consequences of corrosion to cooking appliances and distribution pipes.

From Table 5-1 to Table 5-4 it is clear that all recorded pH levels, except for Kotze08 and Lb02, comply with the Ideal domestic use guideline. Localities Kotze08 and Lb02 both recorded an acidic pH of 4.53 and 4.56 respectively. The water at these localities will have a sour taste, and should be considered unfit for domestic use. Problems associated with corrosion may also be expected.

In general, the proposed project area recorded neutral to slightly acidic pH levels, compliant with the domestic use standards, as indicated by Figure 5.1-1.

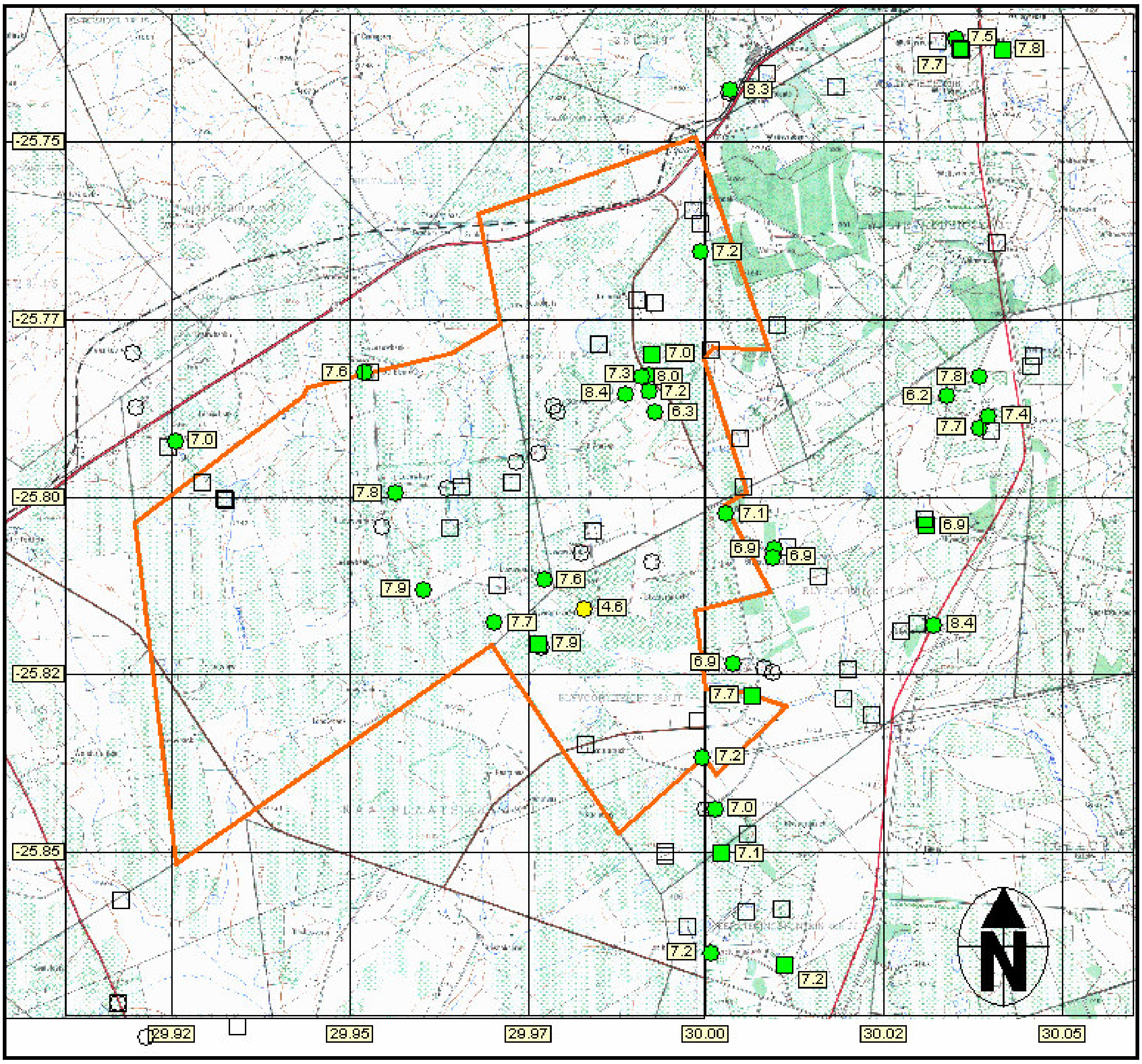


Figure 5.1-1: Spatial variation in the recorded pH values for selected Belfast NBC hydrocensus localities, October 2009.

5.2 Salinity (TDS)

Total dissolved Solids (TDS) is the measurement of the various inorganic salts dissolved in water. Virtually all natural waters contain varying concentrations of TDS as a consequence of the dissolution of the minerals in rock and soils and the decomposing of plant material. Therefore, the TDS of natural water is often dependant on the surrounding geological formations. Hence, TDS is likely to accumulate in moving waters (rivers, streams, etc) as additional salt loads are added to the water body through natural (weathering) or man made processes.

Health effects associated with high TDS concentrations are:

- Disturbances in the salt balances of infants,
- Adverse effects on individuals with high blood pressure and heart disease,
- Adverse effects on individual suffer from any renal disease,

- Laxative effect, especially where high sulphate is also recorded.

Health effects recorded in livestock include:

- Refusal to consume water due to unpalatable taste,
- Symptoms of diarrhoea and dehydration due to the initial exposure to the water,
- Disturbance in the salt balances within the animal i.e. salt poisoning.

As is evident from Table 5-1 to Table 5-4, all localities except Ef05, comply with both the domestic and livestock watering guidelines. The recorded TDS concentrations at locality Ef05 poses slight health risks to sensitive individuals and livestock. Livestock of concern are diary cattle, pigs, and poultry. These animals should only have an initial reluctance to drink, but should be able to adapt quickly. As indicated by Figure 5.2-1, the TDS concentrations in the proposed project area are generally very low (disregarding Ef05). The very low recorded concentrations in TDS will easily be affected by any additional pollution loads caused by potential mining activities. Great care and management of the water resource will have to be implemented, to ensure minimal /no impact on the pristine water qualities recorded.

5.3 Sulphate (SO_4)

Sulphate is the oxy-anion of sulphur and forms salts with various cations such as magnesium (Epsom Salt). Sulphates are a common constituent of water and arises form the dissolution of mineral sulphates in rock and soil, particularly calcium sulphate, and other partially soluble sulphate minerals. The solubility of sulphates in water causes sulphate concentrations to easily accumulate into progressively higher concentrations.

Consumption of excessive amounts of sulphate, typically results in diarrhoea. However, adaptation to high sulphate tends to occur with prolonged use. Sulphate imparts a bitter or salty taste to water. Corrosion of the distribution system is also likely in cases of high sulphate concentrations.

For livestock, high sulphate concentrations may lead to the following health effects:

- Diarrhea,
- Adverse palatability effects,
- Poor productivity

Once again, as for TDS, locality Ef05 was the only non-compliant hydrocensus locality with regards to domestic and livestock watering purposes. The recorded sulphate concentration at this locality would render the water unfit for domestic use, as there is a high risk of adverse health effects.

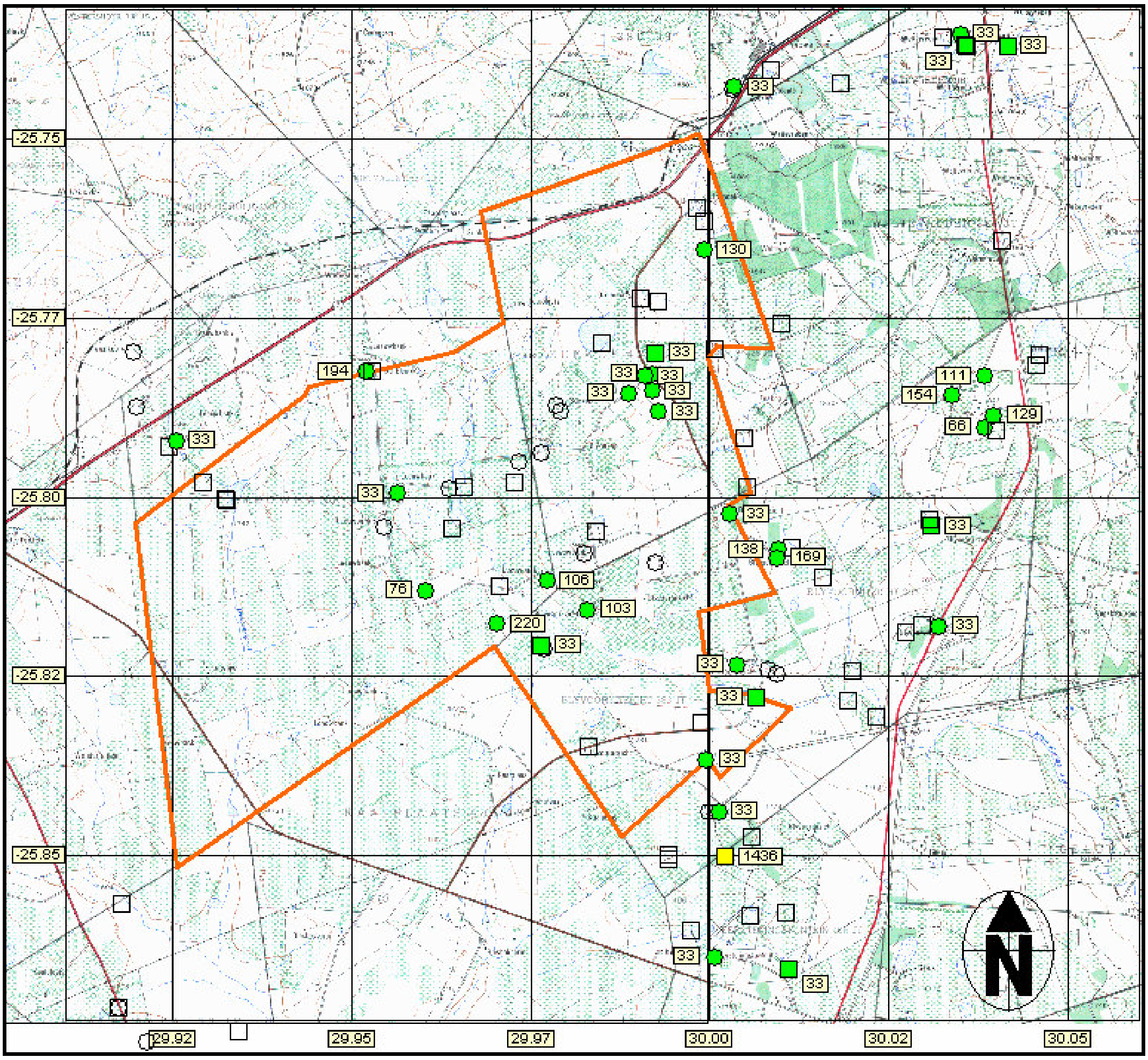


Figure 5.2-1: Spatial variation in the recorded TDS concentrations for selected Belfast NBC hydrocensus localities, October 2009.

