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TECHNICAL COMMUNICATION

A Historical Perspective of Diamond Mine Dewatering Design and Guidelines for a Modern Diamond Mine

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Abstract
Dewatering is an important consideration in kimberlite mining. Early underground mines used water tunnels connected by passageways to divert rainwater and near-surface groundwater from the mine workings. Shafts with multi-stage pumping levels were used to pump water from the deepest mine sections. At the Finsch mine, a 650 m deep water ring-tunnel (combined with a conveyor belt level) and deep pumping boreholes were used to dry the initial block cave to 720 m below the surface. Other mines use rings of surface-pumped dewatering wells (e.g. the Letlhakane and Orapa mines in Botswana). This paper summarises the techniques used to manage pit and underground water, its links with mud rush occurrence, and lessons learned over the last 120 years. The hydrogeology of typical kimberlite mines and various ways to keep water away from the mine workings are described. The paper concludes with a good practice dewatering design and water management strategy for modern mines.

Keywords Monitoring · Groundwater · Feasibility studies · Dewatering · Optimisation · Kimberlite

Introduction

Diamond mining in hard rock, as compared to alluvial diamond mining, has been practised since the late 1800's. Mine dewatering design has been an important consideration in the mining of kimberlites. Cecil John Rhodes made his first fortune supplying pumps to the Kimberley open pits to keep them dry enough to mine.

The mining of kimberlites tends to follow a specific methodology. Diamonds are mined open pit to about 350 m below ground level (bgl). Then, when the cost of driving tonnes of rock to the surface becomes uneconomic, a shaft is sunk and either chambering, blast hole open stoping, sub level caving, or block caving is used. Each mining method has a specific effect on the groundwater surrounding the volcanic pipe containing the diamonds.

Modern dewatering techniques have been developed using experience gained in deep mines, and, when combined with well-designed monitoring networks, are effective in managing groundwater, including reducing mud inrushes. The paper summarises the dewatering techniques used since the 1800's, with photographs from early mining journals to illustrate historic mining conditions, and concludes with good practice dewatering design and water management strategy for modern mines.

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Historical Dewatering Strategies

Groundwater control and prevention of flooding has been a concern since kimberlite mining began. Kimberlites in semi-arid areas world-wide are often overlain by pans and have associated springs. Figure 1 shows the flooding of the original open pit at Kimberley's Du Toitspan mine in 1874. Figure 2 shows the Koffiefontein pit flooded in 1978. Figure 3 shows the pumping engine used to dewater the open pit at De Beers mine in Kimberley in 1906. The Wesselton mine had a spring that flowed into the initial pit at 220,000 m^3/day. Figure 4 shows the spring and drainage trenches used to divert the water from the working areas. Most of the water entering the Kimberley mines was from rainwater and near-surface groundwater, which moved downwards and then flowed along the shale-volcanic rock contact.

As the mines deepened and started mining underground, muck piles were created by slumping of the weathered shales

Fig. 1 Du Toitspan mine flooded pit 1874 (Williams 1906)

Fig. 2 Koffiefontein mine flooded pit 1970 (Bruton 1978)

Fig. 3 De Beers mine steam pumping engine 1879 (Williams 1906)

and kimberlite into the pit. During the early 1900's, the mines experienced mud inrushes underground, with consequent fatalities, caused by water build up in the muck pile and the release of mud into the underground workings.

Perimeter water tunnels were installed at various depths to prevent these inrushes. Figures 5, 6, and 7 are plans of the water tunnels installed in Kimberley, Du Toitspan, Bultfontein, Wesselton, and De Beers mines. Their purpose was to divert water from the open pit and underground workings. In section view, the tunnels are arched and generally 2.5 m high by 1.5 m wide. These tunnels range in depth from 40 to 120 m bgl (De Beers monthly reports (unpublished); Williams 1906).

Fig. 4 Wesselton mine in 1896 with spring flowing at 220,000m^3/d (Williams 1906)

Installation was as close to the kimberlite pipe contact as possible, but outside of the pit perimeter, and in hard rock. The tunnels were sloped at 1.5° towards a shaft equipped with a pump. Drain holes were drilled upwards to drain water from the overlying shales into the tunnels. Any water not captured by the water tunnels was allowed to gravitate to the bottom of the mine and was then pumped out by sumps and a series of stage pumps located near the shaft.

It is important to note that the water tunnels completely encircle the mines, to intercept groundwater flow from all directions, not only from up-gradient areas of the regional catchment. Du Toitspan and Bultfontein mines are very close to each other and share a joint shaft, so there is no water tunnel between them but the two semi-circular tunnels to the northeast and southwest respectively completely encircle the two mines. These water tunnels are still in use.

As the mines deepened, inflows continued. Although the country rock geology tends to become less permeable with depth, the continued pumping from the bottom of the mine created a groundwater sink in the regional catchment. This, combined with the increased hydraulic conductivity of the country rock created by mining, resulted in an expanding cone of drawdown in the phreatic surface around the mine and increased inflows. The mine's response to increased inflow was to install larger capacity pumps. However, this method of passive dewatering can only remove water once it has entered the mine. Modern mines are deeper, and the block cave method is very sensitive to the presence of water. Active dewatering, in which the water is pumped out from below the pit or mine bottom in advance of mining, is necessary to pre-dewater a mine and reduce pressures to below, for example, block cave mining.

