Impact of Groundwater on Mining at Finsch Diamond Mine

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ABSTRACT

The paper evaluates the relationship between mining and ground water at De Beers Consolidated Mines Finsch Mine situated in a semi-arid region of the north western Cape in the Republic of South Africa.

A detailed groundwater investigation was commissioned in May 1992 aimed at evaluating the groundwater regime and to define the possible scale of groundwater occurrence with the downward extension of the mine.

The assimilation of data available prior to the investigation coupled with remote sensing and field techniques, led to an understanding of the groundwater flow and compartmentalisation.

Preliminary results from the investigation indicated that the mine is actively recharged from rainfall events in both the immediate vicinity of the mine and distant karst systems. This led to the development of a recharge simulation model to predict the ground water levels response to rainfall and to determine the water balance for the aquifer for the life of mine.

The understanding derived from the study was of crucial importance in improving the effective management of groundwater and its recognition as an exploitable resource. This led to a number of cost saving strategies.

INTRODUCTION

Finsch Mine is located in the northern Cape Province, some 160km northwest of Kimberley (Fig 1) where mining of a kimberlite pipe has been in progress since 1965. The pipe is a near-vertically sided intrusion of kimberlite into the Ghaap Plateau Dolomite Formation and the Kuruman member of the Asbestos Hills Banded Ironstone formation. The intrusion is roughly circular in shape with an original surface area of 17.9 hectares and which has been almost completely mined out to a depth of 430m below surface.

The mine is situated at the foot of the Asbestos hills close to a paleo spring line. The dolomite forms a significant aquifer in the area and there is evidence of higher water levels at the end of the last ice age. Stone age settlements have been found in dolomite caves some 100 km north of the mine.

With the aim of assessing the potential of major water ingress as the mine is deepened a hydrogeological study was commissioned with KLM Consulting Services in 1992. The first part of the three stage study comprised a desk study of all available information and a borehole census. The second part comprised a site investigation to determine the ground water regime at the mine and the third part currently comprises work into management of the groundwater as a potentially resource.

Each stage was aimed at addressing the impact of ground water on mining of the kimberlite orebody which is highly sensitive to water. It was perceived early on in the study that the continuation of mining at depth could be dependent on the control and abstraction of water from the orebody and that failure to do so could compromise the ability of tunnels to remain serviceable for their required life. By implication the impact of mining on the regional ground water resource was also assessed and which has impacted on the planned management and the recognition of groundwater as a resource.

GEOLOGY

The country rock consists of dolomite and dolomitic limestone, with chert bands and almost pure lenses of limestone and is overlain by Passage Beds and banded ironstones. The banded ironstones cap the mine area but are absent South of the mine. The Dolomite is light grey, very hard, very fine grained and has a distinct sedimentary sequence. Solution channels are both vertical and horizontal. Sink hole development is present but there is little weathered material (wad) at or near surface. The purity of limestone adjacent to the mine has led it its exploitation and which has greatly improved our understanding of its sequence with important correlations having been made. From about 170 metres below ground level (mbgl) to 410 mbgl the upper limestone and dolomite formations are referred to as the "dirty dolomites" containing numerous silt and chert bands. Below this the dolomite is highly crystalline and unweathered, although shearing, faulting, fracturing, and jointing are common. In addition to this sequence, kimberlite and dolerite dykes cross the area which have been recognised as having importance with regards to possible compartmentalisation of water.

From the air the exposed dolomite has weathered to give an 'elephant skin' appearance. Soil cover and weathered rock is very thin.

The kimberlite is made up of various intrusive phases and the kimberlite has been classified into eight types. The most commonly occurring type is the F1, which is a clay-rich kimberlite rich in country-rock material and sensitive to weathering. The second most common type is the F8, a textured tuffsitic kimberlite breccia, which is generally of a higher grade.

A plan of the pipe on the 680m level showing contacts within the kimberlite that were found to be water bearing during drilling exploration is shown in Fig.2.

MINING METHOD

The kimberlite was mined as an open pit until 1990 when it had reached its maximum economic depth by this method. By this time tunnelling had reached an advanced stage and it was possible to establish open stope faces from development holing into the open pit. These faces have become progressively established and now account for approx. 3.6 million tonnes of ore per annum which is processed by the underground ore handing system and hoisted to surface. It is planned to continue with this mining method to a depth of approx. 510m below surface and thereafter to change the method of mining to a block cave which is planned to start production in 2005. This will be established at approx. 620m below surface (where 'artesian' water is currently encountered). Problems have been experienced with the ground handling system associated with the affect of water on the kimberlite.

HYDROGEOLOGICAL INVESTIGATION

Finsch Mine has been dewatering the local aquifer since mining started, KLM Consulting Services [1] This is illustrated in Figure 3 which shows the cone of depression to the west of the mine as monitored in May 1993. The findings of a borehole census show this cone to be elongated because of the joint effect of the nearby Lime quarry which supplies about 31 000 m^3 to the Lime Acres from ground water.

On average Finsch Mine receives underground water inflows in excess of 80 000 m^3/month. In order to design for anticipated increases in inflow as the mine deepens mining depth a study was commissioned to quantify these amounts and to evaluate measures that could be taken to reduce the inflow if required. This objective demanded a thorough understanding of the hydrogeology of the mine and its surrounding area.

The desk study provided an initial understanding of the source and direction of movement of ground water flow but it was not possible to quantify the volume and source of ground water inflow. To achieve a higher level of confidence in the evaluation of the aquifers and assess the volumes of flow which are likely to reach Finsch a limited site investigation was initiated. The two main objectives of the site investigation were:

- Identify the potential for water ingress within the dolomites as tunnelling continues, to assess the volumes and rates possible and to advise on measures to counter this problem.
- Establish the likely distribution and potential sources of water within the pipe and propose strategies to reduce or eliminate its occurrence.

An underground inflow mapping investigation ran concurrent with the main investigation. The objective of the mapping was to gain insight into the mechanisms and distribution of inflows into the mine.

The evaluation of historical data study and the borehole census indicated that the water levels in the mine had been drawn down by about 400 mbgl from the pre mining water levels of about 20mbgl. The cone of drawdown was of limited extent as the mine was located within a dyke bounded dolomite compartment.

Assessment of total mine inflows

Although it was important to determine the main sites of inflow underground it was also important to estimate the total volume of ground water inflow anticipated for the life of mine. A Darcian approach was taken to estimate the inflows, KLM Consulting Services

[2]. This required the drilling of monitoring boreholes on surface with water levels measured. These measurements were used to determine the shape of the cone of drawdown of the water table.

Pressure readings were also taken underground to estimate the position of the water table at the centre of the cone of depression. The results were then modelled to give the present rate of inflow to the mine as measured by flow gauges.

A very simple model was used. The model does not predict inflows on a daily basis but on an average monthly basis. Inflows to the mine are seasonal so the total inflows should be looked at as an annual average.

Once the model was calibrated the cumulative rainfall departure (CRD) method Bredenkamp [3] was used to predict ground water level fluctuations.