As indicated by Figure 5.3-1 below, the proposed project area recorded very low sulphate concentrations in general. Concentrations (disregarding Ef05) ranged between 0.38mg/l to 95 mg/l, indicating a pristine (very fresh) water quality. As with the very low recorded TDS concentrations, the low sulphate concentrations will easily be affected by any additional pollution loads caused by potential mining activities. Great care and management of the water resource will have to be implemented, to ensure minimal /no impact on the pristine water qualities recorded.

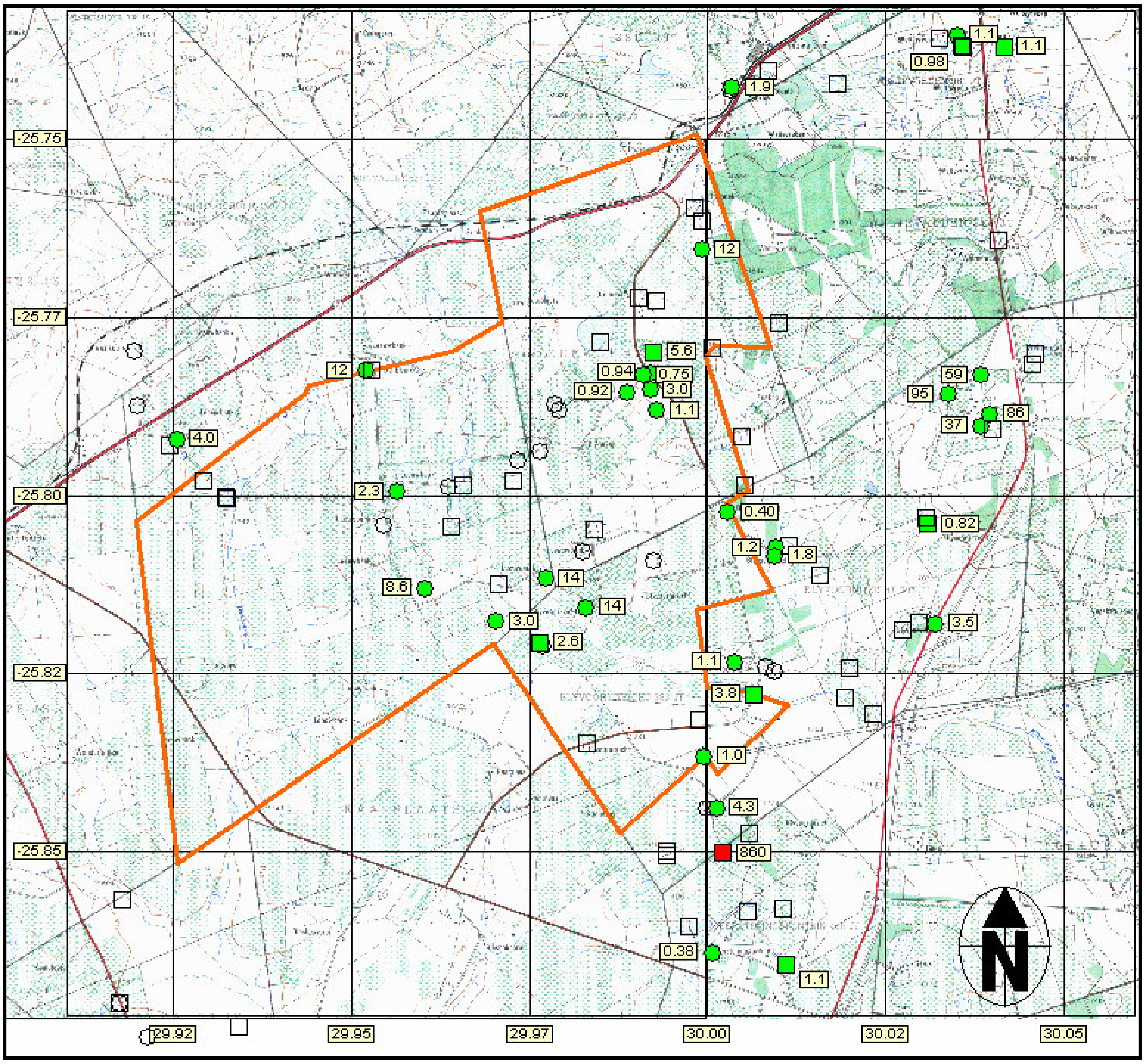


Figure 5.3-1: Spatial variation in the recorded Sulphate (SO_4) concentrations for selected Belfast NBC hydrocensus localities, October 2009.

5.4 Metal Concentrations (Fe)

For the metal concentrations, focus was primarily placed on iron (Fe) concentrations. In water, iron (Fe) can be present in a dissolved state as ferric iron (FeIII), as ferrous iron (FeII), or as suspended iron hydroxides. Iron is the forth most abundant element and constitutes five percent of the earth's crust. It is fond in many minerals such as haematite (Fe_2O_3), pyrite (FeS_2), magnetite (Fe_3O_4), and siderite ($FeCO_3$). As mentioned, pyrite is often associated with coal formations.

Health affects associated with iron (Fe) are:

- Acute poisoning in infants from exposure to massive concentrations,
- Chronic iron poisoning due to prolonged (years) intake of excessive iron concentrations.

As indicated by Table 5-1 to Table 5-4, only locality Zk07, exceeds the domestic use guideline. Even at the recorded concentration at Zk07 (0.52 mg/l) insignificant chance of any health effects occurs, should the water be consumed. As indicated by Figure 5.4-1, the proposed project area shows no elevated concentrations of Iron, indicating a pristine water quality.

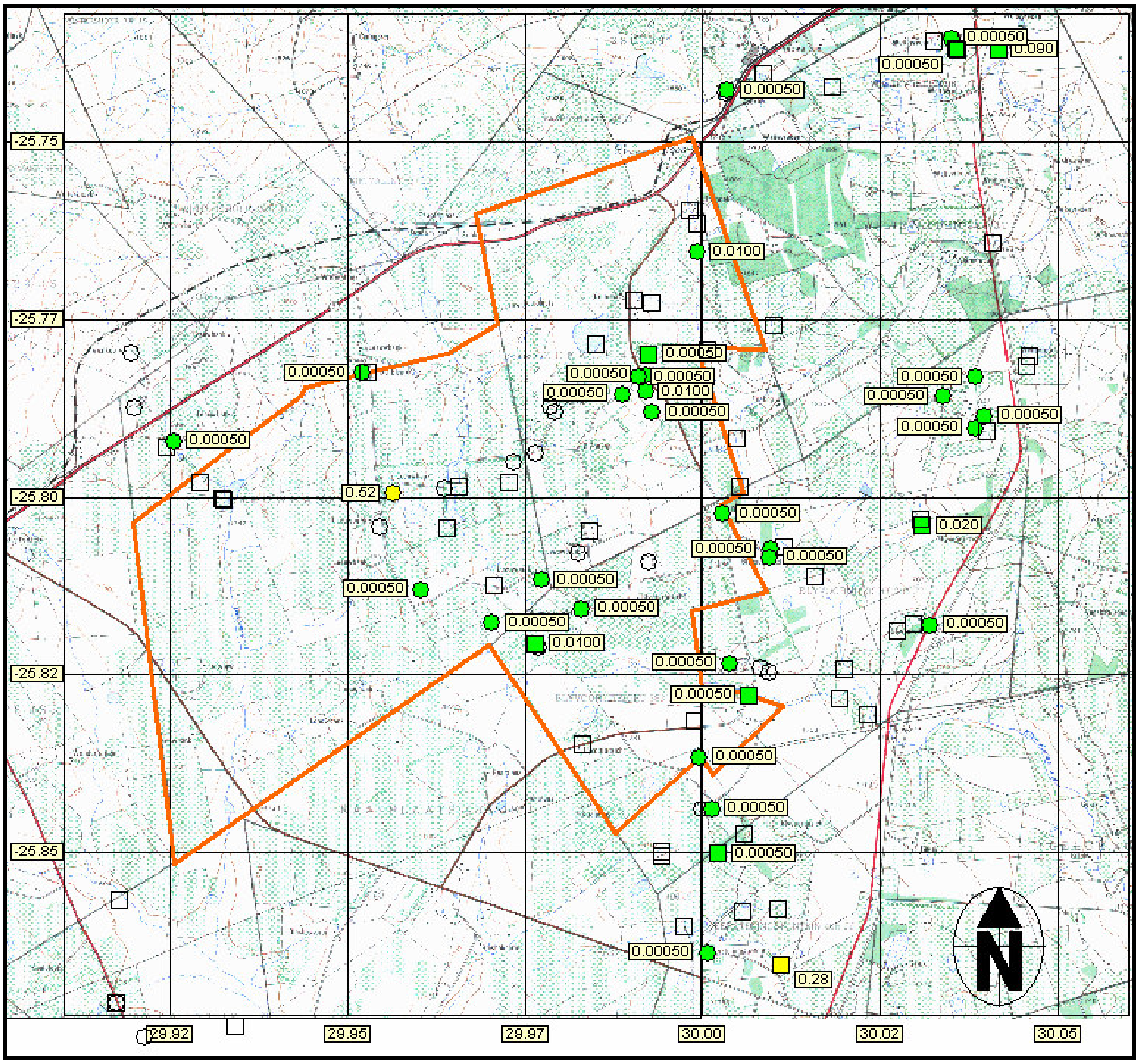


Figure 5.4-1: Spatial variation in the recorded Iron (Fe) concentrations for selected Belfast NBC hydrocensus localities, October 2009.

6. RECORDED WATER LEVELS

Recorded water levels for the hydrocensus borehole localities (site type – B) are illustrated in Figure 6-1. Table 6-1 indicates the measured water levels, for the hydrocensus localities where access to the water level were possible. All water levels are given as meters below ground (surface) level.

Table 6-1: The measured water levels for the hydrocensus localities, October 2009 (Coordinate system Geodetic, WGS84).