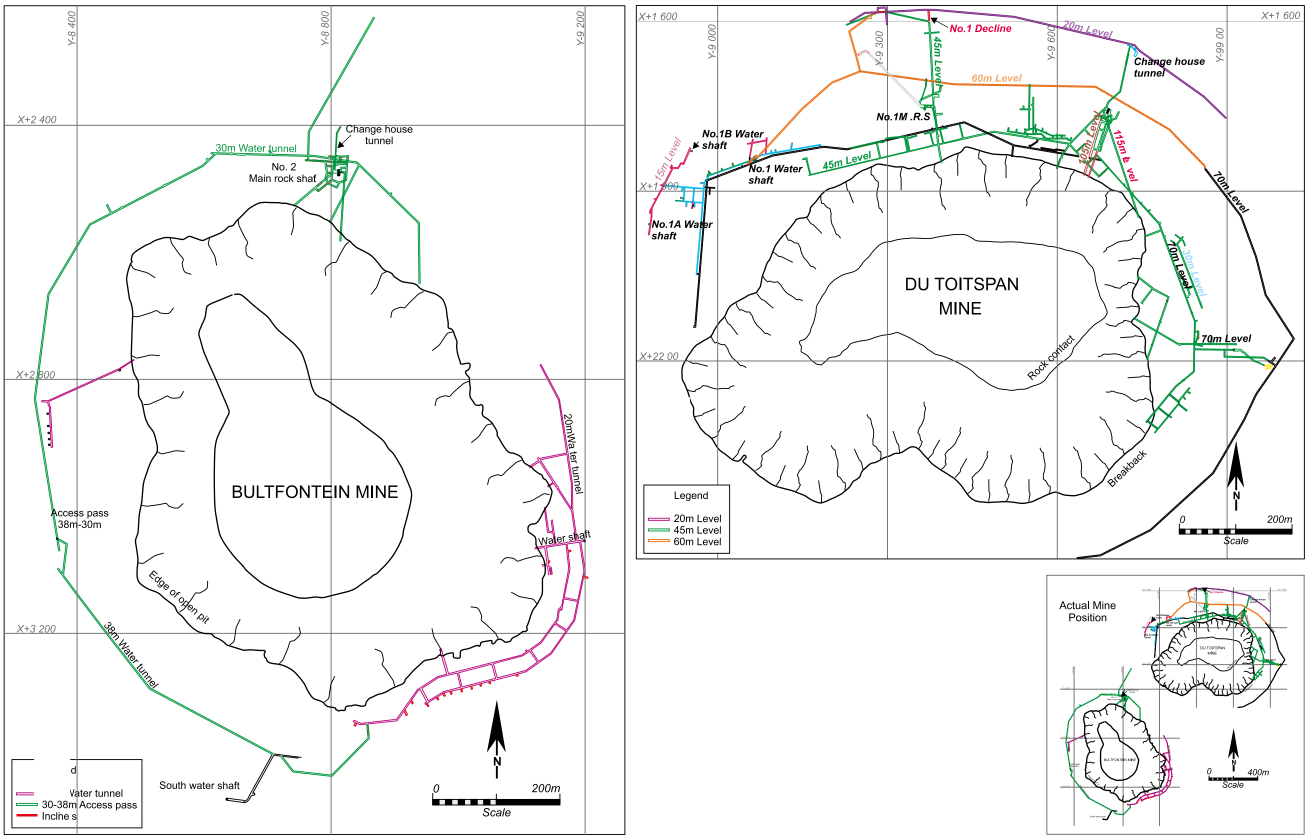


Fig. 5 Plans of water tunnels—Du Toitspan and Bultfontein mines

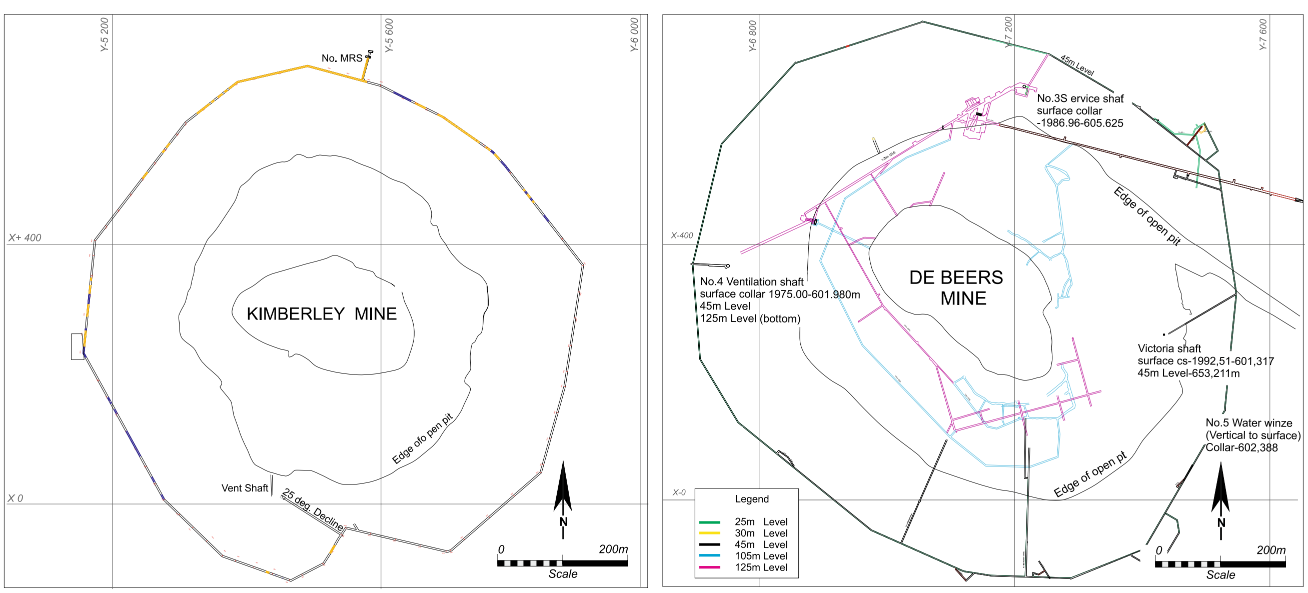
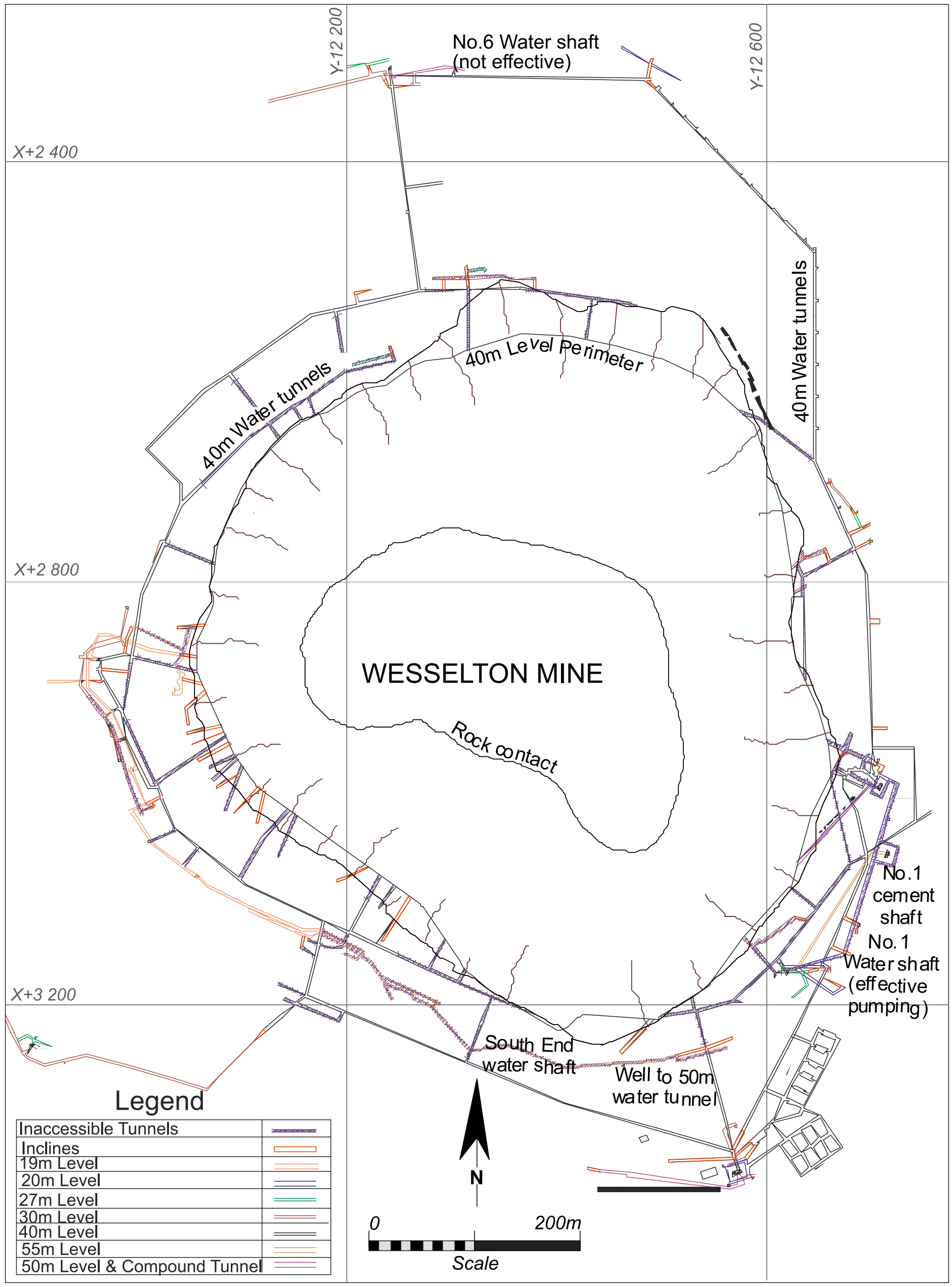


Fig. 6 Plans of water tunnels—De Beers and Kimberley mines

Fig. 7 Water tunnels Wesselton mine



At the Finsch mine, a combination of methods are being used, including a decline, a 650 m deep dewatering ring tunnel (combined with a conveyor belt level), and deep pumping boreholes drilled from the 650 m level to dewater the upper levels and the initial block cave to 720 m bgl.

Hydrogeology of Kimberlites

Kimberlite mines are unique in that they are designed to extract a carrot shaped ore body (called a pipe) that can be very porous in sections and easily made unstable by even small amounts of water. Muck piles develop above the extraction levels and mud accumulates as the mine operates. Weathered kimberlite is very porous and muck piles can hold up to 40% water.

The mine is affected by precipitation, surface water, and groundwater. To be able to design an accurate dewatering system, it is important to understand how groundwater flows into the mine and where the groundwater originates. Fundamental to this approach is knowledge of the hydraulic conductivity of the different mine components, including rock types, contact zones, and geological structures. Kimberlite can be very clay rich and understanding the kimberlite porosity is also important. The hydraulic conductivity of the kimberlite-country rock contact, the kimberlite, and the zone of relaxation as well as the role of the country rock, are discussed below:

The Kimberlite-Country Rock Contact

Kimberlites, particularly the tuffisitic kimberlite breccia (TKB) type, are very porous, but have very low hydraulic conductivities and often contain water-bearing fractures and intra-kimberlite contacts, which also transmit water. Hypabyssal type kimberlites (HK) are very hard, with internal fracturing and jointing and sometimes, the kimberlite pipe is in fractured or in karst dolomitic country rock, again allowing rapid ingress of water.