The changing ground water levels were then used to re-calculate the shape of the cone of drawdown and the consequent change in inflow volumes. The same method was used to model changes in inflow caused by lowering the water levels in the centre of the mine.

The methodology used to determine mine inflows followed three steps:

1. Predict aquifer behaviour in according to cumulative rainfall departures (CRD)

2. Calculate recharge to the compartment

3. Calculate the nett volume of inflow expected:

a) as the mine is deepened

and

b) if the water levels in the area should rise in response to increased rainfall

To achieve these steps it was necessary to delimit the extent of the cone of drawdown in the water levels around the mine, determine aquifer boundaries and examine the ground water quality.

Definition of cone of depression

Ground water levels were obtained from four percussion boreholes. They were sited to the north east of the mine, up to 4 km from the pit (Figure 3) and were supported by a pressure gauge reading from underground which indicated that the water level in the dolomite aquifer within the mine was between 350m level and 430m level).

Dyke verification

Regional water levels measured during the first phase of this project indicated that the mine seems to be located within a ground water compartment. This phenomenon was supported by the finding that water levels measured across dykes were different by up to 30m, which showed that dykes form boundaries to ground water flow East and West of the mine. Dyke positions were mapped using aerial photographs, satellite imagery, ground magnetometery and an airborne total field magnetic contour plan (Unpublished Report, DBCM, 1987). Based upon these findings it is deduced that as the mine deepens water levels on the mine side of the dyke will continue to drop. At some trigger level leakage across the dykes will occur and more water will be drawn into the mine than that received or held by the dewatered dyke compartment.

Aquifer response to rainfall

The hydrogeological information on the area (i.e. rainfall and long term water levels) is too sparse to make very accurate predictions of the recharge and other aquifer characteristics. However it is possible to obtain first estimates.

The method used to determine aquifer response to rainfall events is the Cumulative Rainfall Departure method (CRD). This method assumes that aquifer water levels respond to not only recent rainfall events but also events which occurred some months or years previously.

The basic CRD formula is:

$$CRD_i = CRD_{i-1} + Rf - ARf \qquad (1)$$

where ARf = average rainfall

With the new approach developed by the South African Department of Water Affairs (Bredenkamp, 1993):

i) the rainfall (Rf) term is substituted by an average rainfall (Rf) value over the last months (e. 1,3,6,9,12 months) and mimics the short term memory of an aquifer.

ii) the average rainfall (ARf) term is substituted by an average recent rainfall (Rf) value over the last years (e. 36,60,96,120 months) and mimics the long term memory of an aquifer.

Therefore equation (1) becomes:

$$_i = CRD_{i-1} + \frac{1}{n}\sum_{j=n-i+1}^{i} Rf_j - l\frac{1}{m}\sum_{j=i+1-n}^{i} Rf_j \qquad (2)$$

where n (=1,3,6,9,12 months) and m (36,60,96,120 months) is the short term and long term memory respectively and l is a constant typical to the area (often 1).

Different combinations of "n and m" and m were used to obtain the best CRD fit to the water level reaction in a nominated borehole which it was assumed represented the aquifer behaviour. Through trial and error the best combination of short and long term memory of the Finsch area aquifer is 1 and 36 months respectively.

From this result a representative water level can be forecast. Several rainfall scenarios were modelled, the best fit is presented as Figure 4. The same rainfall and inflow scenarios were used to predict the future inflow to the mine. Variable water levels and increased mine depth were used in the predictions.

The CRD method takes account of the fact that not all rainfall events contribute to ground water recharge. The amount of water the ground can receive depends on parameters such as rainfall frequency as well as it's pre wetted condition.

Ground water recharge

Recharge was calculated using a borehole for which rainfall figures over a period of eight years was available. Based on water levels measured during the drilling programme the plan area of affected aquifer was calculated as 14 778 000 m^2.

A plot of Recharge volume (Re-Q) vs change in volume held in the aquifer (dV) is depicted in figure 6. From this plot a storage coefficient (S) value of 0.001 is inferred. At this stage in the investigation a recharge of 0,41 x 10^6 m^3/year for the upper aquifer is considered accurate enough for the initial modelling of ground water inflows.

Mine inflow calculations

The first assumption is that steady state conditions exist, i.e. the water level in the mine is at equilibrium with abstraction rates equalling the inflow of water. The second assumption is that water levels will react in accordance to the calculated CRD.

The calculations were based on Darcy's law where Q = Tiw.
and

Q = Mine inflow (or excess pumped out)

T = Transmissivity

i = Ground water gradient

w = Cross section of aquifer

Several trial and error approaches were used to estimate transmissivity. In a dolomite aquifer transmissivity values gradually decrease with the depth. This approach was used to model the shape of the cone of depression in the water levels around Finsch Mine. This method provided an acceptable result and was used to compute inflows to the mine for certain conditions.

The nearest observation borehole is 1 300 m from the centre of the mine and the furthest 3 700 m. A cone of depression was inferred according to the decrease in transmissivity values with depth. The modelled cone of depression is plotted on Figure 3.

This plot also takes into account :

- Water levels will tend to follow the topography therefore the cone is modelled as depth below surface.

- The elevation of the mine is about 80 m higher than the collar elevations of the boreholes. Therefore the drawdown in the mine was taken as about 450 mbgl.

The cross section of the cone of drawdown showed a very steep gradient close to the mine and indicated rapidly changing transmissivity values with depth. This correlates well with the near surface karst development present at Lime Acres.

Based on the Darcy equation the volume of water flowing into the mine is sensitive to both the depth of the mine (the lowest point from which water is being pumped from under ground) and the height of the water table around the mine. For the purpose of this modelling exercise the present effective depths of the mine was taken to be at 500 metres below shaft collar.

The future inflows to the mine were therefore predicted based on an increase in mining depth and possible fluctuations in ground water levels around the mine.

The depth of the mine is difficult to determine because it depends on effective depth i.e. enough development at a specific level to allow the aquifer to drain at that point. For the purpose of this modelling exercise the present effective depth of the mine was taken at about 500 m. Inflows were predicted for a maximum effective depth of 1 000 m.

Changes in the depth of the water levels within the mine and changes in the height of the water levels around the mine will increase the gradient of the ground water towards the mine and therefore result in increased flow to the mine. Using Darcy's law the inflow to the mine as a function of higher water levels is given in Figure 7. From this it follows that the inflow to the mine will increase as the mine deepens according to Darcy's law as the inflow to the mine must always balance the form, height and depth of the cone of depression. This is illustrated in Figure 8.

The results of the modelling show that if the rainfall pattern at Finsch does not alter significantly from that received over the last 30 years when the mine development reaches 1 000 m depth an inflow of approximately 160 000 m3 / month can be expected. which is double the present inflow.

If rainfall patterns change and the average annual rainfall increases by say 120 mm per annum water levels in the regional aquifer will rise by about 7 m and inflows to the mine will increase by an additional 14 000 m^3/ month.

The two graphs can be combined, for example at a mining depth of 1000 m plus an increase in average annual rainfall of 120 mm, the mine can expect average monthly inflows of around 174 000 m^3.