Site Name	Ycoord	Xcoord	Zcoord	Site Type	Water level	Water Use
Coet01	-25.80243	30.00287	1801	B	2.71	Domestic, Livestock
Eg01	-25.71260	30.04312	1916	B	1.98	Domestick
Eg02	-25.71705	30.03743	1912	B	3.65	Not in use
Eg03	-25.71705	30.03741	1914	B	3.40	Not in use
JouG01	-25.82348	30.00378	1778	B	15.99	Domestic, Livestock
Kotze01	-25.79028	30.03842	1842	B	8.25	Domestic, Livestock
Kotze02	-25.78876	30.03961	1849	B	4.06	Not in use
Kotze04	-25.78303	30.03855	1864	B	6.44	Not in use
Kotze05	-25.78580	30.03396	1839	B	14.90	Domestic
Lb01	-25.81169	29.97737	1795	B	34.35	Domestic
Lb02	-25.81592	29.98302	1801	B	23.85	Domestic
Lb03	-25.81775	29.97033	1798	B	20.17	Domestic
Lb07	-25.81311	29.96045	1801	B	6.99	Not in use
Lb08	-25.80416	29.95466	1809	B	27.32	Livestock
Pp02	-25.72836	30.03468	1920	B	2.90	Domestic, Livestock
Vaal02	-25.77976	29.91956	1840	B	3.70	Livestock
Vaal03	-25.78752	29.91999	1834	B	3.70	Livestock
VwG01	-25.79223	29.92558	1823	B	6.37	Domestic
Wt02	-25.73549	30.03513	1913	B	6.25	Domestic, Livestock
Z04	-25.78298	29.99199	1844	B	9.50	Domestic
Z05	-25.78311	29.99111	1849	B	1.40	Domestic
Z06	-25.78567	29.98871	1854	B	3.95	Livestock
Z07	-25.78510	29.99202	1843	B	9.75	Not in use
Z08	-25.78809	29.99288	1834	B	0.70	Not in use
Z11	-25.80863	30.00937	1784	B	9.90	Domestic, Livestock
Zk02	-25.78732	29.97854	1839	B	0.81	Domestic
Zk03	-25.78800	29.97922	1846	B	2.04	Not in use
Zk07	-25.79946	29.95647	1814	B	4.65	Not in use
Zoekop04	-25.83668	29.99958	1735	B	3.43	Not in use
Maximum Depth					**34.35**	
Minumum Depth					**0.70**	
Average Depth					**8.38**	

The static groundwater levels varied between 0m (various fountains) and 34.35m (Lb01). As indicated by both Table 6-1 and Figure 6-1, lower groundwater levels (<10m) were recorded for most of the hydrocensus area, with the average ground water level at 8.38m. The deeper groundwater levels, indicated by the larger blue circles on Figure 6-1, were recorded the middle of the proposed project area. It should be noted, that most of the deeper water levels, were recorded at localities equipped with submersible pumps.

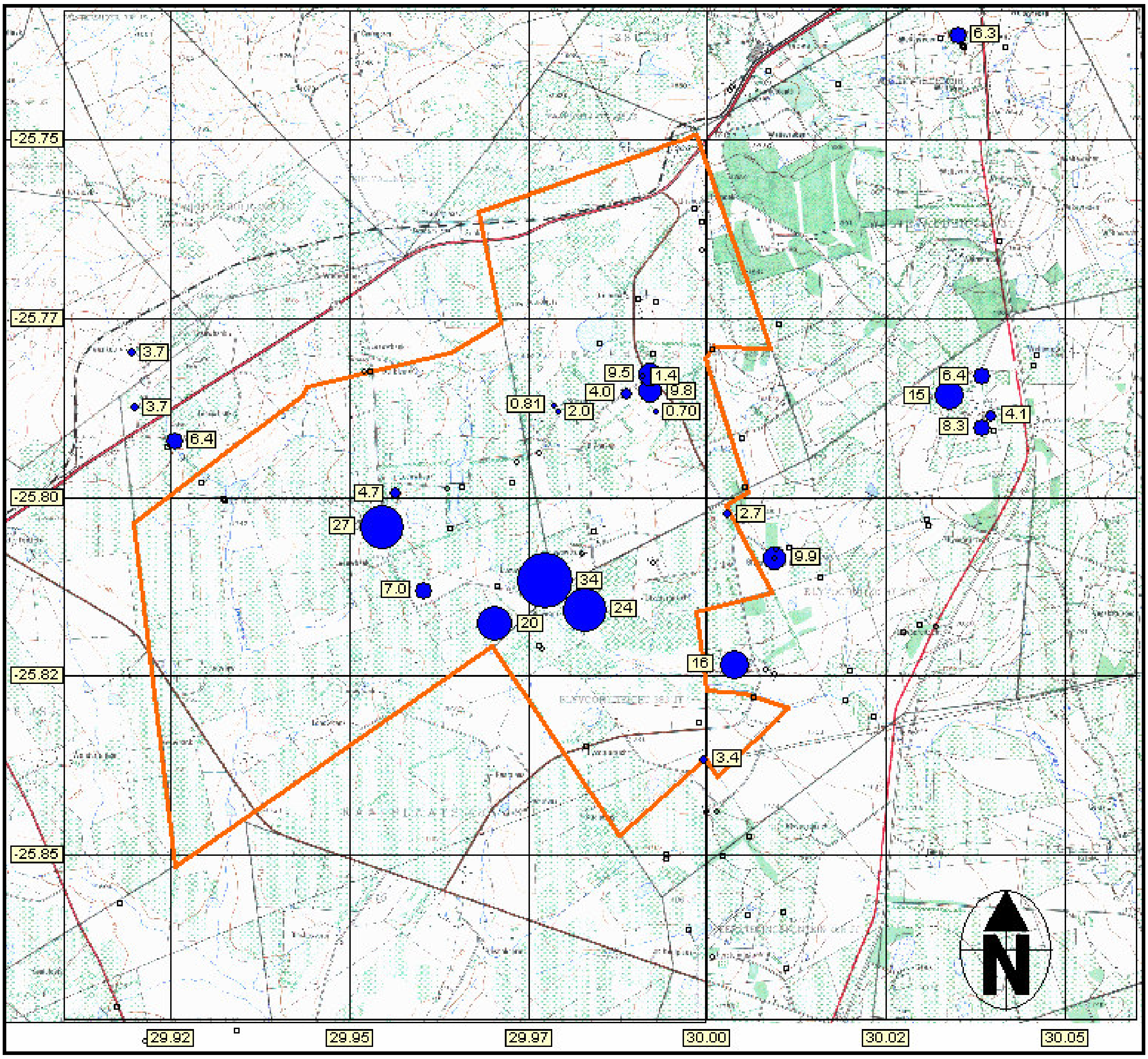


Figure 6-1: Spatial variation in the recorded water levels for selected Belfast NBC hydrocensus localities, October 2009.

7. CONCLUSION

Exxaro Resources is in the process of assessing the feasibility of the Belfast Northern Coal Project (NBC) project, situated some 10 km southwest of Belfast in Mpumalanga, on the farms Leeuwbank, Zoekop, and Blyvooruitzicht. The Belfast project entails the development of an opencast mine to produce 2.0 Mtpa of coal for Eskom and 1.5 Mtpa of A-grade thermal coal for export markets.

Clean Stream Scientific Services was commissioned by Groundwater Complete to conduct the hydrocensus for the proposed expansion. Field work for the hydrocensus was conducted in late August and early September 2009. The proposed mining area as well as the required one kilometre buffer zone was surveyed. The potential surface and groundwater users in the area were identified. Although more than one borehole often exists for a user like a farmstead, all boreholes will be surveyed and water level, use and related info recorded but only the main used borehole will be sampled and analysed for groundwater quality. Water quality will only be analysed for other boreholes if used for a specialized and/or sensitive purpose other than general uses like livestock water supply.

I&AP's

Contact was made with 25 interested and affected parties of which four I&AP refused access to their properties, until Exxaro Resources has set up a personal meeting with the owners. Issues which were raised during the telephone conversation with these land owners can be summarised as follow:

- No communication is currently taking place between Exxaro and the landowner,
- No information regarding the proposed project has been communicated through to the landowner,
- Requests for information regarding the proposed expansion have not been fulfilled,
- Access to the properties is denied until such time that Exxaro has contacted and met with the landowners.

In total, 118 water use localities were logged, and water levels (if possible) were taken. 42 water samples were taken from representative boreholes on each farm, preferable the boreholes used for domestic purposes. The survey indicated that water use was mainly for livestock watering (61%) and domestic use (25%). 14% of the boreholes are currently not in use.

Although a series of chemical parameters were only four chemical parameters was discussed in detail. Focus was places on pH, TDS, SO_4, and Fe which are known indicators of contamination commonly occurring at coal mining operations.

pH

All recorded pH levels, except for Kotze08 and Lb02, comply with the ideal domestic use guideline. Localities Kotze08 and Lb02 both recorded an acidic pH of 4.53 and 4.56 respectively. The water at these localities will have a sour taste, and should be considered unfit for domestic use.

Problems associated with corrosion may also be expected. In general, the proposed project area recorded neutral to slightly acidic pH levels, compliant with the domestic use standards.

Salinity (TDS)

All localities except Ef05, comply with both the domestic and livestock watering guidelines. The recorded TDS concentrations at locality Ef05 poses slight health risks to sensitive individuals and livestock. Livestock of concern are diary cattle, pigs, and poultry. The TDS concentrations in the proposed project area are generally very low (disregarding Ef05). The very low recorded concentrations in TDS will easily be affected by any additional pollution loads caused by potential mining activities. Great care and management of the water resource will have to be implemented, to ensure minimal /no impact on the pristine water qualities recorded.

Sulphate (SO_4)

Locality Ef05 was the only non-compliant hydrocensus locality with regards to domestic and livestock watering purposes. The recorded sulphate concentration at this locality would render the water unfit for domestic use, as there is a high risk of adverse health effects. The proposed project area recorded very low sulphate concentrations in general. Concentrations (disregarding Ef05) ranged between 0.38mg/l to 95 mg/l, indicating a pristine (very fresh) water quality.