The juxtaposition of the fractured country rock and the kimberlite creates a unique groundwater regime. This often results in the rapid transmission of water into the kimberlite contact zones, which, when relaxed by mining, have the potential to distribute water and create a build-up of groundwater pressure in and around the mine. The kimberlite-country rock contact is typically sheared and creates a zone with a higher hydraulic conductivity than the surrounding country rock, readily allowing rapid percolation of water into the mine workings.

The zone of relaxation (ZOR) around the pit is made up of the kimberlite-country rock contact and the relaxed rocks in the pit highwalls. The width and depth of the ZOR is controlled by the age of the open pit and competence of the rocks, but in general can reach 100 m horizontally from the pit shoulder. Figure 8 is a close-up of the exposed smooth, vertical contact between the pipe and country rock within the Kimberley Mine open pit. Here the sheared, unbonded contact between the kimberlite and the country rock becomes an open contact zone, allowing rapid transmission of water into the mine workings. Observations made at the Premier, Finsch, Koffiefontein, Letlhakane and Loxton's Dal diamond mines show that the contact can also become a slip face, which allows movement of the kimberlite against the country rock during mining. One benefit is the contact and associated ZOR can be used to drain groundwater as part of the dewatering strategy.

Figure 9 shows the contact zone between kimberlite and sandstone at Jagersfontein mine in the Free State, South Africa. The sandstone is on the right and the kimberlite on the left. The up-turned previously horizontal sandstone shows the force of the emplacement of the kimberlite. Figure 10 shows the ZOR and wet kimberlite contact in shales

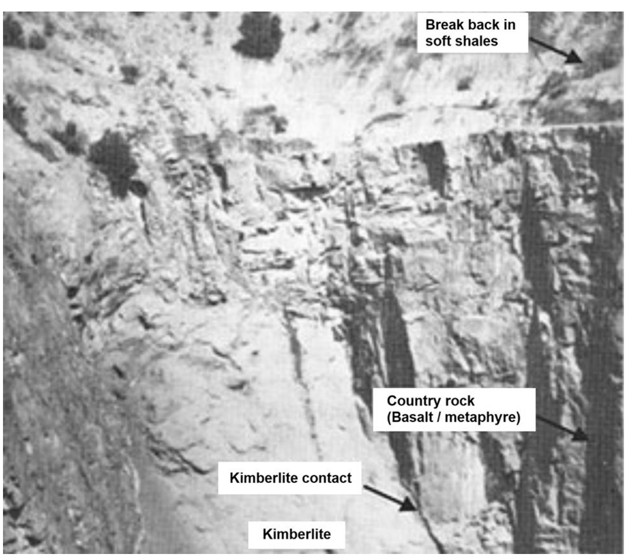


Fig. 8 Kimberley pipe showing clear contact between pipe and country rock (Wagner 1914)

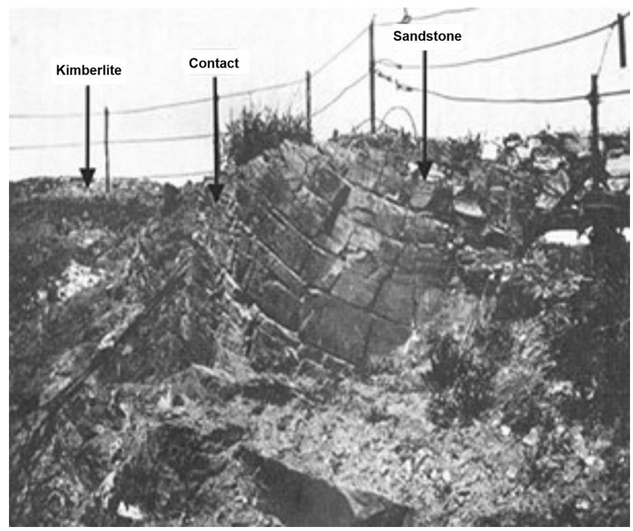


Fig. 9 Upturned sandstone at Jagersfontein (Wagner 1914)

Fig. 10 Jwaneng ZOR and wet kimberlite crater contact (Morton 2008)

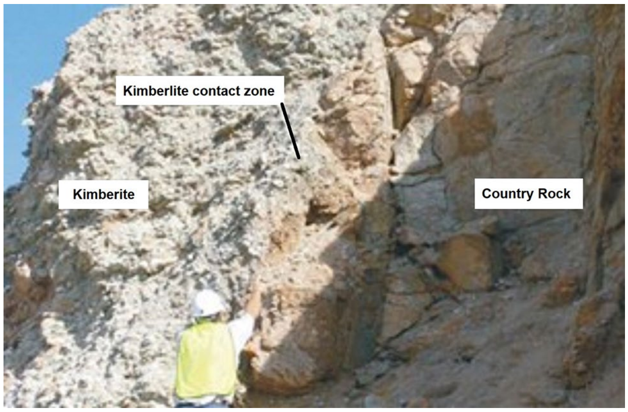


Fig. 11 Kimberlite country rock crater contacts Williamson mine Tanzania (Morton 2008)

(on the right), on the southwestern side of the pit at Jwaneng mine, Botswana. Figure 11 illustrate the wide, sheared, kimberlite contact zone at Williamson mine in Tanzania.

Surface water and groundwater tends to move to the lowest point in the mine. Once mining has started, a ZOR develops in the country rock immediately around the pit and acts as a drain, connecting the surface to the kimberlite contact zone and the underground workings. Figure 12 Illustrates the typical shape of a ZOR around a kimberlite mine in plan view.

Hydraulic Conductivity for Kimberlites

The hydraulic conductivities of different kimberlites have not been consistently studied. However, some results from individual projects in Southern Africa, Canada, and Russia are summarised in Table 1. Values range over some nine orders of magnitude, ranging from a value typical of gravel (1×10^1 m/day), to values for shale and intact metamorphic rocks (1×10^{-7} m/day). The samples in the table include kimberlite from the broken rock in the overshot zone of the open pit footwall as well as undisturbed core. Only glacial till and extrusive volcanic rocks have a similar range.

Kimberlite and Country Rock

Kimberlite is intruded into weak zones in the country rock. Kimberlite types can be very hard (Hypabyssal) to very soft (Pyroclastic, Brecciated or Tuffisitic). Figure 13 shows the generalised model for a southern African kimberlite. The kimberlite has three distinct zones, the: crater, diatreme, and root. The upper zones of the Kimberley kimberlites have all been eroded, so only their root remains.

Impact of Mining on Kimberlite and Country Rock Geology

Water in the country rock will move along the contacts once they are opened (relaxed) by mining. Figure 14 shows the mining methods used to extract ore from a kimberlite pipe and the type of voids created by each type of mining.

The Kimberley mines were originally open pits. Then, when it became uneconomic to load and haul ore using trucks driving in and out of the pits, shafts were sunk and the kimberlite was extracted by chambering from horizontal access tunnels using drilling, blasting, and loading in cocopans that travelled on rails. Numerous levels were used to access the kimberlite and because of the irregular shape of the pipe, many access tunnels were developed to extract the kimberlite and tram it back to the shaft. Each level required ventilation and water drainage; therefore, many tunnels (vertically and horizontally) were excavated over the mine's life, all creating pathways for water movement.