These figures are approximate because the model used to generate them is simplistic. They do not take into account the individual erratic flood events that have been recorded at Finsch but incorporate them within the monthly averages.

It appears from the modelling that the cone of depression in the water table around Finsch mine has reached quasi-equilibrium. If there is no major leakage across the dykes which bound the aquifer and rainfall does not increase above the average for the past 30 years the increase in inflow to the mine will be minimal. At an effective mine depth of 1 000 m inflows should stabilise between 120 000 and 160 000 m^3/month.

More accurate modelling will be possible when the results become available from a monitoring network set up in early 1993 and making use of pressure gauges to be installed at selected sites in 1994.

UNDERGROUND MAPPING OF MINE WATER INFLOWS.

Although it is important to predict the total volumes of inflow for the life of mine it is also important to try to predict problem areas and potential inflow sites. To achieve this detailed mapping of inflows was required for correlation with specific geological structures.

Although several specific inflow zones hinder the handling of kimberlite ore directly, the investigation sought to establish general trends and controls to enable wet zones to be anticipated and enable planning and control measures to be implemented .

Objectives and methodology

The primary objective was to investigate the actual mechanisms and distribution of inflows into the mine.

All inflow and seepage zones were examined with the emphasis on:

- the type of geological structure or feature feeding the flow
- the volume of flow using direct measurement where possible
- the locality and orientation of the feature
- the frequency of water bearing features
- the state and condition (width, openness, type and extent of cementation or filling) of the feature
- the estimated continuity of the feature

This information was correlated with known geological and hydrogeological information for final interpretation.

Types of inflow

There are several types of inflows underground. These range from zones of widespread seepage or dripping from the walls and roof to isolated or localised high pressure and high volume inflows, sometimes intersected by cover drilling.

Flow is driven by high hydraulic heads if in continuity with the regional ground water system, or by gravity if the delayed release of ground water from storage in the weathered and dewatered formations infiltrates into areas of mining.

Regional structure and hydrogeology controls ground water movement into the mining areas, although local or mining induced discontinuities deliver some of the flow into the workings. The regional ground water gradient, the proximity of mining to regional hydrogeological structures, and the geometry of mining operations result in a variation of inflow spatially around the kimberlite intrusion. Variations with depth are a result of the increasing hydraulic gradient established as mine dewatering progresses and the structural condition of the country rocks.

Many short holes drilled for rock bolting and cover drilling have intersected water bearing features. Some of these holes have initially high pressure flows which wane as they dewater the secondary aquifer intersected. This suggests poor interconnection of structures or failure of recharge due to a receding cone of depression.

Fissures are often washed out portions of weathered dyke material or gouge filled faults, and are seldom open for any distance. These have been caused by ground water drainage resulting in headward erosion of weathered material after mining development.

Other fissures resulting from shrinkage during the dolomitisation process, or solution activity along fracture or bedding surfaces can be larger and more continuous. Of note is that these fissures occur mainly in the upper dewatered levels of the mine, and none transmit water into the mine at their potential flow capacity. Hydraulic properties have been developed under the influence of structural deformation and weathering. Permeability and storage are dependent on the interconnection of joints, fractures, faults, bedding planes and fissures.

From Figure 9 it is clear that the kimberlite has been emplaced where a high density of structural features are concentrated or intersect.

Kimberlite emplacement has been responsible for further fracturing and jointing of the host dolomites and banded ironstone formations.

The main structural elements which are hydrogeologically significant are :

- Parallel shear zones tending NW - SE on the west and east side of the pipe respectively. Extensive fracturing developed in sympathy with shearing is prevalent in the north between the two shear zones
- NE - SW tending dyke swarms
- "S" shaped precursor to the main kimberlite pipe
- fracture and dyke intrusion along a ENE - WSW direction
- the main kimberlite intrusions and associated radial fracturing and dyke intrusions
- later fracturing and faulting

The majority of secondary structural features have been shown by geotechnical mapping to be vertical and subvertical in dip.

Zones of inflow

In the vertical dimension, three zones can be differentiated with regard to the dominant hydrogeology. The main classification is based on the ground water movement within each zone. They have been classified as:

Zone 1 Unsaturated dewatered - 290 m level to 430 m level

Zone 2 Vertical flow zone - 430 m level to 620 m level

Zone 3 Flow under pressure - 620 m level to 770 m level

EVALUATION OF KIMBERLITE WATER

Kimberlite and dolomite have significantly different hydrogeological characteristics. Unweathered unfractured dolomite has near zero permeability and porosity. Ground water is only found in the cracks and cavities within the dolomite or associated with changes in the sedimentary sequence e.g. chert or shale horizons.

Kimberlite can have a high porosity dependent on it's alteration and clay content. Permeabilities are usually very low with ground water movement only occurring on contact zones or open fractures.

Kimberlite appears to be self-sealing in that it will absorb any available moisture and swell to fill open cracks or fissures. This property makes kimberlite very difficult to handle in the presence of water.

In the Finsch Mine context although the dolomite aquifers close to the mine have been dewatered it is probable that the kimberlite drainage is delayed and that there will be a "mound" in the water table within the kimberlites. This means that if the kimberlites are to be dewatered then the dolomite water levels will have to be lowered below than proposed mining levels several years in advance to facilitate drainage away from the pipe.

Falling head test results

In order to estimate drainage times within the kimberlite large diameter drill (LDD) holes drilled into the footwall of development on the 680m level were used for falling head tests in order to determine permeability of the kimberlite. Water levels in adjacent holes were monitored concurrently.

The water level in the tested borehole fell 27 cm over 5,5 hours following the introduction of a 40 l slug of water. From this a permeability value of 6×10^{-6} cm/sec was calculated. This is consistent with permeability values measured in kimberlite at Letlhakane mine in Northern Botswana.

FUTURE MINE DEWATERING

Results of the investigations have shown that the volumes of water Finsch Mine can anticipate are manageable in terms of removal from the mine workings. Further work is required however to establish whether the response in the kimberlites to dewatering of the dolomites (either through mine deepening or through an active dewatering programme involving a series of underground wells) will be sufficient to ameliorate the problem of swelling of kimberlite due to water, affecting tunnel stability and of handling wet kimberlite. A feasibility study in this regard is already in progress.

COST SAVING STRATEGIES

The increased understanding of the mechanisms, sources and likely volumes of groundwater has so far been used to assist with ways of preventing water from entering certain areas of the mine . It is presumed that success in this area will reduce (and possibly eliminate) the occurrence of groundpass ""hangups"" with associated benefits to production. In addition the recognition of groundwater as a resource in balance with mining activities has led to its surface exploitation for irrigation purposes. Coupled with an underground dewatering programme it is envisaged these may combine to obviate the need for such large volumes of water that are currently piped 100km from a water treatment plant on the Vaal River. Improvements in water reticulation as a result of this improved understanding are now planned with associated improvements in efficiencies and the reduction of avoidable losses

CONCLUSIONS

The investigation confirmed the extent of the aquifer affected by Finsch mine dewatering as approximately 14 778 000m2 (equivalent to a radius of 3 800 m from the centre of the mine) as well as the approximate depth of dewatering at the mine. This phenomenon is confirmed by the groundwater recharge calculations which show that abstraction by the mine currently exceeds recharge of approx. 5% to 6% of the annual rainfall received.