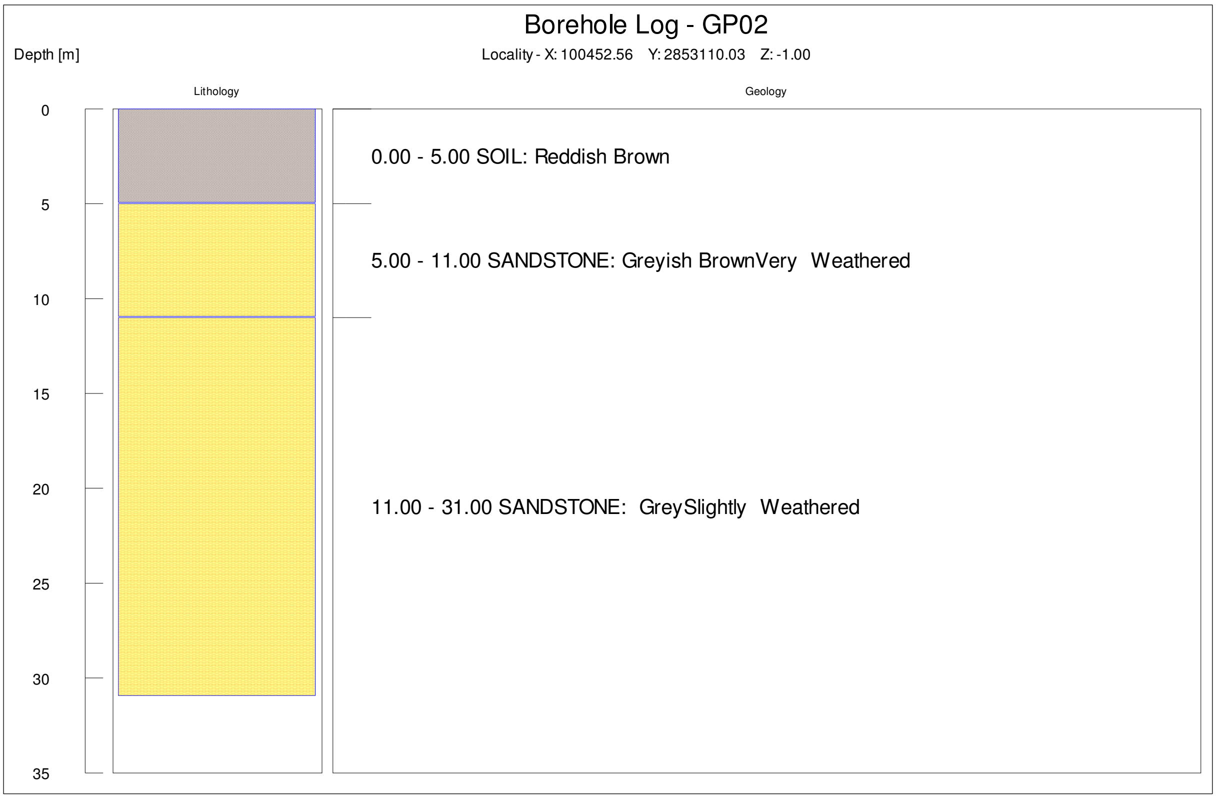
Metal Concentrations (Fe)

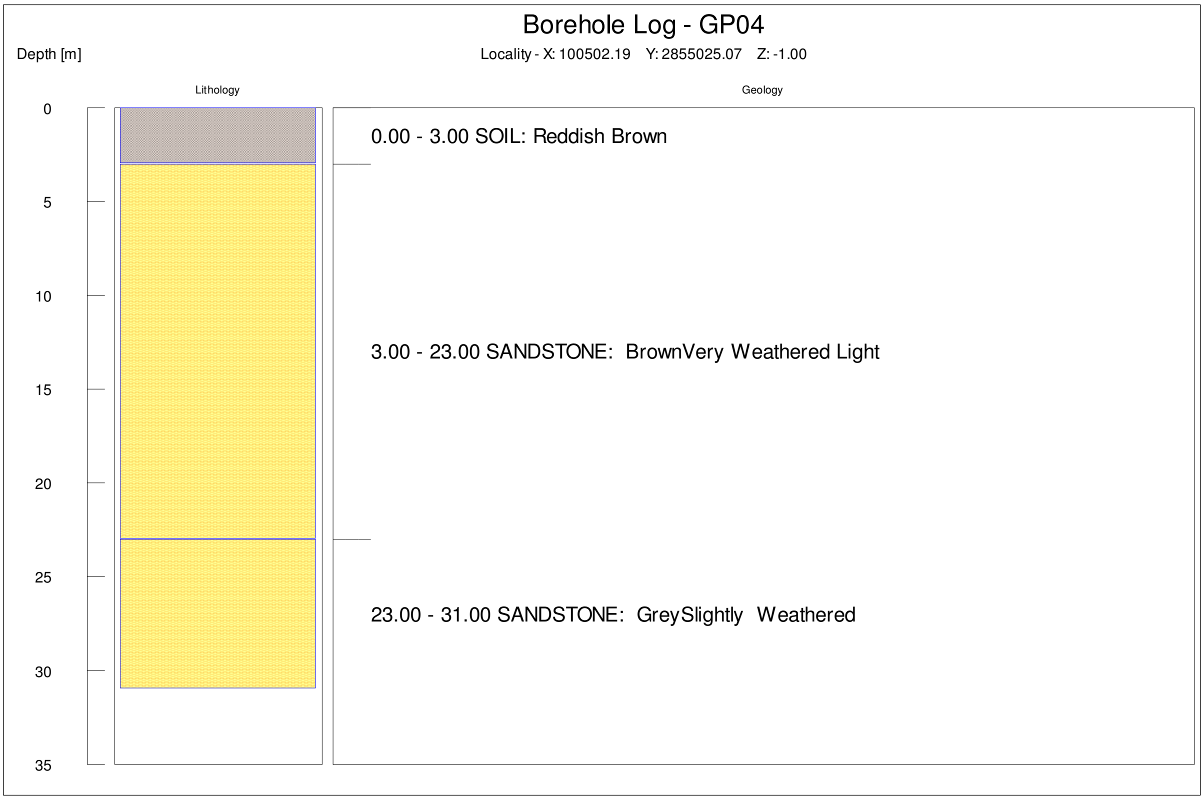
Only locality Zk07 exceeded the domestic use guideline. The proposed project area shows no elevated concentrations of Iron, indicating a good water quality.

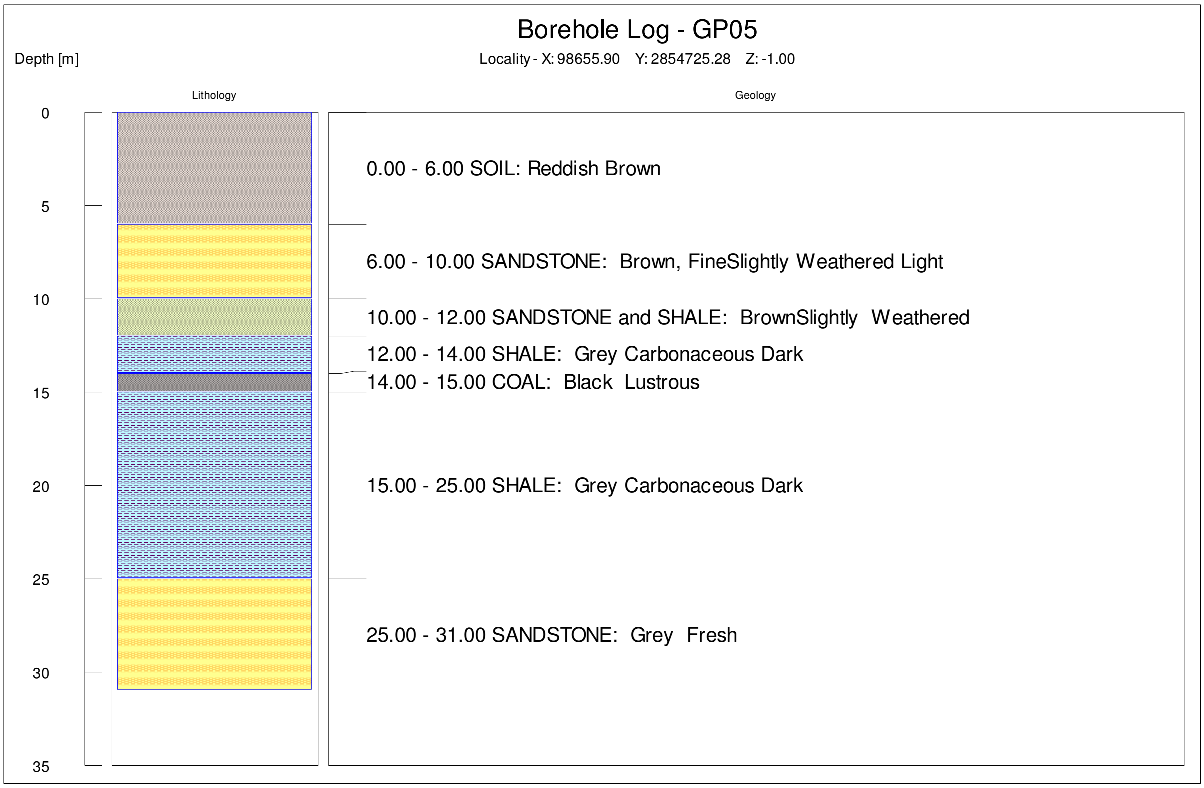
Recorded water levels

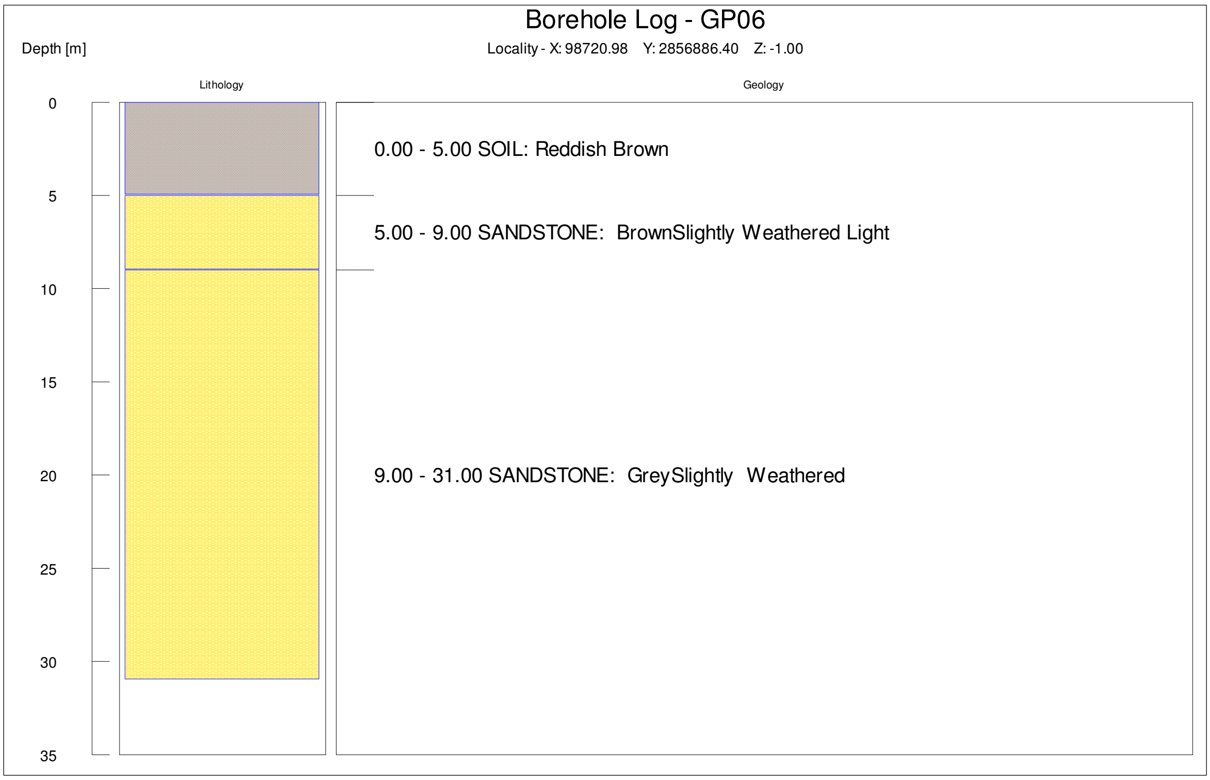
The static groundwater levels varied between 0m (various fountains) and 34.35m (Lb01). Low groundwater levels (<10m) were recorded for most of the hydrocensus area, with the average ground water level at 8.38m.