Fig. 12 Zone of Relaxation around a kimberlite mine

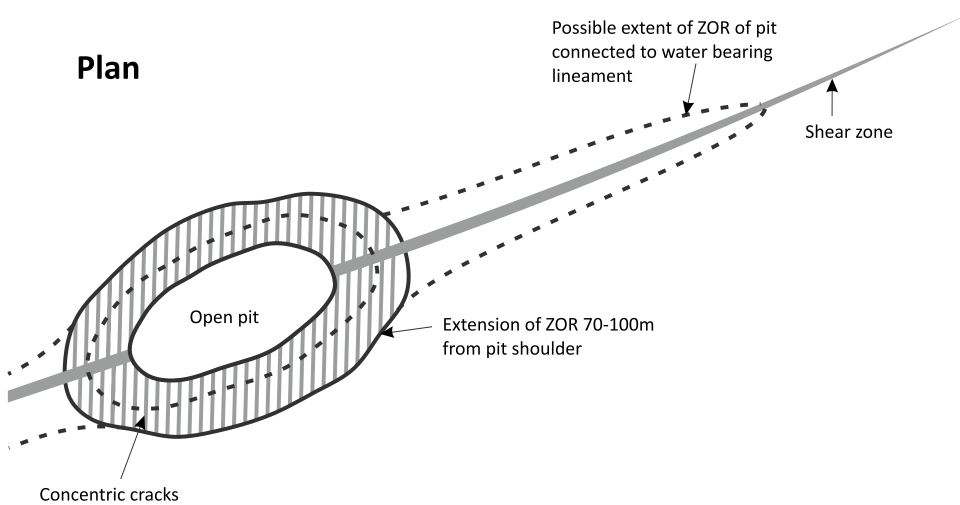


Table 1 Summary of hydraulic conductivities of kimberlites in Southern Africa and Russia (Morton 2008)

Mine	Kimberlite type	Depth mbgl	K m/day	Test method	Source
Orapa DK1 pipe	Fine sedimentary	0–40	8.6×10^{-3}	Lab core	Connelly and Gibson (1982)
Orapa DK 1 pipe	Coarse sedimentary	40–50	4.3×10^{-2}	Lab core	Connelly and Gibson (1982)
Orapa DK 1 pipe	Primary weathered	50–100	1.7×10^{-3}	Lab core	Connelly and Gibson (1982)
Orapa DK 1 pipe	Primary unweathered	> 100	$<8.6\times10^{-4}$	Lab core	Connelly and Gibson (1982)
Letlhakane AK1 pipe	Primary unweathered	0–100	8.6×10^{-3}	Lab core	Connelly and Gibson (1982)
The Oaks	HK	0–200	1.5×10^{-4}–2.2×10^{-5}	Packer	KLMCS (2001)
The Oaks	HK jointed	0–200	1.9×10^{-3}–6.7×10^{-4}	Packer	KLMCS (2001)
The Oaks	Brecciated kimberlite	0–200	1.4×10^{-4}–6×10^{-4}	Packer	KLMCS (2001)
The Oaks	Very brecciated kimberlite	0–200	2.3×10^{-3}–1.5×10^{-4}	Packer	KLMCS (2001)
Venetia K1/K2	Overshot zone TKB	> 5	$14–71\times10^{0}$	Test pumping in pit	Morton and Müller (2003)
Venetia K1/K2	TKB	5–20	2×10^{-2}	Test pumping in pit	Morton and Müller (2003)
Venetia K1/K2	TKB	> 20	4×10^{-4}	Test pumping in pit	Morton and Müller (2003)
Finsch 68L, E2 tunnel, borehole 19	F8 TKB	> 680	5.2×10^{-3}	Falling head test	KLMCS (1994), Beaton et al. (2007), Finsch Mine (1999) and Morton and Meyer (2018)
Finsch	TKB	> 650	9.4×10^{-8}-1.8×10^{-7}	Lab core tests	Finsch (1999)
Udachnaya East- Russia	Porphyritic and brecciated	290–1080	4×10^{-2}	Test pumping	HCI (2002)
Udachnaya East- Russia	Porphyritic and brecciated	1080–1380	1×10^{-1}	Test pumping	HCI (2002)
Udachnaya West- Russia	Porphyritic and brecciated	290–1380	2×10^{-3}	Test pumping	HCI (2002)
Lomonosov Russia	Tuffits, tuff, tuff-sandstones	185–200	3×10^{-1}–8×10^{-1}	Test pumping	HCI (2002)
Lomonosov	Brecciated kimberlite	200–250	1.6×10^{-2}–6×10^{-2}	Test pumping	HCI (2002)
Grib Russia	Not reported	180–250	1.7×10^{0}	Test pumping	HCI (2002)
Grib Russia	Not reported	250–500	0.15×10^{-1}	Test pumping	HCI (2002)
Victor, Canada	Hyperbyssal and pyroclastic	111–275	3 × 10_3to 6.5	6 packer isolated airlift tests	HCI (2006)
Shore Gold Canada	n/a	n/a	0.0002	Single test	Shore Gold (2022)
Diavik Canada	n/a	n/a	0.035	Calibrated model	Kuchling (2022)

HK = Hypabyssal; TKB = Tuffisitic kimberlite breccia

Three sets of fractures, which become conduits for water movement, dominate the movement of water towards the pipe and the mine, as shown in Fig. 15.

The three sets of fractures are:

a. Deep and crustal pre-emplacement structures are the zone of weakness that the kimberlite pushed up through to reach the surface,
b. Radial structures were created by the force of the kimberlite pushing upwards, and
c. Fractures formed by mining and pressure release, including relaxation of the unbonded contact between the cylindrical kimberlite and the country rock

Each type of structure and every excavation created by mining affects the direction and flow of water, with all water moving towards the point of lowest pressure and taking the route of least resistance. Broken rock and mining voids also create space for water storage and can increase infiltration.

Although it is not possible to map all structures carrying water into the workings it is necessary to identify the major stress directions and the most significant water bearing lineaments. Oversight of a major water-bearing structure, of any orientation, will lead to underestimating the mine inflows and unnecessary flooding. In Southern Africa, NE-SW structures tend to be tensional and water bearing along most of their dip and strike, whilst E-W structures are compressional and create compartments.

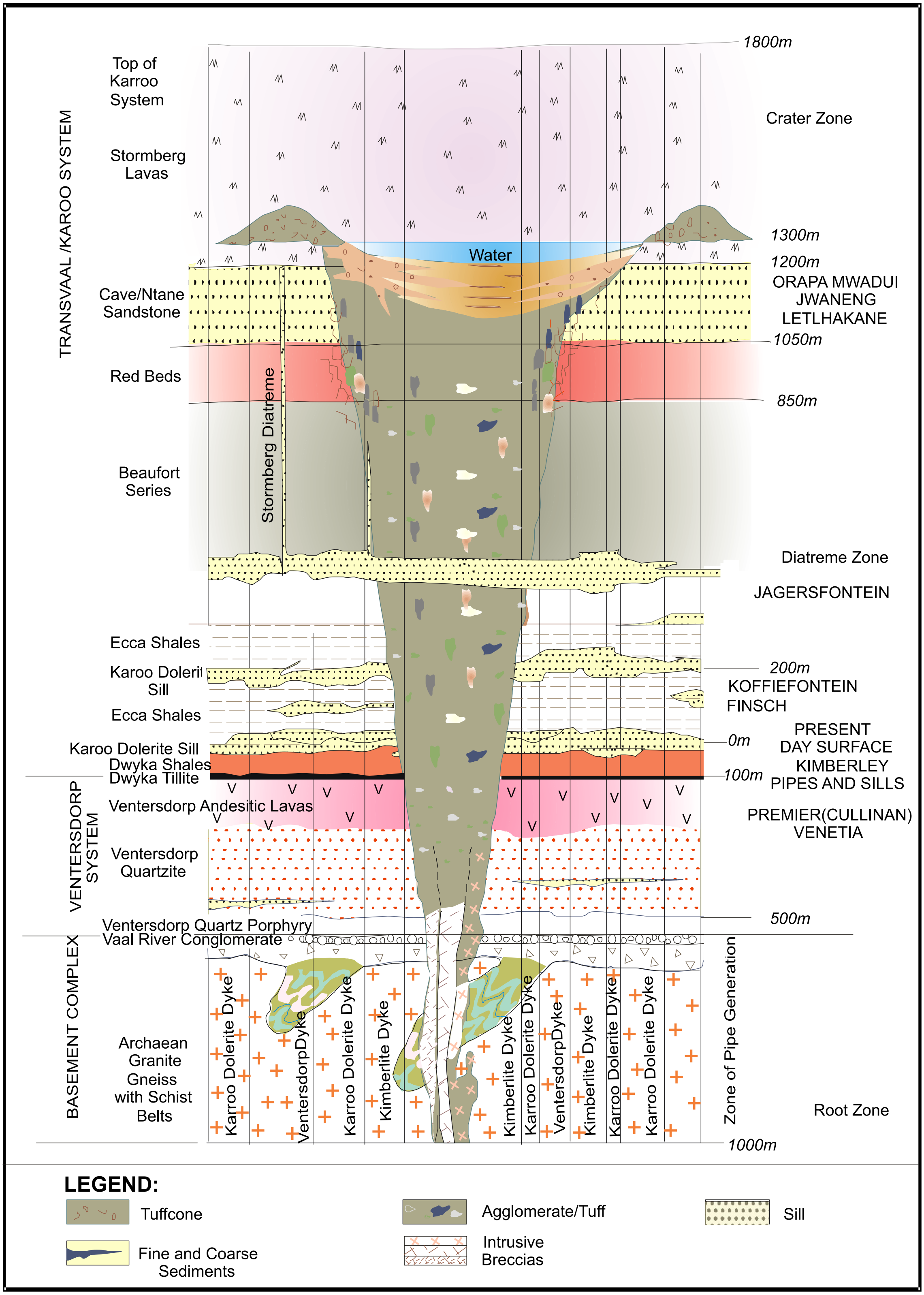


Fig. 13 Model of a kimberlite pipe (after Ellis 1984), the Kimberley Mines are all root sections of the original intrusion