Groundwater inflows as a function of mine deepening and changes in water level (due to rainfall) have been predicted. These values have been used to indicate to the mine its future pumping requirements. The potential to dewater the kimberlites has also been identified.

ACKNOWLEDGEMENTS

Gratitude is expressed to the Consulting Engineer, Anglo American Corporation of South Africa, and to the Management of Finsch Mine for permission to publish this paper.

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Report FIN/1 January 1993

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Report FIN/3 February 1994

3 Bredenkamp D. Cumulative Rainfall Departure Method
Water Research Commission, Pretoria (1993)

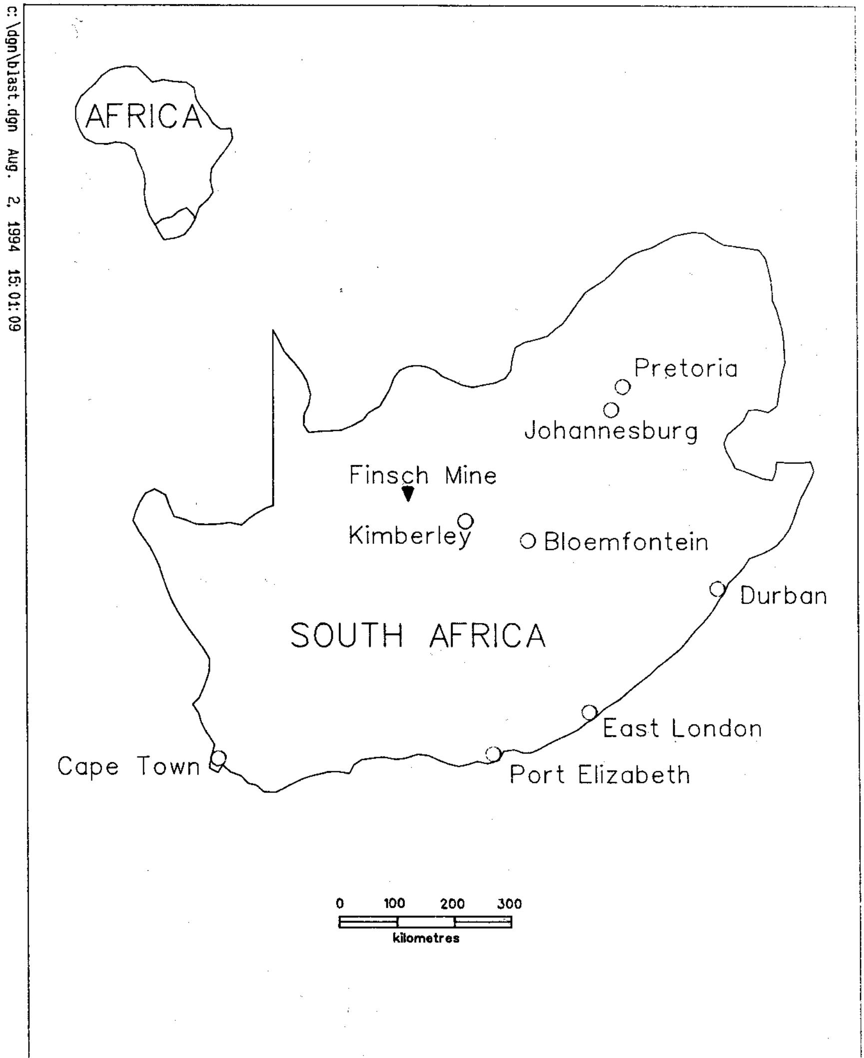
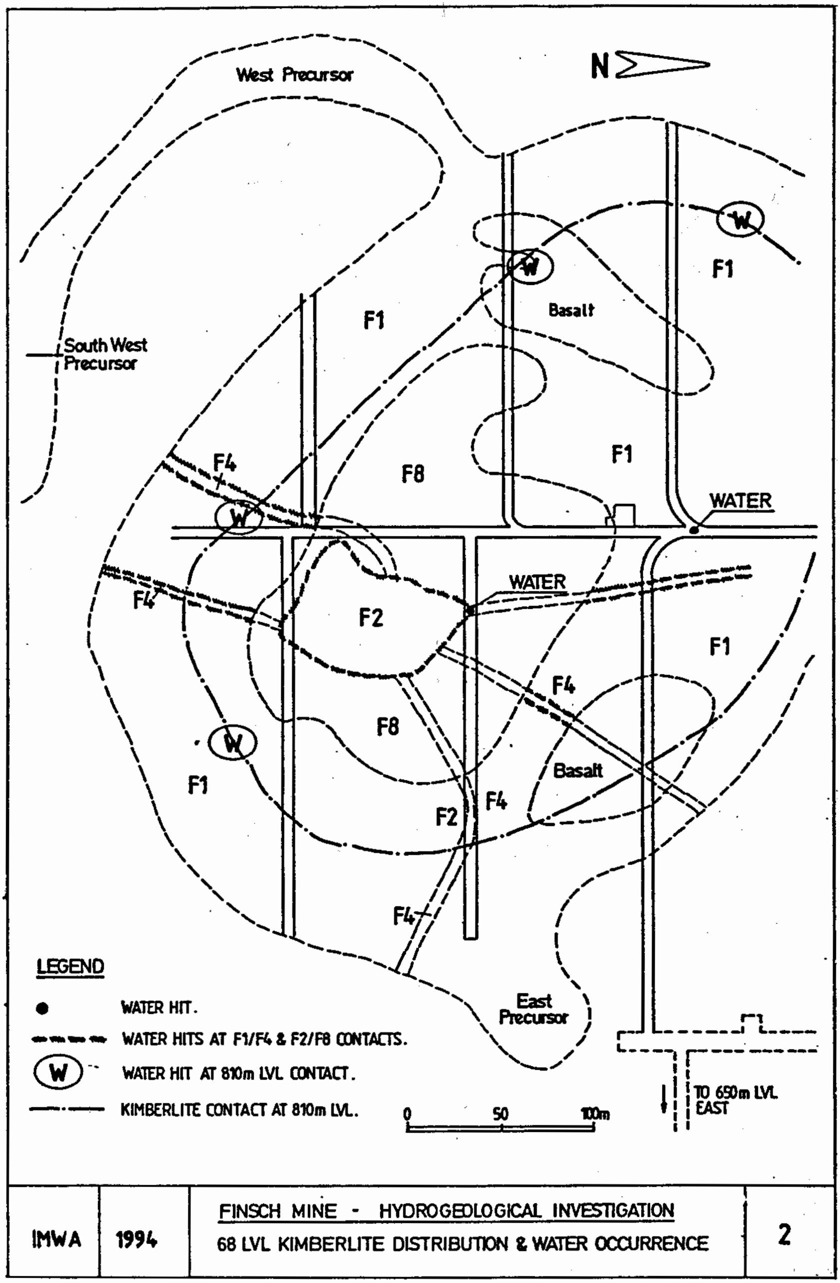
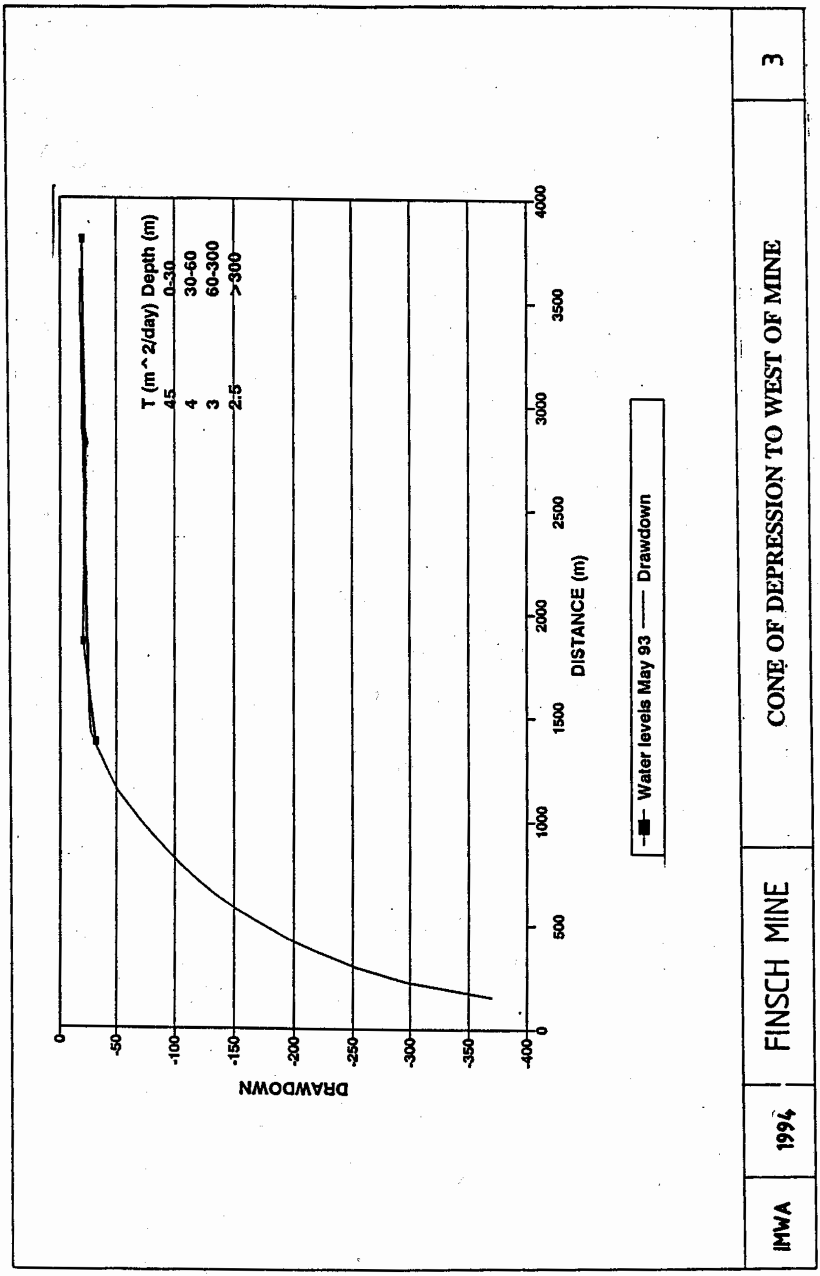
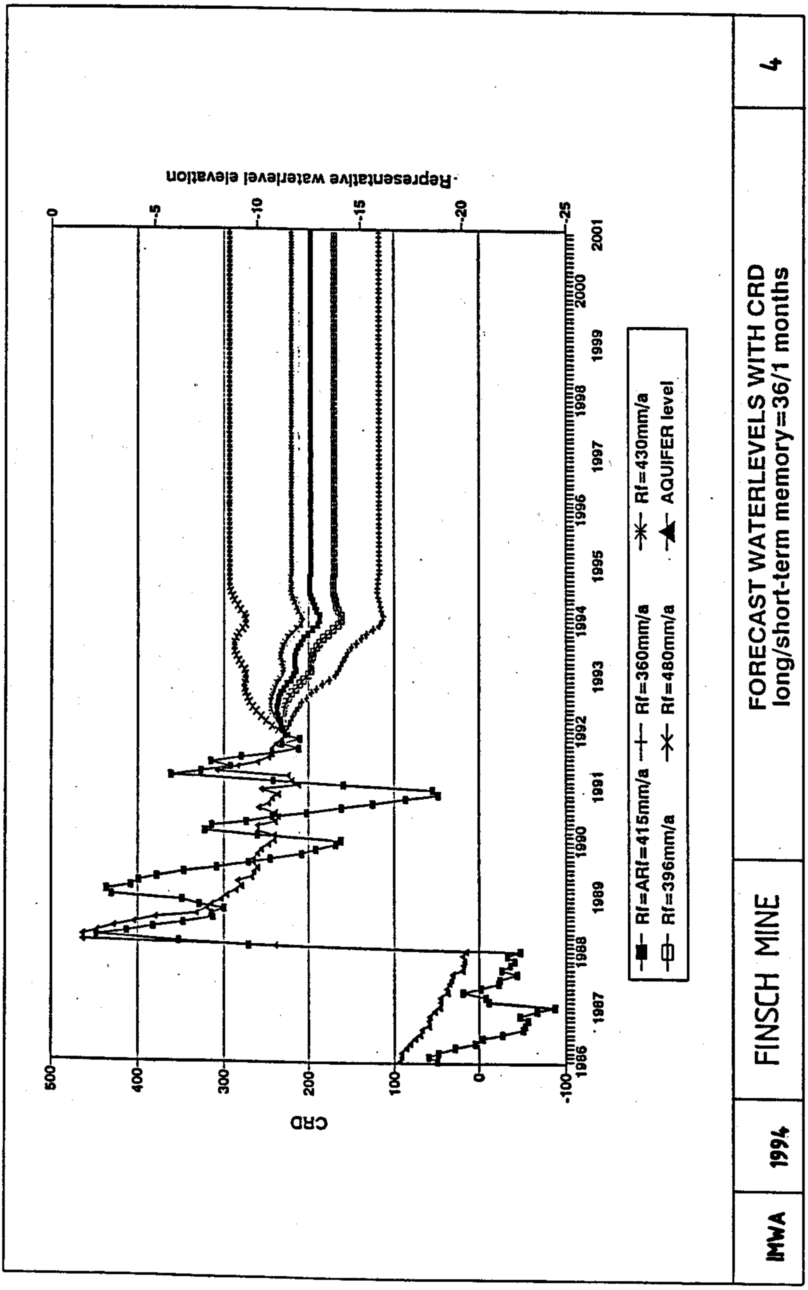