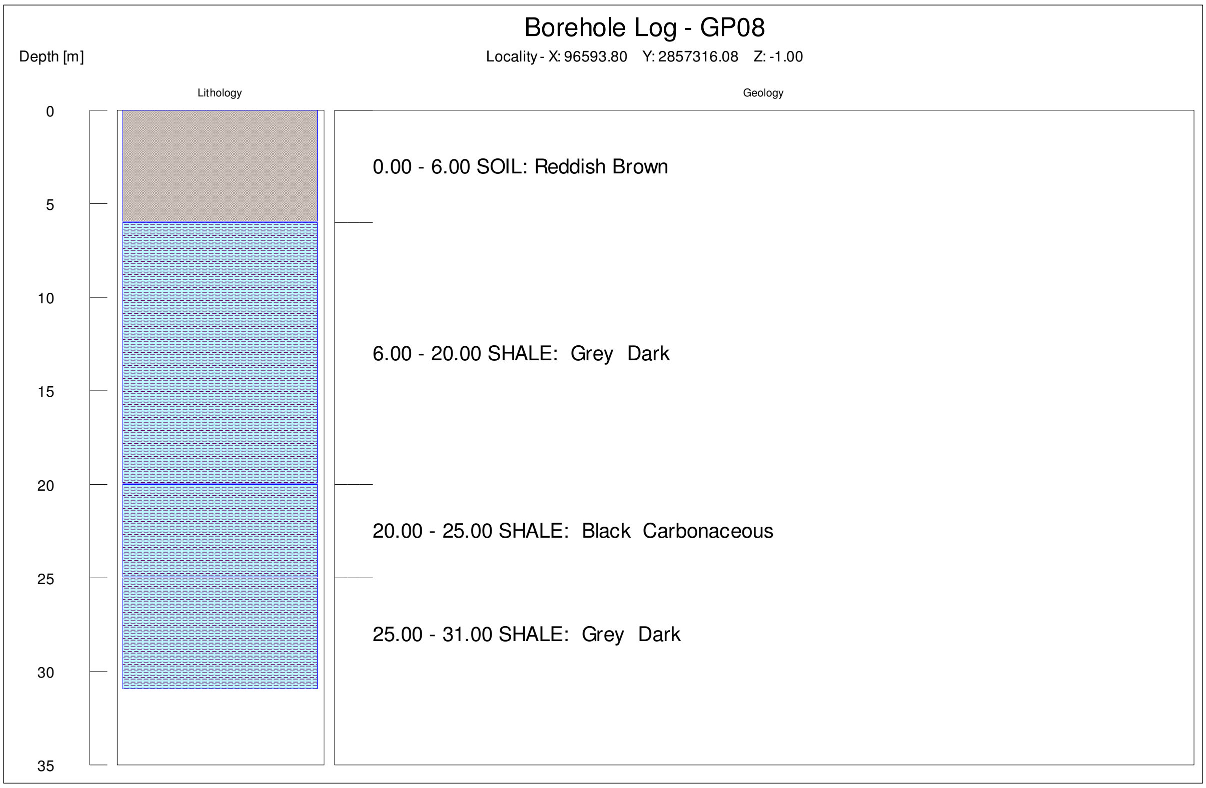
6 APPENDIX B: MONITORING BOREHOLE LOGS

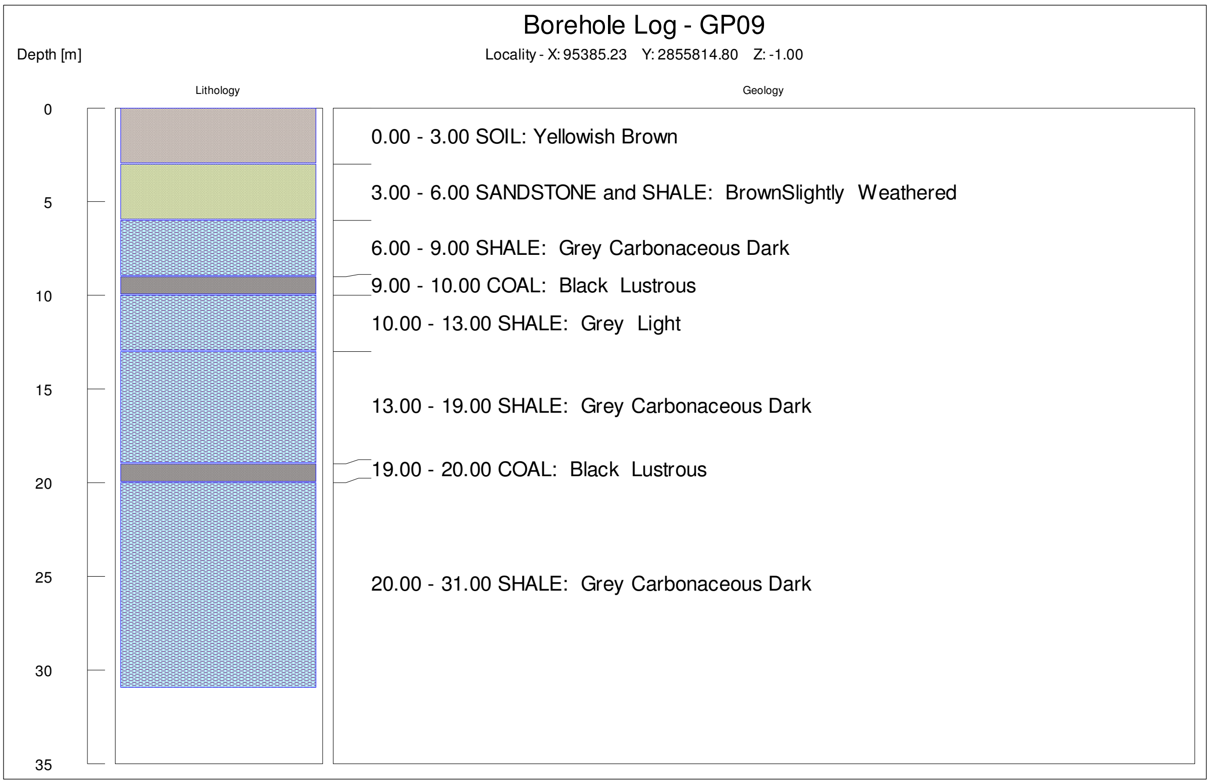


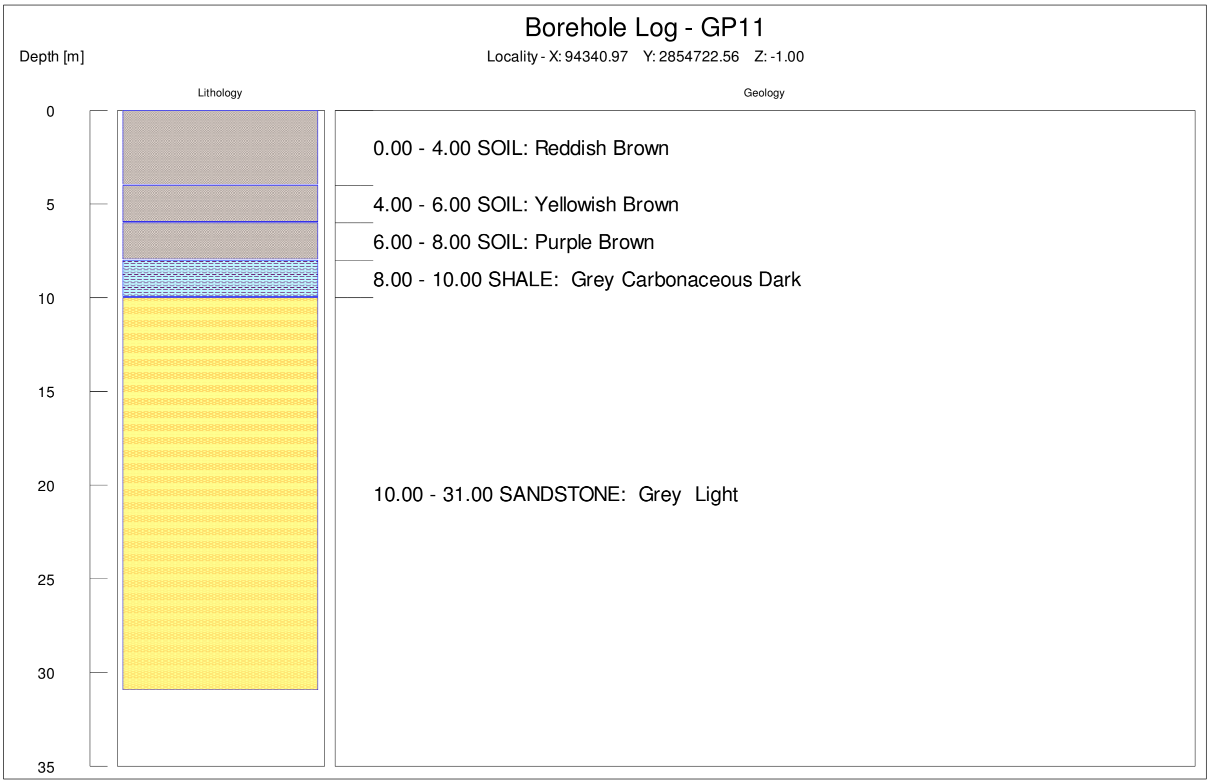



Borehole Log - GP05
Depth [m]
Locality - X: 98655.90 Y: 2854725.28 Z: -1.00
Lithology
Geology
0
5
10
15
20
25
30
35
0.00 - 6.00 SOIL: Reddish Brown
6.00 - 10.00 SANDSTONE: Brown, FineSlightly Weathered Light
10.00 - 12.00 SANDSTONE and SHALE: BrownSlightly Weathered
12.00 - 14.00 SHALE: Grey Carbonaceous Dark
14.00 - 15.00 COAL: Black Lustrous
15.00 - 25.00 SHALE: Grey Carbonaceous Dark
25.00 - 31.00 SANDSTONE: Grey Fresh