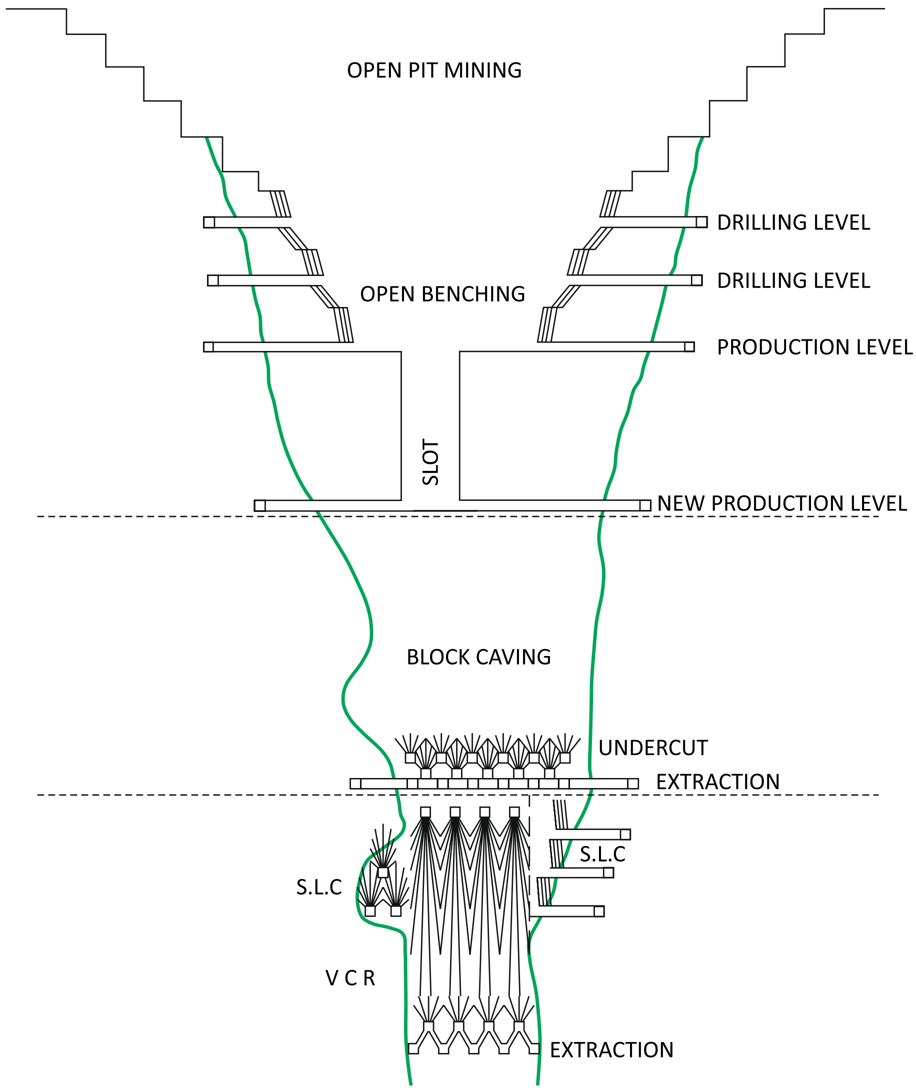


Fig. 14 Mining methods for a kimberlite pipe (Owen and Guest 1994)

Sources of Water and Flow Regimes

During mining, water flows into the mine from the country rock, rainfall and storm water seepage. The main sources of water that reach underground are: direct precipitation) that falls into the pit and muck pile); storm water (rainfall that flows overland and into the pit, break-back zone and ZOR, which can come from overland flow, urban runoff and over topping of nearby water impoundments (in karst country rock, the water can flow along karst pipes and channels); seepage from nearby water impoundments, including waste rock dumps, tailings dams, stockpiles, leaking pipelines and any other source of water near the mine; seepage from the muck pile; near-surface groundwater infiltrated from precipitation and surface water entering permeable zones; and groundwater or permafrost melt from geological structures and aquifers recharged by large catchments.

The area of influence can be represented by a cylinder or cone of water provenance grouped into four major zones: the pit (direct entry, including seepage from the muck pile); the ZOR (seepage of rainwater through broken ground and from nearby water impoundments); the surface water catchment (storm water flow); and the larger regional aquifer, which contributes deep groundwater that moves along fractures and contact zones into the mine. Figure 16 is a schematic of the different sources of water, which create flow towards the lowest pressure point in a mine, typically the sumps and lowest pumping level (Fig. 17).

As each of the cylinders or cones are at various distances from the mine and each cylinder has a different volume and speed of water movement, the response time at the mine is different for each source-type of water. The water arrives in pulses. If multiple rainfall events are received, then the pulses will overlap. Figure 19 illustrates the pulsed arrival of two rainfall events, resulting in cumulative flow.

If there are multiple rainfall events, then the cumulative flow will reflect the events. The sumps and pumps of the deepest part of the mine are usually equipped with water

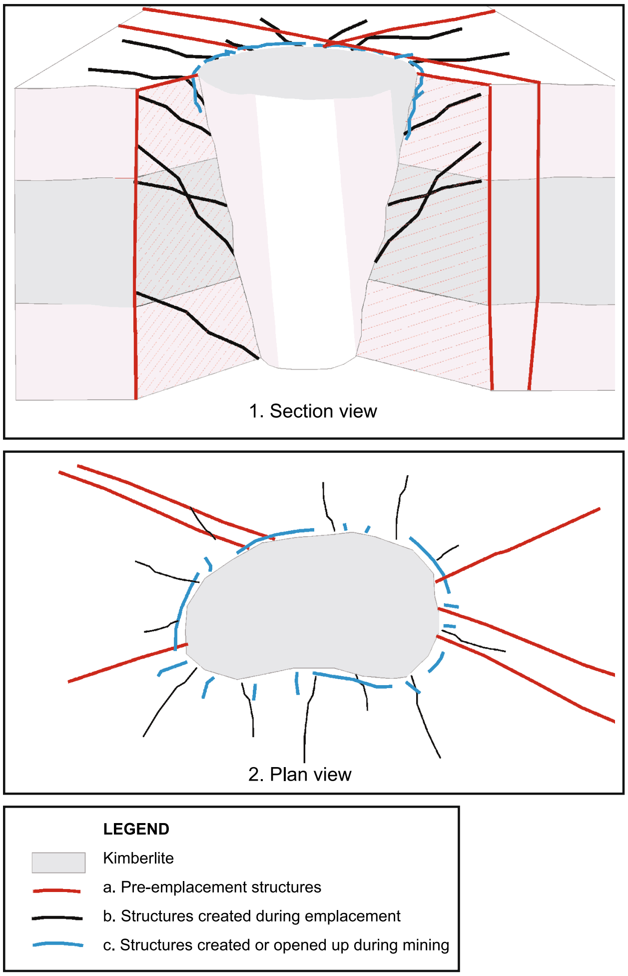


Fig. 15 Summary of structures (open fractures) associated with kimberlites

level gages and flowmeters, which record the increases in flow associated with different rainfall events.

Typically, the precipitation entering the pit and muck pile directly reaches the sumps first (days). Arrivals at the sumps are slower for the water contributed by the break-back zone, the ZOR, and the overall catchment inflows. Cumulative rainfall events can create high inflows to the sumps; overtopping of sumps is managed by having mining levels below the working areas to store water in case of flooding. Figure 18 illustrates the 'during mining' flow lines of water entering the mine at mid-life.

The figure illustrates the 'U' shaped flow of underground water towards the lowest extraction levels and tunnels of a block cave. By creating low pressure zones at the drawpoints, the ore can be extracted very efficiently. However, block caving creates groundwater gradients towards the active mining areas and water is an ever-present hazard.