FIG.1 FINSCH MINE LOCALITY MAP

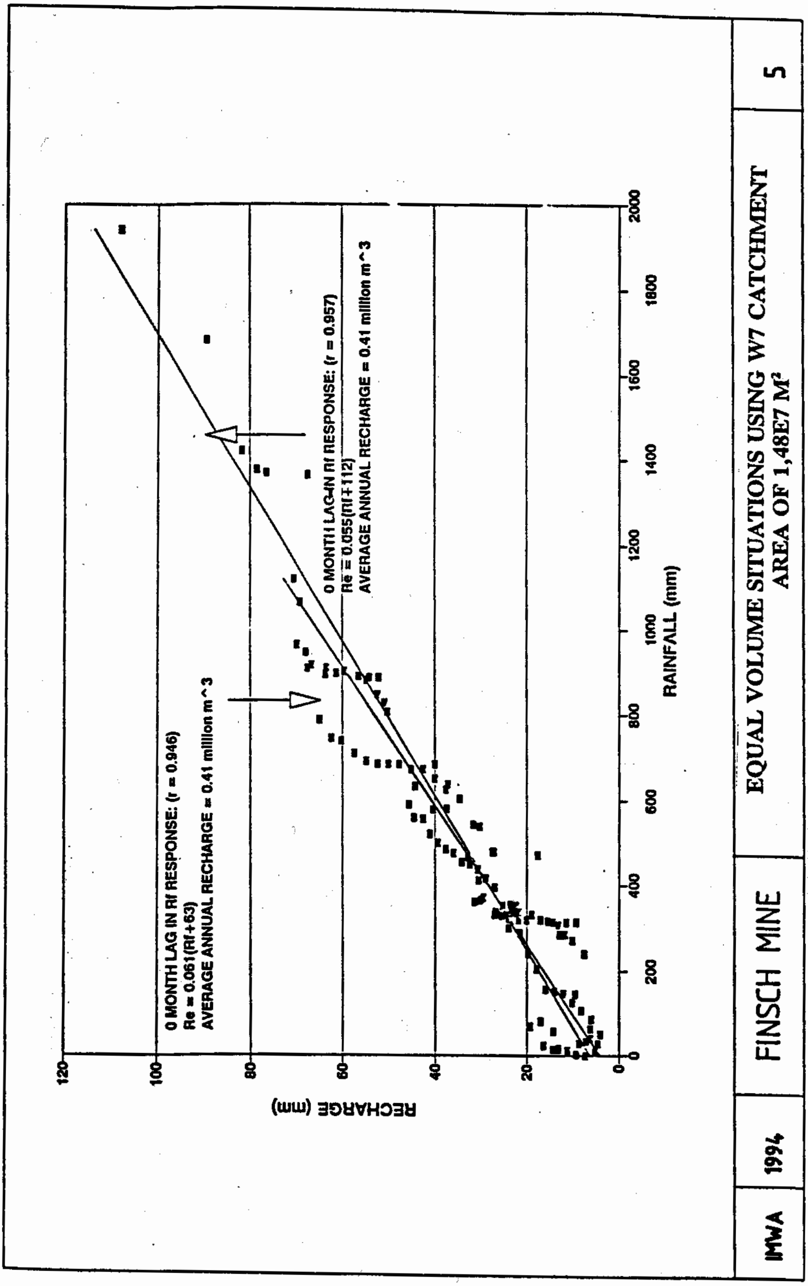


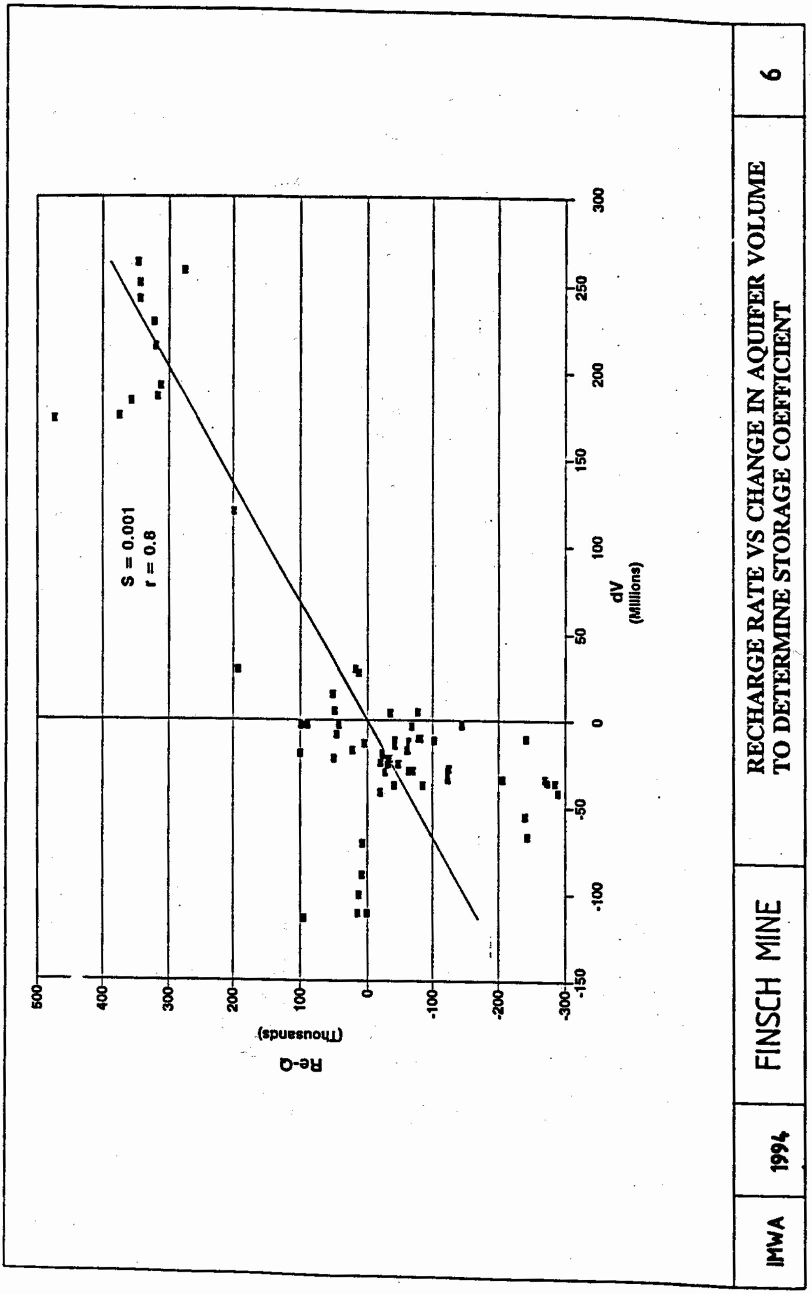
N
West Precursor
South West Precursor
F1
F1
Basalt
F1
F8
F4
WATER
WATER
F4
F2
F1
F4
F8
Basalt
F1
F4
F2
F4
East Precursor
TO 650m LVL EAST
LEGEND
WATER HIT.
WATER HITS AT F1/F4 & F2/F8 CONTACTS.
WATER HIT AT 810m LVL CONTACT.
KIMBERLITE CONTACT AT 810m LVL.
0
50
100m
IMWA
1994
FINSCH MINE - HYDROGEOLOGICAL INVESTIGATION
68 LVL KIMBERLITE DISTRIBUTION & WATER OCCURRENCE
2