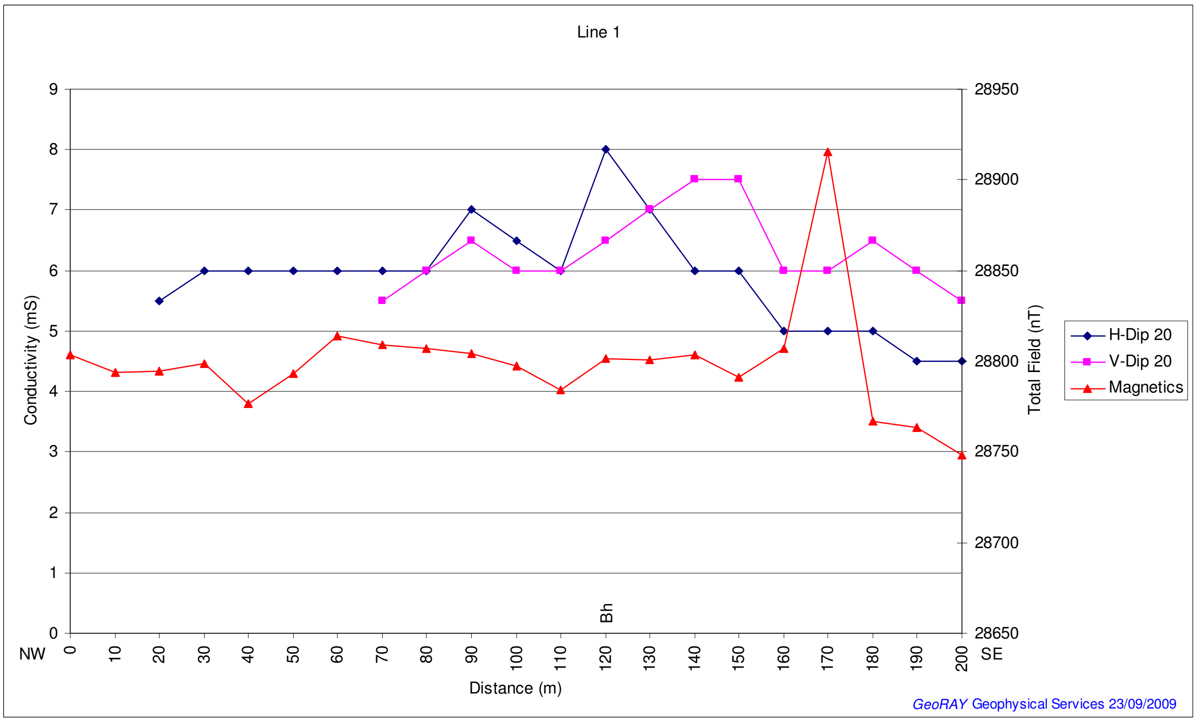

Borehole Log - GP06
Depth [m]
Locality - X: 98720.98 Y: 2856886.40 Z: -1.00
Lithology
Geology
0
5
10
15
20
25
30
35
0.00 - 5.00 SOIL: Reddish Brown
5.00 - 9.00 SANDSTONE: BrownSlightly Weathered Light
9.00 - 31.00 SANDSTONE: GreySlightly Weathered

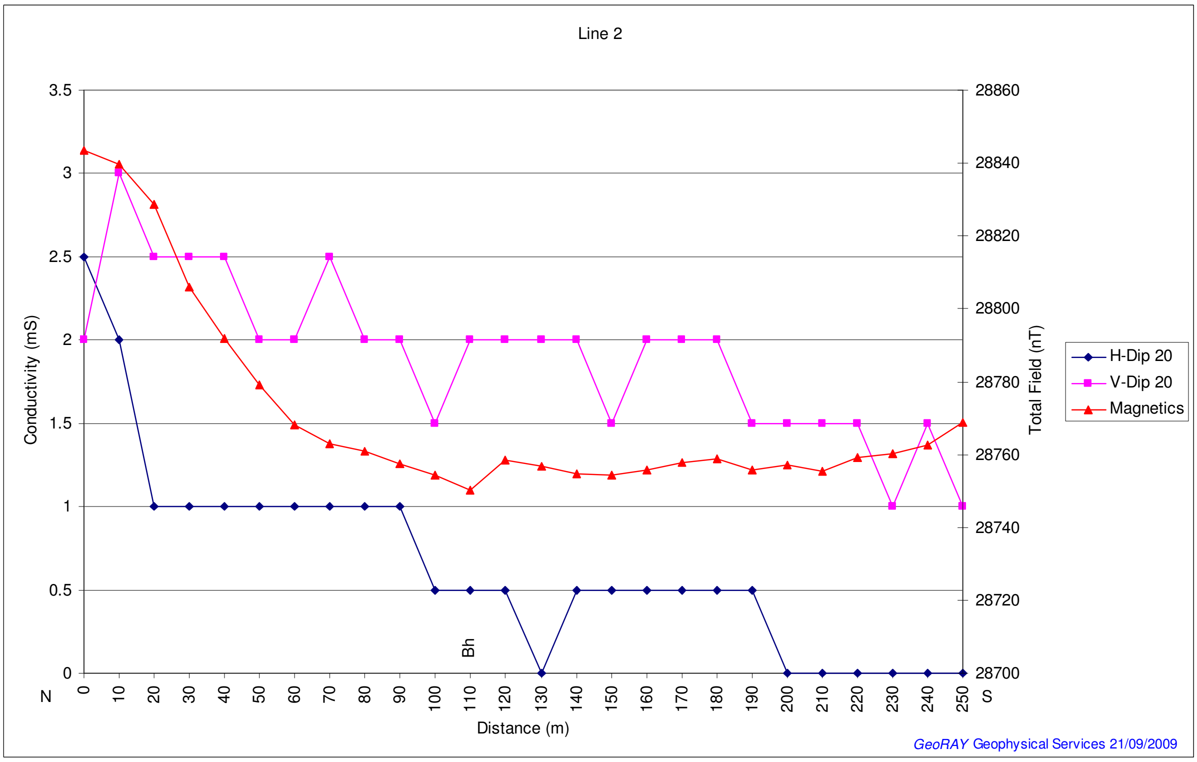

Borehole Log - GP08
Depth [m]
Locality - X: 96593.80 Y: 2857316.08 Z: -1.00
Lithology
Geology
0
5
10
15
20
25
30
35
0.00 - 6.00 SOIL: Reddish Brown
6.00 - 20.00 SHALE: Grey Dark
20.00 - 25.00 SHALE: Black Carbonaceous
25.00 - 31.00 SHALE: Grey Dark

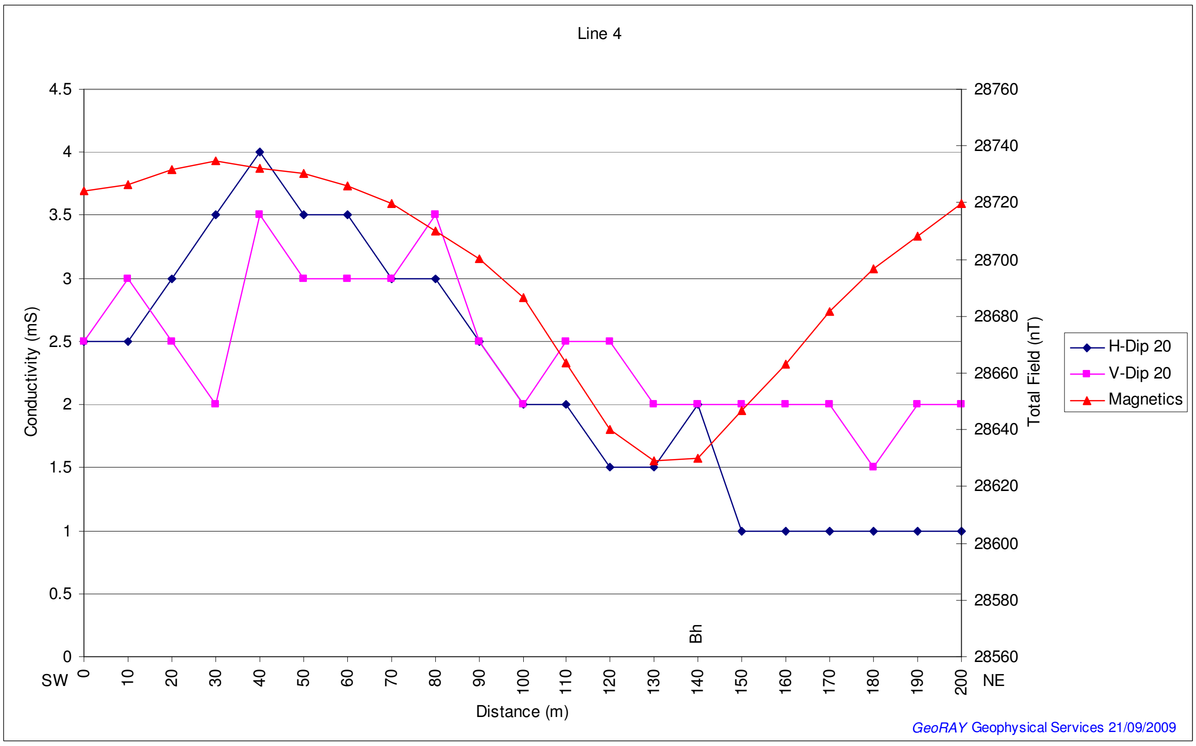

Borehole Log - GP09
Depth [m]
Locality - X: 95385.23 Y: 2855814.80 Z: -1.00
Lithology
Geology
0
5
10
15
20
25
30
35
0.00 - 3.00 SOIL: Yellowish Brown
3.00 - 6.00 SANDSTONE and SHALE: BrownSlightly Weathered
6.00 - 9.00 SHALE: Grey Carbonaceous Dark
9.00 - 10.00 COAL: Black Lustrous
10.00 - 13.00 SHALE: Grey Light
13.00 - 19.00 SHALE: Grey Carbonaceous Dark
19.00 - 20.00 COAL: Black Lustrous
20.00 - 31.00 SHALE: Grey Carbonaceous Dark