Point piezometers installed in the country rock around the pipe are essential for plotting the direction of flows and therefore enabling a design that can intercept the water. For the Russian mines that lie in very cold areas with halite as the country rock, the gradients are threefold: pressure, temperature, and chemical. The combination of all three creates a unique groundwater movement regime. In Canada, the cold temperatures and permafrost require accurate plotting of temperature gradients for management of seasonal water flow changes. Water pressure plotting is an accurate way to understand the directions and rates of flow, thus enabling early cut-off or deflection of water from the working areas.

Mine Water Control Design for Modern Deep Kimberlite Mines

Accurate and cost-effective dewatering design depends on understanding where the water originates from, what it travels along, and where it is stored. Once understood, the recharge can be intercepted, the hydraulic conductivity exploited, and water pressures around the mine monitored to determine effectiveness. The most effective design starts from the top down with accurate control of storm water around the pit and ZOR. Then, control of drainage of the open pit and closed- off upper workings. Water tunnels are very effective at reducing the inflow to underground. Sumps and water passes collect and divert water to settlers and pumping chambers which then transfer water to surface. Care must be taken to avoid recycling of water by ensuring sumps are lined and sited away from relaxed ground.

This requires an integrated approach for the modelling of the: geology (ore body and country rock and structural interpretation), geotechnical parameters (stress regime and opening of joints, fractures, and contact zones), hydrogeology (recharge, hydraulic conductivity, storage, and chemistry), rock mass properties, and the mine layout and speed of mining (influence of the mine on the water and vice versa). Figure 19 Illustrates the integration of the models and the feedback loops.

The knowledge of geological structures is very important as these can control the main flows into the underground mine. Figure 20 shows the dominant structures controlling flow and creating barriers to flow at Finsch mine.

These structures are incorporated into a detailed conceptual hydrogeological model drawn in plan and section. Figure 21 shows the near-mine conceptual model for the Finsch mine in 2005. The mine dewatering design is created and implemented using the understanding that comes from the level of detail in a good conceptual model.

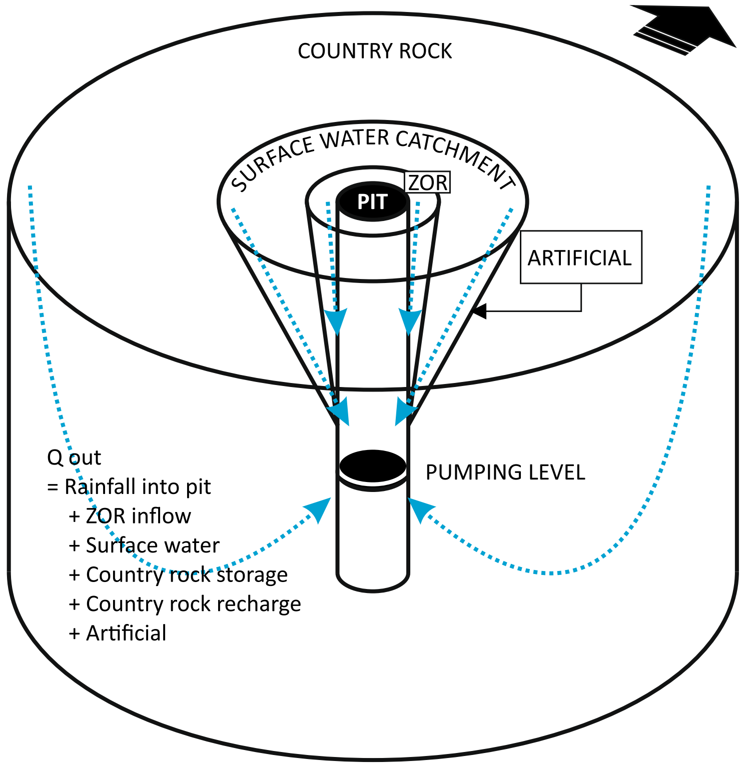


Fig. 16 The sources of water (provenance) to a kimberlite underground mine

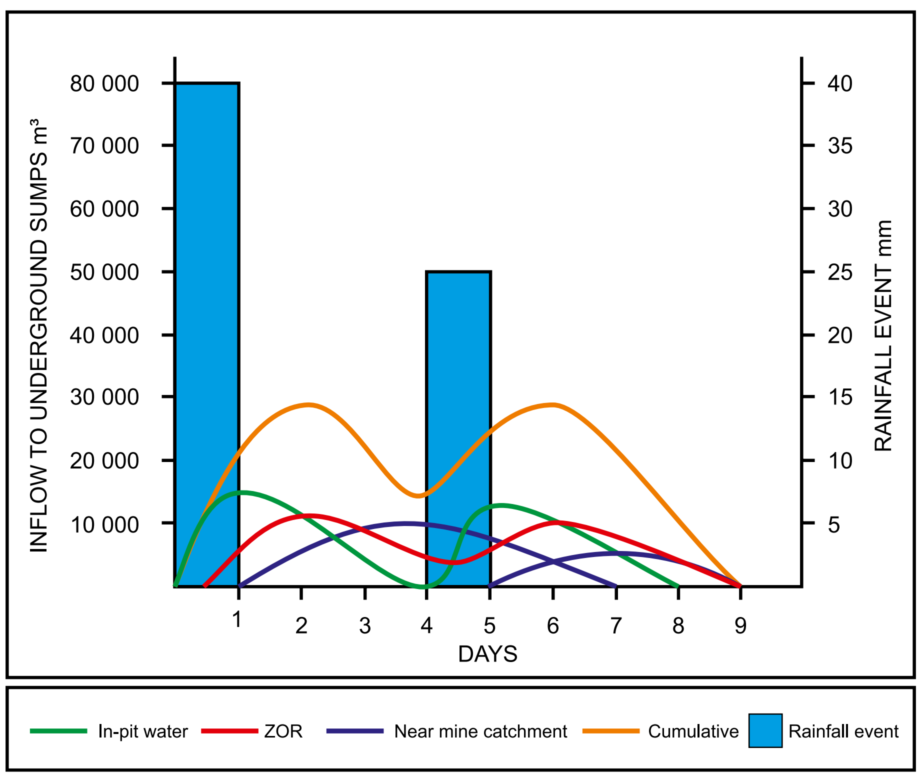


Fig. 17 Pulsed arrival of water from each source into the mine, assuming two rainfall events

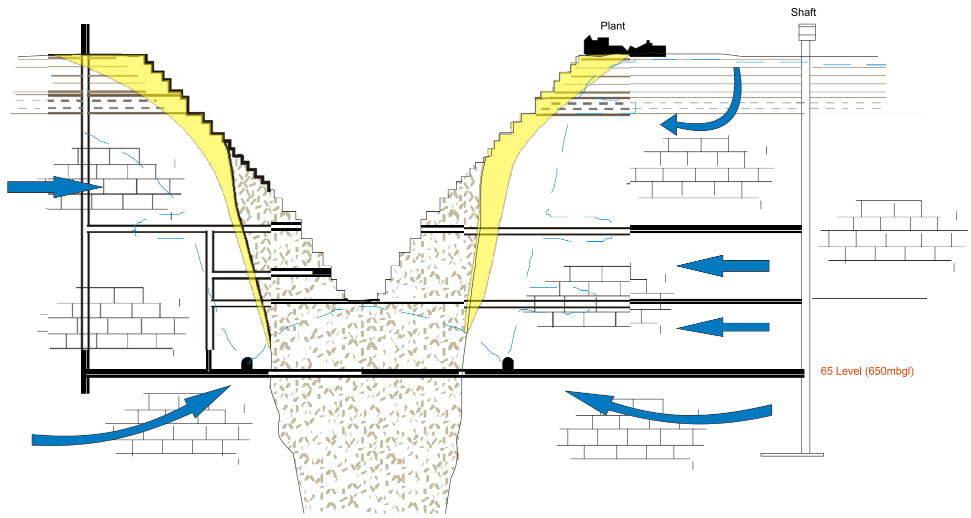


Fig. 18 Mid-life underground hydrogeology of a kimberlite mine (Morton 2008)