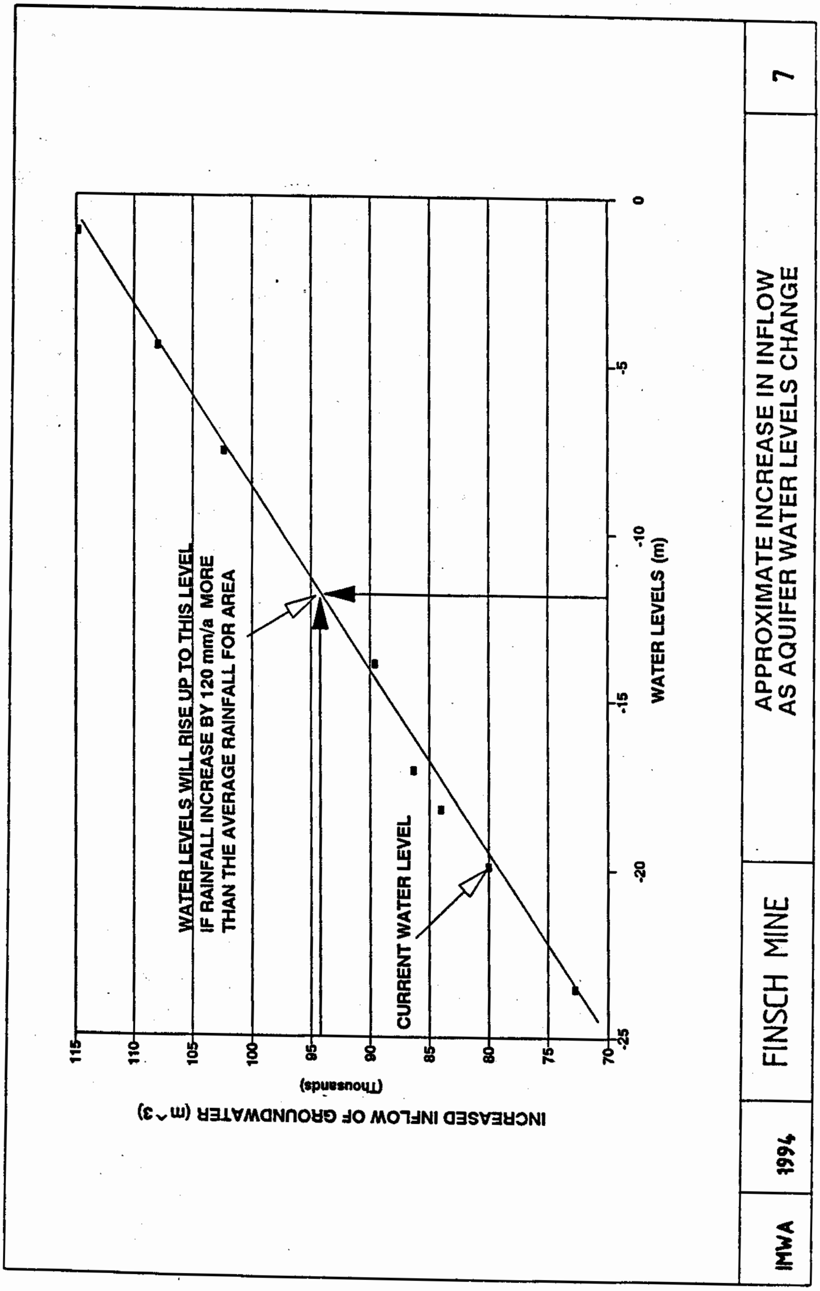

T (m^2/day) Depth (m)
45 0-30
4 30-60
3 60-300
2.5 >300
DRAWDOWN
0
-50
-100
-150
-200
-250
-300
-350
-400
DISTANCE (m)
0
500
1000
1500
2000
2500
3000
3500
4000
Water levels May 93
Drawdown
CONE OF DEPRESSION TO WEST OF MINE
3
FINSCH MINE
1994
IMWA