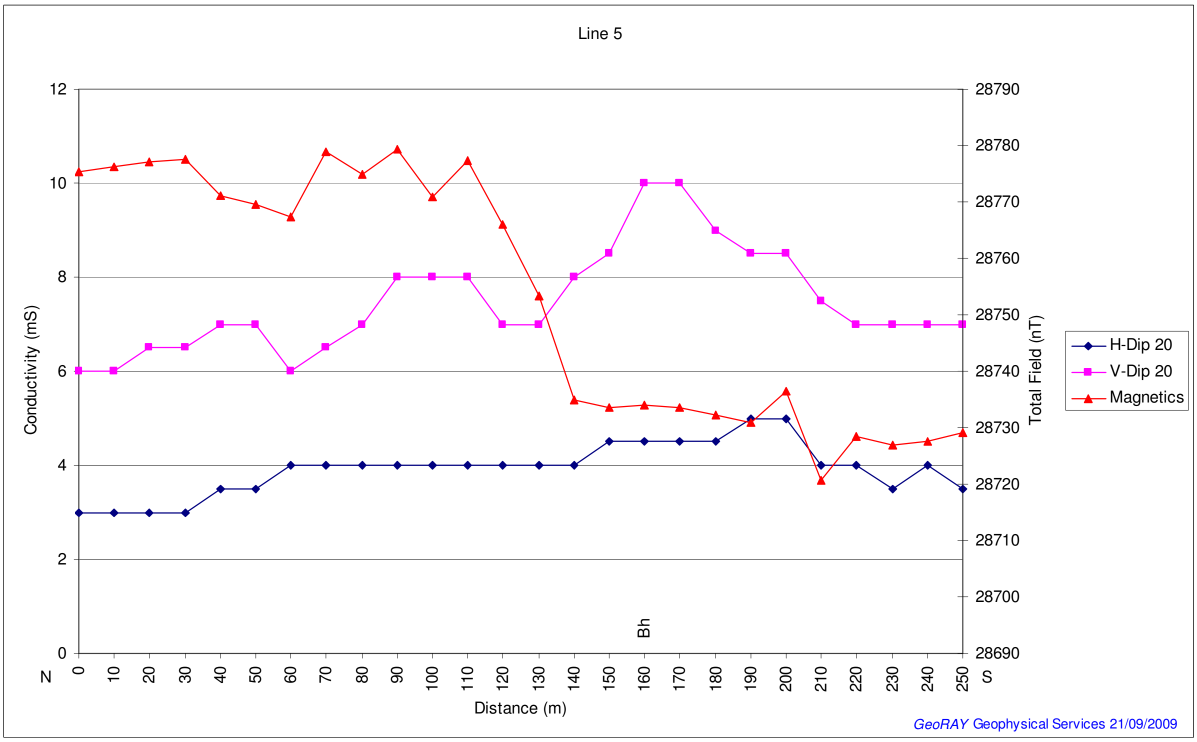

Borehole Log - GP11
Depth [m]
Locality - X: 94340.97 Y: 2854722.56 Z: -1.00
Lithology
Geology
0
5
10
15
20
25
30
35
0.00 - 4.00 SOIL: Reddish Brown
4.00 - 6.00 SOIL: Yellowish Brown
6.00 - 8.00 SOIL: Purple Brown
8.00 - 10.00 SHALE: Grey Carbonaceous Dark
10.00 - 31.00 SANDSTONE: Grey Light