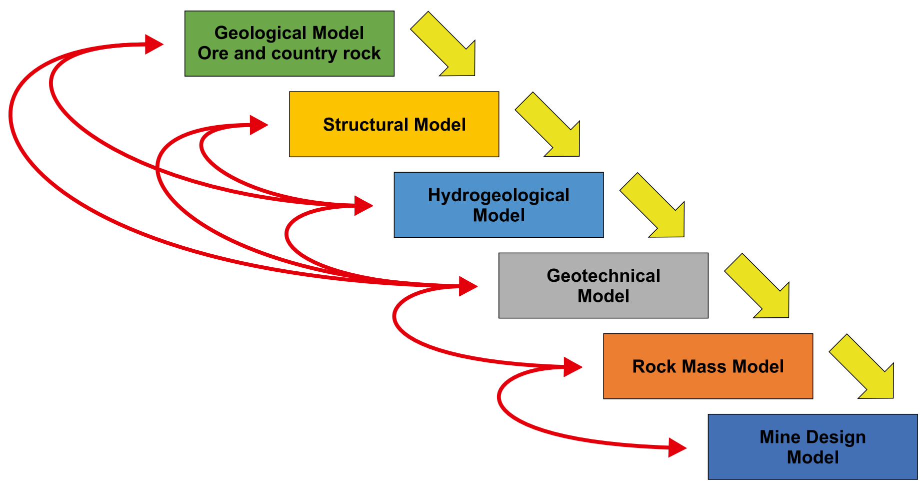


Fig. 19 Model integration to achieve a dewatered mine (AR Guest unpublished)

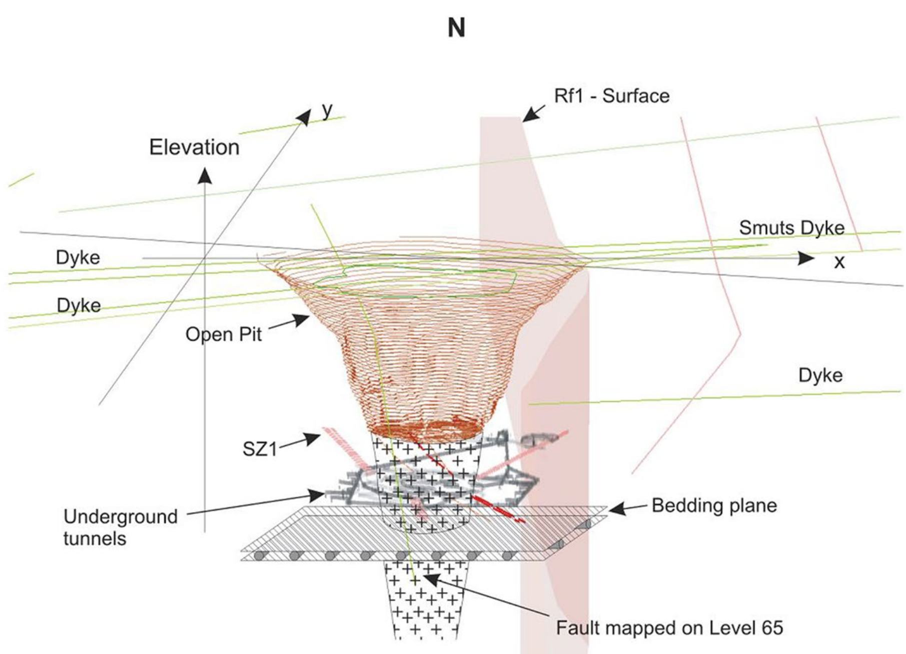


Fig. 20 Water bearing structures around a deep kimberlite mine, isometric sketch (Morton 2008)

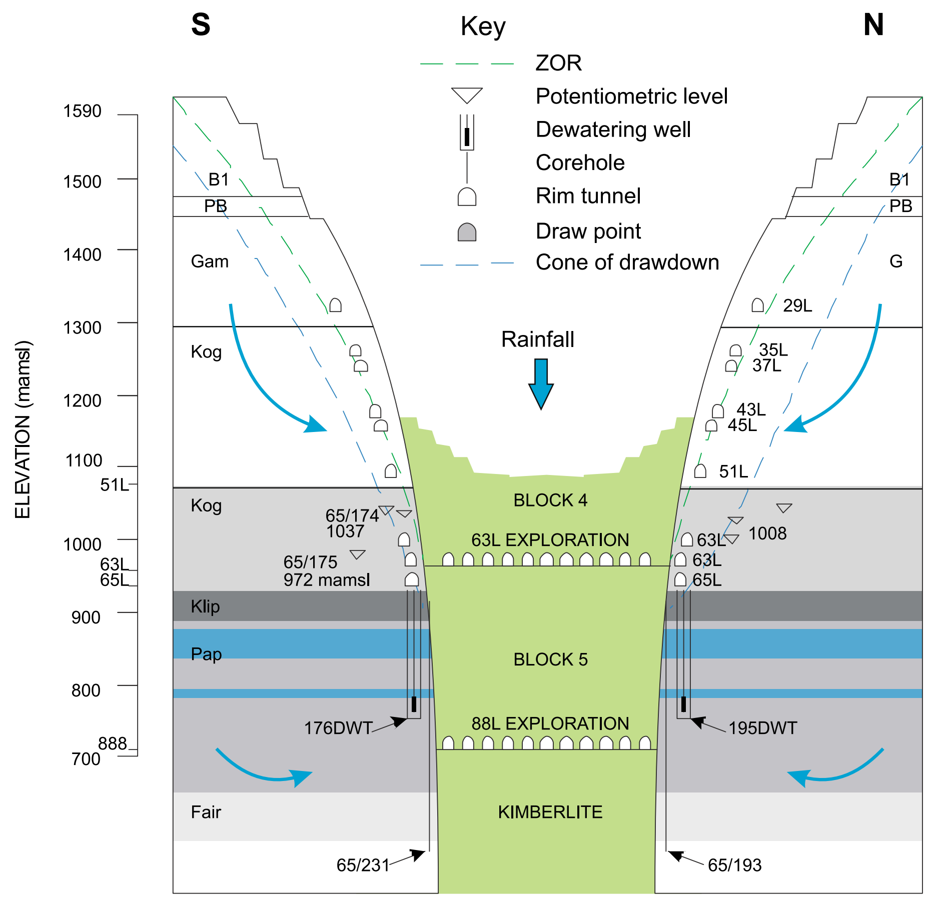


Fig. 21 Near-mine conceptual hydrogeological model in cross section, 2005 (Morton 2008)

The Implementation and Monitoring of Deep Mine Water Control

Depending on economics, any mine can be dewatered in advance of mining. Mines will typically use a combination of methods to keep the mine workings and access roads dry, including:

1. Storm water control at the surface. Large drains and well-designed pumping systems (boreholes, storm water drains, and gullies) are used to divert surface water from the pit, its ZOR, and break-back zone. Pumps are used in the pit to collect the precipitation that falls into the pit and seepage from the ZOR.
2. Water tunnels. Since the late 1800's, circular water tunnels have been used below surface to intercept surface and ground water.
3. Vertical dewatering wells around the pit perimeter (if there is an initial pit). These divert the near-surface water from the ZOR and kimberlite/country rock contact
4. Water passages. These are vertical passes that connect water tunnels and mining levels to divert water into sumps and pumping stations to pump the water up pipelines and out of the mine.
5. Mini sumps. Due to the undulating floors of mining excavations, water can sometimes create ponds underground. Mobile sump pumps are used to pump the water to underground holding sumps and then the water is pumped to surface.
6. Deep water tunnels and underground pumping boreholes. Deep circular water tunnels with drain holes and underground boreholes are used to improve drainage for block cave mines.
7. Deep sumps and flood capacity chambers. These allow for above-average rainfall inflows and create storage to protect working areas from flooding.

A combination of methods is essential to accurately control underground water to protect people, equipment, and ensure efficient mining. The effectiveness of the water control methods is managed using a water level and pressure monitoring system linked to a detailed and shared water balance. The monitoring system measures water levels around the mine and the water balance is used to check that the volume of water pumped out equals the water flowing into the mine.

Good practice water controls include: no pit lake above the mine workings; using of detailed monitoring to plot sources of water and flow lines; using hydrochemistry to identify the source(s) of water; regularly maintaining storm water control drains around the pit; regularly maintaining water tunnels, water passes, pumps, and sump capacity; estimates of maximum flood levels and flood control design to manage flooding; accurate monitoring networks to predict capacity to manage floods; water doors and spare void volume below active workings to contain flooding; spare capacity pumping to remove water quickly; using a detailed weekly water balance to check that the water pumped out exceeds water received and to note unusual retention within a mine and muck pile; and regular re-visits to the conceptual model and re-evaluation of the groundwater models as mining progresses.

Typical maximum open pit depths are about 350 mbgl. Detailed planning can ensure that precipitation and runoff into the pit is collected with sumps and pumps installed and supported on benches, even after the open pit is closed. A decline can be used as part of the underground mine design to both give early access to the ore and to dewater in advance the upper underground workings.