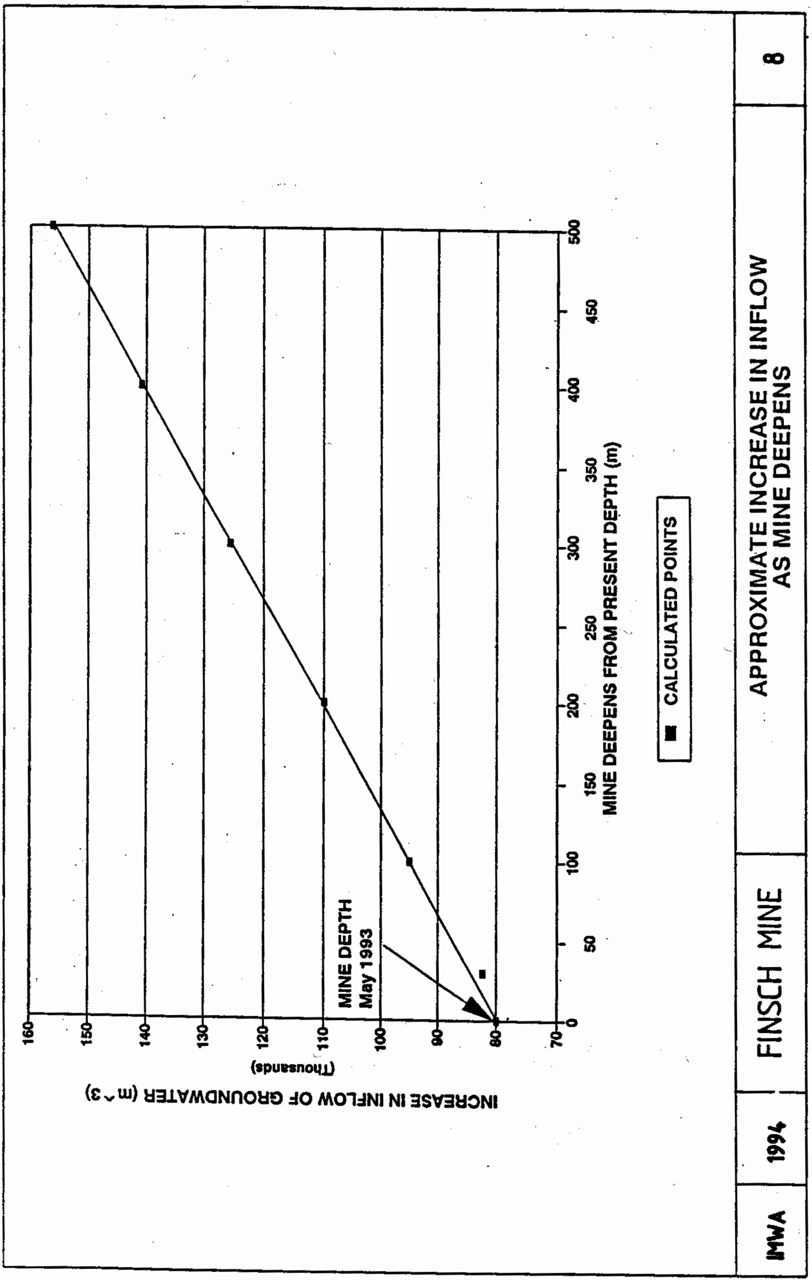


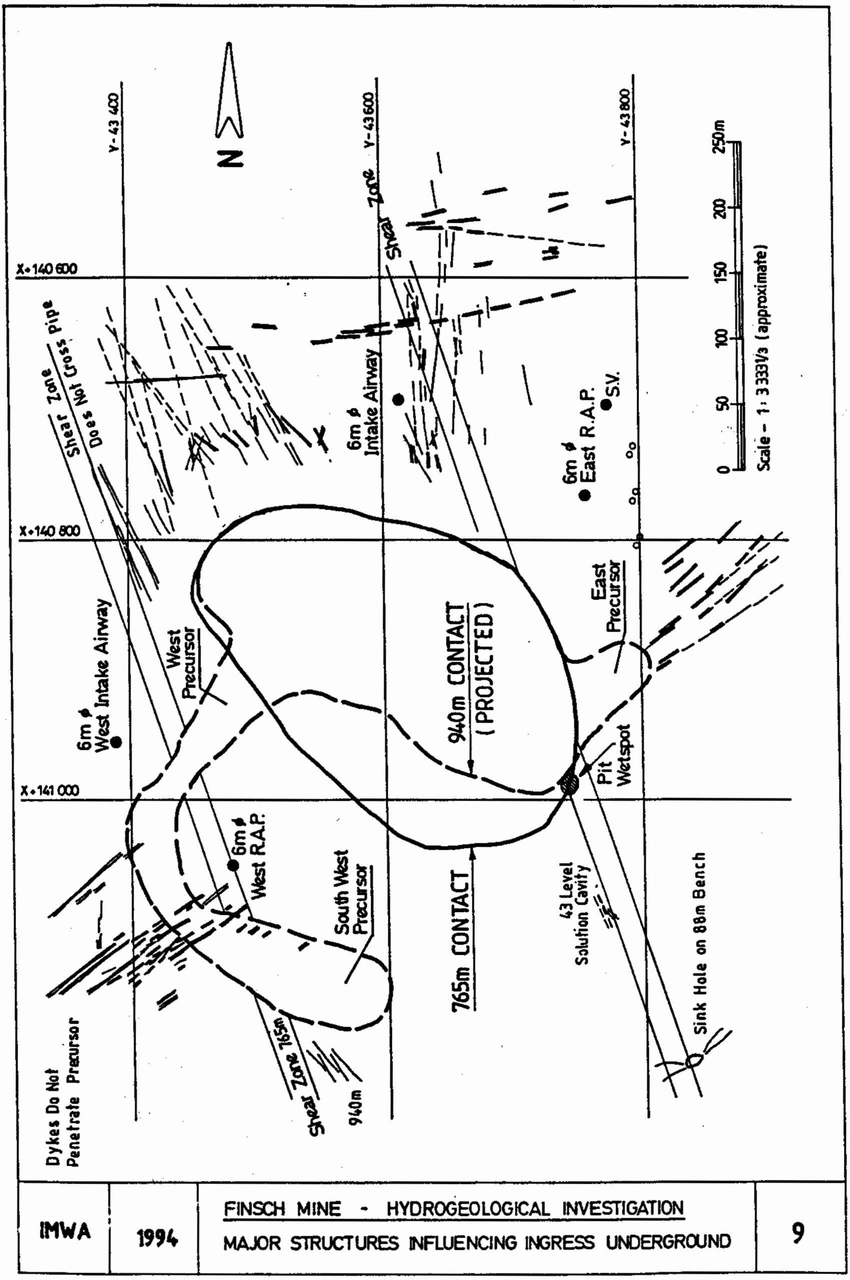
FORECAST WATERLEVELS WITH CRD
long/short-term memory=36/1 months
FINSCH MINE
1994
IMWA
4
CRD
Representative waterlevel elevation
Rf=ARf=415mm/a
Rf=360mm/a
Rf=430mm/a
Rf=396mm/a
Rf=480mm/a
AQUIFER level


0 MONTH LAG IN Rf RESPONSE: (r = 0.946)
Re = 0.061(Rf+63)
AVERAGE ANNUAL RECHARGE = 0.41 million m^3
0 MONTH LAG IN Rf RESPONSE: (r = 0.957)
Re = 0.055(Rf+112)
AVERAGE ANNUAL RECHARGE = 0.41 million m^3
RECHARGE (mm)
120
100
80
60
40
20
0
RAINFALL (mm)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
EQUAL VOLUME SITUATIONS USING W7 CATCHMENT
AREA OF 1,48E7 M²
FINSCH MINE
1994
IMWA
5


RECHARGE RATE VS CHANGE IN AQUIFER VOLUME
TO DETERMINE STORAGE COEFFICIENT
6
FINSCH MINE
1994
IMWA
S = 0.001
r = 0.8
dV
(Millions)
Re-Q
(Thousands)


WATER LEVELS WILL RISE UP TO THIS LEVEL
IF RAINFALL INCREASE BY 120 mm/a MORE
THAN THE AVERAGE RAINFALL FOR AREA
CURRENT WATER LEVEL
WATER LEVELS (m)
0
-5
-10
-15
-20
-25
115
110
105
100
95
90
85
80
75
70
(Thousands)
INCREASED INFLOW OF GROUNDWATER (m^3)
APPROXIMATE INCREASE IN INFLOW
AS AQUIFER WATER LEVELS CHANGE
7
FINSCH MINE
1994
IMWA


8
APPROXIMATE INCREASE IN INFLOW
AS MINE DEEPENS
FINSCH MINE
1994
IMWA
CALCULATED POINTS
MINE DEEPENS FROM PRESENT DEPTH (m)
0
50
100
150
200
250
300
350
400
450
500
INCREASE IN INFLOW OF GROUNDWATER (m^3)
(Thousands)
70
80
90
100
110
120
130
140
150
160
MINE DEPTH
May 1993



N
Y-43 400
Y-43 600
Y-43 800
X+140 600
X+140 800
X+141 000
Shear Zone
Does Not Cross Pipe
6m ϕ Intake Airway
6m ϕ East R.A.P.
S.V.
6m ϕ West Intake Airway
West Precursor
940m CONTACT (PROJECTED)
East Precursor
Pit Wetspot
6m ϕ West R.A.P.
South West Precursor
765m CONTACT
43 Level Solution Cavity
Sink Hole on 88m Bench
Shear Zone 765m
940m
Dykes Do Not Penetrate Precursor
Scale - 1: 3 333⅓ (approximate)
0 50 100 150 200 250m
IMWA
1994
FINSCH MINE - HYDROGEOLOGICAL INVESTIGATION
MAJOR STRUCTURES INFLUENCING INGRESS UNDERGROUND
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