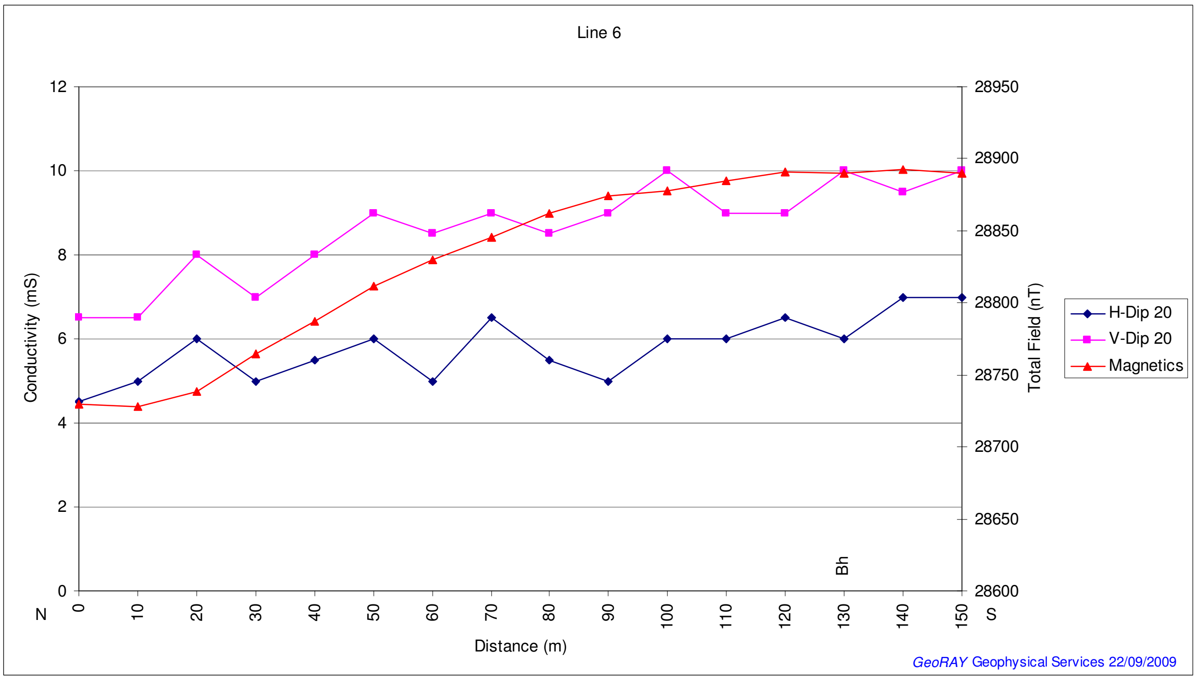
7 APPENDIX C: GEOPHYSICS

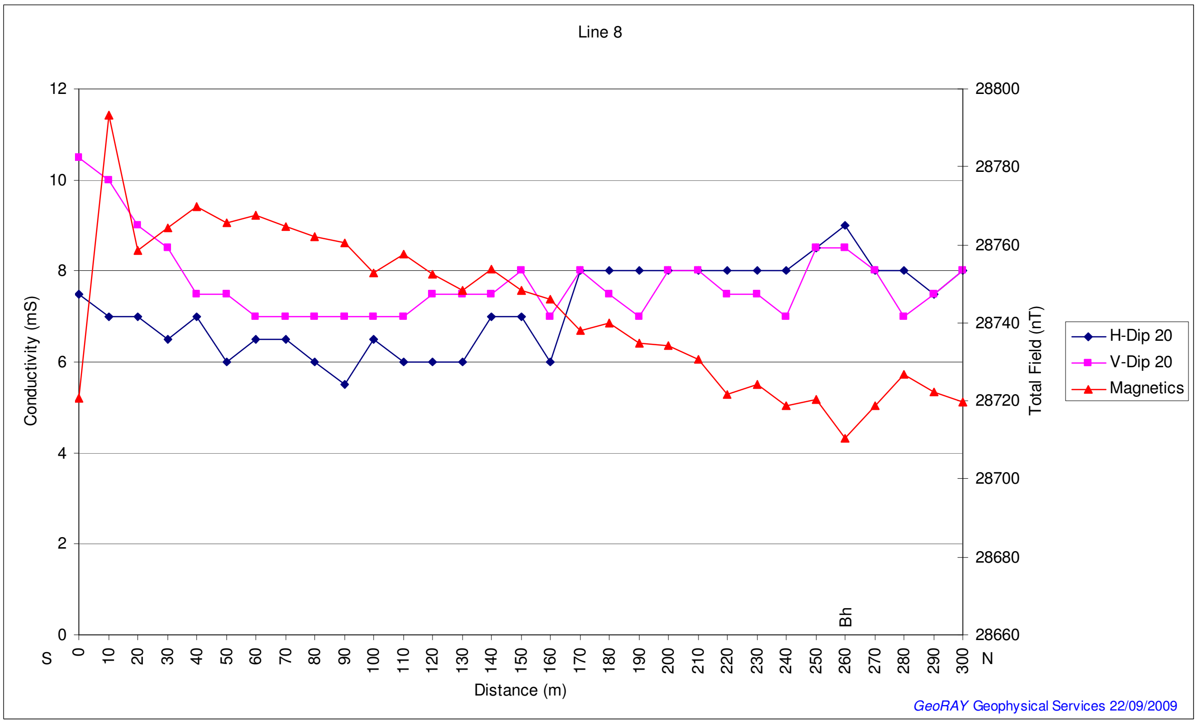


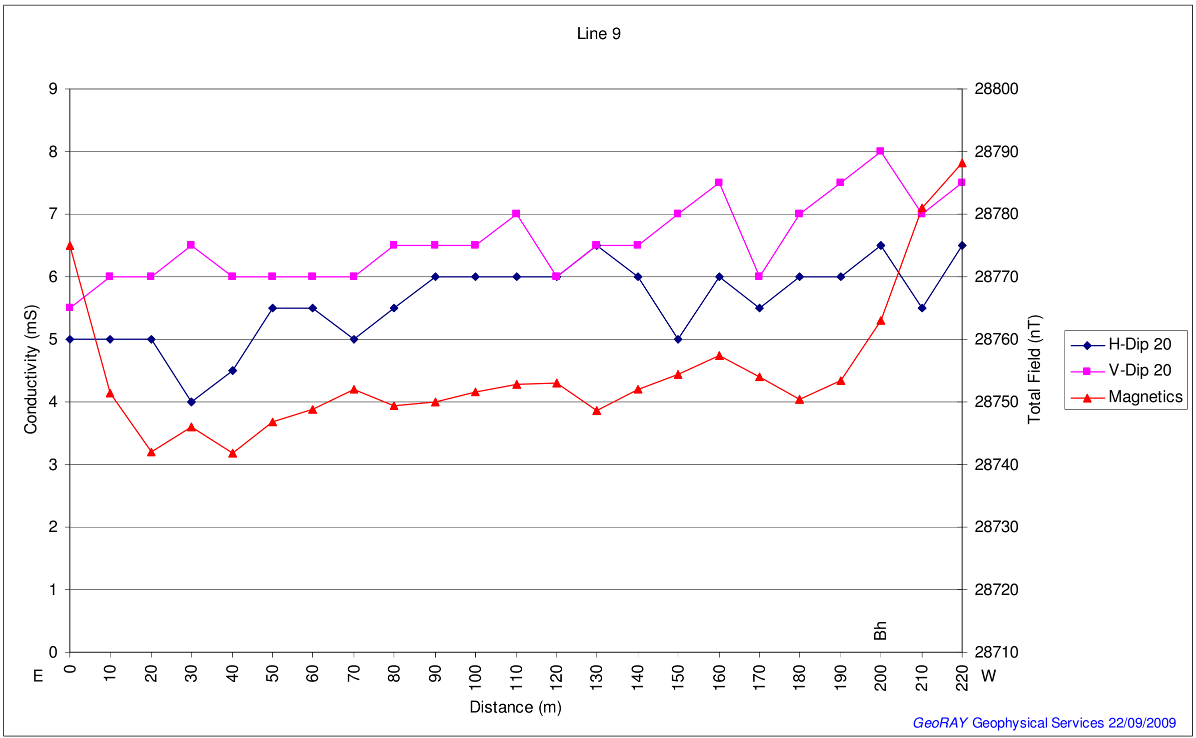


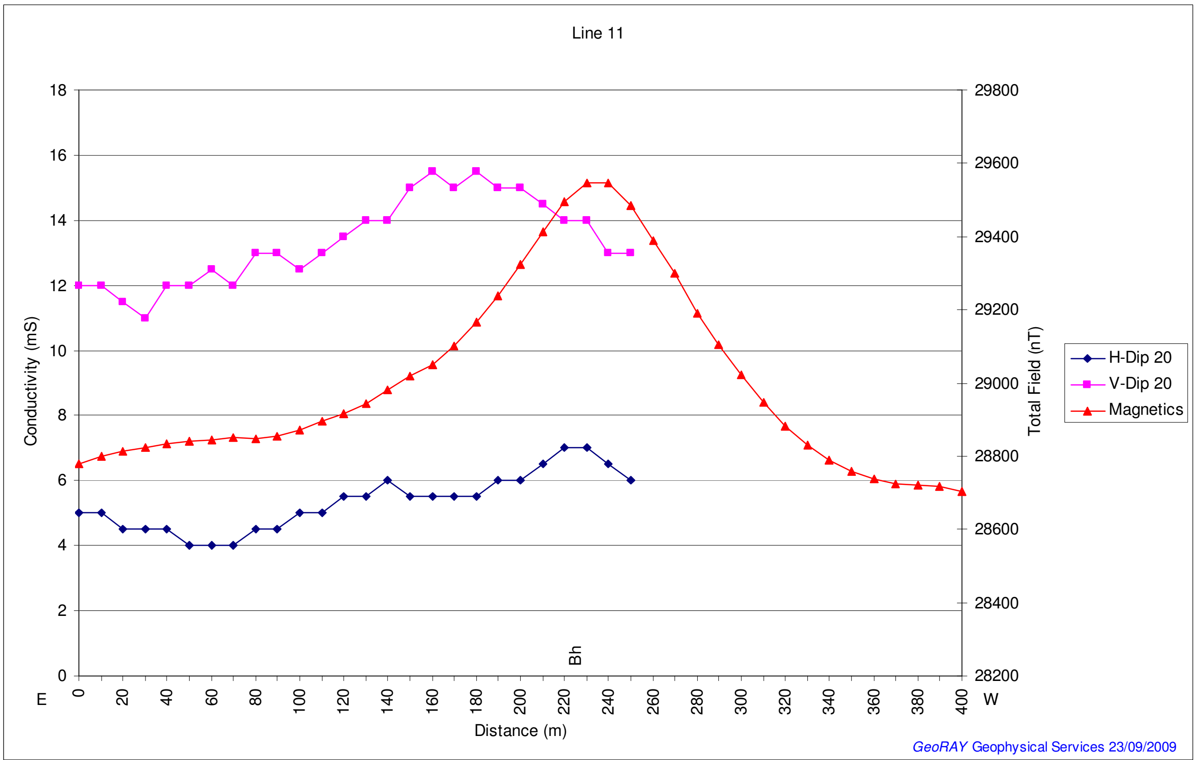

Line 4
Conductivity (mS)
Total Field (nT)
Distance (m)
SW
NE
Bh
H-Dip 20
V-Dip 20
Magnetics
GeoRAY Geophysical Services 21/09/2009


Line 5
Conductivity (mS)
Total Field (nT)
Distance (m)
N
S
Bh
H-Dip 20
V-Dip 20
Magnetics
GeoRAY Geophysical Services 21/09/2009


Line 6
Conductivity (mS)
Total Field (nT)
Distance (m)
N
S
Bh
H-Dip 20
V-Dip 20
Magnetics
GeoRAY Geophysical Services 22/09/2009


Line 8
Conductivity (mS)
Total Field (nT)
Distance (m)
S
N
Bh
H-Dip 20
V-Dip 20
Magnetics
GeoRAY Geophysical Services 22/09/2009


Line 9
Conductivity (mS)
Total Field (nT)
Distance (m)
E
W
Bh
H-Dip 20
V-Dip 20
Magnetics
GeoRAY Geophysical Services 22/09/2009


Line 11
Conductivity (mS)
Total Field (nT)
Distance (m)
E
W
Bh
H-Dip 20
V-Dip 20
Magnetics
GeoRAY Geophysical Services 23/09/2009

8 APPENDIX D: ACID BASE ACCOUNTING RESULTS (WATERLAB)

Acid – Base Accounting Modified Sobek (EPA-600)	Sample Identification				
	LK427 JS/66	LK427 JS/65	ZP426 JS/58	ZP426 JS/59	ZP426 JS/53
Sample Number	10476	10477	10478	10479	10480
Paste pH	6.3	6.6	7.1	6.7	7.4
Total Sulphur (%) (LECO)	0.590	0.500	0.200	0.640	0.170
Acid Potential (AP) (kg/t)	18.44	15.63	6.25	20	5.31
Neutralization Potential (NP)	9.00	10.00	0.75	3.75	12.75
Nett Neutralization Potential (NNP)	-9.44	-5.63	-5.50	-16.25	7.44
Neutralising Potential Ratio (NPR) (NP : AP)	0.49	0.64	0.12	0.19	2.40
Rock Type	I	I	II	I	III

Negative NP values are obtained when the volume of NaOH (0.1N) titrated (pH:8.3) is greater than the volume of HCl (1N) to reduce the pH of the sample to 2.0 – 2.5 Any negative NP values are corrected to 0.00.

Please refer to Appendix (p.2) for a Terminology of terms and guidelines for rock classification

Acid – Base Accounting Modified Sobek (EPA-600)	Sample Identification			
	LK427 JS/39	GP05 - 1	GP08 - 1	GP09 – 1
Sample Number	10481	10482	10483	10484
Paste pH	7.3	7.7	7.6	7.7
Total Sulphur (%) (LECO)	0.290	0.120	1.540	1.340
Acid Potential (AP) (kg/t)	9.06	3.75	48.13	41.88
Neutralization Potential (NP)	0.00	0.00	6.00	4.25
Nett Neutralization Potential (NNP)	-9.06	-3.75	-42.13	-37.63
Neutralising Potential Ratio (NPR) (NP : AP)	0.14	0.53	0.12	0.10
Rock Type	I	II	I	I

Negative NP values are obtained when the volume of NaOH (0.1N) titrated (pH:8.3) is greater than the volume of HCl (1N) to reduce the pH of the sample to 2.0 – 2.5 Any negative NP values are corrected to 0.00.

Please refer to Appendix (p.2) for a Terminology of terms and guidelines for rock classification

APPENDIX : TERMINOLOGY AND ROCK CLASSIFICATION

TERMINOLOGY (SYNONYMS)

Acid Potential (AP) ; Synonyms: Maximum Potential Acidity (MPA)
Method: Total S(%) (Leco Analyzer) x 31.25

Neutralization Potential (NP) ; Synonyms: Gross Neutralization Potential (GNP) ; Syn: Acid Neutralization Capacity (ANC) (The capacity of a sample to consume acid)
Method: Fizz Test ; Acid-Base Titration (Sobek & Modified Sobek (Lawrence) Methods)

Nett Neutralization Potential (NNP) ; Synonyms: Nett Acid Production Potential (NAPP)
Calculation: NNP = NP – AP ; NAPP = ANC – MPA

Neutralising Potential Ratio (NPR)
Calculation: NPR = NP : AP

CLASSIFICATION ACCORDING TO NETT NEUTRALISING POTENTIAL (NNP)

If NNP (NP – AP) < 0, the sample has the potential to generate acid
If NNP (NP – AP) > 0, the sample has the potential to neutralise acid produced

Any sample with NNP < 20 is potentiall acid-generating, and any sample with NNP > -20 might not generate acid (Usher et al., 2003)

CLASSIFICATION ACCORDING TO NEUTRALISING POTENTIAL RATIO (NPR)

Guidelines for screening criteria based on ABA (Price et al., 1997 ; Usher et al., 2003)

Potential for ARD	Initial NPR Screening Criteria	Comments
Likely	< 1:1	Likely AMD generating
Possibly	1:1 – 2:1	Possibly AMD generating if NP is insufficiently reactive or is depleted at a faster rate than sulphides
Low	2:1 – 4:1	Not potentially AMD generating unless significant preferential exposure of sulphides along fracture planes, or extremely reactive sulphides in combination with insufficiently reactive NP
None	>4:1	No further AMD testing required unless materials are to be used as a source of alkalinity

CLASSIFICATION ACCORDING TO SULPHUR CONTENT (%S) AND NEUTRALISING POTENTIAL RATIO (NPR)

For sustainable long-term acid generation, at least 0.3% Sulphide-S is needed. Values below this can yield acidity but it is likely to be only of short-term significance. From these facts, and using the NPR values, a number of rules can be derived:
Samples with less than 0.3% Sulphide-S are regarded as having insufficient oxidisable Sulphide-S to sustain acid generation.
NPR ratios of >4:1 are considered to have enough neutralising capacity.
NPR ratios of 3:1 to 1:1 are consider inconclusive.
NPR ratios below 1:1 with Sulphide-S above 3% are potentially acid-generating. (Soregaroli & Lawrence, 1998 ; Usher et al., 2003)

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