A combination of ring tunnels (both shallow and deep) with dewatering boreholes can be used to intercept near-surface groundwater and dewater to greater depths. The 65 Level ring tunnel at Finsch Mine is a good example. To dewater deeper levels, a raise bore rig can be used to drill vertical large-diameter boreholes downward from underground to below 1000 m to create an underground dewatering ring. Where specific geological structures carry water into the underground mine, a ring tunnel is not necessary; vertical pumping boreholes can be installed in muck bays (also called cubbies) sited above the water-bearing structure.

The success of underground dewatering boreholes depends on having a very good conceptual understanding of the hydrogeology, using a well distributed water level /pressure monitoring network, and setting targets for acceptable water pressures around the working areas. Grouted-in nested point piezometers located in accurately angled core holes to the north, south, east, and west of a mining area enable plotting of the pressures; the flow lines reveal the gradient and direction of flow to the workings. Combined with underground seepage mapping, this provides very good information on the effect of pumping and drainage for specific areas. It is also an early warning system to detect water build up, possible mud rushes, or potential sources of flooding.

Figure 22 shows the plot of water pressure measured at a point piezometer installed at Finsch Mine. The recording water pressure is maintained below 65Level when pumping well 65/195 is pumping at 80L/s. The trend line shows a constant drawdown that dewatered the block cave to 730 m above mean sea level. Figure 23 shows the layout of both dewatering and underground monitoring system for a deep kimberlite mine.

Conclusions

Kimberlite is very susceptible to damage by water. Its method of intrusion means that the kimberlite/country rock contact is often unbonded and becomes a zone of water ingress and movement once mining relaxes the near-surface

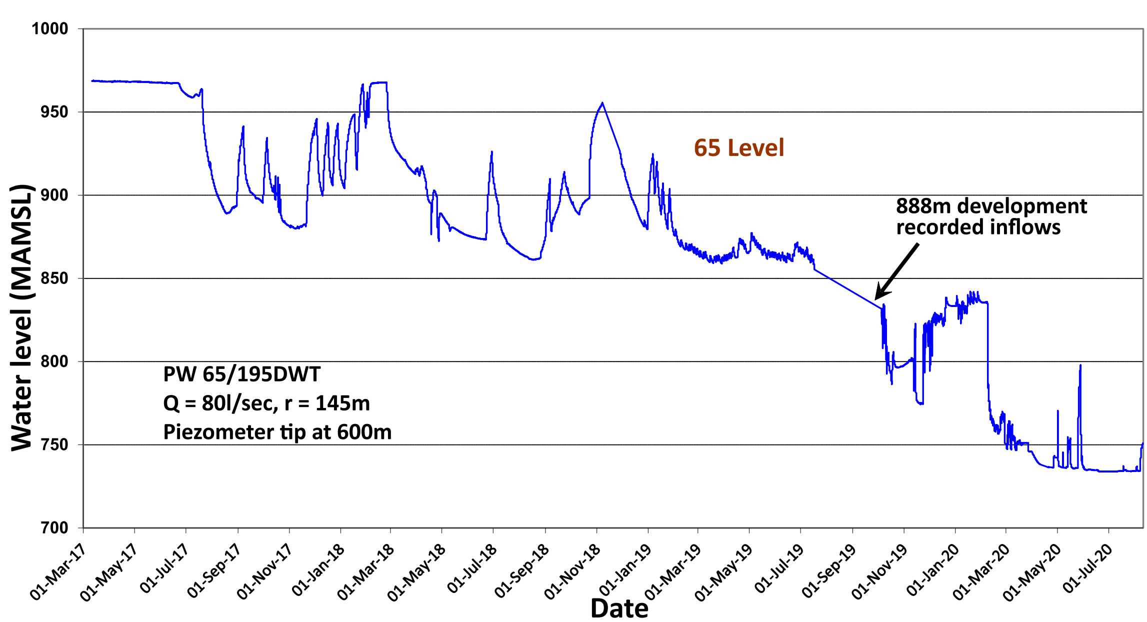


Fig. 22 Pressure monitoring underground

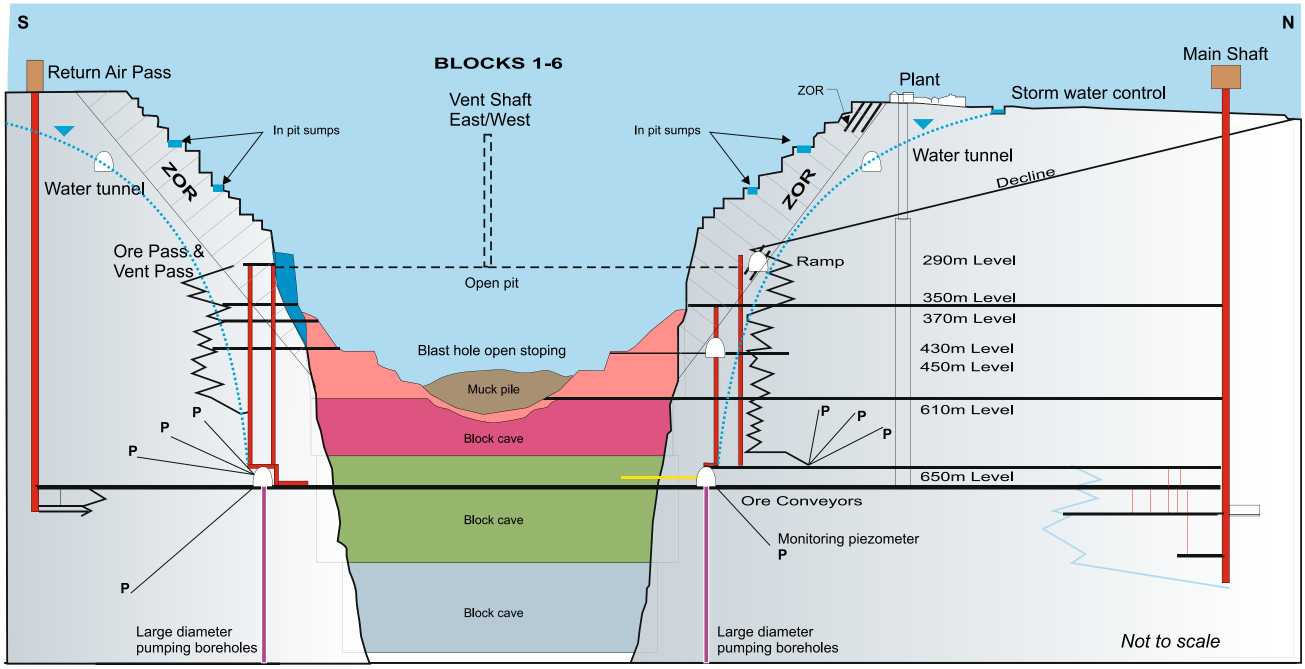


Fig. 23 Suggested layout of a dewatering and monitoring system for the life of a deep kimberlite mine

and deeper contacts. Therefore, even in low rainfall areas, groundwater ingress is of concern to kimberlite miners. This paper has described dewatering methods that have been used and has consolidated good practices for modern mines, which are often operating beneath historic mine workings.

Hard rock diamond mining typically starts as an open pit, which is drained using accurate storm water control and water tunnels at ≈ 40 to 120 m bgl. Some mines also use rings of dewatering pumping boreholes to intercept near-surface groundwater. Water tunnels are very effective over the life of the mine because they intercept the bulk of the inflow water originating from near-surface groundwater or carried into the mine from regional lineaments and bedding planes, such as at Finsch mine. Because of the carrot-shaped kimberlite and unbonded kimberlite/country rock contact, dewatering ring tunnels at greater depths are very effective for underground mines. At Finsch mine, the early installation of the decline was very beneficial. Block caves benefit from dewatering ring tunnels, and these can be used to dewater lower levels to > 1 km deep by installing and equipping vertical large diameter boreholes from underground.

Accurate dewatering depends on a thorough understanding of the sources and flow paths of the water, and then the creation of a detailed hydrogeological conceptual model that details all sources of water, areas of storage, and flow paths. By installing a detailed monitoring network that measures the water levels and pressures around the mine, water can be intercepted in optimum locations in advance of mining. The objective is to draw the water away from the working areas. The success of the implementation depends on setting targets for pressure reduction for each section of the mine using detailed and accurate monitoring of water pressures around the pipe.

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